Executive Secretary’s Summary of Decisions
2017 Post-Season Meeting

The Pacific Salmon Commission held its 2017 Post-Season Meeting from January 9-13, 2017 at the Hyatt Regency Vancouver Hotel, and discussed a number of topics (see attached agenda).

The Commission AGREED:

1. The final report of the expert panel on Chinook forecast methodologies is accepted, and will be published as a PSC Technical Report. The Commission will note this acceptance in its 2016 annual report, express its thanks to the authors, and will consider feasibility of the recommendations via the Chinook Technical Committee (CTC) assignment from October 2016.
2. Tasks 5 and 6 in the CIG's model transition action plan must precede task 4, noting there have been delays in some of this work from data problems identified by the CTC.
Regardless of this ongoing CTC work, the May 2017 Chinook negotiating session will be the opportunity for the CTC to refresh the Commission on Table 1 translation options and for the Commission to give guidance to the CTC on the preferred option.
3. The post-season reports from 2016 are accepted, noting that each Party will make minor technical and clarifying edits to their respective reports and transmit revised versions (with errata sheets) to the Secretariat.
4. The revised process for VHPC guidance to the Joint Fund Committee, as proposed by the CIG, is adopted.
5. The CIG recommendation on CTC work plan task priorities is adopted.
6. The CTC memo to the Commission dated January 13, including the Commission's priority tasks, is adopted and will form the current work plan for the CTC.
7. The next CTC work plan will be due in October 2017, as per the normal PSC schedule.
8. In February 2017, the CSC will share a draft agenda for the International Year of the Salmon (IYS) North Pacific Steering Committee. The Commission will consider this agenda and anticipates a report from the Executive Secretary to the Chair and Vice-Chair in late March about his attendance at the IYS event. The National Sections will consider this report and provide any available guidance on next steps by late April 2017, with follow-up at the October 2017 Fall Meeting.
9. The Southern Panel will report on renegotiation progress for Chapters 5 and 6 early in the February 2017 meeting week.

## ATTENDANCE

PACIFIC SALMON COMMISSION<br>POST SEASON MEETING<br>JANUARY 9-13, 2017<br>HYATT REGENCY VANCOUVER<br>VANCOUVER, B.C.

## COMMISSIONERS

## CANADA

R. Reid (Chair)
S. Farlinger
J. McCulloch
M. Ned
B. Rezansoff
B. Riddell
P. Sprout

UNITED STATES
C. Swanton (Vice Chair)
W.R. Allen
P. Anderson
W. Auger
D. Darm
R. Klumph
M. Oatman

# Draft Agenda <br> Post-Season Meeting <br> January 9-13, 2017 <br> Hyatt Regency Vancouver; Vancouver, B.C. 

1. Adoption of agenda
2. Approval of minutes: October 2016 Fall Meeting
3. Executive Secretary's report

Chinook issues
4. CTC report on Task 4 of the model transition plan
a. Commission direction on short- and long-term implementation
5. CTC report on Tasks 5 and 6 of the model transition plan
6. Review/discuss final report from expert panel
7. CIG report on proposed CTC work plan priorities
8. CTC work plan approval
9. Report from Chinook negotiation team

## Other action items pending

10. Adoption of post-season reports
11. Report on SEAK 2016 mark-selective fishery
12. Reports from Panels and Committees
a. Progress reports on work plans and status update on negotiations
b. CSC report on 2015 environmental anomalies
c. F\&A Committee report
13. Habitat and Restoration Technical Committee - future direction (from October 2014 Commission decision)
14. Public comment

## Review of Methods for

# Forecasting Chinook Salmon Abundance 

## in the Pacific Salmon Treaty Areas

Report to the Pacific Salmon Commission

> by

Randall M. Peterman
Ray Beamesderfer
Brian Bue

14 November 2016

## Acknowledgements

This report presents conclusions and recommendations of an independent panel charged with reviewing the methods for forecasting Chinook Salmon abundance for aggregate abundancebased management of fisheries under the U.S.-Canada Pacific Salmon Treaty. The Panel extends its gratitude to the many participants in the review workshop on forecasting methods in Portland, Oregon for their objective participation, critical perspectives, and patient answers to our innumerable questions. These participants included John Carlile and Bob Clark (ADFG); Antonio Velez-Espino, Diana Dobson, and Gayle Brown (CDFO); Stuart Ellis, Jon Hess, Marianne McClure, and Tommy Garrison (CRITFC); Alan Byrne (IDFG); Robert Kope (NMFS); Ethan Clemons, Jeff Whisler, Matt Falcy, Christine Mallette, John North and Tim Dalton (ODFW); Steve Haeseker (USFWS); Robin Ehlke, Ron Roler, Ben Cox and Lisa Harlan (WDFW); and Roger Dick, Jr. (YN Fisheries).

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## 1 EXECUTIVE SUMMARY

Management of Chinook Salmon harvest in the Pacific Salmon Treaty (PST) areas of Southeast Alaska and British Columbia under an Aggregate Abundance Based Management (AABM) framework depends heavily on forecasts of Chinook abundance prior to the onset of fishing (pre-season forecasts). In response to recent increases in the magnitude of differences between pre-season and post-season abundance estimates in the three AABM areas, as well as concerns about forecasts by regional agencies, the Pacific Salmon Commission (PSC) established an Independent Expert Panel. The mandate of the Panel was to (1) evaluate the accuracy and precision of stock-specific forecasts produced by agencies, and evaluate the differences between the PSC Chinook model's pre-season forecasts of abundance in AABM areas with postseason estimates, (2) provide advice on the strengths and weaknesses of forecasting methods and alternatives, and (3) suggest improvements. The Panel consisted of three members, one proposed by Canada and two by the U.S. Section.

An information-gathering workshop was facilitated by the Panel on 10-11 August 2016 in Portland, Oregon. Participants were responsible for agency forecasts of selected stocks or for forecasts from the PSC's Chinook model (the latter produced by the Chinook Technical Committee, CTC). A total of 23 non-panel participants attended, representing nine agencies. Presentations were made on agency forecasts and annual run reconstruction methods, and on the PSC Chinook Model's calibration and abundance-forecasting procedures. Before and after the workshop, the Panel reviewed large volumes of information from more than 70 documents and spreadsheets related to Chinook forecasting methods and results. Panel members also conducted extensive follow-up with forecasters and modelers by email and phone for additional information and explanations.

The Panel identified a number of issues affecting bias and precision of agency forecasting methods and their effective application - these are not necessarily weaknesses but are rather opportunities for improvement. For agency as well as PSC-model forecasting methods, the Panel identified general conclusions and specific recommendations for improvement. Issues, conclusions, and recommendations represent the consensus of the Panel members.

Recommendations are also qualitatively categorized by urgency and immediacy of potential implementation:

Near-term - Relatively straightforward to implement with likely immediate benefit (within 1 year).

Intermediate-term - Would require moderate investment of time and effort (1-2 years)
Long-term - Would likely require substantial time and effort, but with high potential for long term improvements (3-5 years).

## Agency Forecasts

## Bias \& Precision

1. The forecast of Columbia Upriver Bright Chinook Salmon is nearly unbiased and reasonably precise (mean percent error $=1 \%$; mean absolute percent error $=25 \%$ ). The most recent returns (2013-15) were the largest in the data set and showed the greatest deviation between the forecast and actual terminal returns. There was no obvious time trend of forecasts being either under- or overestimates
2. The forecast of Columbia River Spring Creek Hatchery shows a tendency to overestimate actual abundance and is reasonably precise (mean percent error $=8 \%$; mean absolute percent error $=31 \%$. There are periods of underestimates of the run (2001-2004) and overestimates (2005-2012; Figure 24).
3. The forecast of Columbia Upriver Summer Chinook Salmon was evaluated for the 20052015 returns. Overall, the forecast shows a tendency to overestimate abundance and is reasonably precise (mean percent error $=10 \%$; mean absolute percent error $=22 \%$ ). Forecasts for 7 of the 8 returns between 2005 and 2013 were greater than the observed returns, whereas the returns for 2014 and the record-high 2015 were more than forecast.
4. Forecasts of West Coast Vancouver Island Chinook Salmon are biased low (mean percent error $=-27 \%$ ) and are imprecise (mean absolute percent error $=42 \%$ ). Fifteen of the seventeen forecasts examined were low with over forecasts occurring in 2005 and 2014.
5. Forecasts of North Oregon Coast Chinook Salmon tend to overestimate abundance but are reasonably precise (mean percent error = 8\%; mean absolute percent error = 31\%). However there was an unusually large over forecast in 2007 and when that forecast was removed from the analysis, there was a tendency to slightly underestimate the return (MPE =-2\% and MAPE = 22\%). Following Improvements in stock assessment in 2008 (more age sampling, increases in the speed of scale aging, and improved escapement estimation), forecasts have tended to underestimate the returning escapement (mean percent error $=-6 \%$ ) and forecast precision has been increased (mean absolute percent error = 14\%).
6. A comparison of forecast bias (MPE) for the five stocks examined in this review with the forecast bias for 37 sockeye salmon and 40 chum salmon stocks examined in previous studies showed that the three Columbia River forecasts and the North Oregon Coastal forecast were at the low end of observed MPE values relative to sockeye and chum salmon forecasts. In contrast, the negative bias demonstrated by the West Coast Vancouver Island Chinook Salmon forecast (MPE) fell below the range of MPE observed for either chum or sockeye salmon.
7. A comparison of forecast precision (MAPE) for the five Chinook Salmon stocks examined in this review with the forecast precision for 37 sockeye salmon and 40 chum salmon stocks examined in previous studies showed that the three Columbia River forecasts and
the North Oregon Coastal forecast were at the low end of observed MAPE values for the sockeye and chum salmon forecasts. While the MAPE of $42 \%$ for the West Coast Vancouver Island forecast is higher than the other four Chinook Salmon stocks examined, it is still well within the range of MAPE values examined for chum and sockeye salmon.

## Strengths

$\checkmark$ Reflect the best available stock assessment data in any given year based on the resources and expert judgment of fishery biologists with the greatest familiarity with the stock.
$\checkmark \quad$ Forecasting methods are based on simple and relatively robust models with easily-understood methods and assumptions (given appropriate documentation).
$\checkmark \quad$ Provide generally comparable levels of bias and precision on average compared to those observed for other salmon species.
$\checkmark \quad$ Forecasts are generally useful for fishery management needs in both ocean and freshwater fisheries of British Columbia, Washington, and Oregon.

## Issues

I. The current documentation of agency forecasts of abundance that are sent annually to the CTC does not provide sufficient information for PSC modelers to identify the longterm accuracy and precision of those forecasts, let alone uncertainty about the current year's forecast.
II. Efforts by agencies to provide forecasts as inputs to the PSC model are hampered by an incomplete understanding of (1) the PSC model's information requirements, (2) how those forecasts are used in that model, and (3) how those uses differ from those of fishery managers within regions.
III. The accuracy and precision of stock-specific forecasts are limited by the available stock assessment data; this is more of a problem for some Chinook stocks than others.
IV. There are substantial differences among regional agencies in how stock forecasts are produced and described. These differences cloud the interpretation of the point forecasts of abundance from the PSC model.
V. Forecasting methods for some stocks have not fully incorporated existing knowledge of changing parameters, such as age at maturity, or recent advancements in statistical methods of analysis.
VI. Existing forecasting models used by agencies, especially sibling relationships, are reasonably effective in representing average conditions but are vulnerable to performing poorly for years of very low or very high returns.

## Suggestions for Improvement: Conclusions \& Recommendations

A. More comprehensive documentation is needed by the CTC from regional agency forecasters regarding the agencies' methods, critical assumptions and uncertainties, and
accuracy and precision of past stock-specific forecasts. Agencies should also state the uncertainty in each stocks' annual forecasted abundance. More-frequent in-depth communication between PSC modelers and agency staff is also required.

1. When regional agency forecasters send their stock-specific annual forecasts to the CTC, they should document their model-ranking procedures as well as the past performance of their methods (bias and precision). [See Recommendation 1 (Nearterm)]
2. Agency forecasters should not choose just one best model for forecasting abundance in each age class. Instead, they should conduct analyses across different models that make different assumptions and report the resulting set of forecasts to the CTC for use as inputs to the PSC model. The generally large prediction intervals (not confidence intervals) around point forecasts should also be reported. [See Recommendation 2 (Intermediate-term)]
3. Agency forecasters should also send to the CTC a set of forecasts, each one based on a different model-ranking criterion, as determined by a range of management objectives. As described in section 8.1, the CTC can then conduct sensitivity analyses with the PSC model to determine their effect on forecasts of abundance in the AABMs. [See Recommendation 3 (Intermediate-term)]
4. All assumptions underlying the annual forecast, as well as data related to those assumptions, should be listed in the document provided to the PSC modelers so that everyone is aware of the forecast's strengths and weaknesses. [See Recommendation 17 (Near-term)]
5. A list of the alternative forecasting models examined and the criteria used to select among those models for producing a forecast for the Northern Oregon Coast should be clearly stated in the forecast document provided to the PSC model group, as suggested in recommendations at the start of section 7. [See Recommendation 16 (Near-term)]
B. More explicit direction from the Chinook Technical Committee is needed by agency-based stock forecasters regarding the annually requested forecasts.
6. The Columbia River Technical Advisory Committee and the Pacific Salmon Commission's modeling group should communicate with each other to ensure that they are both working with the same definition of the Columbia River Summer stock and the same sets of data, and that any historical information reflects this change. [See Recommendation 10 (Near-term)]
7. The CTC modeling group and WCVI (West Coast Vancouver Island) forecasters should decide (1) which type of forecast is required from WCVI (based on baseperiod data [1979-1982] or recent years, for example), and (2) the forecast
performance values beyond which an extensive review of forecasting methods should be triggered. [See Recommendation 11 (Near-term)]
8. The CTC should request each regional agency to provide to PSC modelers the forecasts of abundance for the model deemed best for each of the "relevant" ranking criteria (such as MRE, MAE, or RMSE), where "relevant" is defined as those that fit with stated management objectives for the AABMs. [See Recommendation 22 (Near-term)]
C. Substantial improvements in basic assessments of some Chinook stocks are needed to support current PSC model and management applications, otherwise expectations need to be rescaled/reduced to recognize existing data limitations. Further expansion of the PSC model's number of stocks and fishing areas may need to be postponed until the quality of relevant data is deemed suitable.
9. Continue to improve upon the ability to estimate the contribution by stock to all AABM and ISBM fisheries with the objective of obtaining reliable stock contribution estimates by age. The Panel encourages the commitment of extra funding for the implementation of techniques to estimate stock contributions in a timely enough manner that the results can be used for forecasting in the subsequent year. [See Recommendation 7 (Long term)]
10. An evaluation of the WCVI sampling program should be undertaken to determine if (1) there has been a dramatic change in sample collection methods and sampling intensity over the years, and (2) whether the sample design and intensity is adequate to obtain meaningful age composition estimates. If the sample design appears to be adequate, then explore other ways to estimate the age-3 and age-6 components of the returns. [See Recommendation 12 (Intermediate-term)]
11. Continue the increased sampling in the Northern Oregon Coast for age, rapid reading of scales for age, and improvements in escapement estimation. [ See Recommendation 18 (Near-term)]
D. Establishment of a set of "best forecasting practices" and standard definitions can improve the statistical foundation of methods for stock forecasting.
12. We encourage all agency forecasters to apply ForecastR to their regions' stocks. As well, the CTC should run workshops to familiarize agency scientists with the ForecastR program. [See Recommendation 4 (Near-term)]
13. Explore the use of natural-log transformations for sibling regressions. The examination should evaluate both the effect on meeting the regression assumptions and forecasting performance. [See Recommendation 9 (Near-term)]
E. Accuracy, precision, and transparency of stock forecasting methods might be substantially improved by application of more formal model-selection criteria that match clearly defined management objectives, as well as more advanced statistical methods that allow for time-varying parameters.
14. The Columbia River Technical Advisory Committee (TAC) should explore whether using formal statistical model-selection criteria improves the accuracy and precision of their forecasts. [See Recommendation 8 (Near-term)]
F. Development of new models and advanced parameter estimation methods may improve the accuracy and precision of agencies' annual forecasts. Regardless of any such improvements, large uncertainties in forecasts should be expected, especially when they are based on data outside the range of past observations.
15. Agency forecasters should try applying a hybrid sibling model, especially to cases in which the fit of data to a standard sibling model is weak. [See Recommendation 5 (Near-term)]
16. We recommend that agency forecasters try using a Kalman filter estimation procedure for fitting their sibling relationships to account for time-varying parameters. [See Recommendation 6 (Near-term)]
17. The use of recent harvest rates and maturation rates should be explored for the WCVI forecasting model. These analyses should estimate model sensitivity to uncertainties in these rates. All results of these sensitivity analyses, including the associated forecasts, should be provided to CTC modelers along with estimates of uncertainty in the forecasts. [See Recommendation 13 (Intermediate-term)]
18. Explore a different and simpler method of forecasting terminal return to WCVI. The preferred method would reduce the complexity of the forecast by reducing the number of data manipulations and number of parameters and assumptions in the forecasting procedure. As with all new methods, it should be thoroughly evaluated to determine whether an increase in performance is actually obtained in terms of bias and precision. Sensitivity analyses should be performed to determine the influence of uncertainties in model parameters. [See Recommendation 14 (Intermediate-term)]
19. We recommend that Oregon Department of Fish and Wildlife (ODFW) forecasters examine $\log _{e}-\log _{e}$ (natural logarithm sibling regressions, a hybrid sibling model, and a Kalman filter estimation procedure, the latter to account for possible temporal changes in parameters of the sibling relationship. [See Recommendation 15 (Nearterm)]
20. As the population assessment models continue to evolve, North Oregon Coast (NOC) researchers should determine the sensitivity of the resulting forecasts to the uncertainty in estimated parameters in the models and quantify the uncertainty in the forecasts. [See Recommendation 19 (Intermediate-term)]
21. If more detailed data can be obtained from terminal fisheries for NOC, the forecast for this aggregate stock should change to a terminal run forecast instead of an escapement forecast. [See Recommendation 20 (Intermediate-term)]

## PSC model

## Comparisons of pre-season forecasts and post-season estimates of AABM abundance ${ }^{1}$

The PSC model's pre-season forecasts of abundance in each of the three AABM areas can be evaluated by comparing them with the post-season abundance estimates in those same areas. However, both of these values are estimates from the PSC model. There is no independent estimate of actual abundances of Chinook in the AABMs. Thus, there is no way to calculate the bias and precision of the PSC model because there is no reliable way to estimate actual abundance of Chinook in the AABMs. This situation contrasts with approaches to evaluating stock-specific agency forecasting methods, in which catches and escapements can be summed to estimate actual returning abundances to compare with agency forecasts.

1. The magnitude of annual differences between the PSC model's pre- and post-season estimates of abundance in each of the three AABM areas have generally been less than $25 \%$ of the post-season estimates, but those deviations can represent hundreds of thousands of fish.
2. From about 2005 through 2011, forecasts tended to be greater than post-season estimates. For 2012 through 2015, forecasts in two years were overestimates and two were underestimates.
3. Large deviations between pre-and post-season abundance estimates from 2012 through 2015. Those deviations were highly positively correlated across the three AABM areas. That is, overestimates in Southeast Alaska occurred in years when overestimates occurred in Northern B.C. and the West Coast of Vancouver Island, and the same with underestimates.
4. Causes of the recent large discrepancies between the pre- and post-season Als are unclear. However, the strong positive correlation in discrepancies across AABMs areas, along with other evidence, suggests that both the PSC model and the agencies' stockspecific forecasting methods do not properly represent changes in key factors such as time-varying maturation rates, marine survival rates, or exploitation rates.
5. Forecasts of Chinook Salmon obtained from the PSC model after the Agency forecasts were incorporated were relatively unbiased when measured by mean percent error (MPE) for four of the five stocks in this review. The forecast for the West Coast Vancouver Island stock was biased low (MPE=-17\%) but not as biased as the Agency forecast (MPE=-30\%).
[^0]The precision of the forecasts (MAPE) for the five stocks from the PSC model after the Agency forecasts were incorporated was comparable to that obtained from the Agency forecasts.

## Strengths

$\checkmark$ Combines stock-specific forecasts along with other data to produce forecasts of abundance of Chinook in the three AABMs. Those forecasts, which are in units relative to the base-period abundances (1979-1982) help determine maximum catches in AABMs based on the fishery control rules established by the Treaty.
$\checkmark$ Extends terminal forecasts developed by the agencies to pre-fishery ocean abundance for application to AABM fisheries in Alaska and British Columbia.
$\checkmark$ Calibration procedure incorporates current data into the forecasting method.
$\checkmark$ Provides means of forecasting index and other stock abundances and returns to terminal fisheries.

## Issues

VII. Incomplete and out-of-date documentation of the current PSC Chinook model and its calibration and projection procedures (1) threatens loss of institutional knowledge as key staff move on, (2) increases challenges to new CTC members who want to understand the model and its procedures, and in the worst case, (3) increases the chance of errors in the model's application and interpretation.
VIII. The deterministic nature of the PSC model and paucity of routine sensitivity analyses do not provide information about uncertainties in the model's forecasts of abundance in the three AABMs and terminal areas, thereby hampering well-informed decision making by PSC Commissioners and fishery managers in AABM areas.
IX. The PSC model's structure, parameterization, and calibration are complex and subject to substantial structural and parameter uncertainties.
X. Limitations of data and uncertainties associated with stock assessments and forecasting models challenge effective implementation of abundance-based management of Chinook under the Pacific Salmon Treaty.

## Suggestions for Improvement: Conclusions \& Recommendations

G. Comprehensive up-to-date documentation of the PSC Chinook model in a single, central location is necessary to support its effective and credible use and improvement. A succession plan for training new model users is also critical.

1. Additional evaluation and documentation are needed of the PSC model's methods for dealing with stocks for which age-composition data and/or forecasts of terminal abundance or escapement are not available, given the large relative abundance of those stocks in some AABM areas. [See Recommendation 35 (Intermediate-term)]
2. The calibration procedure for the PSC model should be standardized and thoroughly documented to such an extent that a new member of the Analytical Working Group could repeat previous example analyses and come to the same stopping point about which calibration is deemed "final". [See Recommendation 39 (Intermediate-term)]
H. Point estimates of forecasts of abundance indices in the three AABM areas from the PSC model should be accompanied by descriptions of uncertainties in those forecasts. Uncertainties can be derived from extensive sensitivity analyses of effects of different assumptions and input parameters. Expression of uncertainty in these forecasts is essential for determining the confidence to be placed in them and allowing for appropriate consideration by fishery managers.
3. A series of projection runs should be conducted with the PSC model to produce a range of Als for each AABM area. These Als would reflect the different agencies' stock-specific model-ranking criteria that are deemed relevant to AABM management objectives. The set of projection runs will be reduced once the agencies clearly understand the AABM management objectives [See Recommendation 23 (Intermediate-term)].
4. Uncertainty in estimates from the PSC Chinook model should be explicitly represented either by making the model stochastic or running it across numerous sets of assumptions using sensitivity analyses. [See Recommendation 29 (Longterm)]
I. Substantial revision, testing, or possibly even replacement of the existing PSC Chinook model is necessary to effectively serve continuing needs, including the need for statements of uncertainty in the model's forecasts. A subgroup of CTC members should be created to explore such revisions and new models.
5. Functionality of the PSC Chinook model might be enhanced by including, where appropriate, nonlinear relationships such as those found in many other fisheries models, including the effect of fishing on reducing the fish abundance available to subsequent fisheries during a given year. [See Recommendation 24 (Intermediateterm)]
6. Effects of changes in marine spatial distribution of Chinook stocks on functionality of the PSC Chinook model need to be evaluated. [See Recommendation 25 (Intermediate-term)]
7. Sensitivity analyses with the PSC model should be used to explore different assumptions about (1) age structure for stocks without historical age composition data, (2) body-size structure used in the current method for estimating PNV, and (3) alternative structural formulations of the PSC model to calculate changes in age at maturity as a function of changes in body-size distributions. Some of those analyses could also assume various correlations with age-at-maturity schedules of other stocks. [See Recommendation 26 (Intermediate-term)]
8. The differences between pre-season and post-season abundance indices in each of the three AABMs might be reduced by including in the PSC model tendencies for multiple stocks to have positively correlated time series in productivities. [See Recommendation 27 (Long-term)]
9. The PSC model might be improved if factors such as EV and RT were calculated as functions of other variables. [See Recommendation 28 (Long-term)]
10. Ideally, the existing PSC Chinook model and/or its procedures should either be tested and refined or an entirely new model (or models) should be developed. [See Recommendation 30 (Long-term)]
11. Testing of the PSC model (and all other contemplated models) should be a high priority when the Data Generating Model is released. [See Recommendation 31 (Intermediate-term)]
12. Evaluations of the PSC model should include: (1) a check whether there is confounding of parameter estimates in the stage 1 calibration; (2) a series of sensitivity analyses/calibrations exploring alternative values for assumed agespecific natural mortality rates that might affect all other subsequent calculations and forecasts of abundance, and (3) consideration of whether the PSC model is being over-fit. [ See Recommendation 32 (Near-term)]
13. Documentation should be provided regarding the basis of estimates of Ricker stockrecruitment parameters, as well as uncertainty in those estimates. Also, some improvement in performance of the PSC model might be obtained if the Analytical Working Group (AWG) used a Kalman filter that allows for a time-varying maximum productivity parameter in a given stock's Ricker stock-recruitment model. That Kalman filter procedure will explicitly take into account observation error as well as natural variation. [See Recommendation 33 (Intermediate-term)]
14. Given the large number of input parameters, all possible combinations of low, medium, and high values for each parameter may be impossibly time consuming. However, only a subset of those combinations would be needed to produce a range of forecast abundances. [See Recommendation 34 (Intermediate-term)]
15. The Panel generally recommends use of stock-specific forecasts provided by agencies rather than forecasts derived solely from the PSC model in the absence of clear evidence of improvements in accuracy and precision across multiple years for PSC model forecasts. [See Recommendation 36 (Near-term)]
J. Alternative forecasting frameworks, as well as ways of using forecasts of abundance, should be considered for Chinook if current information and resources are not sufficient to effectively conduct adequate analyses and implement provisions of the current Treaty. Those provisions may need to be changed during current negotiations.
16. Considerations of outcome uncertainty (deviation between desired and realized outcomes such as catches), as well as uncertainties in forecasts, will influence expectations of managers of these AABM fisheries when they choose annual fishing regulations. [See Recommendation 37 (Long-term)]
17. The PSC Chinook model should take into account outcome uncertainty when making forecasts and presenting uncertainties in them. [See Recommendation 38 (Longterm)]
18. The abundance forecasts for AABMs areas produced by the PSC Chinook model should convey to managers the net effect of all of the major uncertainties described previously -- structural uncertainty, parametric uncertainty, uncertainty about management objectives, and outcome uncertainty. [See Recommendation 40 (Longterm)]

## 2 Introduction

Chinook Salmon harvests in Pacific Salmon Treaty (PST) areas of Southeast Alaska and British Columbia are managed under an Aggregate Abundance Based Management (AABM) framework. AABM fisheries include southeast Alaska troll, net, and sport; northern British Columbia troll and sport; and West Coast Vancouver Island troll and sport. Annual maximum allowable landed catches in these three AABM fisheries are established based on an aggregate stock abundance index (AI) of contributing stocks to each AABM area. These Als are calculated prior to each fishing season by the Chinook Technical Committee (CTC) using the Pacific Salmon Commission's (PSC's) Chinook model (henceforth "PSC model" or "CTC model"), based in part on stock-specific run forecasts derived by regional fishery management agencies and in part on numerous other sources of input data. ${ }^{2}$

For each AABM area, the Treaty identifies an abundance-based harvest control rule that allows for higher catches at greater aggregate abundances (Table 1 in Chapter 3 of the Treaty). There are several different Al tiers per fishery where the percentage harvest rate steps up to a higher level. Thus, higher abundance forecasts allow for higher harvests because more fish are available to the fishery, and above certain levels, the available fish are harvested at greater rates. Conversely, lower abundance forecasts require lower exploitation and produce lower harvests. There are also provisions in the Treaty that reduce AI catch levels when selected stock and stock aggregates are below conservation objectives recognized by the PSC.

During the recent period of widely variable Chinook abundance throughout the north-eastern Pacific, differences between pre-season (i.e., pre-fishery) abundance estimates in the AABMs and their respective post-season abundance estimates have increased considerably. Relatively large deviations have also been observed for specific stocks between recent pre-season forecasts of terminal run sizes (or escapement) and post-season estimates. Thus, various concerns have been raised about pre-season forecasts provided by agencies as input to the annual calibration procedure of the PSC coast-wide Chinook model (CTC model). To address these concerns, the PSC approved a process and timeline for an independent technical review of "... three methods for predicting stock abundance (agency forecast, CTC model calibration from agency forecast, and CTC model forecast absent agency forecast)". An Independent Technical Panel ("the Panel") was established to do this review.

For agency forecasts, the Panel was asked to focus on five Chinook stocks that have substantial abundance in AABM areas and/or have had recent forecasting performance issues:

- Columbia River Upriver Brights,

[^1]- Columbia River Summers,
- Spring Creek (Columbia River),
- Northern Oregon Coastal Fall, and
- West Coast Vancouver Island.

Objectives of the review include, but are not limited to:

1) Evaluate the bias and precision of alternative methods for predicting the pre- and postseason abundance (Abundance Index, AI);
2) Provide advice on the strengths and weaknesses of each method; and
3) Suggest improvements to current agency pre-season forecast methods for predicting stock abundance.

Additional details regarding this review's objectives and process may be found in the PSC's executive summary of the "Terms of Reference" (see Appendix A).

## 3 The Panel's Process

After approval of this process by the Pacific Salmon Commission, an independent panel of scientists was appointed from nominations by the respective delegations. The Panel consisted of three members, one proposed by Canada (Randall Peterman) and two by the U.S. Section (Brian Bue and Ray Beamesderfer). Brief biographies of Panel members may be found in Appendix B. The PSC Secretariat also alerted agencies affected by the review process and requested that pertinent information be provided to the Panel for review.

An information-gathering workshop was held by the Panel, CTC, and Agency representatives on 10-11 August 2016 at the Columbia River Inter-Tribal Fish Commission in Portland, Oregon (see Appendix C for details of workshop agenda, participants, and PowerPoint presentations). Participants included people directly responsible for the selected agency forecasts and for forecasts from the PSC Chinook model. At the workshop, agency staff provided technical/analytical presentations about the domestic agency forecasts and annual run reconstruction methods. Presentations were also made about the PSC Chinook model in order to familiarize the Panel members with its structure and calibration procedures for incorporating the agency-provided forecasts, as well as other data, including where no agency forecast was available, and forecasting pre-fishery abundances for allocation to mixed-stock ocean fisheries.

The workshop was facilitated by the Panel and encouraged discussions regarding:

- Problems or issues affecting bias, precision, or use of Chinook abundance forecasts, and
- Central issues or improvements in forecasting methods identified by workshop participants for consideration by the Panel with respect to both stock-specific forecasts and the PSC Chinook model's forecasts (see Tables 2, 3, and 4 in Appendix C).

Following the workshop, the Panel reviewed large volumes of information related to Chinook forecasting methods and results. Extensive follow-up was conducted by the Panel with forecasters and modelers by e-mail and phone to obtain additional information and explanations. The Panel conferred frequently by conference calls and e-mail to discuss information, identify key and issues, draw conclusions, and develop recommendations. All conclusions and recommendations in this report represent the consensus of the Panel members.

A draft report was provided to the PSC on September 15, 2016 and distributed to participating agencies for review and comment. Review comments were provided by the agencies with a deadline for receipt of October 1, 2016. Randall Peterman presented preliminary findings to the PSC on October 6, 2016. The PSC also provided additional suggestions on October 24, 2016 regarding the structure of the final report, particularly in the executive summary. The Panel subsequently revised the draft report to address comments and suggestions by the reviewers.

Descriptions of general issues and conclusions regarding forecasting methods are found in Section 6 of this report. More detailed recommendations are found in Section 7 for forecasting models used by Agencies for the five stocks reviewed and in Section 8 for the PSC Chinook model.

## 4 BACKGROUND

This section summarizes Portland workshop's presentations regarding the methods used for making agencies' stock-specific forecasts and PSC model forecasts. The Panel was asked to describe these methods in this report. Thumbnails of PowerPoint presentations from the workshop may be found in Appendix C. The summaries below include some quotes or paraphrases of those slides plus related points from reports or other material provided to the Panel. More detailed descriptions and the Panel's analyses appear in sections 7 and 8.

### 4.1 Pacific Salmon Treaty and Fisheries

Gayle Brown (CDFO) provided a brief history of the Chinook management framework under the Pacific Salmon Treaty and the key tool supporting this framework - the PSC Coast-Wide Chinook Model (the PSC model, also called the CTC model).

The 1985 US-Canada Pacific Salmon Treaty addresses all species of Pacific salmon and fisheries from Cape Falcon, Oregon to Cape Suckling, Alaska. Chinook stocks were generally believed to be depressed coast-wide by the late 1970s and early 1980s. The Treaty was a recognition that a Chinook rebuilding program was required. A rebuilding assessment tool was needed as well.

A Chinook Technical Team (CTC) was appointed under the PST. This team reports to the PSC and includes tribal and agency representatives from Alaska, British Columbia, Washington and

Oregon. Responsibilities include production of extensive yearly reports on Chinook catches and escapements, coded wire tags (CWT), exploitation rate analysis (ERA), and PSC Chinook Model calibrations. Other analyses and reports are also prepared at the request of PSC Commissioners. The Analytical Work Group (AWG), a subgroup of the CTC, produces annual ERA reports and conducts the PSC Chinook Model calibrations and projections of abundance.

The PSC Chinook Model is a cohort analysis model used for assessment. The first version was developed in 1983 with one stock. The model was transferred to BASIC computer code in 1984 and was subsequently ported into newer versions of BASIC code over the years, including the most recent Visual Basic version. In 1985, it was expanded to five stocks and ten fisheries, and those numbers have periodically increased over the years. In 2010, the model was expanded to include 30 stocks and 25 fisheries. Current plans are to expand the PSC model to 40 stocks and 48 fisheries in the future. Initially, the model was used for evaluation of management strategies (catch ceilings, harvest rates, etc.) as the basis for a 15 -year rebuilding program. Since 1999, the model has been used as a management tool by providing forecasts of Chinook abundance for the three AABMs, as described in the Introduction.

### 4.2 Pacific Salmon Commission's Chinook Model

John Carlile (ADFG) and Antonio Velez-Espino (CDFO) described the PSC Chinook model in greater detail. The model is deterministic with annual time periods. All fisheries act on a single pool of fish (no explicit migration occurs among fisheries). Data are incorporated from CWTbased cohort analyses, as are historical data on catch and terminal run/escapement. Abundance is scaled to exploitation rates from a base period (1979-1982).

The model assumes that the ocean distributions of individual stocks are the same as those experienced during the model base period, i.e., static. Hatchery indicator stocks are treated as surrogates for wild stocks in the same geographic area with similar life histories (i.e., age structure, maturation rate, ocean distribution). All stocks of a given age have the same size distribution in a given fishery.

The Pacific Salmon Treaty dictates that management of Chinook fisheries in the three AABM areas is tied to pre-season estimates of abundance indices produced by the PSC Chinook model, so there has been a reluctance to modify or replace that model.

Inputs to the PSC model come from 11 input files that include base-period CWT data, fishery catch data, Chinook non-retention data, past escapement and/or terminal run data, terminal run/escapement forecasts, fishery policy (FP)-exploitation-rate scalars, maturation rate and adult equivalent data, hatchery enhancement data, spawner-recruit parameters, changes in proportion of fish not vulnerable to fishing gear (PNV), and inter-dam loss factors.

Calculations include two calibrations followed by a projection run to generate abundance forecasts for the three AABMs. A CWT Recovery Program summarizes base-period CWT data by
stock. A Base Calibration Program consisting of a backward cohort analysis computes baseperiod exploitation rates, initial cohort abundances, and spawner-recruit parameters. The PSC Chinook model then runs a forward cohort analysis that fits to catches, escapement, terminal runs, agency forecasts, and other data.

Exploitation-rate scalars (FP) account for changes in time and area openings and changes in size limits that have occurred after the base period, 1979-1982. Between 1986 and 1998, 17 of the 25 PSC fisheries had catch ceilings. The RT scalar is used by the Chinook Model to adjust the legal catch to match the observed catch under ceiling management. Thus, stage-1 calibration estimates the RT scalars for ceiling fisheries in order to reproduce the observed ceiling catches. Stage-2 calibration fine tunes the EV scalar estimates that adjust the base-period smolt-to-age 1 survival rates such that the observed escapements and terminal runs are reproduced by the model. The projection run then produces the pre-season estimates of cohort abundance indices for each AABM.

The model calculates the terminal runs (cohort size minus ocean harvest), escapement (terminal run minus terminal harvest), and age 1 cohorts for the next year (from escapement fed into a spawner-recruit function). A starting cohort size is supplied for the first year only, along with average natural mortality rates, average base-period harvest rates, average maturity rates, and average spawner-recruit parameters. Inputs also include observed catches, escapements, and terminal runs. The model loops through all years in the database starting in 1979, estimating the cohort abundances up to the current year.

EV factors scale the number of recruits produced by the stock-specific spawner-recruit parameters to match supplied escapement/terminal run values. EV factors are stock- and brood-year specific, so abundance by age is used in the model. Age compositions are either fed into the model from observed data or generated based on maturity rates from the base period, 1979-1982. Stage-2 calibration generates the EVs that are to be used for the 1-year-ahead projection run, which produces the forecasts of abundance. EVs for different stocks are interrelated (i.e., each iteration of the calibration will potentially change the EVs for all stocks and brood years). If the spawner-recruit parameters are appropriate for a stock, then the EVs can be thought of as survival scalars. If they are not appropriate, then the EVs can be thought of as survival scalars combined with other factors that are assumed constant in the model but that in fact vary in nature.

Agency forecasts for specific stocks are used as inputs to the PSC model's calculation of annual abundance indices for the three AABMs prior to the next fishing season. These stock-specific agency forecasts have generally been used in annual calibrations of the PSC model without being scrutinized by the CTC. Model inputs for the 2016 forecasts include 28 stock-specific sets of time series data, 9 for escapement and 19 for terminal run. All input time series include observed (actual) data starting in 1979. Of the 28 stocks' input time series, 22 include agencyderived forecasts of abundance for that stock, 16 include historical age-composition data, but
only 12 stocks have age-specific forecasts of abundance. Agency forecasts are prepared using the wide range of methods as described later. Model stocks range from individual stocks (Nooksack Springs) to large aggregates of many stocks (Fraser Early). Aggregates are usually mixtures of natural spawning stocks and hatchery stocks. Forecasts are needed in March by the PSC modelers when data from the previous year may not be available because of delays in processing coded-wire tags, but regardless, stock-specific forecasts are produced.

The PSC Chinook model generates stock-specific forecasts of the terminal run (or escapement, depending on the stock) regardless of whether an agency forecast is provided. Where no agency forecast is available, the PSC model's forecast is produced using recent averages of EV, along with many other assumptions. The model calibrates (fits) to the total brood-year terminal run/escapement, but uncertainties exist in estimates of age composition (maturation rate), exploitation rate, etc., especially in stocks for which only total abundance (no age structure data) is provided as input to the PSC model.

Effects of stock forecasts on AABM fishery Als are related to the proportion of total abundance in a given AABM area that each stock represents, with major contributors having more influence on the AI. Such effects also depend on the magnitude of differences in pre-fishery cohort sizes among stocks, which are in turn affected by the PSC model's stock-specific EVs produced with and without agency forecast data. Accuracy (and age composition) of agency forecasts for all stocks have an effect on Als, in part through their influence on estimates of recent EVs. Interactions with other input data and assumptions (e.g., FPs, maturation rates, etc.) also have an effect on Als.

Outputs from the PSC model include (1) catches by fishery, stock, and age, (2) incidental mortalities by fishery, stock, and age, (3) fishery-specific stock composition estimates, (4) exploitation rates by fishery, stock, and age, (5) terminal runs/escapements by stock and age (original intent of the model), and (6) abundance indices (Als) for the Southeast Alaska, Northern British Columbia, and West Coast of Vancouver Island AABMs (current focus of the model). The area-specific abundance index, AI, is calculated as a ratio -- the model's forecasted catch in each fishery (assuming 1979-82 base-period exploitation rates and current-year abundances) divided by the catch under base-period exploitation rates and base-period abundances.

The pre-2013 PSC model applied long-term average maturation rates to recent incomplete broods when calculating Als. However, it was discovered that a number of stocks were maturing at younger ages than in the past (CTC 2016a). Such younger fish are in reality less vulnerable to fishing gear than older fish, but the model was assuming an unchanged, more vulnerable historical older-aged structure. Hence, because Als are calculated for vulnerable cohorts, the PSC model's estimated abundance was too high for affected stocks. A fix was implemented in the 2013 model calibration by replacing long-term average maturation rates with the recent 5-year-average. In 2016, the average maturation rate that had been applied to
incomplete cohorts was re-examined again, and it was found that the recent 9-year average performed better than the 5-year average.

This 2013 change in assumed maturation rates coincided with an end to the chronic overprediction of the pre-season Als, but it is still too early to determine whether the source of that bias has been removed. In 2013 and 2015, pre-season forecasts of Als underestimated postseason Als in all three AABMs, and in contrast, 2012 and 2014 pre-season forecasts of Als were too high (Figure 1).

Causes of the recent large discrepancies between the pre- and post-season Als are unclear. It is unknown how much is due to inaccurate terminal run/escapement forecasts provided by the agencies, as opposed to other sources. As a result of these questions, no CTC consensus was reached on 2015 or 2016 Model calibrations - instead, decisions were settled by the Commission. These concerns led to establishment of this review process.

There is another key point about the deviations between pre- and post-season Als in Figure 1. A previous CTC analysis investigated the association between annual discrepancies in agencies' forecasts and the PSC model's deviations between pre- and post-season estimates in the Als for the AABMs (CTC 2014). The combined error of stocks with the largest contributions (>5\%) to AABM-specific Als is highly positively correlated with errors in PSC model's forecasts of Als in the SEAK, NBC, and WCVI AABMs ( $r^{2}=0.7,0.6$, and 0.55 , respectively) ( $p .126$ of CTC 2014). Of course, this is just a correlation and does not necessarily reflect a causal relationship between agency and PSC model forecasting discrepancies. Another possible reason for the high correlation (not mentioned by the CTC) is that both types of forecasting methods do not properly represent changes in key factors such as time-varying maturation rates, marine survival rates, or exploitation rates, thereby producing similar errors in particular years.

Some support for the latter interpretation is provided by the high positive correlation across the three AABM areas in their annual deviations between pre-and post-season abundance estimates, starting in 2012 (Figure 1). The stock composition differs considerably across the three AABMs, so it is unlikely that errors in stock-specific forecasts would explain that positive correlation in AI discrepancies across AABMs. A more likely explanation is that there have been major changes in large-spatial-scale factors such as maturation rates (which reflect growth rates) or marine survival rates that neither the regional forecasting models nor the PSC Chinook model have fully accounted for. The implication is that both of these types of models should be improved by explicitly estimating and using these time-varying parameters in their forecasting.

The presenters at the Portland workshop identified some alternatives to the PSC Chinook model. A model using continuous catch equations was proposed in 2004 by Gary Morishima and Din-Geng Chen, funded by the US LOA (Letter of Agreement). This model could potentially better account for interactions between fisheries, make temporal stratification of fisheries easier, and provide more information on the variability of stock distributions. However, we
were told that the disadvantage of this model is that estimates of effort would be needed for each fishery, and that those estimates are not readily available for some fisheries. Another alternative model is a catch-at-age model proposed in 2004 by Rishi Sharma and Henry Yuen, but it was never followed up.



Figure 1. Deviations between pre- and post-season Chinook Salmon abundance indices, ([pre-season forecast - post-season]/post-season)*100, derived from the PSC model for the three AABM fisheries (CTC 2016b). A positive deviation means the pre-season forecast was too high.

A Data Generation Model (DGM) is currently being developed that will allow sample datasets to be generated, which will allow for comparison of output statistics from different forecasting models against known parameters (cohort sizes, exploitation rates, etc.).

### 4.3 West Coast Vancouver Island Forecast

Diana Dobson (CDFO) reported that the WCVI terminal run forecast includes Chinook from three major hatcheries and 18 index stocks, many of which are enhanced. This terminal index likely accounts for greater than $95 \%$ of annual WCVI Chinook production, which averages about 150,000 fish (range 40,000 to 300,000 ) (Figure 2). The average terminal age composition is $30 \%$ age $3 \mathrm{~s}, 50 \%$ age 4 s , and $20 \%$ age 5 s . Substantial harvest of WCVI Chinook occurs in AABM fisheries of Southeast Alaska and Northern British Columbia, as well as in terminal fisheries of WCVI (Figure 3).

The forecasting method for WCVI is a complex, multi-stage process. It begins with linear "sibling" regression models (abundances are on the arithmetic scale, not logged) to predict the production (abundance) of older age classes from the observed production of younger age classes from the same brood year. Regressions are developed for CWT-associated production from the Robertson Creek Hatchery ( RCH ) Indicator Stock, which is then expanded to the entire Somass/RCH system. The terminal return of Somass/RCH is then predicted after applying assumptions about pre-terminal fishing mortality, stock composition in pre-terminal fisheries, and maturation rates. The forecast terminal return of Somass/RCH is then expanded for the WCVI index systems.

More specifically, for the Robertson Creek Hatchery (RCH) CWT Indicator Stock, simple linear sibling regressions are developed from production data generated by a cohort analysis, which is based on its own assumed natural morality and maturation rates. Two sibling regressions are computed, as described in more detail in section 7. Model Prod2 uses total terminal return at a younger age class (independent variable) to predict the dependent variable, total production (the surviving cohort in the ocean, i.e., ocean fishing mortality plus terminal run) of a subsequent age or ages from the same brood year. In contrast, Model Prod3 uses estimated total production (total fishing mortality plus escapement) of a younger age class(es) to predict total production of subsequent ages from the same brood year (again, the surviving cohort in the ocean). The forecast for the CWT-associated production for Robertson Creek Hatchery is then expanded for the entire Somass/RCH system based on ratios of earlier returns from the brood year. After the Somass/RCH production for each brood year is forecast, some assumptions are then applied to predict the terminal run size of Somass/RCH Chinook. Those assumptions include an assumed pre-terminal fishing mortality, pre-terminal fishery stock composition, and maturity rate. The latter two are generated by the cohort analysis.


Figure 2. Index of terminal abundance for West Coast Vancouver Island Chinook Salmon (Diana Dobson, CDFO, workshop presentation).


Figure 3. Distribution of West Coast Vancouver Island Chinook Salmon mortalities among fisheries and escapement, 1999-2013 (CTC 2015b).

Pre-terminal fishery mortality needs to be predicted for each age class/brood year. There is some uncertainty as to the correct assumption for WCVI forecasts to be used for PSC model calibration purposes. Is it the pre-terminal fishery mortality that was exerted during the base period, or is it the expected pre-terminal fishery mortality given current fishing regimes? In recent years, both options have been presented, although the latter has been used as the input of WCVI terminal run to the PSC model for its calibration.

The Somass/RCH terminal forecast was expanded for the WCVI index stocks with a similar method to that used for the expansion from RCH CWT production to Somass/RCH total production. In recent years, the Somass/RCH terminal forecast has also been expanded for the WCVI index stocks by adding terminal forecasts that are generated separately for Conuma hatchery and Nitinat hatchery returns and the 18 other index stocks combined. The forecasts generated for those other stocks use information from the RCH CWT cohort analysis (i.e., estimated brood-year survival rate) and similar pre-terminal fishery assumptions, but are modified with stock-specific production and age data.

All years of RCH CWT cohort data are incorporated in the sibling regressions that form the basis of the WCVI forecast (brood year 1983 and onward). Similarly, the WCVI terminal run index has been reconstructed from return year 1979 onward. All data are incorporated into the forecast and analysis. The more challenging issues relate to the varying quality of available assessment data across WCVI systems. There is a general paucity of data for WCVI stocks other than the RCH CWT indicator stock and, in some WCVI areas, few sample data from fisheries. There are low recovery rates for age 2 fish from which age- 3 of the same brood are estimated, and there is a known bias in CWT-recovery data where individual stocks do not comprise a substantial percentage of the catch. A key assumption for WCVI forecasting is that the RCH hatchery indicator stock has similar survival rates, maturation rates, spatial distribution, and exploitation pattern to those of wild WCVI stocks.

In recent years forecasts of WCVI terminal run abundance have consistently underestimated actual values calculated after the fishing season by the PSC Chinook model (see section 7).

Suggestions for improvement in forecasts by Diana Dobson included:

- Resolve what input is required for calibration purposes - build a common understanding.
- Succession and documentation requirement for the process in general misunderstanding or miscommunication of objectives and/or structural modifications could be a source of error.
- Age 3 forecast - a clear structural issue, also an input problem (age 2 data), and also likely related to changing maturation rate - could explore 'leading indicators' as an alternative method for Age 3 forecasting.
- Input data; not all available information is being used (e.g., available mark data and technology such as DNA, otolith marks, etc.)
- Incorporation of uncertainty - not just adding uncertainties to reports of input forecasts, but incorporating them into the entire management and assessment framework for Chinook.
- Simplification of the assessment and management framework - currently data intensive, assumption laden, and staff-limited.
- Separation of hatchery from wild abundance in the Als.


### 4.4 Columbia River Upriver Bright Forecast

Jeff Whisler (ODFW) and Steve Haeseker (USFWS) reported that most upriver bright (URB) fall Chinook Salmon are naturally-produced and destined for the Hanford Reach area of the Columbia River. This stock also returns to the Priest Rapids Hatchery, areas upstream of Priest Rapids Dam, the Snake River, the Deschutes River, and the Yakima River. During 1980-2015, the mean return to the Columbia River was 246,300 . Although there is year-to-year variability, on average $25 \%$ of fish return at age $2,20 \%$ at age $3,37 \%$ at age $4,17 \%$ at age 5 , and $1 \%$ at age 6 (Jeff Whisler, ODFW, personal communication).

CTC reports of the PSC Chinook model outputs estimate the spatial distribution of harvest of this stock. Substantial harvest occurs in the AABM fisheries of Southeast Alaska and Northern British Columbia, as well as terminal fisheries of the Columbia River (Figure 4).


Figure 4. Distribution of Columbia Upriver Bright Chinook Salmon mortalities among fisheries and escapement, 1999-2013 (CTC 2015b).

Annual forecasts of Columbia River upriver bright fall Chinook returns are produced by an expert panel that includes members from WDFW and the U.S. v. Oregon Technical Advisory Committee (TAC). The quality of the data on total returns to the Columbia River and the agecomposition of those returns is relatively high due to extensive sampling of Columbia River fisheries and recoveries of coded-wire tags (CWT). The primary forecasting methods are arithmetic-scale sibling regressions and average cohort ratios (e.g., the average ratio of age- 3 to age-4 returns from the same brood year). When sibling regressions are explored with input data from different periods, the $r^{2}$ value is used to select the best model (Table 1 of WDFW 2016). The approach used to produce forecasts for Columbia River fall Chinook stocks is a modified Delphi method (i.e., open discussion among the expert panel). Output of a suite of stock- and age-specific models is presented to the panel and the merits of each are discussed before the panel comes to consensus. In the past few years, when returns have been setting modern-day record highs, the panel has relied on cohort ratios when regression inputs have been outside the range of the dataset.

In his workshop presentation, Steve Haeseker of the USFWS reported that natural variability in age composition makes forecasting of upriver brights difficult, but recent forecasts have been relatively precise and unbiased. For 1980-2015, mean percent error (MPE, a measure of longterm statistical bias) was $-5 \%$ and mean absolute percent error (MAPE, a measure of precision) was $20 \%$ (Figure 5). However, substantial under- or over-estimates (up to about $\pm 50 \%$ ) of forecasted abundance have occurred occasionally since 2001.

Figure 6 provides an example of a sibling relation showing (1) the typical very large 95\% prediction interval, which illustrates the wide range across which age-3 abundances are likely to occur (with a probability of $95 \%$ ) for a given age-2 abundance from the same brood-year cohort, and (2) the effect of between-year changes in maturity rate and/or survival rates. Both issues create large challenges for forecasting.



Figure 5. For return years 1980-2015, post-season estimates of abundance (thousands, black dots) and pre-season forecasts (yellow squares) (top panel), and percent error, ([forecast actual]/actual) *100, between the pre-season forecasts and post-season abundance estimates for Columbia River mouth returns of Columbia Upriver Bright Chinook Salmon (Steve Haeseker, workshop presentation). Positive errors mean the forecast was higher than the actual return.


Figure 6. Example of a sibling relationship for Columbia River upriver bright Chinook abundances (in thousands), brood years 1962-2012, showing the 95\% prediction interval (Steve Haeseker, workshop presentation). Years with extremely high age-2 abundances have yellow dots.

### 4.5 Columbia River Spring Creek Hatchery Forecast

Steve Haeseker (USFWS) reported that this stock is produced by the U.S. Fish and Wildlife Service's Spring Creek National Fish Hatchery (NFH), located 35 km upriver of Bonneville Dam. The hatchery currently produces 10.5 million sub-yearling (ocean-type) tule fall Chinook Salmon annually. Tule fall Chinook Salmon are native to this part of the Columbia River and originally spawned in the White Salmon River one mile east of the hatchery. During 1980-2015, the mean return of Spring Creek tule fall Chinook to the Columbia River was 65,700. Although there is year-to-year variability, on average $8 \%$ return at age- $2,60 \%$ at age- $3,30 \%$ at age- 4 , and 2\% at age-5 (Jeff Whisler, ODFW, personal communication).

CTC reports of PSC Chinook model outputs estimate that substantial harvest of this stock occurs in the West Coast Vancouver Island AABM fishery and in ISBM fisheries of the Washington/Oregon Coast to the Columbia River (Figure 7).


Figure 7. Distribution of Columbia River Spring Creek Hatchery Chinook Salmon mortalities among fisheries and escapement, 1999-2013 (CTC 2015b).

Annual forecasts of Columbia River Spring Creek Hatchery fall Chinook returns are produced by an expert panel that includes members from WDFW and the U.S. v. Oregon Technical Advisory Committee (TAC). The quality of the data on total returns to the Columbia River and the agecomposition of those returns is relatively high due to extensive sampling of Columbia River fisheries and recoveries of coded-wire tags (CWT). The forecasting methods for the Spring Creek Hatchery fall Chinook are identical to those reported above for Columbia River upriver bright fall Chinook.

In his workshop presentation, Steve Haeseker of the USFWS reported that natural variability in age composition makes forecasting of this stock difficult, but recent forecasts have been relatively precise and unbiased. For 1980-2015, mean percent error (MPE) was $8 \%$ and mean
absolute percent error (MAPE) was 31\% (Figure 8). Considerable under- or over-estimates (up to about $\pm 60 \%$ ) of forecasted abundance have frequently occurred since the mid-1990s -- more frequently than with the upriver brights described above. Overestimates of abundance were commonly forecasted from 2006-2011, but 2013 was a substantial underestimate.


Figure 8. For return years 1995-2015, post-season estimates of abundance (thousands, black dots) and pre-season forecasts (yellow squares) (top panel), and percent error, ([forecast actual]/actual) *100, between the pre-season forecasts and post-season abundance estimates for Columbia River mouth returns of Columbia River Spring Creek Hatchery Chinook Salmon (Steve Haeseker, workshop presentation). Positive errors mean the forecast was higher than the actual return.

A major contributor to the frequent large forecasting errors for this stock over the last 20+ years is likely the large between-year and decadal-scale changes in age composition (Figure 9). Precision of these forecasts (based largely on sibling relations and cohort ratios) will necessarily be reduced when there are such large changes in proportions of age 4 s and 5 s between years, which create large prediction intervals.


Figure 9. Proportions (Y axis) of different age classes of Columbia River Spring Creek Hatchery Chinook Salmon returning to the Columbia River for brood years 1962-2010 (Steve Haeseker, workshop presentation).

### 4.6 Columbia River Summer Run Forecast

Stuart Ellis (CRITFC) reported that the Upper Columbia River summer stock includes a mix of hatchery and wild fish produced in areas upstream of Priest Rapids Dam and the Yakima River. The recent 10-year average return of this stock to the Columbia River is approximately 71,000 (range 37,000 to 127,000 ). On average $13 \%$ return at age $3,46 \%$ at age $4,38 \%$ at age 5 , and $3 \%$ at age 6 (Jeff Whisler, ODFW, personal communication).

CTC reports of the PSC Chinook model outputs estimate that substantial harvest of this stock occurs in AABMs and ISBMs from Southeast Alaska to the Columbia River (Figure 10).


Figure 10. Distribution of Columbia River summer Chinook Salmon mortalities among fisheries and escapement, 1999-2013 (CTC 2015b).

Annual forecasts of Columbia River summer Chinook returns are produced by the U.S. v. Oregon Technical Advisory Committee (TAC). The quality of the data on total returns to the Columbia River and the age-composition of those returns is relatively high due to extensive sampling of Columbia River fisheries and recoveries of coded-wire tags (CWT). The primary forecasting methods are arithmetic-scale sibling regressions and average cohort ratios (e.g., the average ratio of age- 3 to age- 4 returns from the same brood year). The TAC typically provides point-estimate forecasts based on the age-specific best-performing year ranges of input data identified by consensus.

In his workshop presentation, Stuart Ellis of CRITFC reported that natural variability in age composition makes forecasting of this stock difficult, but recent forecasts have been relatively precise and unbiased. For 2005-2015, mean percent error (MPE) was $5 \%$ and mean absolute percent error (MAPE) was 24\% (Figure 11). The run was forecast too high from 2009-2012 but too low in 2014 and especially 2015.



## Return Year

Figure 11. For return years 2005-2015, post-season estimates of abundance (thousands, black dots) and pre-season forecasts (yellow squares) (top panel), and percent error, ([forecast actual]/actual) *100, between the pre-season forecasts and post-season abundance estimates for Columbia River mouth returns of Upper Columbia summer Chinook Salmon (Stuart Ellis, workshop presentation). Positive errors mean the forecast was higher than the actual return.

### 4.7 Northern Oregon Coast Fall Forecast

Ethan Clemons (ODFW) reported that the Northern Oregon Coast (NOC) "stock" is an aggregate of populations returning to small rivers including the Siuslaw, Alsea, Yaquina, Siletz, Salmon, Nestucca, Tillamook and Nehalem. The total aggregate return has varied from about 40,000 (1970s, 2008) to over 170,000 (1988, early 2000s). Age at maturity is typically 3 to 6 years with a small component of 2-year olds.

CTC reports of the PSC Chinook model outputs estimate that substantial harvest of this stock occurs in AABM fisheries of Southeast Alaska and Northern British Columbia as well as terminal fisheries of the Oregon coast (Figure 12).


Figure 12. Distribution of North Oregon Coast Chinook Salmon mortalities among fisheries and escapement, 1999-2014 (CTC 2015b, Ethan Clemons ODFW unpublished data).

The 2008 PST renegotiation highlighted data limitations for stock forecasting for the NOC aggregate. Forecasts at that time were based on a 3-year average of escapement. Spawner index surveys were being conducted, but age sampling was limited and scales were not read in time for use in forecasting. A precipitous decline in escapement from 2007-2010 drew additional management attention to NOC Chinook by ODFW, which led to a change in agency priorities and rapid turnaround of scale aging data starting in 2008. This allowed forecasting of annual returns based on sibling regressions. Forecasting methods have been refined since 2008 based on each year's forecast performance. Several different sibling-regression relationships have been considered, and no single method has been consistently applied to all stocks in all years. In 2016, ForecastR modules were used. They allowed development of ARIMA models for some stocks in time for use for forecasting input to the PSC model.

Forecasts are for escapement only, not pre-ocean-fishing abundance or terminal returns. Current models assume that all fisheries are going to have the same proportional impact as they have had during the years that were used to generate the sibling relationships and time
series models. It is currently not practical to forecast the varying impact of AABM or terminal fisheries in a usable time frame.

Annual escapement is estimated based on spawning ground surveys. Forecasts are generated for each of seven populations and then aggregated into the NOC stock. Expansions are made for unsurveyed areas assuming a static relationship between surveyed streams and unsurveyed streams/basins (expansion by 17\%). Maturation rates and year-to-year survival rates are assumed to be static. Age-specific sampling is assumed to be unbiased (or corrected for known biases).

In his workshop presentation, Ethan Clemons of ODFW) reported that recent forecasts have been relatively precise and unbiased (Figure 13). However, funding reductions have substantially reduced spawning ground survey effort in recent years, so the current quality of stock assessment will not be sustained.


Figure 13. Spawning escapement and forecast/actual escapement data for Northern Oregon Coast Chinook Salmon (Ethan Clemons, ODFW, workshop presentation).

## 5 CONCEPTUAL FRAMEWORK FOR THE PANEL'S WORK

The Panel conducted its review through the "lens" of a general conceptual framework of sources of uncertainty in forecasting methods. Uncertainty is manifested in both accuracy and precision of forecasts. Here "accuracy" is a measure of how close an estimated value is to the "true" value. If repeated estimates over time are consistently too low or too high, they are statistically biased, or inaccurate. "Precision" describes how similar multiple estimates are to each other, regardless of their bias.

If everything were known perfectly, then there would be no forecasting errors, but of course, that is impossible. Scientists have an incomplete understanding of the dynamics of salmonid population dynamics, ecosystems, and fishing dynamics. The resulting uncertainties are reflected in assumptions and hypotheses embedded in the statistical models of regional forecasting agencies and in the PSC's Chinook model. These uncertainties can be grouped into four categories, (1) unclear management objectives, (2) structural uncertainty, (3) uncertainty in parameters, and (4) outcome uncertainty. We define these categories here and give examples of each in sections 6,7 , and 8 , along with recommendations for how to deal with them.

### 5.1 Unclear Management Objectives

Quantitative fisheries analysts know that in order for their analyses to be directly useful to fisheries managers, the calculated indicators of fish stocks and fisheries should fit into clearly articulated management objectives. To choose an extreme hypothetical example, if managers were most concerned about the chance of low salmon abundance occurring during the next 5 years, then it would be inappropriate for modelers to merely show the long-term average abundance expected over that period. Instead, given that management objective, analysts should calculate indicators of frequency and magnitude of abundances below the managers' undesirable level.

This point seems obvious, but it is surprising how often the uncertainty caused by the lack of clearly stated operational management objectives leads to inappropriate scientific advice and/or confusion on the part of scientists and managers. Participants at the Portland workshop expressed this need for clear management objectives, both for stock-specific forecasts made by agency scientists and for forecasts of abundance in AABMs made by PSC modelers. Only with such clarity will forecasting models produce output that directly meets the needs of decision makers.

### 5.2 Structural Uncertainty

Structural uncertainty refers to the lack of certainty about which equations in a model are correct (i.e., reflect reality). If only one form of an equation in a forecasting model is used to represent a given process (for example, a linear instead of nonlinear sibling relation), then
implicitly the analyst is saying that the probability is 1.0 that the underlying natural process is linear and that the probability is zero that any other shape of function exists. Similarly, the assumption in the PSC model that Chinook stocks have the same oceanic spatial distribution now that they had during the 1979-1982 base period implies that there is zero probability that the distribution has changed. Unfortunately, we may be wrong about these assumptions because we have incomplete knowledge of the real world. If those assumptions are indeed wrong, then the single point estimates of forecasts of Chinook abundance are also likely to be wrong. Such point estimates would therefore not reflect the structural uncertainty in forecasts.

### 5.3 Parametric Uncertainty

Uncertainty in model parameters refers to the lack of certainty about quantitative values such as natural mortality rate between ages, maturation rates, exploitation rates, as well as parameters of spawner-recruit models, sibling relationships, or other equations. Such parameters are estimated through various means, but those estimates are likely to differ from the true underlying values because of natural variability in processes that are not fully described by the equation (e.g., spawner-recruit model) and/or observation error in stock composition, abundance of spawners, and catches. Such errors in parameter values in agency and PSC models will lead to errors in forecasts of abundance. The magnitude of forecasting errors will depend on which parameters are wrong in which equations.

### 5.4 Outcome Uncertainty

Outcome uncertainty is a broad term referring to the deviation between some management target and the actual realized outcome (Holt and Peterman 2006). For instance, it refers to the difference between a maximum allowable catch (e.g., 150,000 fish) and the actual catch (e.g., 200,000 ), or between a target harvest rate of $40 \%$ and the actual outcome of $30 \%$, or between an escapement goal of 50,000 and actual escapement of 40,000. Such deviations can arise from at least five sources: (1) the vulnerability of fish to fishing gear (catchability) differed from the expected level because of unexpected changes such as body size, depth, or horizontal location of the fish, (2) non-compliance by fishing vessels with regulations (sometimes referred to as imperfect control, implementation uncertainty, or implementation error), (3) errors in forecasts of abundance, (4) errors in post-season estimates of abundance or catch, and (5) management regulations that were not the correct ones to meet the objectives, even without the problems of sources (1) and (2). Outcome uncertainty is relevant to agency as well as PSC model forecasts of Chinook abundance because both make pre-season assumptions about exploitation rates in AABM fisheries that won't occur until after the forecasts are made.

### 5.5 Implications and Perspective

These four sources of uncertainty provided a useful way for the Panel to organize its review and to develop recommendations. Explicitly defining the types of forecast uncertainties will pave the way for both identifying measures to reduce them and accurately reflecting them in
forecast estimates. The Panel recognizes that regional agency forecasters, as well as CTC modelers (the Analytical Working Group, or AWG), are very experienced quantitative scientists who are already very well aware of these types of uncertainty. Nevertheless, consideration of these uncertainties are not always clearly articulated in their annual reports. For instance, regional agencies produce annual stock-specific point-estimate forecasts that omit uncertainties, and these are sent to the CTC modelers for input to the PSC model. Similarly, the deterministic PSC model produces point estimates of forecasts for use in Table 1 of Chapter 3 of the Treaty.

The Panel recognizes that forecasting abundances of North Pacific salmon populations is difficult, even with the best of data sets and methods, so we begin by placing the forecasts of Chinook Salmon into a broader context. To our knowledge, no synthesis has been conducted that quantitatively compares management agencies' historical pre-season forecasts with actual returns across all major Pacific salmon species, stocks, and areas. However, an almost equally informative analysis was reported by Haeseker et al. (2008), who compared actual returns across decades with forecasts that would have been made in each historical year if those forecasts had been based on the best of 11 statistical forecasting models for each chum salmon stock and each sockeye salmon stock. We see no inherent reason why Chinook Salmon forecasting should be any better or worse than that for sockeye salmon, which shares with Chinook the tendency to mature at 3 or more ages. Chum salmon are also relevant, but most often chum stocks only have two ages at maturity.

The best or top-ranked model based on MPE (long-term statistical bias) varied considerably among chum and sockeye salmon stocks, ranging from sibling models to naïve averages of recent returns, as it did for MAPE (precision of forecasts) (Haeseker et al. 2008). The top-ranked model for each stock produced an average MPE of 19\% across 40 chum salmon stocks and 27\% across 37 sockeye salmon stocks (Haeseker et al. 2008 and spreadsheet). An MPE of zero is the most desirable value, representing no statistical bias.

The frequency distributions of these stock-specific MPE values for chum salmon and sockeye salmon show that the MPE values for all three Columbia River stocks plus the Northern Oregon Coastal stock are at the low end of the range of MPE values observed in chum and sockeye salmon (Figure 14). Given this perspective, the forecasts for these four stocks are doing well, but there is still some possibility of improvement. In contrast, with an MPE of -26.9\%, the WCVI forecasts fell below the range observed for either chum or sockeye, and below all four other Chinook stocks examined here. Clearly some substantial improvement is needed fro WCVI.

On a related point, we note that the CTC's expectation of MPE of $\pm 7.5 \%$ for forecasts of terminal runs or escapements (CTC 2016b) may be too stringent. The Panel learned that the CTC also sets minimum data-quality standards for escapements and catches, which in principle is fine, but over-emphasis on those standards may be misplaced given the large number of
other sources of uncertainties described in this report that are not taken into account in either the agencies' forecasting models or the PSC model.

For the measure of forecasting precision, MAPE, the top-ranked model for each stock produced an average MAPE of $58 \%$ across 40 chum salmon stocks and $66 \%$ across 37 sockeye salmon stocks (Table 1) (Haeseker et al. 2008 and spreadsheet). The frequency distributions of these stock-specific MAPE values for chum salmon and sockeye salmon show that the MAPE values for all three Columbia River stocks plus the Northern Oregon Coastal stock are at the low end of the ranges observed in those other two species (Figure 15), which again reflects good performance for those models, but with some room for further improvement. The MAPE of $42 \%$ for the WCVI forecast is higher than the other four Chinook stocks examined here but is still well within the range of MAPE values for chum and sockeye salmon.

Table 1. Mean percent error (MPE, bias) and mean absolute percent error (MAPE, precision) for forecasts produced by regional agencies for the five Chinook Salmon stocks considered in this review. Also shown are average MPE and average MAPE values for the best (closest to zero) stock-specific model for each of 40 chum salmon stocks and 37 sockeye salmon stocks (Haeseker et al. 2008). Data cover return years 1999-2015 ${ }^{\text {a }}$ for the five Chinook Salmon stocks and from as far back as 1974 through 1999 return years for the chum salmon and sockeye salmon stock. Mean percent error was calculated by [(forecast-actual postseason)/actual post-season] times 100.

| Stock | Mean Percent <br> Error (MPE) | Mean Absolute <br> Percent Error (MAPE) |
| :--- | :---: | :---: |
| West Coast Vancouver Island Chinook | $-26.9 \%$ | $42.1 \%$ |
| Columbia River Summer Chinook | $9.7 \%$ | $22.2 \%$ |
| Columbia River Spring Creek Fall Chinook | $7.6 \%$ | $31.3 \%$ |
| Columbia River Upriver Bright Chinook | $0.9 \%$ | $25.1 \%$ |
| Northern Oregon Coastal Fall Chinook | $8.4 \%$ | $31.3 \%$ |
| Best stock-specific model for each of 40 chum <br> salmon stocks (Haeseker et al. 2008) | $19 \%$ <br> (median 12\%) | $58 \%$ <br> (median 52\%) |
| Best stock-specific model for each of 37 sockeye <br> salmon stocks (Haeseker et al. 2008) | $27 \%$ <br> (median 15\%) | $66 \%$ <br> (median 57\%) |

a Data for 1999-2013 from CTC (2015b, Appendix J1) and preliminary data for 2014 and 2015 obtained from John Carlile (ADF\&G, personal communication, 9 Sept. 2016)


Figure 14. Frequency distributions of of a measure of bias of forecasts, mean percentage error, MPE, [(forecast-actual post-season)/actual post-season] times 100, for the top-ranked model for each stock across 40 chum salmon stocks (top panel) and 37 sockeye salmon stocks (bottom) (Haeseker et al. 2008). The percentile range for the five Chinook stocks examined in this review are shown by arrows in the top panel. Forecasts that are biased high (overestimates) have positive MPE values.


Figure 15. Frequency distributions of a measure of precision of forecasts, mean absolute percentage error, MAPE, for the top-ranked model for each stock across 40 chum salmon stocks (top panel) and 37 sockeye salmon stocks (bottom) (Haeseker et al. 2008). The percentile range for the five Chinook stocks examined in this review are shown by arrows in the top panel.

## 6 General Issues and Conclusions

The Panel identified several thematic issues that apply to forecasts of abundance of specific Chinook Salmon stocks as well as the use of the PSC model. These general issues and conclusions are important enough to the Treaty process that they warrant emphasis at the start of this report. More detailed recommendations consistent with these conclusions are found in section 7 on agencies' stock-specific forecasts and section 8 on the PSC model's forecasts of abundance in AABM areas.

### 6.1 Documentation of Agency Forecasting Methods and Results

Issue I. Current documentation of agency forecasts of abundance that are sent annually to the CTC does not provide sufficient information for PSC modelers to identify the long-term accuracy and precision of those forecasts, let alone uncertainty about the current year's forecast.

As noted in Issue 1 above, biologists for the five stocks that are included in this Panel review, produce annual forecasts of abundance for their own within-region management advice, as well as for input to the PSC Chinook model for estimating pre-fishing ocean abundance indices in AABMs. Agency forecasts are produced by a variety of methods, depending on the stocks and years, as is described in more detail in sections 4 and 7.

While the PSC modelers cannot currently incorporate information about uncertainties in the agencies' forecasting methods directly into their model, they expressed the desire to consider the accuracy and precision of forecasts provided by the regions when reviewing data inputs to the PSC model. Pertinent information should include not just the point estimates of forecasts, but also details of alternative forecasting models that were considered, the basis for selecting the final forecasting model, its critical assumptions and uncertainties, its long-term accuracy and precision documented via a retrospective analysis (defined in section 6.4), and a measure of uncertainty about the current year's forecast.

The Portland workshop also identified discrepancies between numerical values of certain agency forecasts reported by the CTC and forecasts that were originally submitted to the CTC by agency staff. It is unclear whether this was due to incomplete documentation of updated agency forecasts or other issues. Regardless, such errors can be avoided by agency representatives assuming responsibility for both documenting their submissions and reviewing CTC reports to ensure that their information was applied and reported correctly.

> Conclusion A. More comprehensive documentation is needed by the CTC from regional agency forecasters regarding the agencies' methods, critical assumptions and uncertainties, and accuracy and precision of past stock-specific forecasts. Agencies should also state the uncertainty in each stocks' annual

### 6.2 Requirements for Stock Forecasts as Inputs to the PSC Chinook Model

Issue II. Efforts by agencies to provide forecasts as inputs to the PSC model are hampered by an incomplete understanding of (1) the PSC model's information requirements, (2) how those forecasts are used in that model, and (3) how those uses differ from those of fishery managers within regions.

Annual forecasts of stock-specific abundance are typically generated by staff in fishery agencies for terminal runs or escapements to regional management units (e.g., Columbia River, Northern Oregon Coast, or West Coast Vancouver Island). One purpose of agency forecasts is to plan and configure terminal area fisheries to meet established escapement goals, catch or exploitationrate limits, and allocation objectives in those local areas. In addition, terminal run size/escapement forecasts are also sent through the CTC to PSC Chinook modelers who are tasked with taking those terminal run size/escapement forecasts into account and producing pre-ocean-fishery abundance indices (Als) for use in establishing exploitation rates and corresponding catch limits in the three AABM fisheries. In some cases, forecasts for use within regions for management of domestic fisheries differ from forecasts sent to the CTC for the PSC model, and that difference may be quite appropriate because they are intended to be used for different purposes.

However, it was apparent at the Portland workshop that communication between PSC modelers and regional agency forecasters is often incomplete. PSC modelers have specific requirements for annual forecasts, but they are not formally documented and transmitted to agency forecasters. As well, many agency scientists have a limited understanding of how their forecasts are being used in the PSC model.

Potential points of confusion range from relatively simple questions (whether forecasts should include or exclude jacks) to more complex issues (assumptions of appropriate marine exploitation rates for forecasting terminal returns). The WCVI forecast application in AABM fisheries was a particular concern. For instance, it was unclear for the WCVI forecaster and the CTC modeling group, as well as in the PSC model's documentation, how Fishery Policy (FP) adjustments (i.e., scalars to the exploitation rates) have accounted for the change in magnitude and spatial distribution of fishing effort that has occurred since the 1979-1982 base period. As a result, until recently WCVI forecasts have apparently been generated using base-period exploitation rates, which may have been substantially greater than current fishing rates. If this reduction in recent exploitation rates is indeed correct, then it is no surprise that those forecasts of pre-season abundance that were based on base-period exploitation rates have chronically underestimated WCVI Chinook abundance. In recognition of this problem, starting in 2014, separate WCVI forecasts were also generated with exploitation rate assumptions that
reflect recent fisheries, and both types of WCVI forecasts were sent to the CTC for input to the PSC model.

Annual written requests from the CTC to agency forecasters should identify whether agency forecasts should include jacks or not, what units/currency to use for terminal runs and escapement, and whether to use exploitation rates from recent years or the base period.

Conclusion B. More explicit direction from the Chinook Technical Committee is needed by agency-based stock forecasters regarding the annually requested forecasts.

### 6.3 Limitations of Existing Stock Assessment Data

Issue III. Accuracy and precision of stock forecasts are limited by the available stock assessment data; this is more of a problem for some Chinook stocks than others.

At the workshop, the Panel heard several concerns about the quality of data for escapements, age structure, and harvest, as well as how they were being used. These concerns are not new but are important to highlight in view of the expectations of the Treaty's abundance-based management framework and the corresponding use of abundance indices produced by the PSC Chinook model. Accurate forecasts of abundance are essential for effectively implementing abundance-based management. A high potential for measurement error in data fed into the stock-specific and PSC models substantially reduces the ability to make those forecasts accurate. Another concern is that demands for increasing model specificity (such as the ambitious current plan to expand the PSC's model from 25 to 48 fisheries and from 30 to 40 stocks) may easily surpass the quality of the available data.

Finite resources for stock assessment are always a challenge and contribute to substantial uncertainties associated with forecasts for several stocks. For example, the quality of stock assessments of Northern Oregon Coast Chinook stocks appear to have been substantially upgraded in recent years from historical levels. However, current funding for those assessments is expected to decrease, which may substantially reduce the accuracy and precision of future estimates. West Coast Vancouver Island Chinook assessments are similarly hampered by the need to make significant inferences from very limited data. As the Panel understands it, the latter assessments currently rely on Robertson Creek Hatchery data, which are then expanded to represent other WCVI hatcheries and wild-stock production. Uncertainties in this WCVI process are potentially very significant and may lead to substantial over- or underestimation of stock status, including wild and hatchery abundance.

In addition to specific stock concerns, substantial uncertainty is introduced by more systemic limitations of existing information that are already widely acknowledged by the CTC and agency forecasters. Chief among these is the assumption that exploitation rate and marine survival rate of wild fish are identical to those derived from coded-wire-tagged hatchery Chinook indicator
stocks. The potential for consistent underestimation of stock contributions to catches based on a low incidence of CWT observations in some fisheries must also be acknowledged.

Better data are needed for several stocks to support high expectations for forecast accuracy and precision. Conversely, expectations might need to be scaled down to reflect existing uncertainties.

Conclusion C. Substantial improvements in basic assessments of some Chinook stocks are needed to support current PSC model and management applications, otherwise expectations need to be rescaled/reduced to recognize existing data limitations. Further expansion of the PSC model's number of stocks and fishing areas may need to be postponed until the quality of relevant data is deemed suitable.

### 6.4 Definitions and Best Practices for Agency Stock Assessment and Forecasting

## Issue IV There is substantial differences among regional agencies in how stock forecasts are produced and described.

Stock forecasting methods are tailored to the specifics of the information, past practices, and experience of forecasters in each region. Forecasts rely heavily on sibling relationships and average ratios of successive ages in successive years, and all agencies have explored various years of data sets for estimating parameters. It would be counterproductive to try to impose a single standard of forecasting practices across regions, but a set of standard definitions and best practices could be a helpful reference to improve the statistical foundation of methods for stock forecasting by agencies. Many decades of experience by fisheries scientists has led to a set of common practices in fish stock assessment that have proven to be effective.

A few examples of definition and practices identified by the Panel include:
Resolution of forecasts: Annual age- and sex-specific estimates of total escapement should be available. Point estimates should be accompanied by estimates of uncertainty.

Expansion factors: The source of expansion factors from index values to larger aggregates should be documented and some measure of interannual variability of those factors should be quantified.

Measures of forecasting errors: To facilitate comparisons of forecasting errors across stocks and models, the CTC should agree upon a minimum set of standard measures of those errors that should be produced by all agencies as well as the CTC. This simple step will eliminate the current inefficiency and confusion caused by the use of several different measures of forecasting errors in different documents, which preclude direct comparisons. Such diverse measures for stock-specific forecasts include (1) [(forecast - actual)/actual], (2) [(actual forecast)/actual], (3) forecast/actual, (4) actual/forecast, and (5) some of those multiplied by

100 and others not, etc. For abundances produced by the PSC model, the analogous formulas would use pre-season Als instead of "forecast" and post-season Als for "actual". We suggest the format of option 1 above as a default so that overestimates by a forecasting model are displayed as positive values and underestimates as negative values.

Retrospective analysis: The strongest test for evaluating the performance of alternative forecasting models (short of using Monte Carlo simulation models) is to conduct a retrospective analysis. This procedure forecasts abundance for a given historical year based only on data that would have been available up to that year, and then iteratively repeats this process after adding that year's actual returns, and works through the time series of data (see section 7). Limitations of retrospective analyses of alternative models also need to be recognized, though. Model rankings may be affected by (1) which particular years were used to initially fit the model prior to the first forecast, (2) the length of time series used to calculate performance, and (3) the nature of historical variability (whether it will likely encompass future situations).

Align model-ranking criteria with management objectives: Most agencies use more than one ranking criterion or "performance measure" each year for choosing the best forecasting model, and these criteria can differ among years and stocks. However, these ranking criteria implicitly reflect different management priorities, so due diligence needs to be paid by agency forecasters to use model-ranking criteria that provide the most appropriate information (i.e., that is consistent with stated management objectives for both specific stocks and for AABMs). We provide some hypothetical examples below.

Mean raw error (MRE) (the average of positive and negative forecasting errors over many years) and its scaled counterpart, mean percent error (MPE), measure the long-term bias in forecasts (i.e., how much on average a given model tends to over- or underestimate abundance across the entire period). Thus, use of MRE or MPE for choosing the best forecasting model would be appropriate for a management objective that is only concerned with whether there is a long-term tendency for a consistent bias in one direction or the other, i.e., consistently overestimating the run or under-estimating it, and without any concern about the year-to-year variability in forecasting errors. To reflect a management objective focused on the latter variation, though, mean absolute error (MAE) and mean absolute percent error (MAPE) are appropriate because they measure the precision, or average magnitude of annual forecasting errors, regardless of whether they are over or under actual abundance. This ranking criterion fits with a management objective that puts top priority on coming as close to the actual postseason estimate of abundance as possible, regardless of the sign of the error. That objective implicitly places equal weight on over-forecasting by some amount (e.g., 100,000 fish) and under-forecasting by that same amount.

Other model-ranking criteria reflect management objectives such as minimizing both bias and precision (root-mean square error, RMSE) or more heavily weighting overestimates than underestimates (or vice versa). Another criterion, $\mathrm{r}^{2}$, reflects the proportion of variation in year-to-year post-season abundances that is accounted for by a given forecasting model. Finally,
when the new statistical forecasting package, ForecastR, is released, other formal modelranking criteria will become readily available to Chinook forecasters, such as the Akaike Information Criterion for small samples ( $\mathrm{AIC}_{\mathrm{c}}$ ).

Caution is advised, though. All of the model-ranking criteria mentioned above, including AIC $_{c}$, implicitly assume that forecasting errors of a given magnitude in one direction are as undesirable as the same magnitude of forecasting error in the opposite direction, but this may not be appropriate for some management objectives (p. 101 in Walters and Martell, 2004). For instance, if managers place different weightings on errors in different directions, then other model-ranking criteria will need to be developed instead.

In short, agency forecasters can provide forecasts from models that meet a variety of performance criteria, but in order to choose those criteria and produce numerical results that will be most useful to managers, management objectives need to be clearly stated in quantitative, measurable forms. Of course, such discussions between managers and scientists should be seen as a way to ensure that statistical analyses efficiently address management concerns. Such discussions are not intended to have scientists influence the choice of valueladen management objectives, nor to have managers influence assumptions or outcomes of scientific analyses.

Sibling regressions: $\log _{e}-\log _{e}$ model equations are more likely to meet assumptions of regression in sibling age-class models (Peterman 1982), but it is important to apply the usual log-normal bias correction when back-calculating abundance on the arithmetic scale (Haeseker et al. 2005). The ForecastR package described below contains a $\log _{e}-\log _{e}$ sibling model, and we were told that it includes the log-normal bias correction mentioned in the previous sentence.

Kalman filter estimation of sibling regressions: Sibling age-class relationships fit by standard regression assume constant age-specific maturation rates and survival rate between ages. However, large scatters of data points around some sibling relationships, as well as time trends in mean-age-at maturity that have been observed in Chinook Salmon (CTC 2016a) and sockeye salmon (Pyper et al. 1999), suggesting that better forecasts might be possible by fitting sibling models using a Kalman filter estimation procedure (Holt and Peterman 2004). When a sibling model is set up to be estimated via a Kalman filter, the procedure estimates temporal changes in parameters of sibling age-class relationships and takes into account observation error as well as natural variability. This procedure has already proven effective for sockeye salmon and has documented substantial time trends in sibling-model parameters, as well as similar trends across groups of sockeye stocks (Holt and Peterman 2004).

Hybrid sibling forecasting model: For some of the Chinook Salmon stocks and age classes examined here, if the fit to a sibling regression model is poor, forecasters tend to use a naïve model (e.g., forecast is the average of the last $N$ years of returns, or perhaps just last year's value). However, the decision of which model to use is not based on any statistical foundation. A more statistically defensible approach is to use the "hybrid sibling" forecasting model
developed by Haeseker et al. (2007). "Hybrid" in this case means using a sibling model when the variance of residuals around the relationship is below some threshold (i.e., the data are fit well), but above that threshold using some naïve model. Haeseker et al. (2008) used optimization to find the best variance threshold for each of 40 chum salmon stocks and 37 sockeye salmon stocks. When the performance of the hybrid sibling model was compared to that of 11 structurally different forecasting models using retrospective analysis, it garnered the most sockeye stocks ( $35 \%$ ) for which it was the top-ranked model in terms of RMSE and the second-most stocks for chum salmon (29\%) (Haeseker et al. 2008).

Generalized forecasting software: ForecastR is a computer program based on the open-source statistical software code, R. It generates age-specific forecasts of salmon abundance (VélezEspino et al. 2016). This program is currently in a beta version and is due to be completed by the end of 2016. It is being developed to provide a unified forecasting tool that can be used by researchers and managers across different jurisdictions. ForecastR is flexible enough to be used in different ways in various regions for forecasting abundances of specific stocks. It is intended to facilitate communication and sharing of forecasting results. ForecastR allows users to apply a variety of generic models to their data using various statistical modeling and forecasting tools with the aim to improve the quality of forecasts.

ForecastR will provide a graphical user interface (GUI) to facilitate use by people who do not know how to code in R. The program allows users to forecast abundance of individual stocks (e.g., Chinook, chum, coho, sockeye) based on historical data and other available information. Two types of time series are accommodated, age-specific or total abundances representing individual stocks or aggregates.

Individual analysis modules will provide a variety of capabilities:

- Produce Word or HTML reports (including table of contents, numbered figures and tables with captions, and statistical tutorials)
- Point forecast and bootstrap-based interval forecast
- Numerous diagnostics
- Alternative models (ARIMA, Exponential Smoothing, and Complex Sibling Regressions)
- Probability profiles
- Retrospective evaluations of model performance
- Model ranking, which currently takes place externally from the program

The Panel encourages the further development and application of ForecastR for Chinook Salmon, as long as the program is tested thoroughly first. We suggest the addition of modules for the hybrid sibling and Kalman filter models that are described above.

Dealing with changing parameters: Most fisheries models have one or more components that assume parameters are constant over time, and Chinook forecasting models are no exception. However, extensive evidence exists that parameters such as productivity, marine survival rate, and age-specific maturation rate are "non-stationary", that is, their mean and/or variance has
changed substantially over the years. Non-stationarity thus refers to changes in parameters other than high-frequency year-to-year variability. Non-stationarity affects forecasts of abundance of Chinook Salmon by invalidating the assumptions made in most models that such parameters are constant and not time-varying.

There are at least two approaches to dealing with such non-stationarity. First are methods based on modifying static models to allow estimation of time-varying parameters. The Kalman filter version of the sibling model described above is one example of this approach. It updates parameter estimates annually based on the most recent data and down-weights older data. Truncation of data sets is at the other extreme of methods for dealing with time-varying parameters. Instead of including older data in some parameter estimation step, only data after some cutoff year are used. However, the choice of cutoff year must be made in some defensible manner, such as 1977 in the case of Alaska sockeye salmon because that is when a well-documented "regime shift" occurred to increase productivity of those populations. Arbitrary cutoffs should be avoided.

Sensitivity analyses: Sensitivity analyses are a standard approach to taking uncertainties into account and evaluating their influence on outputs. Sensitivity analyses examine how a given model's output changes with different assumptions or input parameters. Such sensitivity analyses should then be presented as a range of forecasts that reflect model uncertainty. in cases where management objectives have not yet been clarified, sensitivity analyses should also be conducted across the range of plausible model-ranking criteria (e.g., minimizing bias, maximizing precision, etc.).

Multiple models: Agency forecasters should shift their focus away from reporting point estimates of forecasts based on finding the single best forecasting model each year. Instead they should evaluate a set of models and report both a most likely value and the resulting range of point estimates of forecasts along with their respective prediction intervals around the mean forecast abundance. Separately reported forecasts from each model would help to realistically represent some uncertainty in those forecasts. Another option for using information from multiple forecasting models is to combine the forecasts of several of the best-ranking models based on $\mathrm{AIC}_{\mathrm{c}}$ weights (which essentially puts a non-zero probability on any one of those models representing the true state of nature and thereby increasing the chance of making a good forecast). This technique of multi-model averaging has a strong theoretical basis (Burnham and Anderson 2002) and is now widely used in ecology (e.g., Connors et al. 2012). A forecast from such a multi-model method would simply be yet another forecast among all the others produced by alternative models.

Centralized relational database: Agency forecasters and the modelers who run the PSC model may obtain increased efficiency in their analyses and production of reports if they were to use a centralized relational database for both input and output data (if they are not already doing so). Such a database can reduce the chance of errors in copying data or formulas in spreadsheets
and make creation of new tables and graphs less tedious. The ForecastR program appears to have already addressed the latter issue.

Continuously updated documents: In fisheries, documentation of models, assumptions, and input data is frequently a low-priority task, and such documents often do not get updated, if they are written at all. Such up-to-date documentation is critical, though, both for understanding model results (particularly unusual ones) and for training new people to use the model. A centralized registry or logbook for documentation may assist with this task (section 6.7)

> Conclusion D. Establishment of a set of "best forecasting practices" and standard definitions can improve the statistical foundation of methods for stock forecasting.

### 6.5 Statistical Rigor of Agency Forecasting Methods

Issue V. Forecasting methods for some stocks have not fully incorporated knowledge of changing parameters or recent advancements in statistical methods of analysis.

At the Portland workshop, we learned that past abundance forecasts for the five focal stocks, as well as for the AABMs, have generally been perceived as reasonably sufficient for management purposes. As a result, forecasting methods for both stocks and AABMs have remained largely unchanged from long-standing practices. However, the large forecasting errors in some recent years should create a substantial incentive to explore improvements in those forecasting methods. This section focuses on improvements to stock-specific agency forecasts, whereas section 6.8 below refers to PSC model forecasts.

Most agency forecasts rely heavily on sibling models in which age-specific numbers of fish returning in a given year are projected from historical relationships with numbers of the preceding age class that returned in the preceding year. These models perform best when productivity and maturation rates are stationary (static) over time. However, freshwater and ocean conditions that affect salmon productivity, growth, and maturation are not stable. They vary from year to year and in temporal trends from widely varying patterns in environmental conditions changing at various time scales. Proportions of fish surviving to a given age and maturing in a given year also vary considerably and affect the numbers surviving to, and maturing at, later ages. The Panel learned that present agency forecasting methods do not explicitly incorporate the dynamics of such factors in their analyses. As a result, long-term patterns and annual variations in productivity and maturation rate are likely a key source of forecasting errors. Changes in maturation rate over time are currently addressed in stockspecific forecasting models primarily through trial-and-error fits to data covering different periods to see which assumed period performs best.

Advanced statistical methods may help by taking into account temporal patterns in productivity and/or age-at-maturity schedules that potentially reduce forecasting accuracy and precision. Formal statistical time-series models such as autoregressive lag-1-year (AR1) or autoregressive integrated moving average (ARIMA) models are one promising alternative. As already noted in section 6.4, a Kalman filter estimation procedure may also improve forecasts by taking into account temporal changes in parameters of sibling age-class relationships.

Participants at the Portland workshop identified a variety of other forecasting model refinements with the potential to improve accuracy and precision. Among other things, these included basing age-specific forecasts on all previous ages of the same cohort (e.g., age 4s predicted by the sum of age 2 s and 3 s ), incorporating marine harvest in run reconstructions for estimating terminal run size, and forecasting hatchery and wild fish independently.

Selection of the best model is often based on expert opinions of groups of scientists rather than formal model-selection criteria. It is unknown how different the choice of the best model would be if forecasters used formal, statistically supportable model-selection criteria (Burnham and Anderson 2002) or other approaches such as multi-model averaging. However, at the very least, transparency and confidence in agency forecasts might increase if such well-established formal model-selection criteria were applied. Agency forecasters should also ensure that modelranking criteria are consistent with management objectives, as noted in section 6.4.

> Conclusion E. Accuracy, precision, and transparency of stock forecasting methods might be substantially improved by application of more formal model-selection criteria that match clearly defined management objectives. Forecasts might also improve by use of more advanced statistical methods that allow for time-varying parameters.

### 6.6 Limitations of Existing Agency Models for Forecasting

Issue VI. Existing forecasting models used by agencies, especially sibling relationships, are reasonably effective in representing average conditions but are vulnerable to performing poorly for years of very low or very high returns.

Years when actual Chinook Salmon abundance is substantially below or above forecast are by far the most challenging for salmon fishery managers. Overestimates of abundance can result in overfishing relative to escapement goals and exploitation-rate/catch limits. Underestimates can result in unnecessary restrictions and substantial foregone harvest. Both situations can substantially disrupt effective fishery implementation and allocation. These errors are particularly troublesome in Chinook Salmon marine fisheries where inseason abundance information is not available to support within-season modifications of fisheries. Forecasting errors are also problematic even in terminal fisheries where inseason information does exist.

The largest discrepancies between actual runs and forecasts typically occur when large numbers of young fish in a cohort do not lead to similarly large numbers of older fish of the same cohort in the next year, or when small numbers of younger fish are followed by uncharacteristically abundant older fish. These patterns are often related to environmentallydriven changes in survival or maturation and are especially common when data used to make forecasts are outside the range of past observations (e.g., abundance of age 3 s is larger than previously seen and yet is used to forecast age-4 abundance). Large forecasting errors might also result from a confluence of simple random chance events and measurement error.

Refinements in statistical methods discussed in sections 6.4 and 6.5 may help improve accuracy and precision of forecasts by better accounting for time series patterns in the dataset. However, it is unlikely that more rigorous statistical analysis of existing data will remove the specific problem of large uncertainty in forecasts based on recent observations that are outliers beyond the range of past data. The reason for this prudence in sibling models, for example, is that the width of the prediction interval (frequency distribution of possible forecasts at a given $X$ value) gets wider as abundance increases, and that prediction interval is usually asymmetric (see examples for Columbia River Chinook stocks in section 7).

The best prospect for reducing forecast errors in general, as well as the breadth of uncertainty arising from outliers beyond the range of past observations, will be to develop alternative forecasting methods that explicitly account for dynamic changes in factors that affect salmon returns. Auxiliary information from other independent variables might potentially help account for anomalous return patterns. Examples might include maturation rate in previous years, agespecific body-size distribution, size and age structure of co-varying stocks, freshwater factors, juvenile abundance, juvenile survival indices, or ocean conditions that affect survival or maturation rate. However, with few exceptions (e.g., Orsi et al. 2012), past efforts to incorporate auxiliary information in forecasting models has generally met with only modest success (e.g., Wertheimer et al. 2015). Additional investigations may prove fruitful for Chinook, though. Without new information or new understandings of factors driving variable returns, substantial improvements in forecast accuracy and precision may be difficult to achieve.

We should also recognize that recent poor performance of forecasting methods compared to previous years may be a temporary phenomenon associated with a period of particularly dynamic years for Chinook Salmon abundance throughout the northeastern Pacific. Forecast accuracy and precision may or may not revert to historical norms in the future.

> Conclusion F. Development of new models and advanced parameter estimation methods may improve the accuracy and precision of agencies' annual forecasts. Regardless of any such improvements, large uncertainties in forecasts should be expected, especially when they are based on data outside the range of past observations.

### 6.7 Documentation of the PSC Model's Forecasting Methods

Issue VII. Incomplete and out-of-date documentation of the current PSC Chinook model and its calibration and projection procedures (1) threatens loss of institutional knowledge as key staff move on, (2) increases challenges to new CTC members who want to understand the model and its procedures, and in the worst case, (3) increases the chance of errors in the model's application and interpretation.

Such weak documentation has made it difficult to conduct an effective review of the PSC model's structure and function. For example, a few queries from the Panel about the model based on the available documentation received the reply, "The model doesn't work that way anymore". Follow-up questions did not always help clarify uncertainties. Nevertheless, the Panel is confident about our general conclusions related to the PSC model and its use, in part based on extensive discussions with members of the Analytical Working Group, AWG.

Because of the incomplete documentation of the PSC model, the Panel heard from more than one AWG member that it has taken them up to two years to understand how the model works and even then, further model "experiments" have been needed to determine how outputs are affected by changes in particular inputs. We learned that some parts of the PSC model are only partially understood, even by some who are involved in interpreting the model. Such lack of familiarity with the inner workings and assumptions of the model, as well as the inter-related inputs from the 11 different input files, increases the chance of errors occurring during the model's application and interpretation.

Another aspect of this situation came to the Panel's attention. We learned that one person, John Carlile in Alaska, has the burden (or honor) of taking the lead on annually running the PSC model's calibrations and projections during a short period each spring. Other members of the 12-person AWG subsequently help by running calibrations and making projections of AABM AIs themselves, and checking input and output files for errors. It is unclear to the Panel the extent to which the entire process depends on John's leadership. It is clear, though, that his lengthy experience and intimate knowledge of the model's behavior and code, as well as its error messages, lends critical experience to the PSC modeling process. However, we are unaware of a succession plan (i.e., training of at least one person to take John's place when he moves on). If there is no such plan, we strongly encourage one to be established, particularly in light of the large economic value of Chinook Salmon fisheries that is affected by the PSC model's forecasts of Als.

Also, apparently there is no single location for registering or logging changes to the PSC model's code, input requirements, or calibration and projection procedures. Such changes may be described in each year's exploitation rate and calibration reports, but the changes are not consolidated in one place, which increases the chance that some subsequent change will unintentionally interact detrimentally with some previous change that is not noticed or remembered. We learned that the AWG has discussed the need for such a central "logbook" of
changes to the PSC model, but it does not yet exist. We encourage one to be developed as soon as possible.

Continued application of the PSC Chinook model would benefit substantially from clear and concise up-to-date documentation of its structure, parameter values, assumptions, and data supporting those assumptions.

Conclusion G. Comprehensive up-to-date documentation of the PSC Chinook model in a single, central location is necessary to support its effective and credible use and improvement. A succession plan for training new model users is also critical.

### 6.8 Statements of Uncertainty about the PSC Model's Output Forecasts

Issue VIII. The deterministic nature of the PSC model and paucity of routine sensitivity analyses do not provide information about uncertainties in the model's forecasts of abundance in the three AABMs and terminal areas, thereby hampering well-informed decision making by PSC Commissioners and fishery managers in AABM areas.

Another element of model transparency deals with documentation of the PSC model's results, i.e., its projections (forecasts) of abundance indices (Als) for each AABM. Just as CTC members have requested more documentation from regional agency forecasters about the reliability of agency models used for stock-specific forecasting, so too should managers of AABMs benefit from knowing the reliability of past PSC model forecasts of abundances in the AABMs, as well as uncertainties about each current year's forecast Als.

The Panel learned that each year the CTC provides to the PSC Commissioners and regional managers the forecast abundance index for each AABM and the associated maximum allowable catch (based on Table 1 in Chapter 3 of the Treaty). However, there is no documentation of uncertainties in the annual pre-season forecasts, and no regularly-produced statements or graphs of the long-term performance of the PSC model in terms of comparing pre- and postseason estimates of Als (Figure 1 above is the only graph we learned about). Only the previous year's point estimate forecast for each AABM is presented annually to Commissioners along with that year's post-season point estimates of Als.

This omission of measures of uncertainty about stock forecasts unfairly invites criticism when forecast errors inevitably occur. Many assumptions are made by forecasting methods and some, such as constant maturation rate, are not well supported, even by the regions' and the CTC's own data. Given the large number of assumptions made by the PSC model, this lack of statements about uncertainty in forecasts can mislead decision makers about the real situation and can lead to inappropriate regulatory decisions. Omission of such information also keeps managers from making well-informed decisions in which risks (created by uncertainties) are
traded off against potential benefits (also uncertain). Other, more complex stock assessment models on many other fish species routinely produce measures of uncertainty around forecasts for fisheries managers (National Research Council, U.S.A. 1998; Walters and Martell 2004; Fisheries and Oceans Canada 2015), so it is not unreasonable to expect it from the PSC model as well. PSC modelers should incorporate the routine practice of showing uncertainties around their point estimates of annual abundance indices (Als) in each the three AABMs.

The advice about regularly conducting extensive sensitivity analyses given above in section 6.2 for agency stock-specific forecasts is equally important for the PSC model. Sensitivity analysis of model output to different assumptions and input data is a standard means of taking uncertainties into account and propagating their effects all the way to model outputs. However, at the workshop the Panel heard that the annual calibration of the current PSC model is too time consuming to conduct more than a few such sensitivity analyses each year. From the Panel's perspective, this response highlights a key limitation of the current PSC model. Given the numerous uncertainties that are known to exist in the real-world system represented by the model, the inability to conduct large numbers of sensitivity analyses (e.g., dozens or more) severely constrains the level of confidence that can be placed in results from the PSC model (not just forecasts of abundance in the AABMs, but also comparisons of pre- and postabundance estimates).

The Panel recognizes the severe problem of limited CTC staff time (especially for members of the AWG). Staff face competing demands to provide a complex set of annual reports during a short period for implementing the Pacific Salmon Treaty, testing and documenting existing methods and models, and exploring improvements in related methods of analysis. Difficult decisions will obviously have to be made by the AWG to rank tasks when all are important but all cannot be thoroughly addressed with existing staffing. One way out of the dilemma of too much work and too little time is to reduce the extent of the CTC's reporting requirements to the PSC by negotiating changes to the next Treaty. Another is to conduct more analyses outside of the intensive early-spring period.

More detailed discussion and recommendations for addressing uncertainty may be found in sections 7 and 8 of this report.

Conclusion H. Point estimates of forecasts of abundance indices in the three AABM areas from the PSC model should be accompanied by descriptions of uncertainties in those forecasts. Uncertainties can be derived from extensive sensitivity analyses of effects of different assumptions and input parameters. Expression of uncertainty in these forecasts is essential for determining the confidence to be placed in them and allowing for appropriate consideration by fishery managers.

### 6.9 Limitations of the Existing PSC Chinook Model

Issue IX. The PSC model's structure, parameterization, and calibration are complex and subject to substantial structural and parameter uncertainties.

Objectives and applications of the PSC Chinook model have evolved over time. The model appears to serve a number of purposes, some for which it may not be ideally configured. These include calculation of an abundance index in currency similar to that used in the base period to establish harvest control rules, inferences of abundance and harvest for stocks for which assessments are not independently derived, estimation of fishery impact rates for reference to objectives, and projections of terminal run sizes in some fishery areas. Estimation of the abundance index in the three AABM areas appears to be the most important current application. The ranking of future PSC modeling tasks could benefit from more explicit definitions of priority uses.

The current model structure is relatively unchanged since 1985. During stage-1 calibration, it assumes that all factors are known except one, the time series of stock-specific EVs, which is estimated by fitting the model to the input data. Trends and variability in productivity and maturation rate can lead to uncertainty in the forecasts of Als. The PSC model currently attempts to take such changes into account by using base-period maturation rate along with annual CWT data, the most recent 9-year average maturity rate (but only for dealing with incomplete broods), and fitting a time series of EV values to observed abundances. The resulting uncertainties in forecasts of abundance indices in AABMs are not clearly articulated in the CTC's annual reports.

Previous sections have already described the need for additional testing and refinement of the PSC Chinook model. The Panel also recognizes that opportunities for such work are limited by competing work demands on members of the CTC. These demands appear to be hampering exploration of alternative and possibly improved forecasting methods.

Given this predicament, continuing exploration of other modeling options is appropriate. Significant effort has already been invested in developing, and in some cases applying, alternative fisheries models. Details of some of these options are provided in section 8.

> Conclusion I. Substantial revision, testing, or possibly even replacement of the existing PSC Chinook model is necessary to effectively serve continuing needs, including the need for statements of uncertainty in the model's forecasts. A subgroup of CTC members should be created to explore such revisions and new models.

### 6.10 Consistency of Management Structures/Policies with the Limitations of Information and Assessments

Issue X. Limitations of data and uncertainties associated with stock assessments and forecasting models challenge effective implementation of abundance-based management of Chinook under the Pacific Salmon Treaty.

Implementation of an effective abundance-based management strategy, as specified in the Treaty, obviously requires sound abundance forecasts and information on harvest rates. Forecasting problems in recent years have hindered effective implementation of abundancebased management in AABM fisheries when post-season abundance estimates have differed greatly from pre-season forecasts.

One avenue for addressing these problems is to improve forecasts by collecting better data, modifying current models or building better ones, and reporting uncertainties about forecasts and post-season estimates. These topics are the main focus of this report, which includes a variety of related recommendations.

Scientists are often inclined to pursue ever more-detailed data and fine-scaled models in an attempt to explain and reduce uncertainty. The danger in this approach is that our expectations and models can easily outstrip the fundamental limitations of the available information and resources. Thus, the other avenue for dealing with forecasting problems is to scale expectations for the forecasts and management strategies to match the limitations of the existing information and methods of analysis. More complex, finer-scale, mechanistic models are not always a better answer. Simpler, more transparent assessments and strategies often prove every bit as effective in achieving desired outcomes as more complex but subjective models loaded with assumptions. The Panel recognizes that references to base-period abundances, age structures, and exploitation patterns are important features of the current Chinook modeling structure, but a more streamlined framework could also be configured to do so.

The existing limitations of CTC reporting, PSC model documentation, testing, and refinement suggest to the Panel that the current analytical framework for Chinook management under the treaty warrants a close look to determine whether an alternative process might be more appropriate. We discuss such alternatives in section 8 .

Conclusion J. Alternative frameworks, as well as ways of using forecasts of abundance, should be considered for Chinook if current information and resources are not sufficient to effectively conduct adequate analyses and implement provisions of the current Treaty. Those provisions may need to be changed during current negotiations.

## 7 Regional Agency Forecasts of Chinook Abundance

### 7.1 General Comments about Agency Forecasts

This section focuses on the five Chinook Salmon stocks investigated as part of this review. Regional agencies generate forecasts for those stocks and send them to the CTC for input to the PSC's coast-wide model. In addition to these forecasts, some regional agencies such as DFO also produce other forecasts for use in management of their domestic or terminal fisheries. This section only discusses the first type of forecasts, the ones used as inputs to the PSC model. The agencies' forecasts are generally sent to PSC modelers by March 1st of each year, but the domestic forecast for WCVI, for instance, is generally done later in the spring when more information from the previous fishing season is available.

Before we deal with individual Chinook Salmon stocks, we cover several topics and recommendations that are relevant to agencies' forecasts for all five stocks.

First, as mentioned in section 6.2, the Panel learned that there is very little communication between the CTC and biologists in the regions who annually submit their stock-specific forecasts to the CTC for input to the PSC model. The CTC thus has no information on the modelranking process or the reliability of those forecasts.

Recommendation 1. When regional agency forecasters send their stock-specific annual forecasts to the CTC, they should document their model-ranking procedures as well as the past performance of their methods (bias and precision).

Second, a key repeating theme in our review of Chinook Salmon forecasting methods is the limited representation of uncertainties in both analyses and the resulting forecasts. The types of uncertainties described in section 5 apply to all Chinook Salmon stocks and need to be explicitly considered when making forecasts. Omission of such uncertainties creates overconfidence in forecasts and may lead to inappropriate management regulations and outcomes. Details about the importance of considering and reporting uncertainties, and methods for doing so, have already been provided in sections 6.2, 6.4, and 6.5, so we refer readers back to those sections. Suffice it to say here that regional agency forecasters can go further than at present toward developing a range of forecasts that reflect various types of uncertainties in their analyses.

Uncertainties about how to represent the natural system are unavoidable when choosing the structural form and parameter values of forecasting models. It is therefore important that forecasters explicitly recognize those uncertainties during their analyses. One way to do so is to admit that the "best" single model, however that is determined, does not have a probability of 1.0 of being the correct representation of nature, and that other models might be useful to consider as well when describing uncertainty in forecasts. Section 6.4 elaborated on this need to avoid the current agency practice of focusing on the single best model.

The set of forecasting models that each agency should consider could be defined using formal model-selection methods (Burnham and Anderson 2002). For example, that set could be identified as those having delta $\mathrm{AIC}_{\mathrm{c}}$ values less than some number (for example, 4 or 6 ). The resulting set of models would be those that have sufficient support to be considered plausible descriptions of the natural system (Burnham and Anderson 2002). The range of forecasts of abundance produced by this set of models would then reflect structural uncertainty and some aspects of parametric uncertainty.

To give a more complete picture of these uncertainties, point forecasts from each model should be accompanied by prediction intervals (not confidence intervals). A prediction interval illustrates the probability distribution from which the single point estimate of the forecast is drawn. For salmon forecasting models, prediction intervals are typically quite large (e.g., Figure 17 for sibling models for three Columbia River Chinook Salmon stocks). These prediction intervals should therefore be passed on to the PSC modelers (CTC) so that the resulting uncertainties can be reflected in the PSC model's forecasts of abundance in the AABM areas. Prediction intervals may be more important than structural uncertainty in terms of generating uncertainty about future abundances, although this may depend on the particular stock and data set. Only future analyses can tell whether the structural uncertainty arising from structurally different models is important enough to justify sending separate forecasts of each model to the CTC for use in the PSC model, but regardless, prediction intervals should be sent to PSC modelers.

## Recommendation 2. Agency forecasters should not choose just one best model for forecasting abundance in each age class. Instead, they should conduct analyses across different models that make different assumptions and report the resulting set of forecasts to the CTC for use as inputs to the PSC model. The generally large prediction intervals (not confidence intervals) around point forecasts should also be reported.

Third, it is often the case in fisheries that the rank order of forecasting models can be substantially affected by which model-ranking criteria are used. The model that has the smallest bias (MPE closest to zero) is often different from the model that has the greatest precision (lowest MAPE). A model that does well with both attributes (reflected by the lowest RMSE) may differ yet again. Model forecasts in a given year can also differ between such models. It is therefore important that forecasters carefully choose their model-ranking criteria. As elaborated upon in section 6.4, the chosen criteria should be consistent with the way that management objectives are stated. Management concerns about long-term statistical bias of forecasting methods would be addressed by using MPE as the model-ranking criterion, whereas MAPE would be appropriate if the greatest concern is the magnitude of yearly deviation between pre- and post-season estimates.

The Panel heard at the Portland workshop, as well as afterwards, that there is uncertainty among agency forecasters about management objectives, both at the regional level and for AABMs (Appendix C). Such clarity is essential so that agency forecasters can design their model-
ranking criteria to produce the most useful information. Until such time as those management objectives are clearly articulated, the Panel recommends that agency forecasters produce forecasts for the top model for each of the three most common ranking criteria, MPE, MAPE, and RMSE. After clear objectives are stated, then only forecasts from the models using the appropriate ranking criteria need to be reported. In all cases, forecasts should be accompanied by their respective prediction intervals, as described in the previous recommendation.

Recommendation 3. Agency forecasters should also send to the CTC a set of forecasts, each one based on a different model-ranking criterion, as determined by stated management objectives. As described in section 8.2, the CTC can then conduct sensitivity analyses with the PSC model to determine their effect on forecasts of abundance in the AABMs.

Fourth, the ForecastR software program explained above in section 6.4 has the potential to improve the statistical basis for stock forecasts in all regions. From what the Panel has seen of the output from a beta version of ForecastR for Northern Oregon Coast Chinook Salmon, this program promises to be a very useful, standardized method for regional agencies to produce their forecasts. It allows users to choose from a wide variety of forecasting models.

## Recommendation 4. We encourage all agency forecasters to try applying ForecastR to their regions' stocks. As well, the CTC should run workshops to familiarize agency scientists with the ForecastR program.

Fifth, sibling regressions do well when the residual variance around the line is small. When this is not the case, forecasters often revert to some type of naïve, or non-biologically based model such as simply using last year's abundance or an average of abundances over several past years. As described in section 6.4, a "hybrid sibling" model provides a statistically sound basis for choosing either a sibling model or a naïve model in any given year (Haeseker et al. 2007). This hybrid model performed well in retrospective analyses.

## Recommendation 5. Agency forecasters should try applying a hybrid sibling model, especially to cases in which the fit of data to a standard sibling model is weak.

Sixth, the CTC has documented a decrease over time in mean age-at-maturity among several west-coast Chinook Salmon populations, as well as changes in survival rates (CTC 2016a). These two changes therefore violate a key assumption underlying the fitting of sibling age-class relationships, namely that parameters are constant over time. Such non-stationarity undoubtedly contributes to forecasting errors, but the Panel does not have enough information to state the magnitude of that contribution relative to other sources of forecasting error. Essentially, such changing maturation rate and/or survival rate would result in time-varying slope and/or intercept of a sibling relationship. A Kalman filter estimation procedure for the sibling relationship estimates such time-varying parameters (Holt and Peterman 2004; also section 6.4). Although Holt and Peterman (2004) used a random-walk residual term in the system equation, an AR1 term may work even better if the changes in maturation rate and/or survival rate are highly autocorrelated in time.

## Recommendation 6. We recommend that agency forecasters try using a Kalman filter estimation procedure for fitting their sibling relationships to account for time-varying parameters.

Seventh, all five of the agency forecasts reviewed were missing a complete assessment of stock contributions to the various AABM and ISBM fisheries. Instead, in all cases it was left to the PSC modelers to fill in the missing components. Although the Panel does not fully understand how those estimates are made, we recognize that surrogate groups of fish marked with coded-wiretags have to be used to represent larger stock groups. For the vast majority of these cases, it is well known that because the marked group is a small component of the overall stock it represents, it may not mimic the actual exploitation and survival rates of the larger stock. It was demonstrated that forecasts of terminal return and escapement can be made without fishery contribution estimates, but the quality of forecasts might improve with better estimates of age composition and numbers of fish in both harvest and escapement. These are the building blocks of strong population assessment programs, as well as good forecasting.

The Panel learned that the United States and Canada both contributed $\$ 7.5$ million to their agencies in recent years to improve their coded-wire-tag programs. We applaud this undertaking but also worry about the form the program will take in upcoming years without supplemental funding.

While there have been dramatic improvements in estimating stock compositions using CWT's, there still are problems with the ability to make those estimates timely. Final estimates from fisheries are typically not available for up to two years after the tags are recovered. Methods to reduce the time delay and improve the usefulness of the information should be evaluated. An example would be the use of in-season creel surveys to obtain marked-to-unmarked fractions prior to receiving the results from post-season mail-out surveys of anglers.

Otolith mass marking has replaced CWT's in many fisheries for estimating stock contributions (Hargreaves et al. 2001; Joyce and Evans 2000). Because otolith marking allows for marking greater numbers of fish, the estimation of stock contributions is often more efficient and timely than with CWT's. The downside to the use of otoliths is the low number of different discernable patterns available to be applied to the otoliths which ultimately limits the number of stocks that can be distinguished.

Genetic methods have found increasing applications in the management of Pacific salmon over the past 20 years (Beacham et al. 2008; Gilk-Baumer et al. 2013). Technologies for the application of these methods have improved rapidly, and it has become increasingly feasible to collect and process large quantities of genetic data in a timely manner at reasonable cost. It is reasonable to expect these new technologies will continue to evolve and become more valuable for the management of ocean salmon fisheries (Pacific Salmon Commission 2008). While there are other methods to explore, parentage-based tagging is a genetic technique that shows promise as an efficient alternative to physical tagging methods such as coded-wire-tags (Larson 2014; Anderson and Garza 2006).

## Recommendation 7. Continue to improve upon the ability to estimate the contribution by stock to all AABM and ISBM fisheries with the objective of obtaining reliable stock contribution estimates by age. The Panel encourages the commitment of extra funding for the implementation of techniques to estimate stock contributions in a timely enough manner that the results can be used for forecasting in the subsequent year.

### 7.2 Columbia River

### 7.2.1 Forecasting Model

The Panel reviewed forecasts for three stocks of Chinook Salmon from the Columbia River -Upriver Brights, Spring Creek Hatchery, and the Summer run. The fisheries in the Columbia River are managed subject to provisions of the continuing jurisdiction of the Federal court in proceedings between the United States, and the State Agencies and Treaty Tribes. A Technical Advisory Committee (TAC) consisting of representatives from each of these entities is tasked with assessing and forecasting salmon returns to the Columbia River. The methods for forecasting all three Columbia River stocks are very similar, so the Panel's comments here apply generally to all three stocks.

A large number of relationships (more than 80 each for the Upriver Bright and Spring Creek Hatchery stocks alone) are examined each year for potential use in forecasting. These relationships include a combination of sibling regressions, cohort ratios, and the average of recent returns. The large number of relationships used to forecast a particular age group arises from exploring numerous sets of brood years of data that are chosen as input to the analyses. The TAC uses an open discussion among its expert panel members to select a relationship for each of the age classes within a stock to use in making the final forecast. The selection criteria include $r^{2}$ values, forecast bias (mean percent error), and forecast precision (mean absolute percent error). Sibling regressions have been selected most of the time (Figure 16). Years to include in the regressions were selected based on recent forecast performance. An average of recent-year returns is occasionally used when a particular age component represents a minor component of the entire return (e.g., <1,000 fish).

While it could be argued that the acquired knowledge of the TAC's experts is sufficient for producing accurate forecasts, people occasionally leave and others move into the group, resulting in both a loss and introduction of knowledge and experience. A more formalized, statistically based process for selecting the final forecasting relationships might lead to improved forecasts. As a starting point, we suggest not using $r^{2}$ as a model-ranking criterion, but instead using the more directly relevant measures of forecasting performance: MPE, MAPE, or RMSE. The Akaike Information Criterion ( $\mathrm{AIC}_{\mathrm{c}}$ ) discussed in Burnham and Anderson (2002) may also be useful, but with the caveat mentioned at the end of Example 2 in section 8.2.

## Recommendation 8. The Columbia River Technical Advisory Committee (TAC) should explore whether using formal statistical model-selection criteria improves the accuracy and precision of their forecasts.

All of the sibling relationships examined for the Columbia River Upriver Bright and Spring Creek Hatchery stocks were regressions using the untransformed number of Chinook Salmon by age estimated to have returned to the terminal area, while some of the relationships used to forecast Columbia River Summer stock were $\log _{e}-\log _{e}$ regressions. Peterman (1982) demonstrated that the use of natural log transformations of sibling data provided relationships that better meet the assumptions of regression such as constant variance across the range of $X$ values. The presentations made by Steve Haeseker and Stuart Ellis at the workshop indicated that the regression fits to the untransformed and transformed data were similar for the majority of observed terminal run sizes, but there was a slight divergence at larger run sizes (Figure 17). While it is easier to explain a regression to non-technical audiences using untransformed data, it may be advantageous to explore the use of natural-log transforms for forecasting. This may be especially appropriate now because recent run sizes are at the upper end of the historically observed data.

Recommendation 9. Explore the use of natural-log transformations for sibling regressions. The examination should evaluate both the effect on meeting the regression assumptions and forecasting performance.

## Columbia River Upriver Brights <br> Age-3, -4, and -5 returns (1980-2015)



## Columbia River Spring Creek Hatchery

Age-3 and -4 returns (1980-2015)


Columbia River Summer Run
Age-3, -4, and -5 returns (2005-2016)


Figure 16. The distribution of models selected in the past by the Columbia River Technical Advisory Committee (TAC) to forecast Columbia Upriver Bright, Columbia River Spring Creek Hatchery, and the Columbia River Summer stocks of Chinook Salmon. From the information presented by Steve Haeseker (USFWS) and Stuart Ellis (CRITFC) at the Portland workshop, August 10-11, 2016.

## Upriver Bright sibling relationships (BY 1962-2012)



## Spring Creek sibling relationships (BY 1962-2012)




Summer Chinook sibling relationships (BY 1986-2012)


Figure 17. Sibling relationships for forecasting Columbia River Upriver Bright, Columbia River Spring Creek Hatchery, and Columbia River Summer stocks of Chinook Salmon. The solid black line indicates the fit of untransformed salmon numbers while the dashed blue line indicates the fit of natural-logged data. Open-circle data points indicate recent extreme abundances.
From the information presented by Steve Haeseker (USFWS) and Stuart Ellis (CRITFC) at the Portland workshop, August 10-11, 2016.

Inherent to both the sibling regression and average ratio methods for forecasting is the assumption that each age class contributes a constant proportion to their brood-year total returns. In other words, it is assumed that there is no year-to-year variability in that proportion and no long-term trend. However, it is clear that the proportion of each age in the brood year returns of all three Columbia River Chinook Salmon stocks examined is not constant (Figure 18, Figure 19, and Figure 20). While some of the variability in the proportion of age in the broodyear return is natural variability in the maturation and/or survival rates, it is more than likely that a portion of the variability is due to changes in exploitation rate between years in the AABM and ISBM fisheries.

The PSC model annually forecasts Abundance Indices (Als) each year for the three AABM fisheries, which are used to set maximum allowable harvests in those areas. Because the AI in a given area is dependent upon the magnitude of up to as many as 28 stocks in the PSC model, it varies from year to year, and ultimately results in varying exploitation rates from year to year. This is especially true when an Al moves between tiers of harvest rates (Table 1 of Chapter 3 of the Treaty). In addition, migratory pathways of salmon stocks are seldom consistent from year to year, and it is likely that stocks experience different rates of exploitation solely based on how and when they enter the fishing areas and how long they remain. As noted near the start of section 7, obtaining estimates of both the contribution of Columbia River Upriver Brights, Columbia River Spring Creek Hatchery, and Columbia River Summer stocks by age to these fisheries and the corresponding estimates of uncertainty about those estimates should provide additional information for dealing with the variability in age composition due to the unequal exploitation.

### 7.2.2 Forecasting Performance

The forecast of Columbia Upriver Bright Chinook Salmon provided for use in the Pacific Salmon Commission (PSC) model is nearly unbiased and reasonably precise (mean percent error = 1\%; mean absolute percent error $=25 \%$; calculation done by Brian Bue using data from CTC 2015b Appendix J1 for 1999-2013 and preliminary data for 2014 and 2015 obtained from John Carlile, ADF\&G). The most recent years (2013-15) were the largest returns in the data set and showed the greatest deviation between the forecast and actual terminal returns (Figure 21). There was no obvious time trend of forecasts being either under- or overestimates (Figure 22).

The forecast of the Columbia River Spring Creek Hatchery stock provided for use in the Pacific Salmon Commission (PSC) model shows a tendency to overestimate the actual abundance and is reasonably precise (mean percent error $=8 \%$; mean absolute percent error $=31 \%$; Figure 23, calculation done by Brian Bue using data from CTC 2015b Appendix J1 for 1999-2013 and preliminary data for 2014 and 2015 obtained from John Carlile, ADF\&G). There are periods of underestimates of the run (2001-2004) and overestimates (2005-2012; Figure 24).

## Upriver Bright age-class proportions (BY 1962-2010)



Figure 18. The proportion of total brood year return by age class and year for Columbia River Upriver Bright Chinook Salmon, 1962-2010. From personal communication by Geoffrey Whisler (ODFW), presented by Steve Haeseker (USFWS).

## Spring Creek age-class proportions (BY 1962-2010)



Figure 19. Proportion of the total brood year return by age class and year for Columbia River Spring Creek Hatchery Chinook Salmon, 1962-2010. From personal communication by Geoffrey Whisler (ODFW), presented by Steve Haeseker (USFWS).

## Summer Chinook age-class proportions (BY 1986-2009)



Figure 20. Proportion of total brood year return by age class and year for Columbia River Summers, 1986-2009. From personal communication by Geoffrey Whisler (ODFW), presented by Stuart Ellis (CRITFC).

## Columbia River Upriver Brights



Figure 21. Comparison of the preseason terminal forecast of Columbia River Upriver Brights provided for use in the PSC model with the actual terminal return, 1999-2015. 1999-2013 data from CTC 2015b Appendix J1; 2014 and 2015 are preliminary and obtained from John Carlile ADF\&G).

## Columbia River Upriver Brights



Figure 22. Percent error by year for the forecast of the Columbia River Upriver Bright stock provided for use in the PSC model, 1999-2015. Percent error was calculated by Brian Bue as (forecast - return)/return; positive values indicate the forecast was larger than the return. The 19992013 data from CTC 2015b Appendix J1; 2014 and 2015 are preliminary and obtained from John Carlile ADF\&G).

# Columbia River Spring Creek Hatchery 



Figure 23. Comparison of the preseason terminal forecast of Columbia River Spring Creek Hatchery provided for use in the PSC model with the actual terminal return, 1999-2013. 1999-2013 data from CTC 2015b Appendix J1; 2014 and 2015 are preliminary and obtained from John Carlile ADF\&G).

## Columbia River Spring Creek Hatchery



Figure 24. Percent error by year for the forecast of the Columbia River Spring Creek Hatchery stock provided for use in the PSC model, 1999-2013. Percent error was calculated by Brian Bue as (forecast - return)/return; positive values indicate the forecast was larger than the return. The 1999-2013 data from CTC 2015b Appendix; 2014 and 2015 are preliminary and obtained from John Carlile ADF\&G).

Although forecasts of the Columbia River Summer run have been made since 1999 for input to the PSC model, it is only appropriate to compare the forecasts and agency estimates of actual return for the years 2005 to the present. Prior to 2005, the Columbia River Summer stock was defined to be those fish that entered the river between June 1 and July 31. In 2005, the definition of the Summer stock was changed to those fish that entered the river between June 15 and July 31.

Recommendation 10. The Columbia River Technical Advisory Committee and the Pacific Salmon Commission's modeling group should communicate with each other to ensure that they are both working with the same definition of the Columbia River Summer stock and the same sets of data, and that any historical information reflects this change.

The forecast of Columbia Upriver Summer Chinook Salmon provided for use in the Pacific Salmon Commission (PSC) model for the years 2005-2015 shows a tendency to overestimate abundance and is reasonably precise (mean percent error = 10\%; mean absolute percent error = 22\%). The forecasts for 7 of the 8 years forecast between 2005 and 2013 were greater than the observed returns, whereas the returns for 2014 and the record-high 2015 were more than forecast (Figure 25, Figure 26).


Figure 25. Comparison of the preseason terminal forecast of Columbia River Summers provided for use in the PSC model with the actual terminal return, 2005-2013. The 2005-2013 data from CTC 2015b Appendix J1, except 2006 from Jeff Whisler, ODFW; 2014 and 2015 are preliminary and obtained from John Carlile ADF\&G).

## Columbia River Summers



Figure 26. Percent error by year for the forecast of the Columbia River Summer stock provided for use in the PSC model, 1999-2013. Percent error was calculated by Brian Bue as (forecast return)/return; positive values indicate the forecast was larger than the return. The 20052013 data from CTC 2015b Appendix J1, except 2006 from Jeff Whisler, ODFW; 2014 and 2015 are preliminary and obtained from John Carlile ADF\&G).

### 7.3 West Coast Vancouver Island

### 7.3.1 Forecasting Model

The forecast of terminal return of Chinook Salmon to West Coast Vancouver Island (WCVI) that serves as an input to the PSC model has been done essentially the same way since it was initiated in 1999. The Panel did not have adequate time to fully understand all components of the analysis but did obtain a general understanding of the process. The forecast for WCVI relies on estimates of the return to the terminal area by age to the Robertson Creek Hatchery (RCH) obtained from both thermally marked otoliths and coded wire tags (CWT). These estimates are expanded to estimates of total run of Chinook Salmon to RCH by age using a cohort analysis. The cohort analysis accounts for both fishing and natural mortality. Two groups of sibling forecasts are made. The first group, called Prod2 by CDFO biologists, relates the estimated terminal return (which is based on CWTs of ages already observed) to the estimated total run based on the cohort analysis for the ages still at sea. The second group, called Prod3, relates the estimated total run (not the terminal run) based on the cohort analysis of ages already observed, to the estimated total run based on cohort analysis for the ages still at sea.

The same set of sibling relationships was estimated for each of PROD2 and PROD3. The relationships used the abundance in younger age classes to estimate the abundance of the subsequent age groups for that brood year. Several alternative sibling relationships were estimated. For example, the returns of age- 2 fish were used to estimate the total run of age- $3+$ age-4 + age-5 fish. Likewise, age-3 fish were used to estimate the total run of age-4 + age-5 fish.

The two groups of sibling forecasts, Prod2 and Prod3, were then combined to produce a forecast of total run to the Robertson Creek Hatchery. The ages $3+4+5$ forecast came directly from the Prod 2 forecast while the ages $4+5$ and age- 5 forecasts were the average of the Prod2 and Prod3 forecasts for those age groups.

The combined forecast of total run for age groups was then expanded to account for the unmarked component of the return to the Somass River system, which is closely associated with the Robertson Creek Hatchery. The expansion factors were based on the annual observed proportions of RCH and Somass stocks in the RCH/Somass area.

A deterministic model was then used to remove fish harvested outside WCVI from the forecasted total run to RCH/Somass, and a maturation rate scalar was applied to estimate the number of fish by age to arrive in the terminal RCH/Somass area. For example: a harvest rate for age-3 fish harvested outside of the terminal area was applied to the age-3 + age-4 + age-5 group to remove the age- 3 harvest. Then the maturation rate scalar was applied to the remainder to estimate the number of age- 3 fish returning to the terminal area. Base period (1979-1982) harvest rates and maturation rates have been used for all years forecasted (19992016), but as noted below, these have changed.

The RCH/Somass terminal return was then expanded to the remainder of WCVI based on the ratio of observed total production (escapements plus all catches) of WCVI to observed production of the RCH/Somass system.

In recognition of reduced harvest rates in recent years compared to the base period, an alternative forecast for WCVI was provided to the CTC modeling group for input to the PSC model beginning in 2013, in addition to the forecast from the long-standing traditional forecasting method described above. For the new forecasts, the harvest rates used in the deterministic model phase were based on the recent 3-year average, whereas the maturation rate remained the same as in the base period. It appears that the forecast using the average of the 3 most recent harvest rates was selected by the CTC as input to the PSC coast-wide model for 2014 and 2015.

### 7.3.2 Forecasting Performance

The forecasts of West Coast Vancouver Island Chinook Salmon provided for use in the Pacific Salmon Commission (PSC) model are biased low (mean percent error $=-27 \%$ without the 2013 data point and $-30 \%$ with 2013 included) and are imprecise (mean absolute percent error $=42 \%$ without 2013 and $45 \%$ with 2013) (Figure 27); (calculation done by Brian Bue using data from CTC 2015b Appendix J1 for 1999-2013 and preliminary data for 2014 and 2015 obtained from John Carlile, ADF\&G). The 2013 WCVI forecast of 27,338 (included in the above statistical calculations) was controversial and was not accepted by the CTC, so the PSC model produced its own forecast of 32,180 (Diana Dobson, personal communication). Both of these forecasts for 2013 ended up being way too low compared to actual returns, $84 \%$ and $82 \%$, respectively (pair of overlapping points in top left corner of Fig. 27). Fifteen of the seventeen forecasts examined were low, although the forecast for 2007 was close (Figure 28).


Figure 27. Comparison of the preseason terminal forecast of West Coast Vancouver Island Chinook Salmon provided by CDFO for use in the PSC model with the actual terminal return, 19992015. 1999-2012 data from CTC 2015b Appendix J1; 2013 (top left partially overlapping data points) from Diana Dobson CDFO and CTC 2015b Appendix J1; 2014 and 2015 are preliminary and obtained from John Carlile ADF\&G).

West Coast Vancouver Island


Figure 28. Percent error by year for the forecast of West Coast Vancouver Island Chinook Salmon provided by CDFO for use in the PSC model, 1999-2015. Percent error was calculated by Brian Bue as (forecast - return)/return; positive values indicate the forecast was larger than the return. The 1999-2012; data from CTC 2015b Appendix J1; 2013 partially overlapping data points from Diana Dobson CDFO and CTC 2015b Appendix J1; 2014 and 2015 are preliminary and obtained from John Carlile ADF\&G).

It is clear to the Panel that the specifics of the type of forecast required for the PSC model have not been properly communicated. The lengthy use of the same forecast method, based on scalars estimated for the 1979-1982 run, contrasts dramatically with the four other stockspecific forecasts evaluated by the Panel. In all other cases, forecasters use (either implicitly or explicitly) more recent information on age composition, exploitation rates, and survival rates in their sibling relationships and cohort ratios and do not attempt to back-calculate to pre-oceanfishery abundance. In addition, the long-term pattern of WCVI forecasts that underestimated returns should have prompted a detailed look at the forecasting methods before now. It is possible that the CDFO staff recognized the chronic underestimates but were under the assumption that the PSC model was taking them into account. CDFO staff recently attempted to address the problem by providing an alternative forecast for input to the PSC model that was based on the recent harvest history, as well as a forecast based on the traditional method, but it does not appear that any specific communication occurred between the CTC modeling group and WCVI forecasters as to how to proceed. It is imperative that both parties know what is being provided and how it is being utilized.

Recommendation 11. The CTC modeling group and WCVI forecasters should decide (1) which type of forecast is required from WCVI (based on base-period data or recent years, for example), and (2) the forecast performance values (bias and precision) beyond which an extensive review of forecasting methods should be triggered.

### 7.3.3 Uncertainty in Parameters

## Sibling Relationships

The Prod 2 sibling relationship used to forecast the age $-3+4+5$ grouping as well as the Prod 2 and Prod 3 relationships used to forecast the age- 5 age class are problematic (Figure 29). The age- 2 to age $-3+4+5$ relationship underestimates the number of age $-3+4+5$ fish for most years (Figure 29, pane A). This is not an uncommon problem because low-abundance age-2 fish are typically difficult to detect in a population without an intensive sampling program. Likewise the Prod 2 and Prod 3 age- 4 to age- 5 relationships overestimate the number of returning age- 6 fish.

Recommendation 12. An evaluation of the WCVI sampling program should be undertaken to determine if (1) there has been a dramatic change in sample collection methods and sampling intensity over the years, and (2) whether the sample design and intensity is adequate to obtain meaningful age composition estimates. If the sample design appears to be adequate, then explore other ways to estimate the age-3 and age-6 components of the returns.


Figure 29. Sibling relationships used to forecast Chinook salmon terminal return to the Robertson Creek Hatchery, West Coast Vancouver Island. Prod 2 and Prod 3 are different groupings of the data and are explained in the text. Lines are regression lines through the origin.

## Harvest and Maturation Rates

The use of base-period harvest rates (1979-1982) to estimate present day returns has the potential to negatively bias the forecast (underestimate the run). Approximately $80 \%$ of the RCH return are age- 3 and age- 4 fish. Two of the ages in the forecast (ages 3 and 4) are presently harvested at a lower rate in the pre-terminal areas than during the base period, and the reverse
is true for age 5 s (Figure 30). The use of a harvest rate that is greater than the current harvest rate would result in forecasts that underestimate total abundance in the WCVI terminal area.

The Panel did not fully examine the effect of the age-specific maturation rates on the WCVI forecast. The maturation rate is the proportion of a group of fish that will return at a given age. For example, when the base-period maturation rate for age-3 (0.17) is multiplied by the forecast number of age-3, 4 , and 5 fish in the brood year return, the result is the number of age- 3 fish expected to return in a given year with the remaining fish returning in future years as age-4 and 5 fish. It is highly unlikely that the maturation rate has remained constant over the past 35 years. Changes in stock productivity, oceanic thermal regimes, and food have been documented in the North Pacific and it is reasonable to expect that these changes have influenced maturation rate.

Recommendation 13. The use of recent harvest rates and maturation rates should be explored for the WCVI forecasting model. These analyses should estimate model sensitivity to uncertainties in these rates, and all results of these sensitivity analyses, including the associated forecasts, should be provided to CTC modelers along with estimates of uncertainty in the forecasts.


Figure 30. Age-specific pre-terminal exploitation rates of Chinook Salmon from the Robertson Creek Hatchery (Diana Dobson, CDFO, Portland workshop presentation).

## Changes in Contribution of Robertson Creek Hatchery

The Robertson Creek Hatchery is the indicator stock for WCVI Chinook Salmon. One assumption underlying forecasts for WCVI is that RCH Chinook Salmon have an identical exploitation rate, maturation rate, and marine survival rate to that of other WCVI Chinook Salmon in the same years. The Panel has little information on the validity of this sweeping assumption for wild populations of Chinook Salmon, but it is clear that fish from RCH have had considerably different survival rates to age 2 than fish from other WCVI hatcheries, Conuma and Nitinat (Figure 31, right panel). Furthermore, RCH fish now contribute a much smaller portion of the total indexed WCVI terminal returns than in the late 1980s (Figure 31, left panel). Thus, the Robertson Creek Hatchery exploitation, maturation, and marine survival rates may no longer reflect those attributes for the majority of other WCVI Chinook Salmon. This issue is critically important because, as we discussed above, the RCH data are the core foundation for the WCVI forecasts. A lack of representativeness of RCH may have contributed to the poor performance of WCVI forecasts (Figure 28).


Figure 31. Contribution of the Robertson Creek Hatchery to the West Coast Vancouver Island Index of Abundance by year and the survival to age-2 for the Robertson Creek (RCH), Conuma (CON) and Nitinat (NIT) hatcheries (Diana Dobson, CDFO, Portland workshop presentation).

### 7.3.4 Suggestions

## Explore New Models

An evaluation of the WCVI forecasting procedures should be undertaken with the goal of simplifying the process. The methods used by the Columbia River forecasters might be a good example. Presently for WCVI, coded-wire-tag, otolith, and age information are collected from the RCH stock and then expanded using a cohort analysis. Then a sibling analysis is done and abundances are further expanded for the contribution of the Somass system. Then abundances are reduced by estimated harvest and maturation rates, and again expanded for the remaining contributing stocks to WCVI. At each step of this process parameters of unknown uncertainty are applied to the basic CWT and age information to make the final forecast. In essence, terminal run information from RCH is expanded to estimate the number of fish still alive for a
particular brood year and is then reduced to an estimate of future terminal return. All of these steps involve several assumptions, any of which could be substantially wrong, and it is therefore likely that a major contributor to the frequent underestimation of WCVI abundance is CDFO's assumptions about harvest rates and maturation rates. The Panel suggests that it might be easier, as well as possibly more accurate, to just forecast the terminal return for each of the three hatcheries, combine the estimates, and then expand those estimates to account for wild fish. While that endeavor would be challenging, the Panel believes it is obtainable because the forecasts for domestic management purposes appear to perform better than forecasts sent to the CTC for input to the PSC model (Diana Dobson, CDFO, personal communication).

## Recommendation 14. Explore a different and simpler method of forecasting terminal return to WCVI. The preferred method would reduce the complexity of the forecast by reducing the number of data manipulations and number of parameters and assumptions in the forecasting procedure. As with all new methods, it should be thoroughly evaluated to determine whether an increase in performance is actually obtained in terms of bias and precision, and sensitivity analyses should be performed to determine the influence of uncertainties in model parameters.

### 7.3.5 Summary

The forecasts of West Coast Vancouver Island Chinook Salmon abundance submitted for use in the PSC model have mostly been low since 1999. The Panel believes that the situation can be improved by using a new forecasting procedure that makes fewer assumptions than the present method. Considerable planning should be committed to maximize improvements in the WCVI forecasts given monetary and time constraints.

### 7.4 North Oregon Coast

### 7.4.1 Forecasting Model

The North Oregon Coast (NOC) forecast includes spawning escapements of Chinook Salmon for an aggregate of populations extending from the Siuslaw River in the south to the Nehalem River in the north. The Panelists understand that considerable improvements have been made to the program since 2008, primarily increased sampling levels for age composition, rapid turnaround in scale aging, and improvements in estimating escapement.

Sibling relationships are now used for NOC forecasts, but no data or graphs depicting the relationships were provided. The Panelists assume the relationships are generally valid, but given the changes in age composition and the scatter around sibling relationships reported above for Columbia River and WCVI Chinook Salmon, we expect that similar issues will exist for NOC stocks. Without more comprehensive data available for NOC Chinook Salmon, examination of a wider variety of forecasting models might improve forecasts (see section 6.4).

Recommendation 15. We recommend that ODFW forecasters examine $\log _{e}-\log _{e}$ sibling regressions, a hybrid sibling model, and a Kalman filter estimation procedure, the latter to account for possible temporal changes in parameters of the sibling relationship.

Ethan Clemons (ODFW) illustrated the development of the 2016 NOC forecast in which biologists selected between two different forecasting methods (sibling relationships and an ARIMA time series model) for each of the seven major rivers in NOC (Figure 32). Although we encourage examination of a wide range of models, it is necessary to follow a standardized model-selection process and to document the methods and criteria used to select which model to include in the overall forecast for NOC (see section 6.4).

Recommendation 16. A list of the alternative forecasting models examined and the criteria used to select among those models for producing a forecast for the Northern Oregon Coast should be clearly stated in the forecast document provided to the PSC model group, as suggested in recommendations at the start of section 7.

| Run year | Nenalem | Tliamok | Nestuca | Siletz | Yaquinà | Alseà | Suslaw | tota |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 2016 forecast sibing ERC | 12,165 | 16,109 | 9,051 | 7,528 | 15,813 | 45,531 | 40,840 | 147,038 |
| 2016 forecast ARMA | 9,629 | 12,073 | 8,481 | 5,362 | 6,992 | 27,259 | 28,701 | 99,097 |
|  |  |  |  |  |  |  | yboid | 119,374 |

Figure 32. Forecasts examined by ODFW staff for inclusion in the 2016 forecast of escapement to the North Oregon Coast aggregate of Chinook Salmon. Numbers highlighted in green were selected for inclusion in the 2016 forecast for the NOC aggregate stock. From the presentation by Ethan Clemons (ODFW) at the forecasting workshop in Portland, August 1011, 2016.

### 7.4.2 Forecasting Performance

The forecast of North Oregon Coast Chinook Salmon provided for use in the Pacific Salmon Commission (PSC) model shows an overall tendency to overestimate abundance, and is reasonably precise (mean percent error $=8 \%$; mean absolute percent error $=31 \%$, but without the unusually large overestimate of the forecast in 2007, the tendency has been to underestimates, $\mathrm{MPE}=-2 \%$ and $\mathrm{MAPE}=22 \%$; calculations done by Brian Bue using data from CTC 2015a Appendix J1 for 1999-2013 and preliminary data for 2014 and 2015 obtained from John Carlile, ADF\&G). The perceived tendency to overestimate abundance is primarily due to the forecast made in 2007 when the actual escapement was about one third of the forecast escapement (Figures 33 and 34). An improvement in forecast performance coincident with improvements in sampling, speed of scale ageing and escapement estimation in 2008 was observed beginning with the next forecast in 2009. Since 2009 there has been a tendency to underestimate the returning escapement (mean percent error $=-6 \%$ for 2009-2015), but forecast precision has been greatly increased (mean absolute percent error $=14 \%$ for 20092015; Figure 34).

## North Oregon Coast



Figure 33. Comparison of the preseason forecast of escapement to the North Oregon Coast aggregate of stocks provided for use in the PSC model with the actual estimated escapement (return), 1999-2015. 1999-2013 data from CTC 2015b Appendix J1; 2014 and 2015 are preliminary and obtained from John Carlile ADF\&G).

North Oregon Coast


Figure 34. Percent error by year for the forecast of escapement to the North Oregon Coast aggregate of stocks for use in the PSC model, 1999-2015. Percent error was calculated by Brian Bue as (forecast - return)/return; positive values indicate the forecast was larger than the return. The 1999-2013 data from CTC 2015b Appendix J1; 2014 and 2015 are preliminary and obtained from John Carlile ADF\&G).

### 7.4.3 Uncertainty in Parameters

While there has been an increase in forecast performance since 2009, there are still many areas that could be improved. A forecast of only escapement essentially assumes that everything that affects the population in the marine environment is constant from year to year, i.e., maturation rates, exploitation rates in AABM as well as terminal fisheries, and survival from one age class to the next. It is obvious that the assumption of constant exploitation rates in the fisheries is violated because Chinook Salmon abundances vary and annual management decisions are made accordingly that can alter exploitation rates. This large source of uncertainty in forecasts for NOC can be reduced if there is concerted and increased effort made to identify stock and age composition in the various fisheries in which NOC Chinook Salmon are caught, and to do so in a timely manner such that the information can be used for forecasting (see recommendation on this topic near the start of section 7). In addition, there is an expansion made to account for escapement into areas that are not surveyed. Again it is assumed that the ratio of escapement between surveyed areas and unsurveyed areas is constant. The Panel realizes that addressing these issues will be a serious challenge if the reduction in funding occurs that we heard about at the Portland workshop.

## Recommendation 17. All assumptions underlying the annual forecast, as well as data related to those assumptions, should be listed in the document provided to the PSC modelers so that everyone is aware of the forecast's strengths and weaknesses.

### 7.4.4 Summary

Improvements have been made for forecasting the escapement to NOC. In addition to those already mentioned, work has been under way in recent years to improve escapement estimation methods. Biologists are presently calibrating spawning ground visual surveys with mark-recapture estimates of escapement (Falcy et al. 2016), and where mark-recapture estimates are not available, visual surveys are combined with information on geomorphology and stream flow (Falcy 2015). Ethan Clemons stated at the Portland workshop that funding for field sampling has dropped precipitously in recent years, with field sampling being minimal to non-existent in some drainage basins. In addition, it now takes more time for a set of scale samples to be aged. The Panelists strongly encourage continued funding of this work so as to not lose the improvements in forecasting that have been gained in the past eight years. In addition, as the evaluation of escapement improves, researchers should be looking at expanding the forecast for NOC to become a forecast of the terminal run, where terminal harvest is also taken into account.

Recommendation 18. Continue the increased sampling in the Northern Oregon Coast for age, rapid reading of scales for age, and improvements in escapement estimation.

Recommendation 19. As the population assessment models continue to evolve, NOC researchers should determine the sensitivity of the resulting forecasts to the uncertainty in estimated parameters in the models and quantify the uncertainty in the forecasts.

Recommendation 20. If more detailed data can be obtained from terminal fisheries for NOC, the forecast for this aggregate stock should change to a terminal run forecast instead of an escapement forecast.

The software package, ForecastR, was beta tested in the NOC area in 2016 with strong acceptance by ODFW forecasters. The formal time series models are useful alternatives to sibling models, especially if data on age composition become less available.

Recommendation 21. The Panelists encourage the continued use of ForecastR for Northern Oregon Coast Chinook Salmon.

## 8 Pacific Salmon Commission's Chinook Model Forecasts

This section on the PSC Chinook model considers two different strategies for making better forecasts of abundance. First, we make numerous recommendations that should help meet that goal if the current PSC Chinook model continues to be the main method for generating forecasts. In this option, substantial changes may be required. The second option is to eventually replace the current PSC model with one or more other models that take a different approach to making forecasts in such highly variable, complex, multi-stock, multi-region systems. We provide guidance for both options.

### 8.1 Forecast Performance of the Pacific Salmon Commission Model

Forecasts of Chinook Salmon abundance obtained from the PSC model after the Agency forecasts were incorporated were relatively unbiased when measured by mean percent error (MPE) for four of the five stocks in this review (Table 2). The forecast for the West Coast Vancouver Island stock was biased low (MPE=-17\%) but not as biased as the Agency forecast (MPE=-30\%; Table 2). While both methods of forecasting North Oregon Coast were relatively unbiased (MPE for PSC model with Agency forecast $=-6 \%$; MPE for Agency forecast $=8 \%$ ) the range in MPE between the two forecasting methods (17\%) was the greatest for the stocks reviewed (Table 2). As with the Agency forecasts, the forecasts obtained from the PSC model after the Agency forecasts were incorporated for the three Columbia River Chinook Salmon stocks and the North Oregon Coastal stock are at the low end of the range of MPE values observed for the chum and sockeye salmon stocks examined by Haeseker et al. (2008; Figure 14). Forecast bias (MPE) for West Coast Vancouver Island was improved and is at the lower end of the range observed for chum and sockeye salmon (Haeseker et al. 2008; Figure 14).

The precision of the forecasts (MAPE) for the five stocks from the PSC model after the Agency forecasts were incorporated was comparable to that obtained from the Agency forecasts (Table 2) and was well within the range of MAPE for chum and sockeye salmon (Haeseker at al. 2008; Figure 15).

An examination of the time series of percent error for the forecasts indicates that errors for both the Agency forecasts and the PSC model with the Agency forecasts incorporated varied together (Figure 29). Of notable interest was the time series of percent error for West Coast Vancouver Island where the Agency forecast was biased lower than the PSC model for all years between 1999 and 2012, with the opposite being true for 2014 and 2015 (Figure 29). The pattern of differences in percent error through time, closely follow the changes in methodology for developing the Agency forecast for WCVI. Namely the use of based period (1979-1982) harvest rates for the 1999-2012 forecasts followed by the use of the recent 3-year average harvest rate for the 2014 and 2015 forecasts (see Section 7.3.1). A similar but opposite pattern is present for the time series of percent error for North Oregon Coast where the forecasts obtained from the PSC model were biased lower from 2005 to 2015 (Figure 29).

The Agency forecasts and the forecasts obtained from the PSC model with the Agency forecasts incorporated were correlated, with North Oregon Coast demonstrating the most variation between the forecasting methods (Figure 30). The tendency for the forecasts obtained from the PSC model with the Agency forecast incorporated to be greater than the Agency forecasts for WCVI is evident, as is the opposite tendency for the North Oregon Coast forecasts (Figure 30).

A review of the bias and precision of forecasts obtained from the PSC model absent input from the Agency forecasts for the five stocks in this review was not performed. Conversations with John Carlile (ADF\&G) indicated that the model would need to be rerun with the Agency forecasts removed in order to determine how the PSC model would forecast absent Agency input. Given the large number of possible ways the model could be examined for the five stocks (one stock removed at a time, all stocks removed, or some combination), extremely limited staff time to do the model runs, and the scope of this review, it was determined that this evaluation would best be performed at a later date.

Table 2. Comparison of bias (Mean Percent Error) and precision (Mean Absolute Percent Error) between the PSC model after the agency forecasts were incorporated and the Agency forecasts for the five Chinook Salmon stocks reviewed.

|  | Mean Percent Error $^{\mathbf{1}}$ |  |  | Mean Absolute Percent Error |  |
| :--- | ---: | ---: | ---: | ---: | ---: |
|  | PSC Model | Agency |  | PSC Model | Agency |
| Columbia River |  |  |  |  |  |
| $\quad$ Upriver Brights | $-1 \%$ | $1 \%$ |  | $25 \%$ | $25 \%$ |
| Spring Creek | $-1 \%$ | $8 \%$ |  | $28 \%$ | $31 \%$ |
| Summers | $10 \%$ | $5 \%$ |  | $22 \%$ | $24 \%$ |
| West Coast Vancouver Is. ${ }^{2}$ | $-17 \%$ | $-30 \%$ |  | $36 \%$ | $45 \%$ |
| North Oregon Coast | $-6 \%$ | $8 \%$ |  | $29 \%$ | $31 \%$ |

${ }^{1}$ Mean Percent error was calculated as (forecast-return)/return; positive values indicate the forecast was larger than the return. The 1999-2013 data are from CTC 2015b Appendix J; data from 2014 and 2015 are preliminary and obtained from John Carlile ADF\&G.
${ }^{2}$ The evaluation of bias and precision for the PSC model from WCVI did not include information for 2013. The Agency forecast was not provided to the PSC modelers prior to the final model calibration and the effect of the missing Agency forecast on the PSC model forecast was unknown.


Figure 29. Percent error by year for the Agency forecasts and the PSC model after Agency forecasts were incorporated into the model. Percent error was calculated as (forecast return)/return; positive values indicate the forecast was larger than the return. The 19992013 data are from CTC 2015b Appendix J; 2014 and 2015 are preliminary and obtained from John Carlile, ADF\&G.


Figure 30. Comparison of the forecast obtained from the PSC model After agency forecasts were incorporated into the model with the Agency forecast. The solid line is where the Agency and PSC forecasts are equal (1:1 line). The 1999-2013 data are from CTC 2015b Appendix J; 2014 and 2015 are preliminary and obtained from John Carlile, ADF\&G.

### 8.2 Unclear management objectives and the PSC Chinook model

The Panel noted that the issue of uncertainty about management objectives for AABM fisheries is relevant to the PSC Chinook forecasting model in the following ways.

Example 1: As of 2016 regional biologists produced forecasts of abundance for the coming year for 23 of the 28 Chinook stocks in the PSC model. Those forecasts are sent annually to the CTC and are used as part of the input to the PSC model for its calibration and projection steps. However, the CTC does not send requests for forecasts to those regions and therefore does not provide specifications for the input data. We have already described the resulting problems in section 6.1 and have identified the need for detailed specifications from the CTC for exactly what it wants as numerical inputs from regional agencies.

Here we focus on a different issue, but it is also related to unclear management objectives for AABM fisheries. Regional agency forecasts from the 23 stocks have traditionally been produced by ranking a variety of models, including sibling age-class relationships, average abundance, and ratios of past returns to successive ages within the same cohort, with all of these estimated from data over various periods (e.g., last 3 years, last 5, etc.). The criteria such as MRE, MAPE, and $r^{2}$ that were used by agencies for ranking these models have differed among stocks, years, and even age groups within a stock. As well, in explorations of different periods of input data for estimating maturation rates to use in the PSC model, the CTC found that the best input data period often depended on the ranking criterion (CTC 2016a).

However, as noted in section 6.4, all ranking criteria are implicitly associated with different management objectives. Some criteria favor models that reduce long-term bias, some favor maximizing precision, and others try to minimize the combination of those two or even unusually large forecasting errors. Although this variety of ranking criteria is legitimate for each region's management objectives, if there are differences in ranking criteria among regions, that means that forecasts that are sent to the PSC model have different statistical characteristics (e.g., some have minimize bias, some have maximized precision). This situation will lead to confusion about what the estimated abundance indices for the three AABMs actually represent. In effect, these forecasted inputs to the PSC model are in different units. To the extent that these regional inputs influence the AABM abundance forecasts produced by the PSC model, this inconsistency in regional model-ranking criteria clouds how to interpret the point forecasts from the PSC model. As a result, when Commissioners and AABM managers look at forecast abundances for AABMs, they are currently not able to know the extent to which those forecasts reflect maximum precision or minimum statistical bias, for example. In other words, statistical uncertainty about any given abundance forecast has already been confounded with uncertainty about what that abundance actually represents (thus failing the "clarity test" of Morgan and Henrion 1990, p. 50). This appears to be an important issue that may have been overlooked by scientists and managers in the PSC, Agencies, and AABM regions.

One solution to this problem would start with clearly stated management objectives for the AABMs, which would then lead to clearly identifying which subset of possible criteria (i.e.,
performance measures) for ranking forecasting models would be appropriate given those objectives. Agency forecasters would then only need to generate forecasts for the one or more models that are highly ranked for those particular performance measures. If more than one performance measure is required to match the management objectives, then agencies should send to PSC modelers the forecasts from the top-ranked model (or set of near-top models) for each relevant performance measure. For instance, that might only include models that are ranked based on MPE and those based on RMSE.

Recommendation 22. The CTC should request each regional agency to provide to PSC modelers the forecasts of abundance for the model deemed best for each of the "relevant" ranking criteria (such as MRE, MAE, or RMSE), where "relevant" is defined as those that fit with stated management objectives for the AABMs .

We emphasize that for each stock, the use by agencies of a range of ranking criteria such as MRE, MAE, or RMSE (and the best forecasting models associated with each) would be solely for the purpose of producing a set of input forecasts to send to the PSC modelers for them to conduct sensitivity analyses across management objectives that are stated for the three AABM fisheries. We would expect each regional agency to continue using its own ranking criteria for making forecasts that are to be used in management of its own terminal fisheries. Managers of different stocks will likely have their own objectives and those may even differ from objectives for AABM fisheries; for low-abundance stocks management objectives will likely be different than high-abundance objectives, for example.

To further clarify our point, the recommendation above is not intended to mean that the PSC modelers should carry out sensitivity analyses across ranking criteria (and hence different management objectives) for regional agencies. No; it is the other way around. Given clearly defined and quantified objectives for AABMs, regional agencies should conduct their own sensitivity analyses to generate forecasts for the different ranking criteria that are deemed appropriate for the management objectives, and then pass those forecasts on to the CTC. The PSC modelers can then produce Als for the AABMs for each of those relevant ranking criteria. The latter procedure will avoid the confusion that is currently present regarding what the forecasts actually represent, as noted in the paragraph before the above recommendation.

Example 2: After the CTC receives agency forecasts that are based on each of the model-ranking criteria deemed relevant and appropriate to the AABM management objectives, the PSC modelers can conduct sensitivity analyses with the PSC model. For instance, the first projection run of the model might use stock-specific forecasts that were made just by each region's model that had the lowest MPE (smallest bias). That run would produce Als for the three AABMs that reflect the least-biased stock-specific forecasts. The second projection run might use the stockspecific input forecasts based on the regions' models that minimized MAE (maximized precision), and so on through the relevant alternative ranking criteria that were deemed relevant to the management objectives for the AABMs. If consideration of model uncertainty
was desirable, projections could also be made for the second- or even third-best agency models for each relevant model-ranking criterion. This iterative procedure of parametric sensitivity analysis would then produce a range of Als for each AABM and each performance measure (and thus each management objective) so that managers could then interpret the Als more sensibly than at present.

Recommendation 23. A series of projection runs should be conducted with the PSC model to produce a range of Als for each AABM area. These Als would reflect the different agencies' stock-specific model-ranking criteria that are deemed relevant to AABM management objectives.

### 8.3 Structural uncertainty in the PSC Chinook model

Example 1: The current PSC model assumes that Chinook Salmon are in one large pool each year for the purposes of calculating catch. In other words, there is no explicit migration from SEAK fisheries, for example, to WCVI fishing areas, as one would have in a so-called "box-car" model. Instead, catches are calculated by simply multiplying the pre-fishing abundance of the cohort (specific to each age, stock, and year) by several terms: a natural survival rate, the proportion of fish that are vulnerable to fishing gear, and the exploitation rate (1979-1982 based-period rate times another factor). However, in reality, at the high rates of exploitation that occur in some fisheries, abundance could be substantially depleted during a fishing season, making fewer fish available both later in the same area and later in fisheries further south. This depletion effect essentially means that there is competition between fisheries for the available fish. As far as the Panel can tell from discussions and the documentation, those depletion/competition processes are not represented in the PSC model, which can contribute to forecasting errors.

This is just one example of where the PSC model contains linear functions in which one or more scalars are simply multiplied by some parameter or independent variable. This basic linear structure contrasts with the workings of most fish stock assessment models, which contain numerous nonlinear functions (e.g., Quinn and Deriso 1999; Walters and Martell 2004).

Recommendation 24. Functionality of the PSC Chinook model might be enhanced by including, where appropriate, nonlinear relationships such as those found in many other fisheries models, including the effect of fishing on reducing the fish abundance available to subsequent fisheries during a given year.

Forecasting errors may be reduced with such changes, although it is impossible to say by how much until those changes are made and new models are tested through numerous future years. A widely used example of a stochastic fish stock assessment model with realistic functions is the stock synthesis model of Methot and Wetzel (2013), which is described later in depth.

Example 2: The PSC model assumes that the marine spatial distribution of Chinook stocks is still the same as it was in the base period of 1979-1982. The Panel has no information on this
assumption, but we would be surprised if that spatial distribution has stayed the same during El Nino or other anomalous ocean years in which distribution has changed for other salmon species. Such changes would affect the model's estimates of exploitation rates in various fisheries. The 7-year-long International Year of the Salmon program currently being developed by the North Pacific Anadromous Fish Commission may provide an opportunity to learn more about where Chinook Salmon currently rear compared with the base period.

## Recommendation 25. Effects of changes in marine spatial distribution of Chinook stocks on functionality of the PSC Chinook model need to be evaluated.

Example 3: Another type of structural uncertainty deals with lack of certainty about relationships between variables such as the effect of body size on maturation rate. The 2016 PSC model included 13 stocks (out of 28) that do not have historical age-structure data for adult returns. For these stocks, we understand that the PSC model assumes that the maturity rates for different ages are the same through time as they were in the 1979-1982 base period. This assumption is likely not valid; the age composition of the 15 Chinook Salmon stocks that actually do have such data has changed from year to year, sometimes dramatically (Appendix B of CTC 2016a), and several stocks are maturing at younger ages than in the past. Such variation is not surprising; it has been observed in other salmon species as well, including sockeye salmon, in which a general increase (not decrease) in the mean age-at-maturity across years has occurred (Pyper et al. 1999).

We recognize that the CTC has investigated alternative ways to estimate maturation rates for stocks with age-structure data, for instance, using the last 3,5 , or 9 years of data to reflect recent changes (CTC 2016a). In that 2016 analysis, they found that the 9 -year average was best, combined with the previous year's EV scalar. Nevertheless, the Panel suspects that the PSC model's current lack of a link between body size and maturation rate could be one of the more influential structural uncertainties affecting the model's forecasting errors. Even for the welldocumented Columbia River upriver brights, the PSC model tends to overestimate the abundance of the age- 3 terminal run and underestimate age 5 s , whereas for the Fraser River late stock, the PSC model produces substantial forecasting errors in both directions for escapement of age 3 s , but age 5 s escapements tend to be over-estimated (Antonio VelezEspino's graphs sent to the Panel on 12 Aug. 2016).

It is well known that body size influences age at maturity in Pacific salmon. All else being unchanged, faster growth is associated with earlier maturation, as reflected by a higher-thannormal proportion of fish maturing at age 3 instead of age 4 , for example. The PSC model already makes assumptions about body-size distributions in order to calculate PNV, the proportion of fish not vulnerable to fishing gear, so there should in principle be no difficulty with also using such body size distributions to calculate annual changes in maturity schedules. We learned that there are two key concerns about the current body-size assumptions as well as our proposed new approach to estimating PNV: (1) the body-size data currently influencing PNV values were gathered years ago and have not been updated, and (2) those data are fishery-
specific as opposed to stock-specific, and in some regions, no body-size data have been collected for many years.

## Recommendation 26. Sensitivity analyses with the PSC model should be used to explore different assumptions about (1) age structure for stocks without historical age composition data, (2) body-size structure used in the current method for estimating PNV, and (3) alternative structural formulations of the PSC model to calculate changes in age at maturity as a function of changes in body-size distributions. Some of those analyses could also assume various correlations with age-at-maturity schedules of other stocks.

The range of output results will then reflect the effects of uncertainty in those structural forms of the PSC model's equations. As introduced in section 6.8, such sensitivity analyses are a routine part of many marine fish stock assessments in the U.S.A. and Canada. Such analyses are either based on a series of separate model runs, each with a different set of hypothesized forms of equations, or through inclusion of probability distributions on particular parameters that alter shapes of equations.

The Panel realizes that given the current structure of the PSC model and its calibration process, such time-consuming sensitivity analyses cannot be done in the few weeks normally available between when final input data come in and the March 1st deadline for producing forecasts for the AABMs. However, it might be possible to conduct such sensitivity analyses at other, less busy times of year. Without results from such sensitivity analyses, the PSC model's current point-estimate forecasts of abundance in each AABM do not reflect their true uncertainty, which thereby makes for less-well-informed decision making. The model's forecasts of abundance should reflect the scientist's own uncertainties about the model's structure.

Example 6: In the calibration stage, the PSC model estimates a time series of Environmental Variable (EV) values for each stock. These EV values are used to scale up or down the abundances calculated from stock-recruitment relations in the model. As we understand it, the model does not assume that EV values of different stocks can be positively correlated with one another. However, it is known for pink, chum, and sockeye salmon (Pyper et al. 2005), as well as Chinook Salmon (Riddell et al. 2013), that many separate stocks have positively correlated yearly variation in productivity (adults produced per spawner), especially stocks that have early life stages in nearby marine areas. In essence, that means that one or both parameters of the stock-recruitment relations are positively correlated across stocks and/or the residual variation around those relations are correlated. Therefore, by not using information on these shared patterns of variation, the calibration stage for the PSC model is missing an opportunity to refine parameter estimates and possibly reduce errors in forecasts of abundance in AABMs.

Recommendation 27. The differences between pre-season and post-season abundance indices in each of the three AABMs might be reduced by including in the PSC model

## tendencies for multiple stocks to have positively correlated time series in productivities.

This can be accomplished during the calibration process by estimating parameters of a hierarchical model that includes parameters for broadly shared parameters as well as stock-specific parameters (e.g., Mueter et al. 2002; Banerjee et al. 2004). This addition of a hierarchical framework will be challenging in the PSC model, but it has been done in other more complex salmon models (e.g., Dorner et al. 2009).

Example 7: Some components of the PSC model (such as EV values, RT scalars) probably vary in the real-world system as functions of other factors. Such processes are not currently explicitly accounted for in the PSC model (as opposed to implicitly in some catch-all adjustment parameter like EV that is estimated during calibration), yet they can change over time, not only owing to inevitable between-year variation, but also to longer term trends that may be caused by climatic change. Such changes that are not explicitly accounted for in the PSC model may partially explain the recently observed increased magnitude of both positive and negative forecasting errors. [Incidentally, the EV term, called "an environmental factor" in some CTC documents, actually includes the net effect of all the other sources of variation that are not explicitly and dynamically included in the model-fitting process, such as shifts in age-at-maturity schedule, survival rates, and assumed harvest rates.]

Recommendation 28. The PSC model might be improved if factors such as EV and RT were calculated as functions of other variables.

There will be additional assumptions and data requirements, but CTC modelers should at least explore how the PSC model's forecasts might be improved by explicitly including such dynamic processes. We recognize that the CTC has explored various ways to improve the PSC model (e.g., p. 130 of CTC 2014), but we suggest going further in that endeavor.

Example 8: As already noted in section 6.8, the PSC model is deterministic, that is, it does not explicitly include any sources of random variation or uncertainty. Thus, for a given set of inputs from its 11 input data files, each time the model is run, it will produce exactly the same singlevalue point forecasts of the abundance index in each of the three AABM areas. Not only do such point estimates fail to reflect the real-world's variability and scientists' uncertainties about the natural system, they also do not indicate to decision makers and members of the fishing industry how low or high abundances could possibly be. This complete absence of uncertainty about forecasts is unacceptable in 2016. Instead, explicit statements of uncertainty in forecasts of abundance are the norm in present-day stock assessments for other fish species.

Recommendation 29. Uncertainty in estimates from the PSC Chinook model should be explicitly represented either by making the model stochastic or running it across numerous sets of assumptions using sensitivity analyses.

For instance, CTC modelers could start by incorporating into the PSC model at least two important variance terms relevant to Chinook Salmon forecasting, maturation rate and
survival rate/productivity. These could be based on empirical analyses of historical changes in those variables. If links to other variables are identified, they could be added as functions, as suggested above, but with some random error term.

Alternatively, an entirely different model, the stock synthesis model of Methot and Wetzel (2013) described below, is just one of many stochastic models that could implement this approach (also see Walters and Martell 2004).

Example 9: We expect that PSC Commissioners and area fisheries managers implicitly assume that the PSC model (like almost all fisheries models) should be able to take into account new conditions and processes. Examples would be spatial and temporal changes in Chinook productivity owing to climatic change, changes in efficiency of fishing gear and its spatial distribution since the base period of 1979-82, and changes in stock composition of fish in a given AABM. We understand that the PSC model attempts to account for such changes by assuming certain time-dependent scalars like FP (fishery policies) and RT ("a scalar to adjust the legal catch to match the observed catch under ceiling management", from John Carlile's presentation at the Portland workshop). The stage 1 calibration also fits a single adjustment factor, the time series of EV (for "environmental factors"). However, this approach of identifying various linearly related scalars is indirect and is less likely to deal adequately with new situations than a model that calculates such scalars as a function of new states (e.g., body size distributions, ocean conditions). The current PSC model also does not reflect uncertainties that are inherent in components of the equations. The larger forecasting errors produced by the PSC model in the last 5 years or so may be a result of changes in underlying dynamics that are not accounted for by the model's current functions and scalars.

In summary to this point, in the Panel's view, the PSC Chinook model's lack of representation of uncertainties in its inputs, assumptions, and outputs does not reflect the current state of the art that one might expect for a model that strongly influences management decisions in multi-million-dollar annual fisheries, especially given that they are also the subject of a major treaty between the U.S.A. and Canada.

## Recommendation 30. Ideally, the existing PSC Chinook model and/or its procedures should either be tested and refined or an entirely new model (or models) should be developed.

We caution though, that the intent should not be to develop one single new model. Instead, to be consistent with the idea that there will always be structural uncertainty, several alternative structural versions of a Chinook model should be developed that differ in their assumptions. They may even differ in the amount and type of data they require. Forecasts generated with each of those models will produce a range of forecasts to illustrate the uncertainty in those outcomes. If those models are stochastic, there will be a further refinement of the probability distribution of forecasts of abundance.

One of the basic tenets of modeling is that the structure of a model should be closely tailored to its use, i.e., what managers need to know to meet their management
objectives. Therefore, the following four examples of alternatives to the current PSC model should be evaluated in part by their suitability for the specific needs of the PSC. Each model can be formulated in several alternative ways using different assumptions.

The first model is the age-structured assessment model developed and tested for Copper River Chinook Salmon in Alaska by Savereide and Quinn (2004). Their "salmon catch-atage analysis" (SCAA) model builds upon an early method of Kope (1987) and draws upon modern stock assessment methods. It uses catch-at-age data, escapements, and spawnerrecruit relationships, and it is adaptable to using different types of data on selectivity of fishing, yet does not require fishing-effort data. Its parameter-estimation procedure takes into account observation (measurement) error, and various other uncertainties when making forecasts. The Panel believes that this Savereide and Quinn (2004) model may be a viable, up-to-date alternative to the current PSC model that will still be able to produce abundance forecasts for the AABMs.

The second possible alternative to the current PSC model is the "stock synthesis" model (Methot and Wetzel 2013). Stock synthesis has been used for a wide variety of species covering 61 stocks worldwide. Key features of this comprehensive modeling framework include the following. It can adapt to various amounts and types of data (including CWT information) and can estimate fishing mortality rates in the absence of a time series fishing effort data. It will forecast future abundances based in part on stock-recruitment relations. It handles multiple spatial areas and growth types, allows for changing parameters in response to environmental factors, and explicitly takes uncertainties into account to produce a range of outputs. In short, this Methot and Wetzel (2013) stock synthesis model appears ideally suited for PSC Chinook Salmon. We therefore strongly recommend that the CTC seriously consider using it, or at least comparing its suitability to the Savereide and Quinn (2004) model.

Two other types of Chinook models were developed by Morishima and Chen (2005) and Sharma (2009), the latter a statistical catch-at-age model originally proposed by Sharma and Yuen (2004) in a grant proposal that was not funded. The CTC is already familiar with these alternative models, so we will not describe them here. We were given four reasons at the Portland meeting why there has been no follow-up by the CTC with one or both of these models:

1. We were told that they would not be able to produce the abundance indices (forecast divided by abundance in the base period, 1979-1982) in column one of Table 1 in Chapter 3 of the Treaty. We do not understand why not. It appears to us that both alternative models could produce such abundance estimates, so the CTC should take another look at those models.
2. The Morishima and Chen (2005) model requires data on fishing effort, which "aren't readily available for some fisheries" according to a presentation at the Portland meeting. It is not clear to the Panel whether a large or small portion of the catch is
taken in the fisheries with missing effort information. If it is small, then the Morishima and Chen model may still be feasible.
3. It takes a huge amount of work by many people to produce the annual forecasts from the existing PSC model, and there is no time to develop other models. Although we acknowledged this problem above in section 6, if other reporting requirements in the Treaty were reduced, or if plans to expand the PSC model to almost double the number of fisheries were postponed, CTC members would have more time to investigate alternative models. At the Portland workshop we heard doubts about the benefits of adding more stocks and fisheries to the PSC model instead of updating it in other ways.
4. When evaluated solely on the basis of the deviation between pre- and post-season abundance indices in the three AABM areas, the PSC model was doing reasonably well up until about 2006 or even 2011 (Figure 1), and we were told that there was no perceived need to change the model. The Panel concluded that the continuation of large forecasting errors, particularly over the last 5 years should be a strong incentive to drastically revise the PSC model to explicitly take into account the dynamics of variables such as productivity, body size, and age-at-maturity that reflect welldocumented changes that are occurring in the ocean and fresh water.

In the long term, the PSC should consider developing a formal, quantitative Management Strategy Evaluation (MSE) framework (Sainsbury et al. 2000). Such a framework entails identifying management objectives and evaluating a range of potential management options to achieve them using a set of alternative but plausible system models (not just "the best" single model) to represent uncertainties in the system's underlying dynamic processes. The output from such a MSE is a set of management strategies that are most robust to uncertainties related to model structure, parameter values, and outcomes of applying harvesting regulations (Sainsbury et al. 2000).

Management Strategy Evaluation is now considered the "gold standard" that most marine fisheries aspire to for fish stock assessment and management decision making. MSE has been used in over two dozen fisheries to derive robust management strategies, including Fraser River, Canada, sockeye salmon (Pestal et al. 2011), and pelagic as well as groundfish species, mostly in North America, Europe, South Africa, and Australia (Andre Punt, University of Washington, Seattle, personal communication).

### 8.4 Uncertainty in parameters of the PSC Chinook model

Example 1: Testing of the PSC model, which has now been used for decades, has never been done to see how well its parameter estimates (as opposed to abundance indices) reflect underlying true parameter values, as determined by independently generated test data sets. This is surprising and unsettling, given the frequency and usefulness of this approach in current fisheries research elsewhere. The Panel respects the work of the CTC, especially the members of the Analytical Working Group (AWG), who have to work within the constraints of a model that was originally built for other purposes. The cleverly designed calibration process is one way of addressing some of those constraints, but evaluation of the PSC model with independent data seems essential.

## Recommendation 31. Testing of the PSC model (and all other contemplated models) should be a high priority when the Data Generating Model is released.

The lack of independent tests of the PSC model will apparently be remedied when a Data Generating Model (DGM) that is currently being developed becomes available. The DGM will have known (but hidden from the PSC model) parameter values, and will generate test data sets to feed into the PSC model. The latter model's estimates of parameters such as stock-specific EVs will be compared with known parameter values to determine the reliability of the PSC model.

Example 2: We find it unlikely that the quantitatively skilled CTC members of the AWG would have missed the following point, but based on our readings of PSC model documents and slides presented in Portland, the Panel believes that some parameter estimates could be confounded in the stage 1 calibration of the PSC model. By confounding, we mean that although a best-fit result is obtained during calibration, it may not give a unique solution; for instance, more than one combination of RT values and EVs might give equally good fits.

The following quote from CTC (2008) raises a related question about confounding of parameter estimates.

In other words, if the observed catch, escapement, terminal runs are
reproduced correctly and the assumptions about harvest rates, survival rates and maturity rate are "reasonable", then the cohort estimate must be "right". After the model is "calibrated", you can forecast the harvest for the upcoming fisheries (footnote on p. 46 in the Frequently Asked Questions section of CTC 2008).

The Panel is concerned with the three assumptions in this quote (harvest rate, survival rate, and maturity rate). These parameters are assumed known in order to estimate the EV factors, which essentially adjust the Ricker stock-recruitment parameters. What if EV was left set=1 and the calibration process instead estimated harvest rates, or survival rates, or maturity rates? We suspect that the resulting forecasts in the projection runs of the PSC model might be different.

In a closely related situation, it appears that the PSC model calculates for each stock the abundance of age 1 recruits from a Ricker spawner-recruit model and the EV multiplier (scalar) described above, which is initially assumed equal to 1 . The model then assumes constant annual natural morality rates between successive ages, starting with $50 \%$ from age 1 to age 2 , $40 \%$ from age 2 to 3 , etc. down to $10 \%$ for age 5 . Then in stage 1 calibration, a vector of annual EV values are estimated for each stock, assuming that all other parameters are known. But if different natural mortality rates were assumed, then the EV values would change, as would the forecasts coming out of the PSC model.

As well, a question came up at the Portland meeting about whether the calibration of the PSC model suffers from over-fitting. In other words, is it attempting to estimate too many parameters given the data? If so, then this creates a problem for the reliability of its forecasts.

Recommendation 32. Evaluations of the PSC model should include: (1) a check whether there is confounding of parameter estimates in the stage 1 calibration; (2) a series of sensitivity analyses/calibrations exploring alternative values for assumed agespecific natural mortality rates that might affect all other subsequent calculations and forecasts of abundance, and (3) consideration of whether the PSC model is being over-fit.

Example 3: The Panel did not find documentation on how stock-specific Ricker stockrecruitment parameters were estimated for the PSC model. There are a few ways to do this, some of which correct for various biases. Regardless, the parameter values are assumed to be fixed, time-independent parameters in the PSC model, despite evidence that Pacific salmon have demonstrated substantial long-term trends in productivity in pink, chum, and sockeye salmon (Peterman et al. 2003; Malick and Cox 2016).

Recommendation 33. Documentation should be provided on the basis of estimates of Ricker stockrecruitment parameters, as well as uncertainty in those estimates. Also, some improvement in performance of the PSC model might be obtained if the AWG used a Kalman filter that allows for a time-varying maximum productivity parameter in a given stock's Ricker stock-recruitment model. That Kalman filter procedure will explicitly take into account observation error as well as natural variation.

The resulting time series of Ricker 'a' parameters would essentially replace, and perhaps improve upon, the portion of the variation in the time series of the EV parameter that represents time-varying productivity. This Kalman filter method has been tested for its ability to track underlying changes in productivity (Peterman et al. 2000) and has been applied to pink, chum, and sockeye salmon (Peterman et al. 2003; Dorner et al. 2008; Malick and Cox 2016). Such a parameter estimation method may provide a more solid theoretical foundation for estimating time-varying parameters that should be used in the PSC model.

Example 4: In the section above on structural uncertainty, we already mentioned parameters such as maturation rates between successive ages in the context that they might be considered as functions of some variable. However, if not enough information is available to develop such functions, then uncertainty in such parameters should be considered in the PSC model by running successive sensitivity analyses. Specifically, separate model runs should be conducted for each important parameter such as maturity rate, with each fixed at either a plausible high, medium, or low value. Many important PSC model parameters might be appropriate for such analyses, including some in the 11 input data files. These could include hard-to-estimate parameters such as (1) "direct estimates of encounters [of fish with fishing gear] during CNR [Chinook Salmon non-retention] period[s] or indicators of fishing effort in the CNR period relative to the retention period", or (2) "incidental mortality rates by fishery for legal and sublegal fish that differ from those used in the base period due to alterations in gear, regulations, or fishery conduct" (CTC 2014).

Recommendation 34. Given the large number of input parameters, all possible combinations of low, medium, and high values for each parameter may be impossibly time consuming. However, only a subset of those combinations would be needed to produce a range of forecast abundances.

Sensitivity analyses conducted with only a subset of all possible combinations of parameter values is routinely done in scenario analysis or ensemble modeling (the latter term used by the Intergovernmental Panel on Climate Change, IPCC, when presenting ranges of projections given various uncertainties). In the case of the PSC Chinook model, one could first choose the best-case values for all parameters with respect to their effect on forecasted abundance, run the model to get the high end of the range of forecasts, and then repeat the process with the worst-case values for all parameters. Such parametric sensitivity analyses are quite common as a way to take uncertainty into account without knowing the proper stochastic equation for variation in parameters (Morgan and Henrion 1990).

Example 5: For the 6 out of the 28 Chinook PSC model stocks (as of 2016) for which agencies do not usually provide annual forecasts of abundance, the PSC model generates its own forecasts. Two of those 6 stocks have no historical age-structure data, and one of them has such age data but only up through 1993. According to the CTC, "Model stocks that do not have annual agencygenerated forecasts represent about $2 / 3$ of the catch in the NBC fishery, $1 / 3$ in the SEAK fishery, but only 5\% in the WCVI fishery" (CTC 2106b). The model assumes an age structure and then generates abundance forecasts through its assumptions about productivity. However, details of this procedure are not fully documented, and correspondence with CTC members failed to clarify it.

Recommendation 35. Additional evaluation and documentation are needed of the PSC model's methods for dealing with stocks for which age-composition data and/or

## forecasts of terminal abundance or escapement are not available, given the large relative abundance of those stocks in some AABM areas.

Example 6: We also learned that proposals have been made recently to use the PSC model's own forecasts of terminal abundance for particular stocks (WCVI and Columbia River summers) instead of what some people perceive as unreliable stock-specific forecasts that are provided by regional analysts. As noted in Section 7, forecasts for those two stocks have mostly tended to be too low.

## Recommendation 36. The Panel generally recommends use of stock-specific forecasts provided by agencies rather than forecasts derived solely from the PSC model in the absence of clear evidence of improvements in accuracy and precision across multiple years.

There are two reasons for this recommendation. First, as noted above, the assumptions are vague and undocumented for the PSC model's procedure for dealing with stocks for which agency-generated forecasts are either not available or are not used by the CTC. Second and most importantly, we have not seen any quantitative evaluation of bias and precision for that PSC-model procedure, so there is no reason to believe a priori that it will be any better or any worse than the current stock-specific forecasting methods (at least in terms of its influence on the estimates of abundances in the three AABMs).

### 8.5 Outcome uncertainty in the PSC Chinook model

Example 1: A comparison of post-season estimates of catch of Chinook Salmon with the maximum allowable catch specified in Table 1 of Chapter 3 of the 2009 Annex to the Treaty illustrates outcome uncertainty (Figure 35). In two of the three AABM fisheries, actual catch exceeded the maximum allowable in most years (CTC 2014). Although that maximum allowable catch was not a target per se, fishery managers presumably did not want it exceeded. The fact that it was exceeded reflects the effect of one or more of the sources of uncertainty listed above.

These three graphs (Figure 35) also illustrate the importance of showing uncertainties in forecasts of abundance indices (AIs) in AABM fisheries, which, to our knowledge, are not currently reported by the CTC to PSC Commissioners or AABM fishery managers. If the PSC model's forecasts of Al turn out to be too high, then the true Al would be to the left of its forecasted location on these graphs, causing catches to be even greater than the maximum allowable amount in the SEAK and WCVI fisheries. The reverse would be true for forecasts that are too low. Our main point is that two key sources of uncertainty interact in these important graphs, yet they are both being overlooked in the current PSC model and reporting process.


Figure 35. Post-season deviations in catch (vertical lines) from maximum allowable catch levels in the SEAK (top), NBC (middle) and WCVI (bottom) AABM fisheries for 2009-2012 (CTC 2014).

## Recommendation 37 Considerations of outcome uncertainty (deviation between desired and realized outcomes such as catches), as well as uncertainties in forecasts, will influence expectations of managers of these AABM fisheries when they choose annual fishing regulations.

Failure to do so may result in not meeting management objectives, either for their own AABM areas or for the Treaty. It is beyond the mandate of this Panel to advise managers on how they should take such uncertainties into account. Suffice it to say that there is considerable experience in doing so in other fisheries, including the Fraser sockeye salmon (Fisheries and Oceans Canada 2015) and many marine fisheries around the world.

Example 2: Outcome uncertainty is relevant here because the PSC model's forecasts of abundance indices in the AABMs and terminal areas are in part based on assumptions about the exploitation rates that will occur in the forecasted year. Those forecasts should therefore reflect the difference between assumed and actual realized exploitation rates. Such differences are inevitable; managers are likely concerned about both their magnitude and direction.

## Recommendation 38. The PSC Chinook model should take into account outcome uncertainty when making forecasts and presenting uncertainties in them.

The Panel is unclear how best to do this, but we are confident that the CTC's AWG can empirically estimate frequency distributions of the magnitude of outcome uncertainty in past years and add those uncertainties to the PSC model.

### 8.6 Other issues related to the PSC Chinook model's forecasts

Example 1: We respect the care and diligence that is taken with the time-consuming annual process of calibrating the PSC model with past data and making projections. Nevertheless, we learned from some CTC members that improvements are sorely needed for that calibration process. For instance, apparently there are no pre-agreed-upon quantitative standards for deciding when a particular calibration is "sufficiently good" to be deemed as "final" by the CTC. Although seven criteria for evaluating calibration results are listed in documents such as CTC (2015, pp. 92-93), we heard that there appears to be a lack of standardized procedures for applying them from one year to the next, and for determining which model assumptions or parameter values need to be changed in subsequent calibrations if initial ones are not acceptable.

Recommendation 39. The calibration procedure for the PSC model should be standardized and thoroughly documented to such an extent that a new member of the Analytical Working Group could repeat previous example analyses and come to the same stopping point about which calibration is deemed "final".

We know that in situations like this one with the PSC model, expert judgment and experience are invaluable. We anticipate that a standardized and well-documented calibration procedure will also help reduce the workload of the CTC (which we repeatedly
heard is onerous) by reducing the time needed for training of new members. Such a step is also good practice for succession planning for replacing CTC members as they retire.

Example 2: As noted previously, the PSC model only produces point estimates for annual abundance forecasts in AABM areas.

Recommendation 40. The abundance forecasts for AABMs areas produced by the PSC Chinook model should convey to managers the net effect of all of the major uncertainties described previously -- structural uncertainty, parametric uncertainty, uncertainty about management objectives, and outcome uncertainty.

The CTC's annual forecast Als should be produced along with measures of uncertainty in the forecasts. We recommended the same in section 7 for stock-specific forecasts. The point estimates could still be compared to abundance values in Table 1 of the Treaty, but the addition of uncertainty measures would help with decisions based on different management objectives.

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# Appendix A - Executive Summary of Review Process 



# Review of Chinook abundance forecast methodology: 

## Summary of process and timelines

Issued by the Executive Secretary

May 24, 2016

## Purpose

Various concerns have been raised about preseason forecasts provided by agencies as input to the annual calibration procedure of the Pacific Salmon Commission (PSC) coast-wide chinook model and how these are incorporated into the calibration procedure which ultimately results in the Abundance Indices (AIs) and total allowable catches for the three Aggregate Abundance Based Management (AABM) fisheries. Thus, the Commission approved a process and timeline for an independent technical review of agency pre-season abundance forecasts and their application in the PSC's Chinook Technical Committee (CTC) coast-wide model. The review will include three methods for predicting stock abundance (agency forecast, CTC model calibration from agency forecast, and CTC model forecast absent agency forecast) and:

1) Evaluate the bias and precision of each method in predicting the pre and post-season abundance (Abundance Index (AI));
2) Provide advice on the strengths and weaknesses of each method; and
3) Suggest improvements to current agency pre-season forecast methods for predicting stock abundance.

## Approach

An Independent Expert Panel ("the Panel") will be established consisting of three members, one proposed by Canada and two by the U.S. Section to review agency and PSC model preseason forecasts.

The Panel will identify appropriate criteria that should be used to evaluate accuracy and precision of pre-season agency forecasts and model projections, and conduct a detailed review of methodology and subsequent performance of agency produced and chinook model produced forecasts. The Panel will identify which years should be used to evaluate forecast performance,
for example the current chapter years 2009 to 2015 or as deemed helpful by the Panel. The review should describe current methods used for agency and model forecasts, how the agency forecasts are incorporated into the chinook model, provide a diagnosis of the deviations between model and agency forecasts, and suggest improvements on current methods to minimize error and improve precision compared with the final-post season estimates.
The project will have four stages:
i. Workshop/Information Collection: The Panel will hold a workshop/meeting in person with officials directly responsible for the selected agency forecasts and the PSC's CTC Chinook model. Agency staff will provide technical/analytical information about the domestic agency forecasts and annual run reconstruction methods. At this session, a document/presentation will also be made on the PSC Chinook Model in order to familiarize the panel members with the Chinook Model calibration procedures:
a. incorporating the agency-provided forecasts,
b. generating forecasts for stocks for which an agency forecast is not available,
c. calculate the pre-fishery cohort abundances which are then allocated to ocean and terminal fisheries.
ii. Develop a draft report: The panel members will review the information and develop a draft report according to the above mentioned requirements.
iii. Review process: The panel will provide the draft report to the agencies in order to check facts, identify errors, and to avoid misunderstandings regarding feasibility of the recommendations to improve the agency forecasts. The agencies will provide comments back to the Panel within two weeks. Should the Panel wish to discuss comments with agencies: phone calls, virtual meetings or ad hoc small meetings should be used to minimize costs whenever possible.
iv. Update to the Commission: A brief update on progress and elements of the draft report will be provided at the Fall Session of the Commission in Vancouver, B.C., 3-7 October 2016. The panel will provide the update virtually or in a way that minimizes costs.
v. Finalize report: The panel will finalize the report and transmit it to the Commission by November 14, 2016.

## Stocks to be considered in the review

The Commission has selected the following stocks for the review to manage the Panel's work and to focus on stocks which have an impact on AABM fisheries and those in which there are performance issues:
i) Columbia River Upriver Brights
ii) Columbia River Summers
iii) Spring Creek (Columbia River)
iv) Oregon Fall Coastal
v) West Coast Vancouver Island

## Timelines

i) Following adoption by the Commission, the Secretariat will alert the agencies affected to the review process and timeline and request their support in the collection of pertinent information to be provided to the Panel in advance of an information collection workshop to be held in early summer. The Panel will confirm dates with the Secretariat and designate a primary panel contact.
ii) The Panel will provide a draft report for fact-checking review to the relevant agency staff by mid-September 2016. Agencies will have two weeks to review the draft and provide comments to the panel by October 1, 2016.
iii) Should they wish, the Panel may follow up with the agencies' staff to discuss any of the errors identified in their fact-check review.
iv) The Panel will provide its final report to the Commission by November 14, 2016.

## Implementation

The PSC Executive Secretary will work closely with the respective National Correspondents to implement the process by:

- Engaging the panel members identified by the Parties through contract for work.
- Arranging the necessary meetings with agency staff, including the initial in-person meeting in Portland, Oregon in early summer 2016 and the other virtual meetings.
- Managing the payments to the panel members and tracking progress.

Panel members are expected to arrange meetings amongst themselves however they may request the assistance of the Secretariat including providing webinar access.

## Budget/Funding

It is proposed that the panel members may use up to 20 days to carry out the review. Should the panel members determine that more days are required to complete the work, while remaining within the timeline for reporting to the Commission, they should notify the Commission by the end of August with a detailed rationale. The Parties will be responsible for the costs of their respective staff in the process. It is envisioned that the panel's costs will be provided by the Parties: two members by the U.S. and one member by Canada.

The sources of funds will be identified internally by the Parties. As determined by each Party, the respective agencies may be offered funding or asked to bear the costs of their experts' participation in meetings including any required travel expenses. Considering that four of the five stocks subject to review are located in Oregon, the first in-person meeting could be held in Portland, Oregon. To contain costs, any further meetings should be held virtually, however if the Panel believes in person meetings are required then they should be held in a location that meets the financial needs of all agencies.

## Appendix B - Independent Panel

Brian Bue, Owner, Bue Consulting LLC. Brian received his undergraduate and graduate degrees from the University of Alaska, Fairbanks. He has provided consultations on Arctic-YukonKuskokwim salmon projects through the Arctic-Yukon-Kuskokwim Sustainable Salmon Initiative. He is retired from the Alaska Department of Fish and Game/Commercial Fisheries Division, and was the project leader for forecasts for Bristol Bay sockeye salmon.

Randall M. Peterman, Professor Emeritus, Simon Fraser University. Randall held a Canada Research Chair in "Fisheries Risk Assessment and Management" from 2001 through 2012 and specialized in quantitative methods to improve fisheries management. His research focused on: (1) fish population dynamics, (2) uncertainties affecting conservation risks and management decisions, and (3) reducing uncertainties.

Ray Beamesderfer, Fish Science Solutions. Ray is a fisheries expert in the Pacific Northwest with specialties in fishery management, statistical analysis, biological assessment, life history, and effects modeling, among other services. Ray last worked for the Oregon Department of Fish and Wildlife in 2000, and since has held positions with a variety of consulting firms.

## Appendix C - Portland Workshop, 10-11 August 2016

## Agenda

Day 1, Wednesday the 10th of August 2016, 8:30 AM - 5:00 PM

## Start 8:30 AM

1. Welcome and logistics -- Ray Beamesderfer, Meeting Facilitator

- Introductions

2. The Panel's process -- Panelists (Randall Peterman, Brian Bue, Ray Beamesderfer)
A. Terms of reference - focus on technical scientific issues
B. Five focal Chinook stocks
C. Time line
D. Conceptual framework
3. Participant Perspectives - All
4. General overview -- Gayle Brown (CFDO) \& John Carlile (ADFG)
A. How the Pacific Salmon Treaty sets the context for the Panel's work on forecasting
B. For each major fishery, what is the percentage catch composition by stock (time series)?
C. For each of the 5 Chinook stocks in this review, what percentage of their catch occurs in each major fishery (time series)?
D. Very broadly, how Chinook forecasts are fed into the annual regulation-setting process
5. Pacific Salmon Commission Chinook model -- John Carlile (ADFG), Gayle Brown (CFDO), and Antonio Velez-Espino (CDFO)
A. Role of model in implementation of the Treaty
B. Past forecasting performance of the Chinook model
i. Comparisons with annual post-season estimates of abundance
ii. Comparisons with stock-specific agency forecasts for those stocks
C. Chinook model
i. General structure
ii. Key assumptions and evidence for how well they are supported by data
D. Annual calibration procedures for the Chinook model
i. Incorporating agency forecasts
ii. Generating forecasts for stocks where an agency forecast is not available
iii. Again, key assumptions and evidence for how well they are supported by data
E. Estimation of the pre-fishery cohort abundances, which are then allocated to ocean and terminal fisheries
F. Estimation of post-season abundances against which forecasts have been compared
G. Alternative versions of the Chinook model that have been explored
H. Suggestions for how to improve forecasts
I. Questions from Panel
6. General discussion
A. Further suggestions for how to improve forecasts for the CTC's Chinook model
B. Alternative performance measures, such as minimizing frequency and/or magnitude of large ( $>\mathrm{X}$ ) forecasting errors, being more concerned about over-estimates than underestimates (or vice versa), etc.
7. Presentations for each of the five Chinook stocks, subject to re-ordering.
[Please note: The Panel respectfully requests that all presentations below (1) begin with describing the historical performance of forecasts (at a minimum, time series as well as measures of bias and precision) in order to set the context for your descriptions of (2) forecasting methods, (3) why certain years were used as inputs to forecasting methods, (4) key assumptions and limitations/weaknesses of existing forecasts and the underlying data, (5) which other forecasting methods have been explored, and (6) suggestions for how to improve forecasts.]
A. West Coast of Vancouver Island (WCVI) (max. 45 min.) -- Diana Dobson (CDFO)
i. Agency's presentation
ii. Questions from Panel

5:00 PM -- [End of first day approximately here]
Day 2, Thursday the 11th of August 2016-8:30 AM - 4:30 PM
8. Continue stock-specific presentations
A. West Coast of Vancouver Island (WCVI) - continued
i. Agency's presentation
ii. Questions from Panel
B. Columbia River Fishery Orientation - Jeff Whisler (ODFW)
C. Columbia River Upriver Brights -- Steve Haeseker (USFWS)
i. Agency's presentation
ii. Questions from Panel
D. Spring Creek hatchery - Steve Haeseker (USFWS)
i. Agency's presentation
ii. Questions from Panel
E. Columbia River Summer run -- Stuart Ellis (CRITFC)
i. Agency's presentation
ii. Questions from Panel
F. Northern Oregon Coast fall -- Ethan Clemons (ODFW)
i. Agency's presentation
ii. Questions from Panel
9. ForecastR package -- Antonio Velez-Espino (CDFO)
10. General discussion
A. Suggestions for how to improve forecasts for the five focal stocks
B. Experience with combining results from multiple forecasting models
C. Alternative performance measures
D. How good is good enough for the forecasts?
11. Next steps and action items, including the Panel's further requests for information - Forms for participants
12. Wrap-up - Panelists

Attendance

| Name | Agency |
| :--- | :--- |
| Alan Byrne | IDFG |
| Antonio Velez | CDFO |
| Ben Cox | WDFW |
| Bob Clark | ADFG |
| Brian Bue | Panel |
| Christine Mallette | ODFW |
| Diana Dobson | CDFO |
| Ethan Clemons | ODFW |
| Gayle Brown | CDFO |
| Jeff Whisler | ODFW |
| John Carlile | ADFG |
| John North | ODFW |
| Jon Hess | CRITFC |
| Lisa Harlan | WDFW |
| Marianne McClure | CRITFC |
| Matt Falcy | ODFW |
| Randall Peterman | Panel |
| Ray Beamesderfer | Panel |
| Robert Kope | NMFS |
| Robin Ehlke | WDFW |
| Roger Dick, Jr. | YN Fisheries |
| Ron Roler | WDFW |
| Steve Haeseker | USFWS |
| Stuart Ellis | CRITFC |
| Tim Dalton | ODFW |
| Tommy Garrison | CRITFC |
|  |  |

## The Panel's Process - Randall Peterman (Panel)



|  | B. Five Chinook stocks <br> - West Coast Vancouver Island <br> - Columbia River Upriver Brights <br> - Columbia River Spring Creek Hatchery <br> - Columbia River Summers <br> - Northern Oregon Coastal fall Chinook |
| :---: | :---: |
| C. Time line for Panel's work <br> - Started 15 July 2016 <br> - Meeting in Portland 10-11 August <br> - Draft report by 15 September <br> -- Will be sent to PSC and area agencies to check facts, identify errors, etc. <br> -- By 30 September, CTC and area agencies to provide comments to Panel on draft report <br> - Verbal report to PSC 3-7 October <br> - Final report by 14 November 2016 | D. Conceptual Framework for Panel's Review: <br> Sources of Uncertainty |
| D. Conceptual Framework for Panel's Review: <br> Sources of Uncertainty |  |


| Uncertainties in hypothesis/assumptions <br> Structural uncertainty <br> Parametric uncertainty <br> Unclear management objectives <br> Outcome uncertainty | Uncertainties in hypothesis/assumptions <br> Structural uncertainty -- forms of equations |
| :---: | :---: |
| "Now that desk looks better. Everything's squared away, yes sir, squaaaaaared away." | Uncertainties in hypothesis/assumptions <br> Structural uncertainty <br> - Linear or nonlinear ? <br> - How include effects of body size, ocean conditions, size-selective fishing, ...? |
| Uncertainties in hypothesis/assumptions $\qquad$ <br> Parametric uncertainty <br> - Imperfect data from observation error <br> - Variations over time and/or space in: <br> -- Maturation rate <br> -- Survival rate / productivity <br> -- Efficiency of fishing gear <br> -- Proportion vulnerable <br> - Input variables (catches, CWT, forecasts, ...) | Uncertainties in hypothesis/assumptions <br> Unclear management objectives <br> Rank order of alternative forecasting models can be affected by ranking criteria: <br> - Minimize bias <br> - Maximize precision <br> - Minimize prob. of large errors (e.g., >30\%) <br> - Minimize frequency of over-forecasts (or under-forecasts) |



## Expectations of non-panel participants at the Portland workshop - Facilitated Discussion

## Table 3. Responses to the question of "what is the single most important problem or issue for improving forecasts?"

1. Unclear management objectives. Uncertainty needs to be described.
2. Model is designed to minimize pre and post season Al's, not fit to the inshore population. For the two types of forecasts, agencies' forecasts of terminal runs/escapement and CTC model's forecasts of abundance indices in AABMs, a model selection process is critical and should be based on retrospective analysis.
3. Would like to better forecast large runs that are at levels above beyond the historical data.
4. Persistent recent bias in WCVI forecast, possibly an environmental effect. There is a difference between agency forecasts used for regional management purposes and the forecasts presented for to the CTC model. Interested in other model inputs besides forecasts. Helpful to put some thought into other inputs. Inseason updating has not been a part of Chinook management.
5. Interested in better age composition information. Also interested in the maturation process. There is no process in place for bringing new information into the PSC model's forecasting process, e.g., winter troll fishery as an early indicator of a big run.
6. Uncertainty in the Al's is absent but should be presented. Different ways to approach the estimation of uncertainty.
7. Interested in what stocks are present in the fisheries. Need an appropriate forecast for the question; forecasts from different regions are incompatible because of different management objectives. Forecasting record- high returns is a concern.
8. Difference in maturation rates between natural and hatchery stocks, yet there is heavy reliance on hatchery data. Lack of good data on age composition of escapements in some stocks; there are strong and weak assessments. Present CTC model is deterministic.
9. Quality and lack of data: Less than half of the stocks feed age-structured forecasts of abundance into the CTC model.
10. Appropriate models unclear -- with recent observations of abundance above the historical range, what do we assume for the shape of the function?; What are we going to do with uncertainty estimates?
11. The five stocks selected for the this review drive fisheries, yet there is no way to judge the quality of stock-specific forecasts being handed to CTC members and SEAK AABM managers. Wants documentation of uncertainty and performance, as well as methods of the stock-specific forecasts.

## Pacific Salmon Treaty \& Fisheries - Gayle Brown (CDFO)

Overview of the PST, the PSC Chinook Model and How Agency Forecasts are Incorporated into Model


John K. Carlile, Alaska Department of Fish and Game Gayle Brown, Canadian Department of Fisheries and Oceans

Chinook Technical Committee (CTC)

- Reports to the Pacific Salmon Commission (PSC); tribal \& agency representatives from $\mathrm{AK}, \mathrm{BC}$, WA and OR.
- Produces yearly reports on Chinook catches and escapements, Coded wire tag (CWT) exploitation rate analysis (ERA) and PSC Chinook Model calibrations.
- Produces other analyses and reports at the request of the PSC Commissioners.
- The Analytical Work Group (AWG) - subgroup of the CTC-produces annual ERA, Chinook Model calibration.

History and Development of the PSC Chinook Model (Part 2)

- 1988 - MS QuickBasic, 27 stocks, 25 fisheries
- 1990-28 stocks, 1993-29 stocks, 1994-30 stocks
- 2004 - MS VisualBasic 6, 30 stocks, 25 fisheries
- 2010 - MS VB.NET, 30 stocks, 25 fisheries
- 1999-Model changed from a rebuilding assessment tool to a management tool


## Very Brief History of the Pacific Salmon Treaty

- 1985 US-Canada Pacific Salmon Treaty
- All species of Pacific salmon and fisheries from Cape Falcon, Oregon to Cape Suckling, Alaska
- Generally accepted by the late 70 s-early 80 s that Chinook stocks were depressed coast-wide
- Recognition that a Chinook rebuilding program was needed
- Rebuilding assessment tool was needed as well

History and Development of the PSC Chinook Model (Part 1)

- Cohort Analysis model
- 1983 - Visicalc Spreadsheet with one stock
- 1984 - Apple Basic with one stock model
- 1985-MS Basic, 5 stocks, 10 fisheries
> Evaluation of management strategies (catch ceilings, harvest rates etc.)
$>$ Basis of the 15 year rebuilding program (catch ceilings)


SEAK Stock Composition Example

| FISHERY: | SE ALASKA ALL GEAR |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
|  | 2015 | Average | 1985-20 |  |  |
| Model Stock | \% of Fishery Catch | \% of Fishery Catch | \% of Stock Catch | \% of <br> Stock <br> Total <br> Return | Associated Escapement Indicator Stocks |
| Columbia Upriver Bright | 30.97 | 18.09 | 25.51 | 13.22 | Columbia Upriver Bright |
| WCVI Hatchery | 10.66 | 15.50 | 52.64 | 18.12 | NA |
| Oregon Coastal North Migrating | 7.75 | 13.46 | 34.01 | 15.14 | Oregon Coastal |
| Columbia <br> Upriver Summer | 7.25 | 3.89 | 36.90 | 15.60 | Columbia Upriver Summer |
| WCVI Wild | 1.37 | 2.97 | 54.14 | 18.21 | WCVI (14 stocks) |
| Spring Creek Hatchery | 0.00 | 0.00 | 0.00 | 0.00 | NA |

Proportion of Model Stock in SEAK Troll


## Stock Distributions

Mean \% total mortality in PSC fisheries and escapement for CWT ERA stocks \& associated natural escapement indicators during the 2009 PST and \% change relative to 1999 PST.

| Escapement Indicator Stock | Expl. Rate Ind. | AABM |  |  |  |  |  | ISBM |  |  |  | ESC |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | SEAK |  | NBC |  | WCVI |  | US |  | CAN |  |  |  |
|  |  | $\begin{gathered} \hline \% \\ \text { Mort } \end{gathered}$ | \% Chg | $\%$ <br> Mort | $\begin{gathered} \text { \% } \\ \text { Chg } \end{gathered}$ | \% <br> Mort | $\begin{gathered} \text { \% } \\ \text { Chg } \end{gathered}$ | $\begin{gathered} \text { \% } \\ \text { Mort } \end{gathered}$ | \% Chg | $\%$ <br> Mort | $\begin{gathered} \hline \% \\ \text { Chg } \end{gathered}$ | \% Esc | $\begin{gathered} \text { \% } \\ \text { Chg } \end{gathered}$ |
| Col R Summer | SUM | 12\% | -7\% | 3\% | -3\% | 9\% | -3\% | 41\% | 19\% | 1\% | 0\% | 35\% | -6\% |
| Col Upriver Bright | URB | 13\% | $-4 \%$ | 5\% | -1\% | 3\% | 0\% | 32\% | 6\% | 1\% | 0\% | 47\% | -2\% |
| Nehalem |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Siletz | SRH | 14\% | -6\% | 10\% | 0\% | 2\% | 1\% | 30\% | 3\% | 0\% | 0\% | 43\% | 2\% |
| Siuslaw |  |  |  |  |  |  |  | Max |  |  |  |  |  |
| Spring Creek | SPR | 0\% | 0\% | 0\% | 0\% | 7\% | -6\% | 60\% | 14\% | 1\% | 1\% | 32\% | -8\% |
| WCVI Hatchery | RBT | 18\% | 1\% | 6\% | 0\% | 3\% | 2\% | 0\% | 0\% | $\begin{aligned} & 25 \% \\ & \text { Max } \end{aligned}$ | -5\% | 48\% | 1\% |
| WCVI Adjusted |  | 19\% | 0\% | 6\% | 0\% | 3\% | 2\% | 0\% | 0\% | $\begin{aligned} & 9 \% \\ & \text { Min } \end{aligned}$ | 3\% | 63\% | -5\% |

Note: "WCVI Adjusted" row shows effect of removing mortalities occurring in terminal fisheries targeting the Robertson Creek hatchery CWT indicator stock; the WCVI 2 rows bound impacts on the natural stocks in the aggregate.

## PSC Chinook Model - John Carlile (ADFG) \& Antonio Velez-Espino (CDFO)

## PSC Chinook Model: The Purpose,

 the Structure and the Use of Forecasts in the Model

John K. Carlile, Alaska Department of Fish and Game Antonio Velez-Espino, Canadian Department of Fisheries and Oceans Gayle Brown, Canadian Department of Fisheries and Oceans

## Chinook Model Basic Facts

- Deterministic approach
- Annual time periods
- Single pool (i.e., no explicit migration)
- Incorporates data from CWT-based cohort analyses
- Incorporates historical data (e.g., catch, terminal run/escapement)
- Scales abundance to ERs from a base period (1979-82)
- Currently 25 fisheries \& 30 stocks ( 48 fisheries \& 40 stocks in the future)
- 1999-Model changed from a rebuilding assessment tool to a management tool


## Alternative Models

- Model using continuous catch equations proposed in 2004 (Gary Morishima, Din-Geng Chen), Funded by US LOA
- Advantages - could better account for interactions between fisheries, temporal stratification of fisheries easier, provide more information on the variability of stock distributions
- Disadvantage - need estimates of effort for each fishery which aren't readily available for some fisheries
- Catch at Age Model proposed in 2004 (Rishi Sharma and Henry Yuen), Not funded by US LOA


## Chinook Model Structure and Assumptions

## Main Chinook Model Assumptions

- Ocean distribution of individual stocks is consistent with those experienced during the model base period (static)
- Hatchery indicator stocks are reasonable surrogates for wild stocks in the same geographic area with similar life histories (i.e., age structure, maturation, ocean distribution)
- All stocks of a given age have the same size distribution in a given fishery


## Why Haven't the Alternate Models Been Explored?

- The Pacific Salmon Treaty dictates that management of a number of Chinook fisheries is tied to abundance indices from the PSC Chinook model so there has been a reluctance to modify or replace the model
- A Data Generation Model (DGM) is currently being developed that will allow sample datasets to be generated
- The DGM datasets will allow for comparison of output statistics from different management models against known parameters (cohort sizes, exploitation rates, etc)

Stocks and Fisheries in the Chinook Model


## Complete Calibration Procedure

CWT Recovery Program
Summarizes Base
Period CWT
Data by Stock.
Base Calibration Program (Backward Cohort Analysis)

Computes Base Period Exploitation Rates, Initial Cohort Abundances and Spawner-Recruit Parameters

PSC Chinook Model
(Forward Cohort Analysis)
Fits to Catclies, FPs, Escapement, Terminal Escapement, Terminal
Rums, Forecist Data, cte.

Chinook Model Calibration Process

## Model Input Data

- Base Period CWT Data
-Fishery Catch Data
-Chinook Non-Retention Data
-Past Escapement and/or Terminal Run Data
-Terminal Run/Escapement Forecasts
-Fishery Policy (FP) - Exploitation Rate Scalars
- Maturation Rate and Adult Equivalent Data
-Hatchery Enhancement Data
-Spawner-Recruit Parameters
-Proportion Non-Vulnerable (PNV) Changes
-Inter-Dam Loss Factors


## Data files used by the Chinook Model

- .STK - Base period data for individual stocks (cohort size, maturation rates, AEQs, exploitation rates)
- .BSE - Stocks, ages, fisheries, start year, end year, ocean net age, Fishery names, Natural Mortality Rates, Incidental Mortality Rates, Ricker Stock-Recruit Parameters
- .ENH - enhancement changes
- .IDL - post-fishery, pre-spawning mortality
- .MAT - annual maturation rate estimates from ERA
- .PNV - proportion non-vulnerable for individual fisheries (size limits)
- CNR - chinook non-retention The main purpose of the
- CEI - catch levels for fisheries FCS file is EV estimation
- FP - fishery policy factors (use ERA harvest rate data)



## Model Calibration Stages

## - Stage-1 Calibration

- Main purpose: estimate preliminary Environmental Variable (EV) factors and generate RT scalars
- Stage-2 Calibration
- Main purpose: fine tune the EV factors for recent broods
- Projection Run
- Main purpose: produce the preseason and postseason estimates of abundance indices


## EVs

- EV factors scale the number of recruits produced by the stock-specific spawner-recruit parameters to match supplied escapement/terminal run values
- EV factors are stock and brood-year specific
- Thus, age composition must be generated
- Stage-2 calibration generates the EVs that are going to be used for the projection run
- EVs are interrelated (i.e., each iteration will change the EVs for all stocks and brood years)
- If the spawner-recruit parameters are appropriate for a stock the EVs can be thought of as survival scalars. If they are not appropriate then the EVs can be thought of as survival scalars combined with "slop" factors

$E V_{t, b y}=$ Most recent completed brood
$M R_{s, b, a}=9$-year average


## Chinook Model Calibration (Stage 1)



## Projection Run (Stage 3)

- The purpose of Stage 1 and Stage 2 is to fit to the brood-year terminal runs/escapements by generating stock and brood year specific EVs
- The purpose of the projection run is to estimate the cohort abundances for the years following the last year with observed data using the EVs from Stage 2



# The Role of Forecasts in the Chinook Model 

## Forecast (FCS) File Data continued...

- Agency forecasts prepared using wide range of methods
- Forecasts needed in March when data from the previous year may not be available (but forecasts produced anyway)
- Forecasts generally used in the Model calibration without scrutiny
- Model stocks range from individual stocks (Nooksack Springs) to large aggregates of many stocks (Fraser Early!)
- Aggregates are mixtures - natural spawning stocks, hatchery stocks

Agency Forecasts have an effect on the most recent EVs: example from 2015 FCS file


## Agency and Model Forecasts

- The Chinook model produces a stock forecast (terminal run/escapement) regardless of whether an agency forecast is provided
- No agency forecast - recent EV averages determine the model forecast
- The model calibrates (fits) to the total brood year terminal run/escapement exactly but the calendar year values differ due to uncertainty in estimating the age composition (maturation rate assumptions etc)

Example of Model Fit (1979-2014)


## Example：WCVI Forecast Data

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What Determines the Effect of a Stock＇s Forecast on Fishery Als？
－The proportion of the fishery that stock represents（major contributors have more of an effect on the AI）
－The magnitude of the difference in prefishery cohort sizes due to model＇s EVs produced with and without agency forecast data
－The accuracy（and age composition）of agency forecasts for ALL stocks
－Interactions with other input data（e．g．，FPs，MRs， etc．）

## Model Outputs

（Not exhaustive）
－Catches by fishery，stock and age
－Incidental mortalities by fishery，stock and age
－Fishery specific stock composition estimates
－Exploitation rates by fishery，stock and age
－Terminal runs／escapements by stock and age （original intent of the model）
－Abundance Indices for Southeast Alaska， Northern British Columbia and West Coast of Vancouver Island（current focus of the model）${ }_{s}$

Sensitivity of the Als to Agency Forecast Data


Model Abundance Indices （and other outputs）

Calculation of the Abundance Index

Where
$\mathrm{Al}=$ Abundance Index
$\mathrm{C}=$ Cohort Size
$\mathrm{SR}=$ Survival Rate
ER－Base Period Exploitation Rate
PNV＝Proportion Non－Vilnerable
$f=$ fishery
$\mathrm{s}=$ stock
$a=$ age
$\mathrm{b}=$ brood year
$x=$ calendur year

Als from the AABM Fisheries

| Year | seak |  | NBC |  | wevi |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Preseasoa | Poatrases | Preseasoa | Porbersoa | Preseason | Poxteavon |
| 1999 | 115 | 112 | 1.12 | 097 | 000 | 050 |
| 2000 | 114 | 110 | 1.00 | 0.95 | 0.54 | Qut? |
| 2001 | 1.14 | 1.29 | 102 | 122 | 086 | 068 |
| 2002 | 1.74 | 1.82 | 1.45 | 1.63 | 0.95 | 0.92 |
| 2003 | 179 | 217 | 148 | 190 | 085 | 180 |
| 2004 | 138 | 206 | 167 | 183 | 0.90 | 0.98 |
| 2005 | 205 | 190 | 169 | 16.5 | 088 | 0.8. 4 |
| 2006 | 1.6 | 1.3 | 133 | 150 | 0.8 | 0.68 |
| 2000 | 160 | 134 | 1.35 | 110 | 467 | 0.57 |
| 2008 | 107 | 101 | 0.95 | व23 | 076 | 0.64 |
| 2009 | 139 | 120 | 110 | 1.07 | 0.72 | 0.61 |
| 2010 | 135 | 131 | 117 | 123 | 076 | 005 |
| 2011 | 100 |  | 188 | (-1) | 114 | (9) |
| 2012 | 112 | 124 | 172 | 119 | 089 | 676 |
| 2013 | 120 | 1.63 | 110 | 131 | 4 7 | 108 |
| 30,4 | 15 | 220 | 110 | 180 | 123 | 112 |
| $20!5$ | 1.45 | 199 | 1.23 | 1\% | 0.85 | 105 |
| +008 | 16. |  | 130 |  | 1712 |  |

Maturation Rates and Their Effect on the Als

## Maturation Rate Issues (Part 2)

- 2013 change in maturation rate average coincided with an end the chronic overprediction of the preseason Als (still too early to determine if the bias is gone for good) BUT...
- 2013-2015, large discrepancies between pre and post-season Als and possible cyclical behavior
- 2016, revisited the maturation rate average and determined that a nine-year recent average would perform better than a five-year average

How well does it work?


## Maturation Rate Issues (Part 1)

- Pre-2013 Model assumed long-term average maturation rates for recent incomplete broods
- Discovered that a number of stocks showed trend toward maturing at younger ages [TCCHINOOK(16)-1]
- Als are calculated on vulnerable cohorts, younger fish are less vulnerable meaning lower abundance but the model assuming older fish
- Fix implemented in 2013 model calibration, replace long-term average maturation rates with recent 5 -year average maturation rates


## Recent Controversy

- What is the cause of the large discrepancies between the pre and post-season Als in recent years?
- How much is due to inaccurate terminal run/escapement forecasts provided by the agencies?
- How should agency forecasts be reviewed (e.g. this workshop)?
- No CTC consensus was reached on 2015 or 2016 Model calibrations (settled by the Commission)


## Discussion of the PSC Chinook Model - Central Questions for the Panel's Focus

Table 4. Central issues or improvements identified by workshop participants for consideration by the panel with respect to the PSC Chinook Model.

| Incorporate uncertainty directly |
| :--- |
| Accommodation of changes in hatchery smolt releases over time |
| Changes in fish distribution among fisheries over time (not constant) |
| Forecasts are not available for all stocks |
| Data vs. assumptions |
| Application of base period to fishery policy inputs |
| Hatchery vs. wild treatment/assumption |
| Pattern of staff succession, transfer of institutional knowledge, documentation |
| Limited CTC capacity relative to Treaty reporting demands (also related to the paucity of <br> work on model innovation) |
| Computer programming support within PSC for analytical modernization |
| Model evaluation criteria |
| Availability of pre and in-season information for recognition of outlier years |
| Incorporation of environmental information for improving forecasts |
| Opportunities for new model construction/application (e.g. Morishima, Sharma) |
| Do nothing (recent anomalies are just atypical years) |
| Strain of adding model complexity \& stratification |
| Clarify objectives of competing model uses (abundance index v. exploitation rate by <br> stock) |
| Model simplification (e.g. simple weighted average of forecast abundance |
| Simplification of fishery management regimes |

## West Coast Vancouver Island Forecast - Diana Dobson (CDFO)





| Age-specific RCH <br> pre-terminal exploitation rate <br> Canadä' | Fisheries and Oceans Pecches moctans <br> WCVI Index Expansion <br> The Somass/RCH terminal forecast was expanded for the WCVI index stocks using a similar method as applied for the expansion from RCH CWT production to Somass/RCH Total production. That is, based on ratios of earlier returning years from the brood: $\qquad$ <br>  $\qquad$ |
| :---: | :---: |
| WCVI Index Expansion <br> - In more recent years, the Somass/RCH terminal forecast has also been expanded for the WCVI index stocks by adding terminal forecasts that are generated separately for Conuma and Nitinat Hatchery returns and the 18 other index stocks (combined). <br> - The forecasts generated for the other stocks use information from the RCH CWT cohort analysis (i.e. estimated brood year suvvival rate) and similar pre-terminal fishery assumptions, but are modified with stock-specific production and age data. <br> Canadä | \\|-1 $\begin{aligned} & \text { Fisheries and Oceans } \\ & \text { Canida }\end{aligned} \begin{aligned} & \text { Pecries et Ockans } \\ & \text { Canada }\end{aligned}$ <br> Indicator Stock Assumption <br> - The objective for developing stock specific WCVI forecasts was to better inform Canadian domestic fishery management. However, variation in stock production/productivity also affects on the WCVI terminal run size forecasts: |
| 1-1. $\begin{gathered}\text { Flanheries } \\ \text { Canada }\end{gathered}$ <br> Input Data / Years <br> - All years of RCH CWT cohort data are incorporated in the sibling regressions that form the basis of the WCVI forecast (BY 1983+) - estimates of production, maturation rates, etc. <br> - Similarly, the WCVI terminal run index has been reconstructed from return year 1979+. All data are incorporated into the forecast and analysis. <br> - The more challenging issues relate to the varying quality of available assessment data across WCVI systems and the robustness of the indicator stock assumption (e.g. requires similar maturation rate, exploitation patterns, etc.). <br> Canadä | Key assumptions, limitations <br> - Indicator stock - survival, maturation, distribution and exploitation patterns similar among WCVI stocks. <br> - Generally paucity of data for WCVI stocks other than the RCH CWT indicator and, in some WCVI areas, sample data from fisheries. <br> - Age 2 recoveries typically low. <br> - Known bias in CWT recovery data. |

## Other methods

- Stock-specific forecasts generated (already described)
- Exploration of alternate indices of WCVI terminal run size - e.g. distant fishery indices using additional mark data (DNA, otolith marks)


## 14- Flaheries and Oceans Pècres moctans

## Suggestions for Improvement

- Resolve what input is required for calibration purposes build a common understanding of the FCS requirement.
- Related - succession, documentation requirement for the process in general - misunderstanding or miscommunication of objectives and/or structural modifications could be a source of error.
- Age 3 forecast - a clear structural issue, also an input problem (age 2 data), and also likely related to changing maturation rate - could explore 'leading indicators' as an alternative method for Age 3 forecasting.

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Fisheries and Oceans Canada

## Suggestions for Improvement

- Input data - not all information is being used - e.g. available mark data and technology such as DNA, otolith marks, etc.
- Incorporation of uncertainty - not just in reporting of input forecasts, but into the entire management and assessment framework for chinook.
- Simplification of the assessment and management framework - currently data intensive, assumption laden, and resource limited.
- Separation of hatchery from wild abundance in the Als.

| U.S. v. Oregon <br> Management Agreement <br> - United States v. Oregon is the on-going federal court proceeding that enforces and implements the Columbia River treaty tribes' reserved fishing rights. <br> - The Parties to U.S. v. Oregon are the states of Washington, Oregon, and Idaho; the United States (represented by NOAA Fisheries, the BIA, and USFWS); each of the Columbia River Treaty Tribes (the Confederated Tribes of the Warm Springs Reservation of Oregon, the Confederated Tribes of the Umatilla Indian Reservation, the Nez Perce Tribe, and the Confederated Tribes and Bands of the Yakama Nation); and the ShoshoneBannock Tribes. <br> - Fisheries in the Columbia River are managed subject to provisions of U.S. v. Oregon under the continuing jurisdiction of the federal court. The 2008-2017 U.S. v. Oregon Management Agreement provides the current framework for managing fisheries and hatchery programs in much of the Columbia River Basin. | U.S. v. Oregon <br> Technical Advisory Committee <br> - The U.S. v. Oregon Management Agreement establishes a Technical Advisory Committee (TAC) consisting of technical representatives from the entities comprising the Parties to the Agreement. <br> - TAC was established for the express purpose of developing, analyzing, and reviewing data pertinent to the US v. Oregon Management Agreement and to make reports and technical recommendations regarding harvest management. <br> - TAC reconstructs Columbia River salmon and steelhead returns post-season and develops pre-season forecasts. <br> - Either TAC alone, or in coordination with state agency staff (e.g. fall Chinook stocks) <br> - TAC reviews salmon and steelhead abundance as the runs progress and provides in-season run size updates for stocks originating upstream of Bonneville Dam. The in-season updates allow the States and Tribes to manage fisheries as necessary in order to remain within ESA limits and management guidelines. |
| :---: | :---: |
| Upper Columbia Summer Chinook | Upriver Bright and Spring Creek Tule Fall Chinook |
|  | Upriver Bright (URB) <br> - Bright Stock <br> - Far-north migrating <br> - Primarily sub-yearling, ocean-type <br> - Wild fish represent majority of return <br> - Majority destined for Hanford Reach, Priest Rapids Hatchery, areas upstream of Priest Rapids Dam, and Snake River. <br> - Minor return to Deschutes and Yakima Rivers <br> - 10-yr average return is nearly 400,000 fish (range 114,500-795,900) <br> - Past three years have been record returns |



Average Run Timing of Fall Chinook over Bonneville Dam, applied to the 2016 Forecast.

Columbia River Upriver Bright Forecast - Steve Haeseker (USFWS)



## Upriver Bright conclusions

- Natural variability in age-composition makes forecasting challenging
- High quality data on abundance and agecomposition
- Forecasts have been unbiased, and demonstrated good precision

Columbia River Spring Creek Hatchery Forecast - Steve Haeseker (USFWS)



|  | Upper Columbia Summer Chinook <br> - Far-north migrating <br> - Mix of yearling and subyearling life histories; ocean-type and stream-type <br> - Mix of hatchery and wild <br> - Destined for areas upstream of Priest Rapids Dam and the Yakima River <br> - Recent 10-year average return to Columbia River is approximately 71,000 (range $37,000-127,000$ ) |
| :---: | :---: |
| Upper Columbia summer Chinook salmon | Upper Columbia summer Chinook salmon forecast summary statistics |
| Summer Chinook returns by age-class (BY 1986-2012) | Summer Chinook age-class proportions (BY 1986-2009) |



## Northern Oregon Coast Fall Forecasts - Ethan Clemons (ODFW)



|  |  |
| :---: | :---: |
|  |  |
| History of Forecasts for NOC <br>  | From Rudimentary to More Complex Duting 2008 renegotitition, ODFW was made an example of as a poor performer or stock orecasting...pecifically for the NOC ags egate <br>  death brod. <br>  |


| From Rudimentary to More Complex-II | Assumptions Made in Current Sibling Regression Forecasts |
| :---: | :---: |
| 2008 saw changes to agency priorities and allowed for rapid- <br> turnaround of scale age read <br> Sibling regression-based forecasts which used recent observations <br> of age composition to allow for moresophisticated modelling of propected returns began for NOC stocks in 2008 . <br> Since 2008 , each year's forecast performance has been $m$ ond analyzed, weighed, debated and (hopefilly) improved. <br> - Several difterantilb-regreston relationshipsconsidered $\qquad$ <br> Forecast? $\qquad$ $\qquad$ |  |
| How are NOC Forecasts Currently Calculated? <br> Individual basins are forecasted - Naive sibling regressions cast through timeseries Additional expansions for unsurveyed areas | 2016 forecasts for NOC <br> - Mixture of both traditional sib-regressions and ARIMA generated forecasts |
| All 7 basins added together <br> - Compared to aggregated forecast <br> Recent additional methods available through Forecast $R$ <br> Exp smoothing, Naive, ARIMA (Mechanistic, Return Rate, <br> Simple sib Regressions, Log-power Sib regressions, Complex Sib Regressions,..all waiting in the wings through Phase 31, ilys <br>  |  |
|  |  |






## Observations to Take Into Next Year

- Virtual non-presence of jacks in 2015 NOC and MOC return
- A total of 6 jacks were observed coast-wide (both NOC and MOC) for RY 2015
- Doesn't bode well for 3 YO return in 2016 and following cohorts
- Blob/E Nino impacts looming on horizon
- Current models do not account for this external knowledge/obseryations


## Closing Slide: Good News for the Future!?!

- Grant money for field projects in NOC has taken precipitous decline in recent years
- Field sampling has dropped to minimal/non-existent in some basins
- ODFW Aging lab had recently weathered retirement/personnel turnover in past years
- Lab has lost a FTE
- We have less money, fewer samples and fewer people to derive estimates that will be facing increasing scrutiny with greater economic impact on an increasingly accelerated time scale.

| ForecastR (Phase-3) | ForecastR Motivation <br> - Expediting completion of forecasts of abundance of salmon stocks (originally for Chinook only) <br> - Produce a unified forecasting tool which can be used by researchers and managers across different jurisdictions <br> - Facilitate communication and sharing of forecasting results (transparency) <br> - Incorporate a variety of statistical modeling and forecasting tools with the aim to improve quality of forecasts |
| :---: | :---: |
| ForecastR Mechanics <br> - ForecastR relies on the open source $\mathbf{R}$ software available at www.r-project.org <br> - ForecastR will provide a graphical user interface (GUI) to facilitate interaction with the users <br> - Users will not need to know how to code in R to use ForecastR <br> - ForecastR's GUI is being built with functionality available via the $R$ package PBSmodelling | ForecastR Features <br> - ForecastR allows users to forecast abundance of individual stocks (e.g., Chinook, Chum, Coho) based on historic data and other available information <br> - ForecastR primarily accommodates two types of time series (age-specific or total abundance) representing individual stocks or aggregates |
| ForecastR Features <br> - ForecastR recognizes three different kinds of abundance metrics: | ForecastR Workflow |
|  | Step 1: Enter Input Information |
|  | Step 2: Conduct Statistical Modeling |
| Escapement (ESC) | Step 3: Check Modeling Diagnostics |
|  | Step 4: Produce Abundance Forecast(s) |
| Terminal Run (TR) | Step 5: Assess Retrospective Forecast Performance |
| Production (PROD) | Step 6: Check Forecast Diagnostics |
|  | Step 7: Report Results |



## Step 5 (cont'd): Ranking of models for getting

"best" point forecast
Given an abundance stock and an abundance metric, find the "best" model for each age class among a set of competing models for producing point forecasts of stock abundance. ("Best" model vields "best" point forecast.)

| Age k | MRE | MAE | MIPE | MAPE | RMSE | Average Rank |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Model 1 | 1 | 2 | 1 | 4 | 3 | 2.2 |
| Model 2 | 5 |  |  |  | Step 2: Compute the average |  |
| Model 3 | 4 |  |  |  | rank corresponding to each model. |  |
| Model 4 | 3 |  |  |  |  |  |
| Model 5 | 4 |  |  |  | Note: |  |
| Step 1: Rank all models with respect to the values of each performance metric (e.g., MRE), |  |  |  |  | User can choose which metrics are meaningful to them (e.g., MRE, MPE and RMSE only) and average ranks only across those metrics. |  |

## Step 5 (cont'd): Ranking of models for getting "best" point forecast

After applying steps 1 and 2 described on previous slide for all available age classes, we'll end up with:


## Step 5 (cont'd): Ranking of models and total abundance

Approach No. 1
a) Find "best" model for Age 2
b) Find "best" model for Age 3
c) Find "best" model for Age 4
d) Find "best" model for Age 5
e) Compute total abundance by adding up the point forecasts produced by the "best" model for each age

Approach No. 2
a) Compute total abundance by adding up the point forecasts produced by the same madel
Model 1:
Age 2 + Age 3 + Age 4 + Age $5=$ Total [1]
Miodel 2:
Age 2 + Age $3+$ Age 4 + Age $5=$ Total [2]

Model 5:
Age 2 + Age 3 + Age $4+$ Age $5=$ Total [5]
b) Rank models ta find the "best" point forecast of total abundance across models.

## Step 6: Perform Forecast Diagnostics

ForecastR includes visual and numeric forecast diagnostics, such as:
$\checkmark$ Histograms/boxplots of retrospective forecast errors
$\checkmark$ Scatterplots of forecasted versus actual stock abundance values
$\checkmark$ Percentage of retrospective forecast intervals that capture the actual stock abundance value (showing how well models are doing over time)
$\checkmark$ Probability Profiles

## Step 7: Report Results



ForecastR produces two types of reports:
A. Executive Summary
B. Full Report

INDIVIDUAL-MODULES PROGRESS (completed: $\downarrow$; partially: $\Delta$; little progress:(0)


## Individual-Modules capabilities

- Produce Word or Html reports (include table of contents, numbered figures and tables with captions, and stats tutorials)
- Point forecast and bootstrapped-based interval forecast
- Numerous diagnostics
- Model selection (ARIMA, Exponential Smoothing, and Complex Sibling Regressions)
- Probability profiles
- Retrospective evaluations of model performance
- Model Ranking takes place externally

Appendix: Prototype GUI


## Discussion of Agencies' Forecasts - Facilitated Discussion

Table 5. Central issues or improvements identified by workshop participants for consideration by the panel with respect to stock forecasts.


## Panel Impressions - Randall Peterman



| Hybrid sibling model (standard sibling + naïve) <br> - Standard sibling models good when residual variance is LOW but ... <br> - Naïve models such as $R_{t}=R_{t-4}$ good when residual variance is HIGH <br> - Hybrid model: <br> 1. Uses standard sibling model if its residual variance $<\mathrm{X}$ <br> 2. Uses naïve model if variance $\geq X$ <br> - Search for optimum X <br> (Haeseker et al. 2007, NAJFM 27:634) 7 | Optimal variance threshold for sockeye hybrid sibling model <br> (Haeseker et al. 2007, NAJFM 27:634) в |
| :---: | :---: |
|  <br> (Haeseker et al. 2007, NAJFM 27:634) | Structural uncertainty - 5 <br> 1. Explore alternative models <br> - Sibling <br> -- Fit untransformed abundances <br> -- Fit $\log _{e}$ (abundances) <br> -- Hybrid sibling (standard sibling + naïve) <br> (Haeseker et al. 2007) <br> -- Estimate time-varying parameters: Kalman filter |
| Sockeye | Results of retrospective analyses |


| Good candidate: Spring Creek tule fall Chinook <br> (Whisler 2016, submission to this panel) |  |  |
| :---: | :---: | :---: |
| Structural uncertainty - 6 <br> Explore alternative components of CTC model <br> - Effects of: <br> -- Body size on age at maturity <br> - Ocean conditions on survival rate <br> -- Fleet's changing q, spatial distribution, ... <br> -- Covariation among stocks in matur. rate, surv. rate | 15 | Structural uncertainty - 6 <br> Long term: develop alternative models such as <br> - 3 options: improve existing, substitute more complicated alternative, substitute simpler alternative that captures essential elements <br> - Continuous catch equations (e.g. Morishima \& Chen) <br> - Statistical catch-at-age models (e.g. Sharma \& Yuen) <br> - Management-strategy evaluation models (MSE) used in several marine fisheries and Fraser sockeye |
| Structural uncertainty - 7 <br> 2. Retain forecasts from the alternative models <br> - Prediction intervals on forecasts (CTC + regional) <br> - Multi-model averaging based on $\mathrm{AIC}_{c}$ weights (Burnham and Anderson 2002) <br> - Stock-specific forecasts and CTC's AABM Als | 17 | WCVI AABM fishery, 2009-2012 <br> p. 98 of TCCHINOOK 14-1_Vol1 (2014) |

SEAK AABM fishery, 2009-2012

## Unclear management objectives

Alternative stock-specific forecasting models should be ranked using criteria that match managers' objectives.

How can managers use information on uncertainties in Als?

## Outcome uncertainty

- Deviations from targets
(e.g., desired vs, realized exploitation rates)

Early Stuart sockeye salmon, B.C. (1986-2003)

(Holt and Peterman 2006)

If all else fails ...


| Appendix E - List of Acronyms \& Abbreviations |  |
| :--- | :--- |
| AABM | Aggregate Abundance Based Management |
| ADF\&G | Alaska Department of Fish and Game |
| AEQ | Adult Equivalent |
| Agreement | June 30, 1999 PST Annex and the related agreement |
| AI | Abundance Index |
| AIC | Akaike Information Criteria |
| APC | Average Proportion Correction procedure |
| AUC | Area-Under-the-Curve |
| AWG | Analytical Working Group of the CTC |
| BC | British Columbia |
| BY | Brood Year |
| BYER | Brood Year Exploitation Rate |
| CBC | Central British Columbia (Kitimat to Cape Caution) |
| CDFO | Canadian Department of Fisheries and Oceans |
| CI | Confidence Interval |
| CLB | Calibration |
| CNR | Chinook Nonretention |
| CPUE | Catch per unit effort |
| CR | Chinook Retention |
| CRITFC | Columbia River Inter-Tribal Fisheries Commission |
| CTC | Chinook Technical Committee |
| CV | Coefficient of Variation |
| CWT | Coded Wire Tag |
| CWTIP | Coded Wire Tag Improvement Program |
| CWTIT | Coded Wire Tag Improvement Team |
| CY | Calendar Year |
| CY | Catch Year |
| FFO | Department of Fisheries and Oceans Canada |
| DIT | Double Index Tag |
| ER | Exploitation Rate |
| ERA | Exploitation Rate Analysis |
| ERI | Exploitation Rate Index |
| ERA Endangered Species Act |  |


| FR | Fraser River |
| :---: | :---: |
| FSC | Food, Social, and Ceremonial |
| GMR | Genetic Mark-Recapture |
| GW | Gitwinksihlkw |
| HR | Harvest Rate |
| HRI | Harvest Rate Index |
| iid | Independent Identically Distributed |
| IM | Incidental Mortality |
| ISBM | Individual Stock Based Management |
| JDF | Juan De Fuca |
| LAT | Low Abundance Threshold |
| LC | Landed Catch |
| LGS | Lower Strait of Georgia |
| LIM | Legal Incidental Mortality |
| MOC | Mid-Oregon Coast |
| MR | Mark-Recapture |
| MRE | Mature-Run Equivalent |
| MSE | Mean Squared Error |
| MSF | Mark-Selective Fishery |
| MSY | Maximum Sustainable Yield for a stock, |
| NA | Not Available |
| NBC | Northern B.C. Dixon Entrance to Kitimat including Haida Gwaii |
| NBC T | North British Columbia Troll |
| NC | North Coastal |
| NM | Nautical Mile |
| NMFS | National Marine Fisheries Service |
| NOC | North Oregon Coast |
| NWIFC | Northwest Indian Fisheries Commission |
| ODFW | Oregon Department of Fish \& Wildlife |
| ORC | Oregon Coast |
| PNV | Proportion non-vulnerable |
| PS | Puget Sound |
| PSC | Pacific Salmon Commission |
| PST | Pacific Salmon Treaty |
| PT | Pre Terminal |
| PV | Proportion vulnerable |
| QCI | Haida Gwaii (Queen Charlotte Islands) |
| QIN | Quinault Indian Nation |
| RE | Relative Error |


| ROM | Ratio of Means |
| :--- | :--- |
| SA | Simple Average |
| SAFT | Stock, Age, Fishery and Time Period |
| SEAK | Southeast Alaska Cape Suckling to Dixon Entrance |
| SEAK T | SE Alaska Troll |
| SIM | Sublegal Incidental Mortality |
| SMSY | Escapement producing MSY |
| SPFI | Stratified Proportional Fishery Index |
| SPS | South Puget Sound |
| SSP | Sentinel Stocks Program |
| SUS | Southern US |
| TAC | Total Allowable Catch |
| TAC | U.S. v Oregon Technical Advisory Committee |
| TBR | Transboundary Rivers (Alsek, Taku, Stikine) |
| TLA | Three Letter Acronym |
| TM | Total Mortality |
| UAF | University of Alaska Fairbanks |
| UGS | Upper Strait of Georgia |
| UMSY | Exploitation Rate at MSY |
| UMT | Upper Management Threshold |
| URB | Columbia Upriver Brights |
| US | United States |
| USFWS | U.S. Fish \& Wildlife Service |
| VB | Visual Basic |
| WA/OR | Ocean areas off Washington and Oregon North of Cape Falcon |
| WAC | Washington Coast |
| WCVI T | West Coast Vancouver Island Troll |
| WCVI | West Coast Vancouver Island excluding Area 20 |
| WDFW | Washington Department of Fish and Wildlife |

# POST-SEASON REPORT FOR 2016 CANADIAN TREATY LIMIT FISHERIES 

Prepared by: Fisheries and Oceans Canada
Revised January 20, 2017

Pg. 1

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## 1 INTRODUCTION

The chapters in Annex IV of the Pacific Salmon Treaty outline the joint conservation and harvest sharing arrangements between Canada and the United States of America (U.S.) for key stocks and fisheries subject to the Treaty. On December 23, 2008, Canada and the U.S. ratified new provisions for five chapters under Annex IV of the Pacific Salmon Treaty. These chapters came into effect on January 1, 2009 and remain in force until 2018. Chapter 4, which covers Fraser River sockeye and pink salmon, was revised in July 2014 and these revisions cover fisheries in 2014 through 2019. All management regimes under Annex IV continue to be implemented by Fisheries and Oceans Canada (DFO) for the 2016 season.

Annex fisheries are reported in the order of the Chapters of Annex IV. Comments begin with expectations and management objectives, escapements (where available and appropriate) and catch results by species. The expectations, management objectives, catches and escapements focus on those stocks and fisheries covered by the Pacific Salmon Treaty.

Annually, DFO releases a Salmon Outlook document which is referenced in various sections of this report; this document provides a preliminary indication of salmon production, and associated fishing opportunities by geographic area and species stock groups called an Outlook Unit for the coming season.

Note: The catches reported in this document provide the best information available to December 1st, 2016, and may change once all catch information for 2016 has been reviewed. The catches are based on in-season estimates (hailed statistics); on-grounds counts by DFO, logbooks, dockside tallies, landing slips (First Nation fisheries), fish slip data (commercial troll and net), creel surveys and observers (recreational and commercial). Appendix 1 summarizes 1996-2016 catches in Canadian fisheries that have at some time been under limits imposed by the Pacific Salmon Treaty. All Southern commercial, recreational, First Nations, Excess Salmon to Spawning Requirements (ESSR) and test fisheries are reported in Appendices 8-11. The majority of the tables are incomplete as all of the catch data is not available at this time.

## 2 TRANSBOUNDARY RIVERS

### 2.1 Stikine River

Canada’s 2017 (domestic) Transboundary Rivers Integrated Fisheries Management Plan established specific management strategies for Stikine River salmon fisheries, based on the catch sharing and management arrangements outlined in Annex IV, Chapter 1, Paragraph 3 of the Pacific Salmon Treaty (PST). Accordingly, the 2016 management plan and associated preseason management strategy was designed to meet agreed escapement targets and the following harvest objectives: 1) to harvest $50 \%$ of the total allowable catch (TAC) of Stikine River sockeye salmon in existing fisheries; 2) to allow additional harvesting opportunities in terminal areas for enhanced sockeye that were surplus to spawning requirements; 3 ) to harvest up to 5,000 coho salmon in a directed commercial fishery; and 4) to harvest up to 4,740 chinook salmon in a directed fishery, in-season abundance permitting, in addition to a harvest of up to 2,300 chinook salmon as a base level catch in the directed sockeye fishery. A pre-season forecast of 33,900 chinook exceeded the pre-season allowable catch threshold run size of 28,100 which allowed for a directed chinook fishery in 2016.

The 2016 Stikine River commercial fishing season opened on May 1 (statistical week 19) and ended September 2 (statistical week 36). From statistical weeks 19 through to 23, the commercial fishing fleet engaged in a directed chinook fishery. From statistical weeks 26 through 34 a directed sockeye fishery was implemented followed by a directed coho fishery which ended in statistical week 36.

Commercial gear consisted of one 135-metre ( 443 ft .) gill net per licence holder. The maximum mesh size allowed was 204 mm (8") through June 4, after which time the maximum mesh size was restricted to $140 \mathrm{~mm}(5.5$ "). The lower Stikine commercial fishing grounds covered the area from the international (U.S. / Canada) border upstream to near the confluence of the Porcupine and Stikine Rivers, and also included the lower 10 km (6 mi.) reach of the Iskut River.

In the upper Stikine commercial fishery, located upstream from the Chutine River, fishing periods generally mirrored those in the lower Stikine commercial fishery, but lagged by one week. Commercial fishers were permitted the use of one gill net. As in past years, the commercial fishing area was extended upstream to the mouth of the Tuya River. This action was taken in order to provide for a terminal fishing opportunity on Tuya River bound sockeye salmon, specifically at sites located upstream of the Tahltan River. For the eighth consecutive year, no commercial fishing activity occurred at this site. The Tuya sockeye salmon run, which consists entirely of sockeye produced from the Canada-U.S. Stikine enhancement program, has no spawning escapement requirement since these fish are unable to return to Tuya Lake due to several velocity barriers located in the lower reach of the Tuya River. Tuya sockeye are released into Tuya Lake as young of the year juveniles.

The First Nation Food, Social, and Ceremonial (FSC) fishery located near the community of Telegraph Creek, British Columbia (B.C.) was active from the first week in May to the third week in August, with no time or gear restrictions imposed in 2016.

Most of the chinook salmon sport fishing effort in the Stikine River watershed typically occurs in the lower reach and at the mouth of the Tahltan River. Additional activity occurs less intensively
in the Iskut River and other areas within the Stikine River drainage. Sport fishing activity was minimal as area and size restrictions were enacted due to a below expected (poor) return of chinook salmon returning to the Stikine River. In 2016, the Tahltan First Nation encouraged its members to not fish in a chinook salmon holding area that is located below the slide area near the beginning of the Tahltan River canyon.

### 2.1.1 Chinook Salmon

The pre-season forecast of 33,900 large (i.e. fish with a mid-eye to fork length of $>660 \mathrm{~mm}$ ( $\sim 26$ ") or a fork length of $>735 \mathrm{~mm}$ ( $\sim 29$ ") Stikine River chinook salmon, as developed by the Canada / U.S. Technical Committee for the Transboundary Rivers (TCTR) allowed for a directed chinook fishery in 2016. A pre-season forecast run size of $<28,100$ precludes Canada or the U.S. from scheduling a directed fishery, whereas an in-season run size of >24,500 large chinook is required to permit a targeted chinook fishery. Based on the pre-season forecast and an escapement goal of 21,000 the allowable catch (AC) in the directed chinook fishery was 4,740 and the base line catch (BLC) in the directed sockeye fishery was 2,300.

The directed chinook fishery commenced on May 1 (statistical week 19) and ended on June 4 (statistical week 23) ahead of schedule due to in-season projections that identified the chinook salmon run was well below the preseason forecast and no longer provided an allowable catch (AC) to Canada. As a result, an assessment fishery was conducted in statistical weeks 24-25 (June 5-18) which had a combined catch of 483 large and 39 jack chinook salmon. The total combined gill net catch of chinook salmon in the First Nation and commercial fisheries included 2,731 large chinook salmon and 794 jacks compared to 2006-2015 averages of 5,273 large chinook salmon and 1,269 jacks, while the sockeye test fishery yielded a harvest of 20 large chinook and 16 jack chinook salmon compared to the 2006-2015 averages of 17 large chinook salmon and 17 jack chinook salmon. The 2016 sport fishery is believed to have no harvest of chinook salmon due to the restrictions that were in place. The 2006-2016 averages are 45 large chinook salmon and 16 jack chinook salmon.

The preliminary post-season estimate of the terminal run was 15,335 large chinook salmon, including an in river run size based on mark-recapture data of 13,606 large chinook salmon and a total U.S. catch estimate of 1,729 large chinook salmon. Accounting for the total Canadian catch of 3,234 large chinook salmon (includes commercial, First Nation, sport and test catches), the total system-wide spawning escapement was estimated at approximately 10,372 large chinook salmon. The lower Tahltan River rockslide, which occurred in 2014 and resulted in a velocity barrier at certain flow levels, is not believed to have impeded chinook salmon passage due to below average water levels. The escapement estimate of 10,372 is $60 \%$ below the target SMSY escapement goal of 17,400 large chinook salmon and did not reach the escapement goal range of 14,000 to 28,000 large Chinook salmon. The post-season run size of 15,335 chinook salmon translated into no allowable harvest in Canadian or U.S. directed fisheries.

The 2016 chinook salmon escapement enumerated at the Little Tahltan weir was 923 large chinook and 320 jack chinook salmon The escapement of large chinook salmon in the Little Tahltan River was well below both the SMSY estimate of 3,300 fish and the lower end of the escapement goal range of 2,700-5,300 large chinook salmon. The proportion Little Tahltan escapement to the Stikine wide escapement was only 3\%, while on average the contribution of
this stock exceeds $14 \% .2016$ is the tenth consecutive year that the lower end of the escapement objective was not achieved for Little Tahltan chinook salmon.

In addition to the mark-recapture study, the Little Tahltan weir project and aerial surveys, genetic samples were collected on a weekly basis from chinook salmon caught in the U.S. District 108 fishery, and from weekly catches taken in the Canadian commercial fishery. Data collected from U.S. fisheries were used to determine the total U.S. interception of Stikine River chinook salmon while the in-river samples will be analysed to assess stock specific run timing and run size.

### 2.1.2 Sockeye Salmon

The forecast for Stikine River sockeye salmon, as developed by TCTR, was for a terminal run size1 of 223,000 fish including: 129,000 Tahltan Lake origin sockeye salmon (87,000 wild and 42,000 enhanced); 38,000 enhanced Tuya Lake sockeye; and 56,000 non-Tahltan wild sockeye salmon, which constituted an above average forecast. For comparison, the previous 10 -year average (-2006-2015) terminal run size was approximately 172,000 fish.

Preliminary combined catches from the Canadian commercial and First Nation gill net fisheries in the Stikine River totalled 86,729 sockeye in 2016; above the 2006-2015 average of 51,221 fish. The lower Stikine River commercial fishery harvested 75,752 sockeye, while the upper Stikine River commercial and First Nation fisheries harvested a total of 333 and 10,644 sockeye salmon, respectively. The preliminary estimate of the total contribution of sockeye salmon from the Canada/U.S. Stikine sockeye enhancement (i.e. the fry-planting program) to the combined Canadian First Nation and commercial catches was 31,425 fish (or $36 \%$ of the catch).

In addition to these catches, 1,747 sockeye salmon were taken in the stock assessment test fishery located near the U.S/ Canada border. A total of 38,610 sockeye salmon was counted through the Tahltan Lake weir in 2016, 40 \% above the average of 27,639 fish and above the escapement goal range of 18,000 to 30,000 fish. An estimated 12,643 fish ( $33 \%$ ) originated from the fry-planting program, which was close to the $30 \%$ contribution observed in smolts leaving the lake in 2013, the principal smolt year contributing to the 2016 return. A total of 4,315 sockeye salmon were collected for broodstock and an additional 173 were removed for stock identification purposes (ESSR), resulting in a spawning escapement of 34,122 sockeye salmon in Tahltan Lake. The total estimated run size of 144,224 Tahltan Lake sockeye was approximately 12 \% above the pre-season expectation of 129,000 fish.

The spawning escapements for the non-Tahltan and the Tuya stock groups are calculated using stock identification, test fishery and in-river commercial catch and effort data. The average of the test fishery and the commercial fishery catch-per-unit of effort (CPUE), which operated over the full duration of the run, were used as the principal tool in assessing the spawning ground escapements of non-Tahltan Lake and the Tuya sockeye stock groupings. Based on the run reconstructions generated from the test and commercial fishery CPUE, the preliminary escapement estimates for 2016 were 33,092 non-Tahltan and 7,370 Tuya sockeye salmon. The non-Tahltan spawning escapement estimate was within the escapement goal range of 20,000 to 40,000 and was $10 \%$ above the mid-point escapement goal of 30,000 sockeye salmon (above the

[^2]10 year average of 24,436 fish). The estimated escapement of 7,370 Tuya Lake sockeye salmon was below the recent 10 year average of 12,854 fish. These fish do not contribute to the natural production of Stikine River sockeye salmon due to migration barriers that obstruct entry to their nursery lake and potential spawning areas.

Based on the in-river run reconstruction of the Tahltan Lake run expanded by run timing and stock identification data in the lower river and estimated harvests of Stikine River sockeye salmon in U.S. terminal gill net fisheries, the preliminary post-season estimate of the terminal sockeye run size is approximately 238,653 fish. This estimate includes 144,224 Tahltan Lake origin fish, 33,481 Tuya Lake origin fish, and 60,948 sockeye of the non-Tahltan stock aggregate. A Stikine River run size of this magnitude is above the 2006-2015 average terminal run size of $\sim 172,000$ sockeye salmon and is approximately $7 \%$ above the preseason forecast of 223,000 fish.

Based on the preliminary post season estimate, Canada had an allowable catch of 88,699 Stikine River sockeye salmon compared to the actual harvest of 86,742 .

### 2.1.3 Coho Salmon

For the eighth consecutive year, most of the commercial fishing fleet remained in the fishery to harvest coho salmon resulting in a total catch of 5,346 coho salmon. A catch of 4,957 coho salmon was taken during the targeted coho fishery in statistical weeks $35-36$. The total catch was above the recent 10 year average of 4,360 fish.

A coho salmon test fishery was not conducted in 2016. Incidental catches and CPUE taken in the sockeye salmon test and commercial fisheries were below average. The CPUE observed in the targeted coho salmon fishery was below average for statistical weeks 35 and 36. Aerial surveys of six index spawning sites yielded below average counts taken under excellent viewing conditions.

### 2.1.4 Joint Sockeye Salmon Enhancement Program

Joint Canada/U.S. enhancement activities continued from 2015 through 2016 with the collection of sockeye salmon eggs from Tahltan Lake in British Columbia, transportation of eggs to the Snettisham Hatchery in Alaska where they were raised to fry, and subsequent transportation and release at out-plant sites in British Columbia.

Through May 9 to 13, 2016 approximately 3.4 million fry were out-planted into Tahltan Lake. No fry were released into Tuya Lake. The fry originated from the 2015 Tahltan Lake egg-take and were mass-marked at the Snettisham hatchery with thermally induced otolith marks. Green egg to released fry survival was approximately $76 \%$. No Tahltan Lake origin fry reared at the Snettisham hatchery were lost due to Infectious Hematopoietic Necrosis virus (IHNv). Sockeye salmon enhancement programs have been subject to IHNv outbreaks before as the disease is naturally occurring in Stikine sockeye stocks.

In the fall of 2016, approximately 5.3 million sockeye salmon eggs of a targeted 4.91 million were collected at Tahltan Lake and transported to Snettisham Hatchery in Alaska. Canada determined an increased egg take target based on escapement evaluation results in-season. As in previous years additional efforts beyond beach seining were employed to acquire brood stock including angling and temporarily holding female brood stock to mature in floating net pens in
the lake. Some challenges were faced this year including similar concerns to 2014 and 2015 regarding salmon passage around a recent rock slide barrier on the Tahltan River.

### 2.2 Taku River

As with the Stikine River, the fishing plan developed by Canada for the Taku River was based on the arrangements in Annex IV, Chapter 1, Paragraph 3 of the PST in effect for 2009 through 2018. Accordingly, the plan addressed conservation requirements and contained the following harvest objectives: 1) harvest $20 \%$ of the TAC of Taku River sockeye salmon (adjusted as necessary according to projections of the number of enhanced sockeye), plus the projected wild sockeye in-river escapement in excess of 1.6 times the spawning escapement goal; 2) to harvest enhanced Taku River sockeye salmon incidentally to wild sockeye salmon; 3) to harvest 5,000, plus any excess over the escapement target of 70,000 coho salmon in a directed coho salmon fishery, dependent on in-river run size projections; and 4) to consider a directed chinook salmon fishery once weekly in-season estimates suggested an allowable catch.

The 2016 commercial fishing season on the Taku River opened on June 19 (statistical week 26), and closed on October 8 (statistical week 41). Fishing area and gear restrictions were as per recent years, and incorporated the maximum gill net length of 36.6 metres, established in 2008 for drift gill nets and in 2009 for set gill nets.

The Taku River commercial fishing grounds in Canada consist of the mainstem of the river from the international border upstream approximately 18 km ( 11 miles ), to a geological feature known locally as Yellow Bluff. Almost all fishing activity takes place in the lower half of this area, downstream of the Tulsequah River.

The First Nation FSC fishery is primarily located in the lower Taku River in the same area as the commercial fishery described above. However, small numbers of fish are also harvested on the lower Nakina River and at the outlet of Kuthai and King salmon lakes. There were no time or gear restrictions imposed on the First Nation fishery in 2016.

Most of the chinook salmon sport fishing effort in the Taku watershed typically occurs on the lower Nakina River. Less intensively-used sport fishing sites exist on the Tatsatua River, the Sheslay River and other areas within the Taku River drainage. Sport fishing effort and harvest is difficult to determine to an absolute level, but are believed to be negligible for all species except chinook salmon and steelhead (due to the remote nature of the watershed and difficult access). In 2016, restrictions were in place to prohibit the retention of chinook salmon over 65 centimetres after June 19 in response to run projections that projected the minimum escapement objective would not be met.

### 2.2.1 Chinook Salmon

The bilateral pre-season forecast was for a terminal run of 29,200 large chinook salmon, approximately $8 \%$ below the previous 10-year average of 31,607 fish. The forecast generated by the Taku River chinook salmon model was 32,600 fish. However, due to persistent overestimation in recent years coupled with a pattern of decline in chinook salmon stocks in the North Pacific, the forecast was reduced by $12 \%$. A run size of 29,200 fish was slightly above the SMSY escapement goal of 25,500 fish, and as a result, there was no allowable catch (AC) for either the U.S. or Canada, and a minor adjustment to the base level catches (BLCs) of 1,500 fish
for Canada and 3,500 fish for the U.S. was required. The test fishery allocation of 1,400 large chinook was unchanged.

The catches of large chinook salmon in the Canadian fisheries were: 1,021 in the test/assessment fishery; 508 large chinook salmon captured incidentally in the directed commercial sockeye and coho salmon fisheries; 91 large chinook salmon in the First Nation FSC fishery; and an estimated 10 large chinook salmon in the sport fishery (prior to June 19). The total base level and test/assessment fishery harvest of 1,630 large chinook salmon was within the allowance of 2,900 fish. In-season run projections did not identify an AC for the Canadian directed commercial fishery.

The bilaterally agreed Taku River large chinook salmon spawning escapement estimate for 2016 was 11,484 fish which was below the SMSY target of 25,500 and the goal range of 19,000 to 36,000. The 2006-2015 average spawning escapement is 25,254 large chinook (which was associated with a higher target until 2009). During aerial surveys of five index areas, a total of 1,720 large chinook salmon were observed; this was $52 \%$ below the average of 3,603.

The Canadian catch of large chinook salmon was $70 \%$ below the 10-year average of approximately 3,000 fish (excluding test/assessment fisheries). The 2016 harvest of small chinook was 205 fish ( 195 commercial and 10 First Nation FSC), 64\% below the 10-year average of 571 fish.

### 2.2.2 Sockeye Salmon

The Canadian pre-season run outlook for wild sockeye salmon was 200,000 fish, approximately $16 \%$ above the previous 10 -year average total run size of 172,000 fish. In addition, approximately 10,300 adult sockeye salmon of Tatsamenie Lake origin were expected to return from fry out plants associated with the Canada/U.S. joint Taku sockeye salmon enhancement program. The forecasted return of enhanced Tatsamenie Lake origin sockeye salmon was $36 \%$ above the average return of 7,600 fish.

The Canadian sockeye salmon catch was 37,624 fish, of which 37,301 were taken in the commercial fishery, 200 in the First Nation FSC fishery, and 123 in assessment/test fisheries. This harvest was $81 \%$ above the 10-year average total of 20,760 fish (3rd largest on record), with the contribution of sockeye salmon from the bilateral enhancement program estimated at 4,043 fish ( $11 \%$ of the total Canadian catch).

To reduce by-catch of chinook salmon, the maximum permissible mesh size in the first four weeks of the directed sockeye salmon fishery which commenced in late June was 140 mm (5.5"). Projections of the total wild sockeye salmon run size, TAC, and total escapement were made frequently throughout the fishing season. As in past years, projections were based on the joint mark-recapture program, the estimated catch of Taku River sockeye in U.S. fisheries, the catch in the Canadian fishery, and historical run timing information. Projections in 2016 ranged from 118,000 in statistical week 28 (July 3-9) to 220,000 in statistical week 30 (July 17-23). The preliminary post-season estimate of run size is 294,851 fish (comprising 275,322wild sockeye and 19,529 enhanced sockeye). Subtracting the escapement target of 75,000 from the wild run of 275,322 fish, resulted in a TAC of approximately 200,000 wild fish. The Canadian allowable catch, based on a $23 \%$ harvest share (which in turn is associated with an enhanced return of 15,001 to 25,000 fish), was 46,100 fish; the actual catch was 33,472 wild fish, representing $17 \%$

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of the TAC of wild fish. Likewise, the U.S. allowable catch of wild fish, based on an 77\% harvest share, was 153,900 fish; the actual catch was 77,310 fish, representing $39 \%$ of the TAC of wild fish.

The estimated spawning escapement of wild sockeye salmon in the Canadian section of the Taku River was 164,430 fish which was well above the target range of 71,000 to 80,000 fish. The escapement is $63 \%$ above the 10 -year average of 101,021 fish. Based on weir counts, escapements of sockeye salmon to the Kuthai were 1,496; Little Trapper were 7,771; Tatsamenie were 32, 934 and King Salmon lakes were 6,388. Escapements to all the lakes were above average in 2016 with the exception of Trapper Lake which was near average.

### 2.2.3 Coho Salmon

The catch of 9,513 coho salmon (9,466 commercial and 47 First Nation FSC) was $8 \%$ above the 10 -year average of 8,793 fish. The catch during the directed commercial coho salmon fishery, i.e. after statistical week 33, was 7,483 fish. A test/assessment fishery was implemented in 2016, catching a total of 2,007 coho. Based on mark-recapture data, the preliminary bilateral estimate of the run into the Canadian section of the drainage is 99,224 fish. In accordance with PST harvest arrangements for the 2016 Taku River coho salmon season; at a run size of this magnitude, Canadian harvesters were entitled to harvest 5,000 fish for assessment purposes plus any surplus over 75,000 starting in statistical week 34 . The preliminary post-season spawning escapement estimate is 87,704 fish, $4 \%$ below the previous 10 -year average of 91,675 fish. The 2016 escapement was above the recently revised target of 70,000 but within the goal range of 50,000 to 90,000 fish.

### 2.2.4 Joint Sockeye Salmon Enhancement Program

Joint Canada/U.S. enhancement activities continued from 2015 through 2016 with sockeye salmon fry hatched at Snettisham Hatchery in Alaska transported back to Tatsamenie Lake, British Columbia (where these fish were collected as eggs in 2015).

Approximately $77 \%$ of the 1.3 million sockeye salmon eggs collected in 2015 from Tatsamenie Lake survived to the fry stage at the Snettisham Hatchery in Alaska. Approximately 89,100 preemergent fry from one incubator were destroyed due to Infectious Hematopoietic Necrosis virus (IHNv). Sockeye salmon enhancement programs have been subject to IHNv outbreaks before and while unfortunate the losses are within normal occurrence levels.

Between May 14 and May 27, 2016 approximately 384,000 emergent sockeye salmon fry were out-planted into Tatsamenie Lake. In addition, as part of an onshore extended rearing project, approximately 86,250 fed fry were released into onshore rearing tanks and a trial net rearing pen. The project was successful with remarkably low rearing losses. Net pen reared fry were released at 4.2 grams on July 13 and Capilano trough reared fry were released at 5.6 grams on August 11. Smolt production for the year was slightly below average with a preliminary estimate of 420,000 coming off a weak brood year. A breakdown of the origin of the smolts to evaluate annual release strategies is underway pending otolith results.

No eggs were collected from King Salmon Lake in 2016 however, results of the first adult returns appeared in the Taku fishery with significant numbers and the escapement to the lake was well above average. Specific enhancement feasibility results are pending.

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For 2016, the agreed bilateral Taku River enhancement production plan (TEPP) identified collection of up to 2.0 million sockeye salmon eggs from Tatsamenie Lake and 250,000 eggs from Little Trapper lake for transport to Snettisham Hatchery in Alaska for incubation and thermal marking. Approximately 2,200,000 sockeye salmon eggs were collected from Tatsamenie Lake and a new record escapement was established (33,000). Eggs were collected from Little Trapper in September in the amount of 271,000. The resulting fry will be released to Trapper Lake, upstream of a barrier, to establish a small escapement of salmon (approximated at 250 adults) for barrier passage evaluation beginning in 2020. Barrier removal project plans were established in 2016 as part of a 2016 Northern Fund project and are ongoing in support of a potential sockeye enhancement program for Trapper Lake.

### 2.3 Alsek River

Although catch sharing provisions for Alsek River salmon stocks between Canada and the U.S. have not yet been specified, Annex IV of the Pacific Salmon Treaty calls for the development and implementation of cooperative abundance-based management plans and programs for Alsek River chinook and sockeye salmon. In 2013, escapement goal ranges for Alsek River chinook and sockeye salmon were accepted by the Transboundary Rivers Panel, these are: 3,500 to 5,300 chinook and 24,000 to 33,500 sockeye salmon. Additionally, the escapement targets were revised for Klukshu River chinook and sockeye salmon, these are: 800-1,200 chinook and 7,500-11,000 sockeye. The principal escapement-monitoring tool for chinook, sockeye, and coho salmon stocks on the Alsek River is the Klukshu weir, in operation since 1976 by DFO in cooperation with the Champagne-Aishihik First Nation (CAFN).

Total drainage abundance programs are being investigated as part of the development of abundance-based management regimes and to accurately assess whether the escapement goals for Alsek River chinook and sockeye salmon stocks are appropriate and achievable. At this time, there are no programs in place to estimate the drainage-wide coho salmon escapement. A large and variable proportion of the escapement of each species is enumerated at the weir on the Klukshu River. Current escapement monitoring programs include the Klukshu River weir, Village Creek counter, and post-season run reconstructions using genetic stock identification analyses which allow for annual comparisons of escapement indices. The most reliable long-term comparative escapement index for Alsek River drainage salmon stocks is the Klukshu River weir count.

The harvest estimate for the 2016 First Nation FSC fishery comprised of the fish taken from the Klukshu River weir (elders only) and an estimate of catches above/below the weir (based on the past relationship with the weir count and harvest). An estimated 10 chinook, 815 sockeye and zero coho salmon were harvested in the FSC fishery. The recent average catches are 60 chinook, 1,159 sockeye, and 4 coho salmon. Preliminary catch estimates for the Tatshenshini sport fishery were an estimated 20 chinook salmon retained, and 10 sockeye salmon retained. There were no coho recorded, although this value is considered incomplete as some effort and harvest may have occurred after monitoring ceased. The catches were $45 \%, 71 \%$, and $0 \%$ of average for chinook, sockeye and coho salmon, respectively. Retention of chinook salmon was not permitted after July 26th as in-season projections suggested that the escapement objectives would not be met.

The preliminary weir count and escapement estimates of Klukshu River sockeye salmon in 2016 were 7,584 and 11,363 fish, respectively. The count of 1,405 early run fish (count through

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August 15) was below the average of 2,659 as was the count of 6,179 late run fish, with an average of 9,022 . The total escapement of 11,363 fish was above the upper end of the escapement goal range of 7,500 to 11,000 fish. The sockeye salmon count at Village Creek was 410 fish; the average is 2,000 fish.

The most reliable comparative chinook salmon escapement index for the Alsek River drainage is considered to be the Klukshu River weir count. The preliminary chinook salmon weir and escapement estimate in 2016 was 651 fish, below the average of 1,154 fish. The 2016 escapement estimate of was below the lower end of the escapement goal range of 800 to 1,200 Klukshu River chinook salmon.

The Klukshu River coho salmon weir count was 2,141. The 2016 count, as in past years, is not considered a complete indicator of run strength as the weir is removed prior to the end of the coho salmon run to the Klukshu River.

## 3 NORTHERN BRITISH COLUMBIA (NBC) CHINOOK AGGREGATE ABUNDANCE-BASED MANAGEMENT (AABM)

### 3.1 ObJectives and Overview

Chinook fisheries are managed by either an aggregate abundance-based management (AABM) or individual stock-based management (ISBM) regime. Allowable harvest impacts in AABM areas are determined by provisions in the Pacific Salmon Treaty and subject to domestic considerations, such as conservation and allocation. For NBC fisheries, a single AABM quota is applied to troll fisheries Pacific Fishery Management Areas (PFMA) 1 to 5, 101 to 105 and 142 and to recreational fisheries in PFMA's 1, 2, 101, 102 and 142.

Once the AABM quota was defined for the combined troll and recreational fishery, he projected recreational catch was subtracted from the quota, with the remainder allocated to the troll fishery. The entire 2016 Northern B.C. troll fishery was conducted under a system of individual transferable quotas.

The North Coast B.C. troll fishery was opened for chinook fishing from June 21 to August 1 and from August 25 to September 30. DFO managed commercial troll fisheries in the North Coast to a 3.2\% exploitation rate ceiling on total WCVI chinook return to Canada. The size limit was 67 cm and barbless hooks and revival boxes were mandatory.

Preliminary estimates indicate a total catch of 190,180 chinook salmon; 147,381 caught in commercial troll fisheries and 42,800 caught in sport fisheries.

### 3.2 Stock Status

The pre-season abundance index for North Coast B.C. troll and Haida Gwaii sport fisheries in 2016 was 1.70 , which permitted a total allowable catch of 248,000 chinook salmon in these fisheries.

No troll test fisheries were conducted in the North Coast of B.C. in 2016.

### 3.3 Recreational Fisheries

Sport fishing was open with a daily limit of two chinook/day and a possession limit of four chinook. An estimated 42,800 chinook were caught in the Haida Gwaii (Queen Charlotte Islands) sport fishery. A minimum size limit of 45 cm was in effect and barbless hooks were mandatory in the sport fishery. Preliminary estimates of AABM chinook releases from sport fisheries included 29,711 fish. Virtually all sport releases in AABM areas are legal sized.

### 3.4 Commercial Fisheries

The preliminary estimate of AABM commercial troll catch is 147,381 chinook. Preliminary estimates of AABM chinook releases from commercial troll fisheries is 1,510 legal sized fish and 12,786 sublegal sized fish.

## 4 NORTHERN BRITISH COLUMBIA CHINOOK INDIVIDUAL STOCK-BASED MANAGEMENT (ISBM)

### 4.1 ObJectives and Overview

Fisheries included in this category are commercial net fisheries throughout north and central B.C., marine sport fisheries along the mainland coast and freshwater sport, and First Nations FSC fisheries in both marine and freshwater areas. The PST obligations in these fisheries are for a general harvest rate reduction (estimated in aggregate across fisheries) for ocean mixed stock fisheries and for stock-specific objectives (i.e., achieving the escapement goal) in terminal areas.

### 4.2 Stock Status

A total of 392 large chinook and 107 jacks were caught in the Tyee Test fishery on the Skeena River. The 2016 chinook catch was the lowest catch by the test fishery since 1995. Chinook catches at the Tyee Test Fishery in 1995 and 2016 were the lowest experienced since 1984.

Since assessments of the ISBM fisheries are relative to the escapements achieved in the chinook indicator stocks, a brief overview of the 2016 returns is provided. Northern B.C. terminal runs to the Nass and Skeena Rivers declined significantly after modest improvements in 2015.
Preliminary estimates of chinook escapements to the upper Nass River were 9,581. Preliminary Skeena River chinook escapements were approximately 33,297. Preliminary Atnarko River chinook escapements were estimated at 21,254, down from the record return of 57,615 chinook salmon in 2015.

### 4.3 First Nations Fisheries

Catches by First Nations in the North Coast exceeded 9,051 chinook in 2016. Nisga'a and Gitanyow catches from the Nass River were 5,445 chinook. Catches by First Nations fisheries in the Skeena River were estimated at 3,606 chinook. Estimates of First Nations catches on Haida Gwaii were not provided.

Catches by First Nations in the tidal portion of the Central Coast were not available at the time of this report. Non-tidal catches by First Nations included 25 chinook from Area 6 and 17 chinook from Area 7. The First Nations’ non-tidal catch in Area 8 was 1,870 chinook from the Atnarko River. No chinook catches were reported by First Nations in Rivers Inlet or Smith Inlet (Areas 9 and 10).

### 4.4 Recreational Fisheries

### 4.4.1 Tidal Recreational Fisheries

Preliminary estimates for tidal sport catches near the mainland coast of Northern B.C. were 10,043 from a creel survey conducted in Areas 3 and 4 in 2016. The 2016 catches in the mainland sport fishery in Areas 5 and 6 were not available at the time of writing.

Tidal sport catch from lodges operating in the Smiths Inlet, Rivers Inlet, Hakai Pass and Bella Bella areas were estimated using log books. Approximately 5,559 chinook were retained at lodges in these areas in 2016, approximately half of the 2015 catch.

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### 4.4.2 Non-Tidal Recreational Fisheries

The preliminary estimate from a freshwater creel survey conducted in the Skeena River below Terrace in 2016 was 2,246 large chinook and 984 jacks.

### 4.5 Commercial Fisheries

### 4.5.1 Commercial (A-H Fisheries includes ATP)

North Coast commercial gill net catches totalled 1,262 chinook from Areas 3 to 6 (from hailed catch data). Chinook catch in Areas 3 and 4 were 830 and 392 chinook, respectively. No chinook were reported caught in Area 5 and only 40 were caught in Area 6. These preliminary estimates of gill net catches include chinook less than 5 pounds (graded as jacks and small red fleshed chinook) not normally included for PSC accounting. Small chinook typically make up less than $5 \%$ of commercial gill net catches. Hail catch data tend to underestimate catch reported in fish slips by 25 to $30 \%$.

Central Coast commercial gill net catches totalled 3,192 chinook with 3,185 from Area 8 and 7 from Area 7 (from hailed catch data).

Johnstone Strait commercial fisheries including Area B seine and Area D gill net were managed by South Coast and corresponding catches are reported in the South Coast section of this report.

## 5 NORTHERN BRITISH COLUMBIA PINK SALMON

## Areas 3-1 to 3-4 Pink Net Catch

For 2016, Canada was to manage the Area 3-1 to 3-4 net fisheries to achieve an annual catch share of $2.49 \%$ of the annual allowable harvest (AAH) of Alaskan Districts 101, 102 and 103 pink salmon. At this time, the total return of the Alaskan Districts 101, 102 and 103 pinks was not available.

In the Canadian Northern Boundary area, pink salmon returns were anticipated to be average to below average for Area 3 and Area 4, based on brood year return strength. Actual returns to Areas 3 and 4 were below average. The 2016 preliminary Canadian pink salmon catch in Subareas 3-1 to 3-4 was 430,435. The Alaska stock component of this catch has yet to be estimated.

## Area 1 Pink Troll Catch

For 2016, Canada was to manage the Area 1 troll fishery to achieve an annual catch share of $2.57 \%$ of the annual allowable harvest (AAH) of Alaskan Districts 101, 102 and 103 pink salmon. At this time, the total return of the Alaskan Districts 101, 102 and 103 pinks was not available.

The Canadian commercial troll fishery targeting pink salmon was open in the Northern portion of Area 1 (Dixon Entrance AB Line) from July 1 to September 30. Pink retention was also permitted during the chinook directed fishery in parts of Area 1 which opened from June 21 to August 1 and again from August 25 to September 30. Area 1 pink salmon directed effort was very minimal and the fishery harvested a total of 32,287 pink salmon. The Alaska stock component of this catch has yet to be estimated.

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## 6 SOUTHERN B.C. CHINOOK AGGREGATE ABUNDANCE-BASED MANAGEMENT (AABM)

### 6.1 ObJEctives and Overview

Chinook fisheries are managed by either an aggregate abundance-based management (AABM) or individual stock-based management (ISBM) regime. Allowable harvest impacts in AABM areas are determined by provisions in the Pacific Salmon Treaty and subject to domestic considerations, such as conservation and allocation. In Southern B.C., all AABM chinook fisheries are located off the West Coast Vancouver Island (WCVI), including components of the recreational fishery, First Nations fisheries, and the Area G troll fishery.

For the period October 2015 through September 2016, the forecast chinook abundance index was 0.89 of the PST base period. Therefore, under treaty provisions, the maximum allowable catch was 133,300 chinook for WCVI AABM fisheries; which includes a $30 \%$ reduction consistent with the treaty provisions that came into effect in January 2009.

Of this total, 69,248 was the pre-season expected catch for the offshore recreational and First Nations fisheries. The remaining 64,052 chinook were allocated to the commercial fisheries (Area G and T'aaq-wiihak).

Further considerations for managing chinook catch in WCVI AABM fisheries are driven by concerns regarding the low status of natural WCVI, Lower Strait of Georgia (LGS), Fraser River Spring 42, Spring 52, Summer 52 chinook, and Interior Fraser coho populations.

Several ocean fisheries in Canada intercept WCVI origin chinook, including northern troll, Haida Gwaii recreational, WCVI troll and WCVI recreational. Ocean fisheries in Canada are limited to a $10 \%$ exploitation rate, even if PST provisions allow for a higher catch. Management measures are in place to reduce the impact of fisheries on WCVI origin chinook while still providing harvest opportunities.

Continued efforts were made in 2016 to limit the impact of the troll fishery on low status chinook populations, including time and area constraints, and limits on effort (boat-days) to protect stocks of concern.

AABM chinook catch and release information from all fisheries can be found in Appendix 2.

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Table 6-1: Pre-Season Total Allowable and Preliminary Catch Estimates for October 2015September 2016 WCVI AABM Chinook

|  | Pre-Season | Post-Season |
| :--- | :--- | :--- |
| WCVI AABM Abundance Index | 0.89 | under review |
| WCVI AABM chinook TAC* | 133,300 | under review |
| AABM Recreational Catch | 60,000 | 37,809 |
| First Nations Catch (FSC) | 5,000 | Under review |
| Maa-nulth First Nations Catch (FSC) | 4,248 | $310^{* *}$ |
| T'aaq-wiihak Catch | 7,536 | $6,049 * * *$ |
| Area G Troll Catch | $\mathbf{5 6 , 5 1 7 *}$ | 49,119 |
| Total AABM Catch | $\mathbf{1 3 3 , 3 0 0}$ | $\mathbf{X X X , X X X}$ |

*The total Area G troll TAC is calculated as the difference between the WCVI AABM chinook TAC less offshore recreational catch, NTC First Nations Expected FSC catch, Maa-nulth Domestic Allocation and T’aaq-wiihak Allocation.
**First Nations catch is preliminary.
***Preliminary catch based on independent dockside monitoring program still requires reconciliation with T'aaqwiihak data.

### 6.2 Recreational Fisheries

The WCVI AABM recreational chinook fishery primarily takes place in offshore Areas 121-127 from June to September. Chinook catch from inshore Areas 21-27 in June and Areas 21-24 in July are also included in the AABM estimate. Catch and effort are largely driven by abundance and weather, and together both have impacts on annual harvest. Previous sampling has indicated that there is minimal AABM catch and effort outside of this period.

Chinook management measures are in place in the near-shore AABM areas to protect migrating WCVI origin chinook. In 2016 there were significant changes to these management measures for WCVI chinook in Areas 21-27. These changes included removing portions of the WCVI chinook corridor, increasing the finfish closures in several areas, increasing terminal chinook nonretention areas, and focussing recreational opportunities in areas where DNA samples indicate that WCVI chinook presence is lower.

Chinook catch in the AABM sport fishery is estimated through several catch monitoring programs, including a creel survey, a logbook program and DFO's electronic survey information (iREC). The creel survey continues to be the most utilized catch monitoring program in this area particularly because it collects effort (number of boat trips), and catch per unit effort data. Catch for any given species within a defined time-area stratum is estimated by multiplying effort estimates by CPUE. Total effort is estimated through vessel counts, gathered through either aerial or on-water boat surveys of the fishing area. CPUE is estimated from interviews with anglers at specific landing sites and from trip logbooks and manifests submitted by lodges and guides through a voluntary monitoring program. Logbook effort is removed from effort estimates where there is overlap. Data regarding the daily activity profile of the fishery, fishing
locations, and the proportion of guided versus un-guided effort are also gathered from angler interviews.

The total chinook catch in the 2016 WCVI AABM fishery was estimated to be 37,809 , which is down $40 \%$ from the 5 year average of 62,900. The total chinook released in the 2016 WCVI AABM fishery was estimated to be 22,512, which is down $60 \%$ from the 5 year average of 52,000. Effort in the AABM area for 2016 was 28,197 boat trips, which is down about $10 \%$ from 2015. Please see Figure 6-1 below which illustrates catch and effort from 1995 through 2016.


Figure 6-1: Preliminary Recreational WCVI Chinook AABM Catch and Effort, 1995-2016

### 6.3 Commercial Fisheries

### 6.3.1 Commercial (A-H Fisheries includes ATP)

After the completion of the April 2016 Chinook Technical Committee (CTC) chinook model calibration, the WCVI AABM Canadian allowable harvest was 133,300. The FSC harvest was set at 9,248 ; and the expected recreational catch was 60,000 , leaving 64,052 chinook available for commercial harvest. The commercial TAC was apportioned with $88.2 \%$ to Area G Troll and $11.8 \%$ to the T'aaq-wiihak First Nations Demonstration fishery. The Area G Troll TAC was 56,517 chinook. In early August, the expected recreational catch was reduced by 10,000 to 50,000 based on preliminary creel survey results through July. In early September, the expected recreational catch was further reduced to 41,000 chinook based on preliminary catch results through the end of August. This increased the total commercial TAC to 83,052, the Area G TAC to 73,281 and the T'aaq-wiihak TAC to 9,771 chinook. The total estimated commercial catch

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was 55,168 of which the Area $G$ troll catch was 49,119 and the T'aaq-wiihak catch was 6,049 . (Please note that the preliminary T'aaq-wiihak catch is from the independent dockside monitoring program and still requires reconciliation with the T'aaq-wiihak supplied data.)

For the 2015/2016 chinook year (October 1, 2015 to September 30, 2016), fisheries continued to be shaped by conservation concerns for the following domestic stocks: Fraser River Spring 42, Spring 52, Summer 52 chinook, Interior Fraser River coho, WCVI origin chinook salmon, and LGS chinook.

## Area G Troll Summary

The Area G Troll annual management plan is designed to maintain exploitation rates on stocks of concern within established limits, by the use of fishing time and area closures in conjunction with fishing effort limits. The management plan distributes catch and effort throughout the fishing year.

The management plan is subject to change as required to address specific conservation concerns as they arise. For the 2016 fishing season the following changes to annual fishing plan were implemented:

- Conservation measures introduced in the Area G troll fishery in 2011-12, to address low returns of Fraser River Spring $4_{2}$, Spring $5_{2}$, and Summer $5_{2}$ chinook were implemented again in the 2015-16 season. For Area G troll this includes a fishery closure for the month of June and the July fisheries were delayed until the third week of July.
- To avoid exceeding the overall WCVI AABM TAC, 5,000 chinook of the Area G TAC was allocated to September fisheries. If preliminary AABM catch estimates indicate the overall WCVI AABM TAC may be exceeded, the Area G TAC set aside for September would be used to assist Canada with staying within its overall WCVI chinook TAC.
- Retention of marked coho salmon by-catch was permitted in all openings between September 15 and December 31.


## Area G Troll Fishing Periods:

October to March period:
During the period from October 1 to March 15, a harvest level of approximately 20\% of the Area G annual TAC was recommended, based on the PST chinook model calibration and assigned harvest levels for the outer WCVI area.

## March 16 to April 18 period:

A full time-area closure was maintained from March 16 to April 18 annually to avoid interception of Fraser River Spring $4_{2}$ and Fraser Spring \& Summer $5_{2}$ chinook.

## Late April/ mid-June period:

During the period from April 19 to June 15, a harvest of approximately 40\% of the Area G annual TAC was recommended, based on the PST chinook model calibration and assigned harvest levels for the outer WCVI area. In addition, total effort (boat-days) was limited and

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areas of southwest Vancouver Island were closed until May 7 (partial openings from May 2 to 7), in order to avoid interception of Fraser River Spring $4_{2}$, Spring $5_{2}$, and Summer $5_{2}$ chinook.

June 16 to July 23 period:
A full time-area closure was maintained from June 15 to July 23 in Management Areas 125 to 127, and from June 16 to July 31 in Management Areas 123 to 124, to avoid interception of Fraser River Spring $4_{2}$, Spring $5_{2}$, and Summer $5_{2}$ chinook.

July 24 through early August:
Area G did not fish until August 6 and then the fishery stayed open until Sept 30. During this period, a harvest of approximately $20 \%$ of the Area G annual TAC was recommended, based on the PST chinook model calibration and assigned harvest levels for the outer WCVI area. In addition, the fishery was managed to minimize mortality on wild coho through: a) a maximum interception of coho; and b) the mandatory use of large (minimum 6") plugs. As well, the fishery was managed to minimize mortality of WCVI origin chinook through the use of timearea closures of near shore areas where WCVI chinook stocks are prevalent.

## September period:

During the September period, a harvest of approximately 20\% of the Area G annual TAC was recommended based on the PST chinook model calibration and assigned harvest levels for the outer WCVI area. The Area G harvest level in September has the potential to increase if there is available remaining WCVI AABM TAC after accounting for First Nation FSC and recreational fisheries. However, if First Nations or the recreational sectors catches are larger than projected, the available commercial TAC is reduced. During harvest opportunities between September 15 and December 31 retention of marked coho by-catch was permitted.

For all troll fisheries, selective fishing practices were mandatory, including single barbless hooks and revival tanks for resuscitating non-retention species prior to release.

Since 1999, a major objective for the management of the WCVI troll fishery has been to distribute the catch throughout the fall-winter-spring-summer periods. This objective was continued in 2015/2016.

The late July and August plug fisheries were monitored to determine encounter rates of other species and estimate numbers of released chinook. Biological sampling was conducted for size distributions, and stock compositions (Coded Wire Tags, DNA and otolith samples).

Table 6-2: Post-Season Preliminary Monthly Catch Estimates for 2010/11 to 2015/16 WCVI AABM Chinook Area G Troll Fisheries

|  | $\mathbf{2 0 1 5 / 2 0 1 6}$ | $\mathbf{2 0 1 4 / 2 0 1 5}$ | $\mathbf{2 0 1 3 / 2 0 1 4}$ | $\mathbf{2 0 1 2 / 2 0 1 3}$ | $\mathbf{2 0 1 1 / 2 0 1 2}$ | $\mathbf{2 0 1 0 / 2 0 1 1}$ |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| October | 178 | 213 | 2,358 | 3,344 | 0 | 0 |
| November | 13 | 56 | 28 | 230 | 57 | 0 |
| December | 1 | 0 | 25 | 312 | 188 | 0 |
| January | 51 | 186 | 49 | 1,018 | 129 | 0 |
| February | 342 | 612 | 586 | 358 | 542 | 1,849 |
| March | 315 | 731 | 1,422 | 501 | 243 | 875 |

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| April | 6,456 | 3,841 | 13,345 | 1,374 | 10,493 | 8,670 |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| May | 31,799 | 27,405 | 40,336 | 25,737 | 22,334 | 41,239 |
| June | 0 | 0 | 0 | 0 | 0 | 34,394 |
| July | 0 | 0 | $26,494^{*}$ | 0 | 0 | $15,619^{*}$ |
| August | $7,574^{*}$ | $13,953^{*}$ | $10,02^{*}$ | 0 | $4,280^{*}$ | $21,284^{*}$ |
| September | $2,390^{* *}$ | 7,341 | 15,360 | 2,519 | 17,264 | 0 |
| Total | $\mathbf{4 9 , 1 1 9}$ | $\mathbf{5 4 , 3 3 8}$ | $\mathbf{1 1 0 , 0 0 5}$ | $\mathbf{3 5 , 3 9 3}$ | $\mathbf{5 5 , 5 3 0}$ | $\mathbf{1 2 3 , 9 3 0}$ |

*Plug fishery.
**Plug fishery until September 15.

### 6.3.2 First Nation Commercial Harvest

In 2016 the Department authorized an AABM chinook salmon demonstration fishery for the T'aaq-wiihak Nations with an initial TAC of 7,536 pieces. The fishery was carried out in portions of Areas 24, 25, 26, 124, 125 and 126 on the west coast of Vancouver Island discontinuously between May 27 and September 30, 2016. In early August, the expected recreational catch was reduced by 10,000 to 50,000 based on preliminary creel survey results through July. In early September, the expected recreational catch was further reduced to 41,000 chinook based on preliminary catch results through the end of August. This increased the T'aaqwiihak TAC to 9,771 based on their share of the commercial AABM TAC (11.8\%). Total sold catch estimated for the fishery was 6,049 chinook. Retention of marked coho was permitted after September 15 and 414 coho were landed for sale. Several groundfish species were also permitted to be retained for sale. Please note that the preliminary catch numbers are from an independent dockside monitoring program. These numbers still need to be reconciled with the data provided by the T'aaq-wiihak. Reported releases for this fishery were 1,663 sub-legal chinook, 25 legal chinook, 417 coho, 3 chum and 1 pink.

### 6.4 FIRST NATIONS

Total AABM chinook reported for First Nations FSC and domestic fisheries (to date) is 2,346.

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## 7 SOUTHERN B.C. CHINOOK INDIVIDUAL STOCK BASED MANAGEMENT (ISBM)

### 7.1 ObJectives and Overview

In addition to the PST regime, Canada implemented management actions as required to ensure conservation of Canadian origin chinook and to meet domestic allocation requirements. These chinook fisheries were managed to harvest rates on an individual stock basis (ISBM).

Measures were taken in 2016 in First Nations FSC, recreational and commercial chinook fisheries to protect WCVI, LGS, Fraser River Spring $4_{2}$, Spring $5_{2}$, and Summer $5_{2}$ chinook stocks. FSC management actions included time and area closures and reduced fishing times. Recreational measures included barbless hooks, time/area closures, size restrictions and mark selective fisheries. Commercial measures included barbless hooks, time and area closures, gear restrictions, mandatory use of revival tanks, daily catch reporting and mandatory logbooks. Postrelease mortality information for chinook included in ISBM management was determined from studies conducted in 2000-2001.

Specific management actions were taken to protect WCVI origin chinook in Canadian ocean fisheries (not including enhanced terminal areas), the harvest of which was restricted to an exploitation rate of $10 \%$. Fisheries that this limit applies to are the northern troll, Haida Gwaii recreational, WCVI troll and WCVI recreational. Most Southern B.C. fisheries were regulated so that impacts on WCVI wild chinook stocks was minimized, with the exception of terminal recreational, commercial and First Nations FSC fisheries.

LGS chinook stocks are improving from historic lows seen in 2009 and are rebuilding slowly. Significant management measures in recreational and commercial fisheries continued to be in place throughout 2016 to protect these stocks. Some LGS chinook stocks are seeing a gradual increase in terminal returns, particularly in the Cowichan River, which is encouraging; however, their productivity and Salmon Outlook category remains low.

Fraser River Spring $4_{2}$, Spring $5_{2}$, and Summer $5_{2}$ chinook stocks had specific management measures in place to reduce exploitation in FSC, recreational and commercial fisheries. FSC management actions in the Fraser River included time and area closures, and reduced fishing times. Recreational fisheries in Juan de Fuca Strait, the lower Strait of Georgia and the approach waters of the Fraser River had specific time, area, size and mark selective restrictions designed to minimize the amount of exploitation on these chinook stocks. Fraser River tidal and non-tidal sport fisheries had delayed starting dates, implemented to protect Fraser River Spring $4_{2}$, Spring $5_{2}$, and Summer $5_{2}$ chinook stocks. In addition, due to extreme environmental conditions in 2015, the chinook directed sport fisheries in the approach waters to and in the Fraser River were even further delayed to late July and early August. The Area G and T'aaq-wiihak commercial troll fisheries on the WCVI were also managed with time and area closures in 2016 for Fraser River Spring $4_{2}$, Spring $5_{2}$, and Summer $5_{2}$ chinook stocks.

ISBM chinook catch and release information from all fisheries can be found in Appendix 3.

### 7.2 StOck Status

### 7.2.1 West Coast Vancouver Island Chinook

Wild WCVI chinook are a stock of concern. While stocks are low and stable, they are below target and have not rebuilt from low abundances that resulted from a decline in productivity observed during the early to mid-1990s. Of particular concern are those stocks that originate from the SWVI area conservation unit (i.e. Clayoquot Sound).

Hatchery production supports terminal fisheries directed at surplus production with management measures in place to reduce impacts on wild origin stocks. For WCVI hatchery stocks, the terminal return is defined as total catch (First Nation FSC, recreational and commercial) in the near approach areas of the hatchery plus escapement (brood collection plus natural spawners). In these hatchery approach areas, catch is dominated by the hatchery stock (e.g. >95\%), therefore, higher exploitation rates are permitted than in times and areas dominated by naturally produced WCVI chinook stocks.

### 7.2.2 Strait of Georgia Chinook

## Strait of Georgia Chinook

## Fall:

Total returns to Strait of Georgia streams north of Nanaimo, virtually all of which are enhanced, have been relatively stable for the last fifteen years. In general, 2016 chinook escapements were similar to or higher than 2015 in this area. The abundance of Englishman River chinook was much lower than 2015 however the chinook returning to Little Qualicum was higher than the abundance in 2015.

In the southern Strait of Georgia, total returns have been on a decreasing trend over the last 25 years. Specifically, the Nanaimo River chinook abundance has been generally stable since 1995 and the Cowichan River chinook abundance has decreased since the very high escapements in the 1990s to the low in 2009. Since that year the spawner abundances have slightly increased to approximately half of the long term average. In 2016, the Nanaimo and Cowichan River chinook abundance increased over the previous year. Goldstream River chinook continue to have very low numbers of spawners.

Despite strong returns in 2016 relative to expectations, this population continues to be a stock of concern. There are continuing improvements to the returns to Cowichan River, to the point of getting near the escapement target, however it continues to be a stock of concern until such time that the run can be considered to be no longer at risk. Three generations would be the time frame (9 years).
In 2016, chinook escapement to Cowichan River was much higher than the previous year. The preliminary analysis from the enumeration project is an estimate of 9,000 spawners (all ages) and 427 broodstock taken for the Cowichan River Hatchery. Approximately $62 \%$ of the spawners are age $3+$ ('adults') and the other $38 \%$ are age 2 ('jacks’ and 'jills'). This high component of age 2 chinook is suggestive of additional increases in the 2017 and 2018 returns. Water levels were low from April until mid-October although upstream migration occurred during this period. The number of chinook caught in local First Nation FSC fisheries has not yet been reported.

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On the mainland side of the northern Strait of Georgia, Sliammon and Lang hatcheries continue to have variable returns, however in the last five years the returns to Lang Creek have been stronger than in previous years. There are a few very small, wild populations remaining in the Theodosia and Skwakwa rivers, and those rivers entering Jervis Inlet, where assessment data are poor or not available. Historically, a large proportion of the chinook stock aggregate originating from rivers north of Nanaimo migrate into central and northern B.C. and Alaska. Exploitation rates on this stock aggregate have gradually been reduced over the last 15 years, thus the stable trend in annual returns to rivers over this period suggests a reduction in marine survival.

## Spring/Summer:

The Puntledge, Nanaimo and more recently the Cowichan system have identified early runs of Chinook in the Strait of Georgia. Cowichan Summer run chinook were monitored this year and preliminary results show an abundance of 200 individuals. These were shown to move upstream into the Cowichan Lake through the summer, dropping downstream in August and September to spawn. Efforts to recover Puntledge summers to viable levels have resulted in improved returns to the river since 1999. The 2006 and 2007 natural spawning escapements ranged from 200 500 adults (not including brood capture), which is down from the record high in 2005 of approximately 2,500 adults, but is substantially higher than escapements recorded in the previous decades. The preliminary estimate for 2016 escapement to Puntledge is approximately 843 adults which is a continuation of the increasing abundance trend over the past four years. Monitoring of Nanaimo spring and summer chinook escapement did not occur this year.

### 7.2.3 Johnstone Strait Mainland Inlet Chinook

## Johnstone Strait/Mainland Inlet Chinook

Currently only three systems are monitored consistently in Areas 12 and 13. The Nimpkish River is assessed using standardized swim surveys and stream walks by hatchery staff. An intensive mark-recapture program is carried out by Quinsam Hatchery to estimate escapement on the Campbell/Quinsam system. A mark-recapture program has been in development over the past few years on the Phillips River, with the plan to eventually establish it as a mainland chinook indicator. Other systems are covered using intermittent visual surveys.

## Nimpkish River

In 2016, the coverage of the chinook timing was greatly impacted by flow conditions during late October to early November, which made coverage of the watershed difficult. Assessment coverage up until that time period will be used to determine escapement to the system for 2016. Hatchery staff were successful in collecting approximately $75 \%$ of their broodstock target prior to the significant rain events. The preliminary escapement estimate of just over 1,400 individuals is similar to the last few years and is a continued improvement over the low but stable returns seen prior to 2012, which averaged around 600 adults.

## Campbell/Quinsam System

The Campbell/Quinsam, a long-term chinook indicator, has been assessed by carcass markrecapture since 1984. Preliminary results for the 2016 program have the combined system chinook estimate at approximately 8,400 adults; which is possibly a conservative estimate, due to challenges presented by the frequent adverse river conditions this fall. This improved estimate
exceeds those of past years, and is the largest return since 2006. However, estimate precision declined on both systems compared to 2015.

With very limited opportunities for seining, hatchery staff attained their brood target from the abundance of swim-ins.

## Phillips River

Preliminary results from the mark-recapture program on the Phillips River indicate the chinook escapement is in the range of 2,200 adults, consistent with the $2,000-2,500$ trend of the past few years. Estimate precision for this program has continued to improve, falling below $10 \%$ this year.

Broodstock was again collected in 2016, the local hatchery plans to release approximately 90,000 coded wire tagged chinook smolts next spring to contribute to the assessment program.

### 7.3 First NAtions Fisheries

## WCVI FSC Fisheries

The Hupacasath and Tseshaht First Nations caught a total of 1,991 chinook by gillnet, rod and reel and as by catch during other salmon fisheries in Area 23. Catch reports for Maa-nulth domestic harvest indicate a combined ISBM FSC chinook harvest of 378 pieces. NTC First Nations ISBM catch reported to date is 1,157 pieces.

The total WCVI FSC chinook catch to date is 3,526 pieces.

## Strait of Georgia FSC Fisheries

Data are still being compiled on various First Nations catches in the Strait of Georgia; however, preliminary catch is estimated at 650 chinook.

## Johnstone Strait FSC Fisheries

Data are still being compiled on various First Nations catches in Johnstone Strait; however, preliminary catch is estimated at 347 chinook.

## Fraser River FSC Fisheries

FSC fisheries took place in the Lower Fraser River between the mouth and Sawmill Creek from May through November 2016. A total of 5,812 chinook were harvested, with 3,413 taken in chinook-directed fisheries, and the remaining chinook harvested as bycatch in sockeye and chum-directed FSC openings. Additionally, the following bycatch occurred during chinooktargeted FSC openings: 189 sockeye kept and 54 sockeye released; 163 coho kept and 518 coho released; 14 chum kept.

Chinook directed FSC fisheries took place in the Fraser River above Sawmill Creek from May through September 2016. A total of 3,985 chinook were harvested. Bycatch estimates are currently being finalized. Preliminary data indicate that less than 500 sockeye were released and less than 300 coho were released in chinook directed FSC fisheries above Sawmill Creek.

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### 7.4 COMMERCIAL

In 2016 there were commercial fisheries in Barkley Sound and Nootka Sound which targeted ISBM chinook.

## Area B Seine

No seine fisheries occurred for WCVI ISBM chinook in 2016.

## Area D Gill Net

In 2016, due to the expected abundant return of 4 year old Robertson Creek chinook commercial gillnet fisheries were opened in late August and through September. The fisheries occurred in Subarea 23-1, upper Alberni Inlet, targeting chinook returns to Robertson Creek Hatchery. The fisheries occurred on August 22, September 5 and, 10. The fisheries were not successful, with a total catch of 774 pieces. The remaining commercial chinook catch for Area 23 was taken in the same area during coho directed openings with chinook bycatch of 781 pcs. The total ISBM chinook catch in Area 23 for Area D was 1,555 pcs.

In 2016, gill net fisheries occurred in Tlupana Inlet targeting chinook returns to the Conuma River hatchery. Fisheries occurred 2 nights per week from Aug 17 to September 7. The total estimated catch during the chinook directed fishery was 3,451 chinook and 35 chum retained with 1 coho and 4 chum reported being released.

## Area E Gill Net

No Area E gill net fisheries occurred for ISBM chinook in 2016.

## Fraser River Economic Opportunity and Inland Demonstration Fisheries

## Lower Fraser Area

In 2016, no sockeye-directed economic opportunity or demonstration fisheries took place in the Fraser Area; therefore there was no incidental impact on chinook from these fisheries.
In mid-October through early November limited economic opportunity/ demonstration fisheries to access available chum salmon TAC were initiated. Although the retention of chinook salmon was not authorized during these economic opportunity demonstration / fisheries, there was some by-catch retention reported. In chum economic opportunity/demonstration fisheries the total chinook harvested was 4 kept and 283 released.

## Mid Fraser / Thompson area

Economic opportunity or inland demonstration fisheries did not occur in 2016 for ISBM chinook in either the upper or lower reaches of the Fraser River.

An inland commercial fishing enterprise (CFE) operated by Riverfresh (Secwepemc Fisheries Commission), received an allocation for chinook in the B.C. Interior but did not conduct a fishery due to sockeye constraints. Dual fishing is in place for this fishery but low returns of sockeye in the area resulted in the CFE deciding to not conduct the fishery.

FIRST NATIONS COMMERCIAL HARVEST

In 2016 an agreement was reached with the Hupacasath and Tseshaht First Nations for an Economic Opportunity fishery. There was an opportunity for several commercial chinook openings August $21^{\text {st }}$, September $7^{\text {th }}$ and $12^{\text {th }}$. The total catch of chinook in these openings was 10,248 pcs with a bycatch of 2,764 pcs of coho. These fisheries were very successful for chinook and the total catch was 10,248 pieces.

The Department authorized an ISBM chinook salmon demonstration fishery in Area 25 for the T'aaq-wiihak Nations in 2016. This fishery targeted both the Conuma River and Burman River enhanced chinook returns using troll and gillnet gear. Fishery openings occurred discontinuously from July 1 to September 1. A total of 56 chinook from the Conuma targeted fishery and 261 chinook from the Burman targeted fishery were sold with no bycatch reported.

### 7.5 Excess Salmon Spawning to Requirements (ESSR) Fisheries

## WCVI ESSR Fisheries

The Tseshaht and Hupacasath First Nations were issued a joint Excess Salmon to Spawning Requirements (ESSR) Licence for chinook at the Robertson Creek Hatchery facility. The total sold was 29,698 chinook (this total includes 4,778 jacks). The Ditidaht First Nation was issued an ESSR Licence for chinook at Nitinat Lake and the Nitinat Hatchery. The total harvested was 2,557 chinook. The Mowachaht/Muchalaht First Nation was issued an ESSR licence to harvest chinook from the Conuma River and hatchery. The catch from this ESSR fishery was 5,067 chinook (including 132 jacks). The total catch for all WCVI ESSR chinook fisheries was 37,322 pieces.

## Strait of Georgia ESSR Fisheries

ESSR harvest at the Big Qualicum hatchery included catch of 3,028 chinook (total includes 1,325 jacks).

## Capilano Hatchery ESSR Fisheries

There were ESSR fisheries at the Capilano hatchery in 2016 that included chinook salmon. The total harvest of chinook salmon was 841 pieces (total includes 430 jacks).

## Fraser River ESSR Fisheries

There were ESSR fisheries at the Chilliwack hatchery in 2016 that included chinook salmon. The total harvest of chinook salmon was 5,871 pieces (total includes 2,638 jacks).

There were ESSR fisheries at the Inch Creek and Chehalis hatcheries in 2016 however no harvests of chinook salmon took place.

## Johnstone Strait ESSR Fisheries

Currently there are no ESSR opportunities on chinook in Johnstone Strait.

### 7.6 RECREATIONAL

West Coast Vancouver Island

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WCVI recreational ISBM fisheries are managed to fall within Canada’s 10\% exploitation rate on WCVI wild chinook. To help achieve this objective management measures are put in place along the coast in areas that tagging studies have shown to be the main WCVI chinook migratory routes. Prior to 2016 this area was managed using a chinook Conservation Corridor, which was an area one nautical mile seaward of the surf line, extending from Areas 123 to 127. In 2016 management measures were put into place that increased finfish closed areas, increased terminal chinook non-retention areas, and provided increased recreational access to areas where hatchery stock composition was considered to be the highest.

Chinook management measures depend on forecasted abundance and should change annually based on the WCVI chinook abundance forecasts.

These management measures went into effect starting July 15 in those waters north of Estevan Point and August 1 for those waters south of Estevan Point. In 2016, a high return of 4 year old chinook was expected to return to the WCVI. Actual returns were slightly below forecast, but still provided good recreational fishing opportunities in many areas. Other management measures in effect to reduce recreational impacts on chinook include barbless hooks, a minimum size limit, daily limits and annual limits.

Figure 7-1: Sport WCVI Chinook ISBM Catch and Effort, 1995-2016

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*Note this doesn't include Areas 22, and the WCVI portion of Area 20.

## Inside Areas: Strait of Georgia, Johnstone Strait, and Juan de Fuca Strait

2016 sport fisheries in these areas were designed to minimize impact on returning Fraser River Spring $4_{2}$, Spring $5_{2}$, and Summer $5_{2}$ chinook. Management measures put in place to protect these stocks included mark selective fisheries and size limits in specific areas/times.

In those waters near Victoria between Cadboro Point and Sheringham Point (Subareas 19-1 to 19-4 and Subarea 20-5), retention regulations were adjusted from March 1 to June 17 where anglers were permitted to retain two chinook per day either wild or hatchery marked between 45 cm and 67 cm or hatchery marked only chinook over 67 cm in length. In this same waters, with the addition of Subarea 20-4, retention regulations were adjusted from June 18 to July 17 where anglers were permitted to retain two chinook per day either wild or hatchery marked between 45 cm and 85 cm or hatchery marked only chinook over 85 cm in length. The minimum size limit in these waters is 45 cm in length. This is the Zone 1 management measure for Fraser chinook.

The Strait of Georgia "chinook corridor" extending from Subareas 18-1 to 18-6, 18-9, 18-11, 195 and a portion of 29-4 and 20-5 that lies south from a point on the east side of Valdes Island and extending 57 degrees true for 5 nautical miles remained in place in 2016. In this corridor the daily limit was two chinook of which only one could be over 67 cm from May 9 to July 17. In 2016, retention regulations in these waters were adjusted from June 181 to July 15 where anglers were permitted to retain two chinook per day either wild or hatchery marked between 62 cm and 85 cm . The minimum size limit is 62 cm . This is the Zone 1 management measure for Fraser chinook.

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Drought like conditions in the summer of 2016 elevated the concern for Lower Georgia Strait chinook, including Cowichan River chinook due to reduced river flows and high river temperatures. Chinook non-retention measures were put into effect from July 25 - October 14 in Subareas, 18-6 to 18-8 during this period of concern. Improved flow and temperature conditions were observed in September and October, as well as strong chinook returns to the Cowichan River. The terminal finfish closure in Cowichan Bay was lifted and replaced with a chinook nonretention regulation to allow recreational opportunities in this area.

For the Johnstone Strait and Strait of Georgia areas chinook management measures also included an annual limit of 15 chinook, a daily limit of two chinook and a minimum size limit of 62 cm . For the Canadian portion of Juan de Fuca Strait south of Cadboro Point, regulations included an annual limit of 20 chinook, a daily limit of two chinook and a minimum size limit of 45 cm .

In 2016 marine sport fisheries were monitored by creel surveys in three main areas; 1) Juan de Fuca including Victoria (south of Cadboro Point) and Juan de Fuca Strait through Subareas 20-1; 2) Portions of the Strait of Georgia including Areas 14 through 18, that portion of Area 19 north of Cadboro Point, Areas 28 and 29; and 3) Johnstone Strait including Areas 11 to 13. Monitoring of the Strait of Georgia sport fishery took place from June-October (not all areas were surveyed every month), and Juan de Fuca Strait sport fishery (March to October) has been fairly consistent from year to year using an access point (landing site) survey for collecting catch, CPUE, and biological information combined with an aerial survey for effort counts. In addition, logbook programs, directed at estimating the sport catch by fishing guides during guided trips, were conducted in the Campbell River and Victoria Areas in 2016. The Johnstone Strait creel survey commenced in Area 13 in May and continued through until the end of September, and from June through August to included Areas 11 and 12.

Effort, catch and release information from marine fisheries are summarized in Table 7-2.
Table 7-1: Preliminary Catch and Effort Estimates for Southern B.C. Inside Sport ISBM Fisheries in 2016.

| Fishing Area | Survey <br> Period | Chinook Kept | Chinook <br> Released |
| :--- | :--- | :--- | :--- |
| Strait of Georgia | Jun - Oct | 27,443 | 55,474 |
| Johnstone Strait | Jun - Aug | 8,349 | 7,146 |
| Juan de Fuca Strait | Mar- Oct | 22,866 | 23,886 |
| WCVI Inshore | Jun-Sep | 33,574 | 37,098 |
| Fraser River | ** | Jul - Oct | 1968 |
| TOTAL |  | 126 |  |

** Complete Lower Fraser recreational fisheries estimates not yet available at the time of this report.

## Region 1 Vancouver Island Tributaries-

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Fresh water restrictions were in effect in most tributaries on Vancouver Island due to drought like conditions in 2016. Rivers on the southern half of Vancouver Island (Regions 1-1 to 1-6) were closed to angling from July 1 to September 16. Portions of Region 1 (Regions 7-13) remained open. The Qualicum Nitinat, Somass and Conuma Rivers provided some recreational opportunities to harvest enhanced chinook stocks during this time period.

## Qualicum River

Qualicum River opened for chinook on August 1 for four per day less than 62 cm . On October 16 the regulation changed to four chinook per day of which 2 could be greater than 62 cm . The Qualicum River was not monitored by creel survey during 2016.

## Somass/ Stamp

During 2016 there was a non-tidal opening on the Somass/Stamp River (Area 23) with chinook retention. The fishery opened from August $25^{\text {th }}$ until December 31, 2016, and the daily limit was one chinook salmon greater than 77 cm and one less than 77 cm . The Somass/Stamp Rivers were not monitored by creel survey during 2016.

Nitinat During 2016 there was a planned non-tidal opening for the Nitinat River (Area 22) from September 2, 2016 to September 30, 2016. The daily limit was two with only one greater than 77 cm . The salmon fishery was closed for retention of chinook from October 1 until October 14 to protect chinook salmon during the peak spawning period. The salmon fishery re-opened from October 16 until December 31 with non-retention of chinook salmon. The Nitinat River was not monitored by creel survey during 2016. The area above Parker Creek was closed to fishing.

## Conuma

Angling for chinook opened on August $25^{\text {th }}$-Dec 31, 2016. The daily limit was two with only one greater than 77 cm .

## Fraser River and Tributaries

Fraser River Spring $4_{2}$, Spring $5_{2}$, and Summer $5_{2}$ chinook stocks required additional management measures again in 2016 due to continued concerns about stock status.

In Subareas 29-6, 29-7, 29-9 and 29-10, the 2016 fishing regulations were as follows:

- May 1 to July 31, no fishing for chinook salmon.
- August $1^{\text {st }}$ to August 11, daily limit was two chinook (wild or hatchery marked) with a minimum length of 62 cm .
- August $12^{\text {th }}$ to September 18th, no fishing for salmon. This management measure was in place to protect co-migrating sockeye salmon.
- September 19th to December 31, the daily limit was two chinook (wild or hatchery marked) with a minimum length of 62 cm .


## Tidal Fraser and Region 2 Fraser River:

In the tidal waters of the Fraser River and in that portion of the Fraser River in Region 2 the following regulations were in place for 2016:

- January 1 to July 31, no fishing for salmon.
- August 1 to August 11, the daily limit was four chinook per day with only one over 50 cm allowed to be retained.
- August 12 to September 18, no fishing for salmon. This management measure was due to potential impacts to co-migrating sockeye salmon.
- September 19th to December 31 the daily limit for wild or hatchery marked chinook salmon was four with only one over 62 cm allowed to be retained.


## Fraser River Tributaries:

There were several tributaries to the Fraser River in which chinook retention was permitted. These included:

- Alouette River: daily limit of one chinook from September 1 to December 31;
- Chehalis River: daily limit of four with only one over 50 cm from June 1 until August 31 and a daily limit of four chinook with only one over 62 cm from September 1 until December 31;
- Chilliwack/Vedder River: daily limit of four with only one over 62 cm from July 1 until August 31, daily limit of four with two over 62 cm from September 1 to December 31;
- Coquitlam River: daily limit of one chinook from September 1 to December 31;
- Harrison River, there was no chinook fishery on the Harrison River in 2016 due to a low forecast of terminal abundance.


## Tributaries to the Fraser River above Sawmill Creek in which chinook retention was authorized included:

Region 3 - Fraser River Tributaries

- Kamloops Lake August 22 to September 15, daily limit of four chinook, only one over 50 cm.
- South Thompson River: August 16 to September 22, daily limit of four chinook, only two greater than 50 cm . There is a monthly quota of six chinook from the South Thompson River.


## Region 5A

There were no recreational chinook fisheries in 2016.

## Region 7

There were no recreational chinook fisheries in 2016.

## Region 8

Note: there is a monthly limit of four chinook in Region 8.

- Mabel Lake and Lower Shuswap River: August16 to September 12, daily limit of four chinook per day, only two greater than 50 cm . The open area in Mabel Lake was smaller than usual this year due to an area that remained closed off the mouth of Middle Shuswap River due to concern for co-migrating Middle Shuswap chinook.
- Middle Shuswap River: did not open in 2016 due to low brood year concerns.

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## 8 FRASER RIVER SOCKEYE

### 8.1 ObJEctives and Overview

The 2016 Fraser sockeye forecast had an $80 \%$ prediction interval of $0.8 \mathrm{M}-8.2 \mathrm{M}$. From this distribution, the Fraser River Panel (FRP) adopted a run size forecast of 2.3M Fraser sockeye for planning purposes based on the 50\% (p50) probability level forecast for all run timing aggregates. The majority of the total return ( $\sim 74 \%$ ) was expected to be from the Summer run sockeye run timing group. As the Canadian TAC at the p50 run size forecast was less than one million sockeye, pre-season planning focused on First Nations Food, Social and Ceremonial (FSC) fisheries and staying within constraints to minimize impacts on less abundant stock groups and species of concern.

Pre-season plans incorporated provisions to meet escapement objectives and meet conservation objectives for stocks of concern while considering international and domestic objectives. Significant effort was placed on developing a pre-season plan for anticipated fisheries. The preseason plan included the following assumptions and guiding principles in no particular order:

- The Fraser River Panel operated in accordance with Chapter 4, Annex IV of the Pacific Salmon Treaty, which came into effect prior to this season;
- The U.S. share of the annual Fraser River sockeye salmon total allowable catch (TAC), harvested in the waters of Washington State was set at $16.5 \%$ of the aggregate. To the extent practicable, the Fraser River Panel shall manage the United States fishery to implement a fishing plan that concentrates harvest on the most abundant management group or groups.
- It is understood that the U.S. harvest may exceed $16.5 \%$ of the TAC for one or more of the less abundant management groups by a small but acceptable amount despite concentrating the harvest in this manner;
- For computing TAC by stock management groupings, the Aboriginal Fishery Exemption (AFE) of 400,000 Fraser River sockeye, shall be allocated to management groups as follows: The Early Stuart sockeye exemption shall be up to $20 \%(80,000)$ of the Fraser River AFE, and the remaining balance of the latter exemption shall be based on the average proportional distribution of First Nations Food, Social and Ceremonial catch for the most recent three cycles and modified annually as required to address concerns for Fraser River sockeye stocks and other species, and as otherwise agreed to by the Fraser River Panel;
- It was anticipated that an in-season run size estimate for Cultus Lake sockeye would not be possible due to low abundance relative to co-migrating sockeye stocks. As a result the Cultus exploitation rate is assumed to be the same as the exploitation rate from the similarly timed Late run stocks (excluding the Birkenhead and Birkenhead-type miscellaneous stocks), caught seaward of the confluence of the Fraser and the Vedder Rivers;
- The four run timing aggregates identified under the Pacific Salmon Treaty Annex generally contain stocks with similar timing in the marine area. Recent trends in timing of some stocks, including Raft River and North Thompson (in the Early Summer run prior to 2012), and Harrison River (in the Late run prior to 2012) sockeye now differs substantially from the other stocks in their respective historical run timing groups. Fisheries and Oceans Canada continues to manage these stocks as part of the Summer run aggregate to better align these
stocks with other stocks of similar run timing. Escapement plans, management adjustments and harvest rules have been adjusted to account for this change;
- Canada's escapement plan specified escapement requirements that varied with run size for each of the run timing aggregates;
- The Total Allowable Mortality (TAM) cap describes the upper range of the total mortality (including management adjustments and exploitation rate). The TAM cap was $60 \%$ for all run timing/management groups.
- At low abundances, low abundance exploitation rates (LAERs) are implemented to protect $90 \%$ of the run timing aggregate ( $10 \%$ LAER) while allowing for fisheries on more abundant co-migrating run timing groups and/or other species. The exception is the Late run aggregate where a $20 \%$ LAER has been implemented consistent with recent years' practice.
- In 2016, Early Stuart sockeye window closures and other fishing restrictions were planned for commercial, recreational and First Nations fisheries to protect a significant proportion ( $90 \%$ ) of the Early Stuart return. These measures included a rolling window closure based on run timing of the Early Stuart sockeye migration through various fishery areas.
- Conservation concerns for other sockeye stocks and species continued to impact the planning of sockeye fisheries. The stocks and species of concern in 2016 were: Cultus Lake sockeye, Nimpkish River sockeye, Sakinaw Lake sockeye, Interior Fraser River coho, Fraser Spring $4_{2}$ chinook, Fraser Spring and Summer 5 2 chinook, and Interior Fraser River steelhead.


### 8.2 StOck Status

### 8.2.1 Pre-season Assessment

Pre-season expectations were for a median run size (p50 level) of 2,271,000 Fraser River sockeye salmon and a one in two chance that the run size would be between 1,296,000 and $4,227,000$. Table 8-1

Pre-season expectations of migration parameters included a 75\% diversion rate for Fraser River sockeye through Johnstone Strait. Expected Area 20 50\% migration dates were July 3 for Early Stuart, July 21 for Early Summer, August 6 for Summer, and August 14 for Late-run sockeye. Table 8-2 (top)

Pre-season spawning escapement goals were 36,000 Early Stuart, 178,800 Early Summer, 722,000 Summer and 111,000 Late-run sockeye for a total of $1,047,800$ sockeye spawners. The goals for each sockeye management group were established by applying Canada's Spawning Escapement Plan to the forecasted run size. For pre-season planning purposes, Early Stuart and Late-run sockeye were respectively constrained by a $10 \%$ and a $20 \%$ Low Abundance Exploitation Rate (LAER). Table 8-3

Management Adjustments (MAs) of 105,500 Early Summer and 79,400 Summer-run sockeye were added to the spawning escapement targets to increase the likelihood of achieving the targets. The application of a LAER for Early Stuart and Late-run sockeye indicates that spawning escapement targets are unlikely to be reached and therefore obviates the need for management adjustments for these two groups. Table 8-2 (top)

The preseason MAs were derived from proportional difference between estimates (pDBE) for the Early Summer and Summer-run aggregates. These in turn were estimated as the weighted average of each component's median pDBE using historic data and their median preseason

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forecast abundances. For Early Summer-run, the three components consisted of Chilliwack, Pitt and the remaining Early Summer-run stocks while the Summer-run aggregate was divided into Harrison and non-Harrison components. The median pDBE for Chilliwack was calculated using dominant/subdominant years, while the median for all other component groups was based on all years. Table 8-2 (top)

The projected Total Allowable Catch (TAC) of Fraser River sockeye salmon based on the median forecasted abundances and agreed deductions was 647,700 sockeye, of which $16.5 \%$ (106,000 sockeye) were allocated to the United States (U.S.). Table 8-2 (top)
Pre-season model runs indicated it was unlikely the Summer-run TAC could be fully harvested due to fisheries constraints required to achieve spawning escapement targets for co-migrating Early Summer and Late-run stocks.

### 8.2.2 In-season Assessment

Marine migration timing was earlier than pre-season expectations for most management groups: 1 day for Early Summer and 6 days for both Summer and Late-run. Early Stuart timing was as forecast. No delay was detected in the migration behaviour for Late-run. Figure 8-1

The overall Johnstone Strait diversion rate was $50 \%$ compared to a pre-season forecast of $75 \%$.
Returns for all management groups were substantially below median pre-season forecasts (Early Stuart run: 50\% below median forecast, Early Summer run: 46\% below median forecast, Summer-run: 69\% below median forecast and Late-run: 37\% below median forecast). In context to the pre-season forecast range, the Early Stuart return was between the p10 and p25 forecast, Early Summers slightly above the p25 forecast, Summers below the p10 forecast, and Lates slightly above the p25 forecast. Table 8-1

Fraser River discharge remained low for the duration of the season while river temperatures remained high. Despite the high temperatures, the in-season model estimates of differences between potential spawning escapement and the actual number of spawners on the spawning grounds (DBE) were similar to the preseason median values used for Early Summers. While the in-season model estimates for Summers were higher than pre-season median values, no in-season updates to DBEs were adopted in-season in 2016. As the in-season run size for Early Stuart, Summers and Lates resulted in these groups being managed under a low abundance exploitation rate (LAER) scenario, DBEs were not required. Table 8-2 (bottom)

### 8.2.3 Post Season

Returns of adult Fraser sockeye totalled 853,000 fish, less than half the brood year abundance of 2,057,700 fish in 2012. This return was the smallest over the last 50 years. Divided into management groups, preliminary estimates of adult returns totalled 18,000 Early Stuart, 240,000 Early Summer-run, 527,000 Summer-run and 70,000 Late-run sockeye. Table 8-1

Catches of Fraser River sockeye salmon in all fisheries totaled 147,000 fish, including 137,000 fish caught by Canada, 2,000 fish caught by the U.S. and 9,000 fish caught by test fisheries. Almost all the Canadian catch occurred in First Nations FSC fisheries (Food, Social and Ceremonial, 136,000 fish). In Washington, catches were in non-commercial and Treaty Indian commercial fisheries (1,000 fish each). Excluding a yet to be determined catch of Fraser Sockeye
in Alaskan fisheries, the overall harvest rate was $17 \%$ of the run, which is the smallest in recent years, excluding 2009 and 2013. Table 8-4

DFO's near-final estimates of spawning escapements to streams in the Fraser River watershed are still in progress. Preliminary estimates of the 2016 spawning escapements are shown in Table 8-5

In-season management decisions are based on targets for spawning escapement, which are represented in-season by potential spawning escapement targets (i.e., spawning escapement targets plus MAs). In-season estimates of potential escapement (i.e., Mission escapement minus all catch above Mission) were 10-20\% under the target for all management groups: Early Stuart sockeye ( $11 \%$ under), Early Summer-run ( $11 \%$ under), Summer-run ( $20 \%$ under) and Late-run sockeye ( $15 \%$ under). Table 8-6

There was no TAC (Total Allowable Catch) of Fraser sockeye, based on the calculation method set out in Annex IV, Chapter 4 of the Pacific Salmon Treaty and the February 17, 2011 Commission Guidance. The Washington catch of 1,700 Fraser sockeye was 1,700 fish more than their $16.5 \%$ share. The total Canadian catch of 136,800 Fraser sockeye (excluding the ESSR catch of 0 Weaver sockeye and including a catch of 800 fish in the Albion test fishery) was 800 fish more than the Canadian $83.5 \%$ of international TAC + AFE. In these calculations, the TAC is fixed on the date that Panel control of the last U.S. Panel Area was relinquished (October 1 in 2016), while catches are preliminary post-season estimates. Table 8-7

## Tables \& Figures

With the exceptions of Tables 8-1 \& 8-3, all tables and figures are adapted from or courtesy of the Pacific Salmon Commission.

Table 8-1. Pre-season run size abundance forecast range and final in-season estimate of run size by management group for Fraser Sockeye.

|  | Probability that Return will be at/or Below Specified Run Size |  |  |  |  | Final in-season |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 10\% | 25\% | 50\% | 75\% | 90\% |  |
| Early Stuart | 13,000 | 22,000 | 36,000 | 59,000 | 89,000 | 18,000 |
| Early Summer | 120,000 | 217,000 | 447,000 | 1,003,000 | 2,703,000 | 240,000 |
| Summer | 640,000 | 992,000 | 1,677,000 | 2,962,000 | 5,023,000 | 520,000 |
| Late | 41,000 | 65,000 | 111,000 | 203,000 | 366,000 | 75,000 |
| Total | 814,000 | 1,296,000 | 2,271,000 | 4,227,000 | 8,181,000 | 853,000 |

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Table 8- 2. Pre-season (top) and Preliminary post-season (bottom) values for TAC and other management parameters.

| Date | Management Group | Total Abundance | TAC* |  |  |  |  |  |  | Available Harvest ** | Catch <br> to date | Mission Passage to date | 50\% <br> Migration <br> Date |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  | Spawning <br> Escapement <br> Target*** | pMA | Management Adjust. | Test Fishing **** | Aboriginal Fishery Exemption | Total Deductions | Total Allowable Catch |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  | Area 20 |
| O000000 | Early Stuart | 36,000 | 36,000 | NA | NA | 100 | 3,500 | 36,000 | 0 | 0 |  |  | 3-Jul |
|  | Early Summer | 447,000 | 178,800 | 0.59 | 105,500 | 3,800 | 79,400 | 367,500 | 79,500 | 162,700 |  |  | 21-Jul |
|  | Summer | 1,677,000 | 722,000 | 0.11 | 79,400 | 11,200 | 296,100 | 1,108,700 | 568,300 | 875,600 |  |  | 6-Aug |
|  | Late | 111,000 | 111,000 | NA | NA | 400 | 21,000 | 111,000 | 0 | 0 |  |  | 14-Aug |
|  | Sockeye | 2,271,000 | 1,047,800 |  | 184,900 | 15,500 | 400,000 | 1,623,200 | 647,800 | 1,038,300 | 0 | 0 |  |
| $\begin{array}{ll} -1 & 0 \\ \vdots & \# \\ 0 \\ 0 & 0 \\ \vdots & U \\ 0 & 1 \end{array}$ | Early Stuart | 18,000 | 18,000 |  |  | 175 | 1,300 | 18,000 | 0 | 0 | 1,600 | 17,900 | 3-Jul |
|  | Early Summer | 240,000 | 156,000 | 0.59 | 92,000 | 3,000 | 22,700 | 240,000 | 0 | 0 | 26,300 | 228,700 | 20-Jul |
|  | Summer | 520,000 | 520,000 | 0.11 | 57,200 | 6,000 | 101,000 | 520,000 | 0 | 0 | 113,200 | 476,000 | 30-Jul |
|  | Late | 75,000 | 75,000 |  |  | 1,000 | 5,400 | 75,000 | 0 | 0 | 6,200 | 64,700 | 8-Aug |
|  | Sockeye | 853,000 | 769,000 |  | 149,200 | 10,175 | 130,400 | 853,000 | 0 | 0 | 147,300 | 787,300 |  |

* The TAC is determined by the run sizes and TAC deductions (spawning escapement targets, management adjustments, projected test
fishing catches and AF Exemptions) that were in effect when Panel control of the last U.S. fishery area was relinquished.
** Available Harvest = Total abundance minus spawning escapement target and Management Adjustment.
*** Spawning Escapment Target not in place until July 12 Panel meeting
**** Test Fishing deductions not in place until July 15 Panel meeting

Table 8- 3. 2016 Fraser sockeye Escapement Plan and application of plan to each management group across a range of forecast abundances.

|  | Harvest Rule Parameters <br> Low Abundance |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- |
| Lower Fishery |  |  |  |  |
| Reference Point |  |  |  |  | | Upper Fishery |
| :--- | Reference Point | Pre-season pMA |
| :--- |

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| Management |  | ason Forec |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Unit |  | p10 | p25 | p50 | p75 | p90 |
| Early Stuart | forecast | 13,000 | 22,000 | 36,000 | 59,000 | 89,000 |
|  | TAM Rule (\%) | 0\% | 0\% | 0\% | 0\% | 0\% |
|  | Escapement Target | 13,000 | 22,000 | 36,000 | 59,000 | 89,000 |
|  | MA | 9,000 | 15,200 | 24,800 | 40,700 | 61,400 |
|  | Esc. Target + MA | 22,000 | 37,200 | 60,800 | 99,700 | 150,400 |
|  | LAER | 10\% | 10\% | 10\% | 10\% | 10\% |
|  | $E R$ at Return | 0\% | 0\% | 0\% | 0\% | 0\% |
|  | Allowable ER | 10\% | 10\% | 10\% | 10\% | 10\% |
|  | available harvest | 1,300 | 2,200 | 3,600 | 5,900 | 8,900 |
|  | 2016 Performance |  |  |  |  |  |
|  | Projected S (after MA) | 7,000 | 12,000 | 19,000 | 31,000 | 47,000 |
|  | BY Spawners | 26,233 | 26,233 | 26,233 | 26,233 | 26,233 |
|  | Proj. S as \% BY S | 27\% | 46\% | 72\% | 118\% | 179\% |
|  | cycle avg S | 35,861 | 35,861 | 35,861 | 35,861 | 35,861 |
|  | Proj. S as \% cycle S | 20\% | 33\% | 53\% | 86\% | 131\% |
| Management |  | ason Forec | turn |  |  |  |
| Unit |  | p10 | p25 | p50 | p75 | p90 |
| Early Summer | lower ref. pt. (w misc) | 156,000 | 156,000 | 156,000 | 156,000 | 156,000 |
| (w/o RNT) | upper ref. pt. (w misc) | 390,000 | 390,000 | 390,000 | 390,000 | 390,000 |
|  | forecast (incl. misc) | 120,000 | 217,000 | 447,000 | 1,003,000 | 2,703,000 |
|  | TAM Rule (\%) | 0\% | 28\% | 60\% | 60\% | 60\% |
|  | Escapement Target | 120,000 | 156,000 | 178,800 | 401,200 | 1,081,200 |
|  | MA | 70,800 | 92,000 | 105,500 | 236,700 | 637,900 |
|  | Esc. Target + MA | 190,800 | 248,000 | 284,300 | 637,900 | 1,719,100 |
|  | LAER | 10\% | 10\% | 10\% | 10\% | 10\% |
|  | $E R$ at Return | 0\% | 0\% | 36\% | 36\% | 36\% |
|  | Allowable ER | 10\% | 10\% | 36\% | 36\% | 36\% |
|  | available harvest | 12,000 | 21,700 | 162,700 | 365,100 | 983,900 |
|  | 2016 Performance |  |  |  |  |  |
|  | Projected S (after MA) | 68,000 | 123,000 | 179,000 | 401,000 | 1,081,000 |
|  | BY Spawners | 276,018 | 276,018 | 276,018 | 276,018 | 276,018 |
|  | Proj. S as \% BY S | 25\% | 45\% | 65\% | 145\% | 392\% |
|  | cycle avg S | 132,183 | 132,183 | 132,183 | 132,183 | 132,183 |
|  | Proj. S as \% cycle S | 51\% | 93\% | 135\% | 303\% | 818\% |

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Table 8-4. Preliminary post-season catch and exploitation rate estimates by management group by US, Canada, and Fraser Panel test fisheries.

|  | Early Stuart | Early Summer | Summer | Late | Total |
| :---: | :---: | :---: | :---: | :---: | :---: |
| CANADIAN CATCH | 1,400 | 23,300 | 106,600 | 5,500 | 136,800 |
| Commercial Catch | 0 | 0 | 0 | 0 | 0 |
| Panel Area | 0 | 0 | 0 | 0 | 0 |
| Non-Panel Areas | 0 | 0 | 0 | 0 | 0 |
| First Nations Catch | 1,400 | 23,100 | 106,000 | 5,400 | 136,000 |
| Marine FSC | 0 | 4,300 | 24,900 | 2,900 | 32,100 |
| Fraser River FSC | 1,400 | 18,800 | 81,100 | 2,600 | 103,900 |
| Economic Opportunity | 0 | 0 | 0 | 0 | 0 |
| Non-commercial Catch | 10 | 100 | 600 | 90 | 800 |
| Marine Recreational | 0 | 0 | 0 | 0 | 0 |
| Fraser Recreational | 0 | 0 | 0 | 0 | 0 |
| Charter (Albion) | 10 | 100 | 600 | 90 | 800 |
| ESSR | 0 | 0 | 0 | 0 | 0 |
| UNITED STATES CATCH | 10 | 600 | 900 | 90 | 1,700 |
| Washington Total | 10 | 600 | 900 | 90 | 1,700 |
| Commercial catch | 10 | 300 | 500 | 50 | 800 |
| Treaty Indian | 10 | 300 | 500 | 50 | 800 |
| All Citizen | 0 | 0 | 0 | 0 | 0 |
| Non-commercial Catch | 0 | 300 | 500 | 40 | 800 |
| Ceremonial | 0 | 300 | 500 | 40 | 800 |
| Recreational | 0 | 0 | 0 | 0 | 0 |
| Alaska | not yet available |  |  |  |  |
| TEST FISHING CATCH | 200 | 2,500 | 5,700 | 600 | 8,800 |
| PSC (Panel Areas) | 200 | 1,800 | 4,000 | 400 | 6,400 |
| Canada | 200 | 1,800 | 4,000 | 400 | 6,400 |
| United States | 0 | 0 | 0 | 0 | 0 |
| Canada (non-Panel Areas) | 10 | 600 | 1,600 | 200 | 2,400 |
| TOTAL RUN accounted to date (22-Sep) | 18,000 | 240,000 | 527,000 | 70,000 | 855,000 |
| Total Catch in All Fisheries | 1,600 | 26,400 | 113,200 | 6,200 | 147,400 |
| preliminary ER | 9\% | 11\% | 21\% | 9\% | 17\% |

Table 8-5. Preliminary Spawning escapement by management group.

|  | Preliminary | Spawning Escapement |  |  |  |
| :---: | :---: | ---: | :---: | :---: | :---: |
| Management | post-season | Post-season | Adult | Difference |  |
| Group | run size | Target | Estimate | Fish | $\%$ |
| Sockeye salmon | 855,000 | 771,000 | 165,400 | $-128,400$ | $-44 \%$ |
| Early Stuart | 18,000 | 18,000 | 8,600 | $-9,400$ | $-52 \%$ |
| Early Summer | 240,000 | 156,000 | 156,400 | 400 | $0 \%$ |
| Summer | 527,000 | 527,000 | assessments underway |  |  |
| Late | 70,000 | 70,000 | assessments underway |  |  |

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Table 8-6. Comparison of in-season targets and in-season estimates of potential spawning escapement (PSE) for adult Fraser River sockeye salmon.

| Management Group | Final In-season Abundance Estimate | Potential Spawning Escapement (PSE) |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | Spawning Escapement Target | Management <br> Adjustment * | $\begin{gathered} \hline \text { In-season } \\ \text { PSE ** } \\ \text { Target } \\ \hline \end{gathered}$ | PSE *** <br> Estimate | Difference |  |
|  |  |  |  |  |  | Fish | \% |
| Adult sockeye | 853,000 | 769,000 | 149,200 | 853,000 | 708,000 | -145,000 | -17\% |
| Early Stuart | 18,000 | 18,000 | NA | 18,000 | 16,000 | -2,000 | -11\% |
| Early Summer | 240,000 | 156,000 | 92,000 | 240,000 | 214,000 | -26,000 | -11\% |
| Summer | 520,000 | 520,000 | 57,200 | 520,000 | 414,000 | -106,000 | -20\% |
| Late | 75,000 | 75,000 | NA | 75,000 | 64,000 | -11,000 | -15\% |

* Adjustment of spawning escapement targets to achieve spawning escapement goals.
** Spawning escapement target + MA. If the spawning escapement target + MA exceeds the total abundance, then the target equals the total abundance.
*** Mission passage minus all catch above Mission.

Table 8-7. Total Allowable Catch table


Figure 8- 1. Pre-season projections and post-season reconstructions of daily Fraser River sockeye salmon abundance by management group.


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### 8.3 First Nations Food Social and Ceremonial and Treaty Fisheries

There were directed harvest opportunities for Fraser sockeye in First Nations FSC fisheries in both the marine and freshwater areas. For preliminary catch estimates, see Table 8-4.

### 8.4 Recreational Fisheries

There were no recreational fisheries directed on Fraser River sockeye.

### 8.5 COMMERCIAL

### 8.5.1.1 Commercial Harvest

No directed commercial fisheries directed on Fraser River sockeye in Canada.

### 8.5.1.2 First Nation Commercial Harvest

There were no First Nation commercial harvest opportunities directed on Fraser River sockeye.

### 8.6 Excess Salmon to Spawning Requirements (ESSR) Fisheries

There were no ESSR opportunities directed on Fraser River sockeye.

## 9 FRASER RIVER PINK

Pink salmon return to the Fraser River in significant numbers on odd years only; negligible numbers of pink salmon returned to the Fraser River in 2016.

## 10 SOUTHERN B.C. COHO

### 10.1 ObJEctives and Overview

Coho stocks in Southern B.C. are managed domestically and through international Abundance Based Management provisions which are outlined in the Pacific Salmon Treaty. Harvest levels are outlined in the Treaty's Southern Coho Management Plan, which provides maximum exploitation rates dependant on abundance, and it is Canada's responsibility to ensure that its domestic stocks are not harvested beyond the maximum exploitation rate as outlined in the Treaty.

In Southern B.C., coho management measures in commercial and recreational fisheries are implemented based on their impacts to specific stocks. Southern B.C. coho management is primarily based on managing Interior Fraser River, Lower Fraser, Strait of Georgia, Johnstone Strait and WCVI coho stocks or MUs.

Beginning in 1997, DFO implemented a number of fishery management measures to reduce the harvest impacts on Interior Fraser River coho, with more severe measures being implemented starting in 1998. From that time to 2013, Canadian fisheries impacting these stocks were curtailed to limit the exploitation rate to 2 to 3 percent, with an additional 10 percent permitted in U.S. fisheries (as per the Pacific Salmon Treaty management regime). In 2015, an exploitation rate of up to $10 \%$ was permitted in Canadian fisheries. Despite some improvements to forecast returns and spawner abundances in some recent years, there is no evidence that IFR coho has departed from the 'low’ productivity regime that has persisted since the 1994 return year. Current productivity is still well below that in the relatively high productivity period of 19781993. Spawner abundances in 2015 were well below recent years’ levels and pre-season expectations based on projected fisheries impact and the 2015 forecast range highlighting continued uncertainties about stock productivity and/or fisheries impacts.

In 2016 an exploitation rate of 3-5\% was permitted in Canadian fisheries with an additional 10 percent permitted in U.S. fisheries (as per the Pacific Salmon Treaty management regime). Coho management measures varied in Southern B.C. in 2016, depending on the area of harvest and impact on specific coho stocks.

In 2016, Canada did not articulate a specific ER objective for IFR coho domestically given that the models for assessing fisheries impacts were under review and could not measure compliance with an ER objective. Instead, the objective articulated domestically was "to manage Canadian fisheries in a highly precautionary manner with fisheries management measures similar to those in place prior to 2014".

While the status of Interior Fraser coho stocks has generally remained poor in spite of the low total exploitation rate limit, there are indications in recent years that their condition might be improving. In addition there have been improved returns of coho in Northern B.C., the west Coast of Vancouver Island and inside Strait of Georgia stocks in recent years.

The aggregate wild coho escapement (generation 2012-2014) to the Interior Fraser River watershed averaged 39,500 adults (geometric mean). This is an increase over previous generational averages since conservation measures were implemented in 1997-1998, Based on

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analysis of the returns and exploitation rate (ER) analysis a decision was made to increase the ER from 3 percent to a maximum of 10 percent for Canadian fisheries in Southern BC. For Canadian fisheries, management measures were relaxed for FSC fisheries in the BC Interior and the lower Fraser including mainstem areas. In the marine recreational fishery, retention of additional enhanced coho and in some areas and times retention of one unmarked coho was allowed. Commercial fisheries, including First Nation economic, demonstration and commercial fisheries, were not permitted to retain coho in most southern BC waters. Additional fishing effort for more abundant stocks and species was permitted resulting in increased impacts on coho as release mortalities in these fisheries.

No specific management measures were in place in 2016 to protect Strait of Georgia coho stocks beyond measures put in place for Interior Fraser River coho.

Management measures in place for WCVI coho provided opportunities for recreational and commercial fisheries harvest, in WCVI areas where Interior Fraser coho were not considered to be impacted. These were largely terminal opportunities in portions of Area 23-27, where stock composition information showed that Interior Fraser River coho were not found.

In WCVI areas/times where Interior Fraser River coho are known to be prevalent, non-retention of unmarked coho remained in effect. Commercial troll fishery plans permitted marked coho retention on the WCVI once Interior Fraser River coho were considered to have moved through the area.

Preliminary coho catch and release information from all fisheries can be found in Appendix 6.

### 10.2 STOCK STATUS

### 10.2.1 Upper Fraser

Field programs to estimate escapements are still underway, and only very preliminary results are available for some systems. Early returns to the Interior Fraser River indicate that escapement may be similar to 2013 brood escapements. Very preliminary data indicate returns to the entire Interior Fraser River may be above 50,000; however, preliminary estimates are not yet available for many systems, and near final estimates will not be available until early February 2017, as most field studies are not yet completed.

### 10.2.2 Lower Fraser River

Escapement studies are currently underway, and many populations have not reached peak spawning at the time of writing. Preliminary escapement estimates for the surveyed systems should be available by late February 2017.

A hatchery coho indicator stock is provided by Inch Creek hatchery. Adult escapement is assessed annually and marine survival and exploitation rates are calculated, these estimates are not yet available. Adult coho visual surveys are conducted for a number of systems within the lower Fraser River sub-area as part of multi-species assessments; however estimates are not yet available as the field programs will not be complete until late January or early February 2017.

### 10.2.3 Strait of Georgia

Coho salmon have been in a low productivity regime since the early 1990s. Marine survivals have been less than replacement levels for several years, but have been slowly increasing since the late 2000s. 2016 estimates are not yet complete so the information presented below must be considered preliminary and subject to change.

## Hatchery stocks

The preliminary 2016 coho escapement estimates of monitored hatcheries show mixed results over the previous year. Escapements to northern Strait of Georgia stocks (Puntledge, Qualicum, and Lang) are higher than the previous year and similar to than the five year average.
Escapements to southern Strait of Georgia stocks are not monitored outside of Goldstream River, where results will not be available until January. Early results indicate that escapements are below the five year average with the exception of Shawnigan Creek.

## Wild stocks

In the past, both Black Creek and Myrtle Creek have served as indicators of Strait of Georgia Coho. Myrtle Creek was discontinued as an indicator in 2014. Only a few other wild populations are monitored with any consistency. The Colquitz River, near Victoria, is one of those systems. It has been monitored by local community groups for over 10 years. This year, the abundance of coho returning to the Colquitz River was twice the four year average.

## Black Creek

The 2016 Black Creek adult project is on-going; escapement to date has been below average. The majority of adult Coho moved past the fence during rain events of Oct $5^{\text {th }}$-Oct $14^{\text {th }}$; the fence was breached shortly thereafter during the high water that followed. As the carcass recovery portion of the program is on-going, the escapement estimate for this population is not yet available, but will likely be similar to last year's return of approximately 3,500 adults. The smolt production contributing to the 2016 return (from the 2013 parental brood of 10,378 adults) was the lowest juvenile migration recorded since 1996, possibly due to the drought conditions of 2014. The 2016 adult return may have also been impacted by poor marine conditions existing during the 2015-2016 marine residence of Strait of Georgia coho salmon.

### 10.2.4 West Coast Vancouver Island

In most recent years, spawning abundances for wild WCVI coho populations are near historic levels. However, the overall production of WCVI coho is lower than historic levels - i.e. less fish are caught in fisheries because low fishery impacts are maintaining spawning levels. Hatchery production has also been reduced. Data are not finalized for 2016; however preliminary results suggest about average returns relative to recent years.

### 10.2.5 Johnstone Strait and Mainland Inlets

The Keogh River plays an important role as the wild coho indicator stock for the upper Johnstone Strait area. Smolt production in 2015 was around 112,000, the largest outmigration

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since the inception of the program in 1977. Preliminary indications from the resulting adult escapement in 2016 are that marine survival was again low relative to the steady improvements we had seen prior to 2015. Adult returns in 2016 were an improvement over last year’s low return with a preliminary estimate of 1,700 coho. Smolt production from the Keogh in 2016 of approximately 92,000 is again well above the long term average of 74,000. This strong smolt production will hopefully buffer the poor marine condition anticipated to persist through 2016 and 2017. Expectation in 2017 will be for below average returns.

The marine survival indicator for Area 13 is the Quinsam River Hatchery. Consistent with a continuation of poor marine conditions, the Quinsam coho return was below average, at approximately 8,000 similar to that of 2015. The jack component was also noticeably lower than in past years.

Preliminary extensive escapement reports for coho in many systems are indicating moderate to low abundances, a decline from last year and slightly below average. The building trend of the past few years looks to have reverted back to average to below average escapements and indications are that poor coho returns will likely continue in 2017.

### 10.3 FIRST NATIONS

## WCVI FSC and Treaty Fisheries

There were FSC gill net and hook and line openings during the summer and fall season. The Somass First Nations harvest was 1,867 pieces. The Maa-nulth domestic harvest was 578 pieces. The remainder of WCVI First Nation's reported catch was 4,254 pcs coho. The combined harvest was 6,699 coho.

## Lower Fraser

There were no coho-directed fisheries in the Lower Fraser in 2016. Lower Fraser FSC fisheries targeting other species of salmon encountered 2,611 coho, of which 2,067 were kept and 544 were released. Both hatchery marked and wild coho were authorized to be retained in FSC fisheries.

## B.C. Interior

There were no EO, Demonstration or ESSR fisheries in the B.C. Interior (Fraser River above Sawmill Creek) targeting coho in 2016. FSC fisheries in the area target sockeye, chinook or pink salmon. In 2016, First Nations were requested to release unharmed any coho caught as bycatch. Directed opportunities were permitted, subject to abundance, in Dunn Creek and the Bonaparte River, tributaries to the Thompson River. Preliminary catch reports indicate 53 coho were retained in directed FSC fisheries in the Thompson River system.

## Strait of Georgia FSC Fisheries

Data are still being compiled on various First Nations catches in the Strait of Georgia with total preliminary catch estimate at 2,048 coho caught in FSC fisheries.

## Johnstone Strait

Data are still being compiled on various First Nations catches in the Johnstone Strait with the total preliminary catch estimated at 701 coho caught in FSC fisheries.

### 10.4 Recreational Fisheries

### 10.4.1 Tidal Recreational Fisheries

Tidal sport fisheries can be categorized as occurring in: mixed stock areas, where multiple stocks are found concurrently in the same fishing area, and in terminal areas where local single stocks dominate the catch. Areas where mixed stocks occur typically have more restrictive management measures in place that are designed to protect Interior Fraser coho stocks. In terminal areas, opportunities are provided based on abundance forecasts. From 1998-2013, all Canadian recreational, commercial and First Nations fisheries were managed to limit the exploitation rate on Interior Fraser coho stocks to 3\%. In 2014 DFO approved a temporary increase in the exploitation rate on Interior Fraser coho up to 16\%, based on improved abundance forecasts. In 2015 DFO reduced the Canadian exploitation rate to a maximum of $10 \%$, again based on forecasted abundance. In 2016 DFO returned to a 3\% exploitation rate on Interior Fraser coho. The table below outlines the areas in Southern B.C. and the general coho regulations pertaining to them.

Table 10-1: Southern B.C. coho fishery regulations in 2016.

| Mixed stock fishing area | Daily Limit (marked or unmarked) | Size <br> Limit | Coho Season |
| :---: | :---: | :---: | :---: |
| Johnstone Strait | 2, 1 may be unmarked | 30 cm . | June 1 - Jul 31 |
| Johnstone Strait | 2 marked | 30 cm . | Aug 1 - Dec 31 |
| Northern Georgia Strait | 2 marked | 30 cm . | June 1 - Dec 31 |
| Southern Georgia Strait | 2 marked | 30 cm . | June 1 - Dec 31 |
| Southern Georgia Strait (19) | 2, 1 may be unmarked | 30 cm . | Oct 1 - Dec 31 |
| Juan de Fuca Strait | 2 marked | 30 cm . | Jun 1 - Dec 31 |
| Juan de Fuca Strait (20-5 to 20-7) | 4, 1 may be unmarked | 30 cm . | Oct 1- Dec 31 |
| WCVI - Inshore | 2 | 30 cm . | June 1 - Dec 31 |
| WCVI - Offshore | 2 marked | 30 cm . | June 1- Dec 31 |

* For specific management measures in specific areas refer to the information provided in the Fishery Notices.

The table below outlines coho catch and release information for sport coho fisheries in Southern B.C. The WCVI coho fisheries use the surfline as a boundary between distinguishing coho catch in the mixed-stock fishery (offshore) and catch in the terminal area (inside the surfline).

Table 10-2: Preliminary recreational coho estimates for Southern B.C. in 2016.

| Area | Kept | Released |
| :--- | :--- | :--- |
| WCVI - Inshore (20W - 27) | 16,132 | 8,030 |
| WCVI - Offshore (21 - 127) | 5,692 | 9,000 |
| Strait of Georgia (13-19 May - Sep*) | 8,142 | 29,525 |
| Fraser River** | 8 | 0 |
| Juan de Fuca (19-20 Feb - Oct) | 7,581 | 16,194 |
| Johnstone Strait (11-12 Jun-Aug) | 4,449 | 4,461 |
| TOTALS | $\mathbf{4 1 , 9 9 6}$ | $\mathbf{6 7 , 2 1 0}$ |

** Lower Fraser recreational fisheries estimates not yet available at the time of this report.
Note: Fraser R. data represents in-season preliminary info to Sep. 15, 2016 and is subject to further updates from Fraser R. Stock Assessment.

### 10.4.2 Non-Tidal Sport

## Region 1 Vancouver Island Tributaries

Fresh water restrictions were in effect in most tributaries on Vancouver Island due to drought like conditions in 2016. Rivers on the southern half of Vancouver Island (Regions 1-1 to 1-6) were closed to angling on July 1st 1. Region 1 rivers were re-opened on September 16 due to improved water flows and near-normal temperatures.

## Northern Vancouver Island

Typical non-tidal openings for coho are available on:

- Cayeghle River (including the Colonial River) from April 1 to March 31 for one per day;
- Campbell/Quinsam River from October 1 to December 31 for four per day, two of which could be marked over 35 cm ;
- Cluxewe River from April 1 to March 31 for two per day, hatchery marked only;
- Kokisilah River from April 1 to March 31 for one per day, maximum size limit of 35 cm ;
- Nahwitti River from April 1 to March 31 for one per day; and
- Quatse River from June 15 to March 31 for two per day, hatchery marked only.


## Strait of Georgia

Typical non-tidal openings for coho are available on:

- Qualicum River from October 16 to December 31 for four per day, two of which could be over 35 cm ;
- Chemainus River from October 15 to March 31 for one per day, maximum size limit of 35 cm ;
- Nanaimo River from November 1 to March 31 for one per day, maximum size limit of 35 cm; and


## West Coast Vancouver Island

- Somass/Stamp River from August 25 to December 31 the daily limit was two, marked or unmarked. The Somass/Stamp Rivers were not monitored by creel survey during 2016. A single barbless hook restriction is in effect all year and there is a bait restriction in the Upper Somass and Stamp from May 1 to October 31.
- Nitinat River from October 15 to December 31 the daily limit for coho was two, marked or unmarked. The 2 week closure between October 1 and October 14 provides protection to chinook salmon during the peak spawning period. The Nitinat River was not monitored by creel survey during 2016. The area above Parker Creek is closed to fishing. A single barbless hook restriction is in effect all year and there is also a bait restriction in effect.
- Conuma River opened August 25th with a daily limit of two coho, marked or unmarked but was reduced to one per day from September 26 to December 31 based on observations of lower than expected abundance in-river. The Conuma River was not monitored by creel survey during 2016.
- Washlawlis River and Waukwass River and other West Coast Rivers are open year-round with a daily limit of one coho, marked or unmarked. Barbless hooks are required. No creel survey information is collected. Other rivers receiving some directed effort for coho stocks are the Wakeman, Artlish, Zeballos, Tahsis, Burman, Ash, Taylor, Pacheena, Toquart and Leiner. The quota for all west coast streams unless identified above is zero.


## Fraser River and Tributaries

During 2016, the retention of two hatchery marked coho per day was permitted once the majority of the Interior Fraser wild coho population was through the area. The dates by area were as follows:

- From the CPR Bridge at Mission, B.C. upstream to the Highway \#1 Bridge at Hope October 11 to December 31.
- From the Highway \#1 bridge at Hope to Sawmill Creek - October 16 to December 31.
- There are no directed coho openings in the Fraser River or tributaries upstream of Sawmill Creek.

The following tributaries to the Fraser River were open during the dates stated below:

- Alouette River and De Boville Slough from October 1 to December 31 for one per day.

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- Coquitlam River from September 1 to December 31 for one per day.
- Kanaka Creek from November 1 to November 30 for one per day.
- Chilliwack River/Vedder for four per day from July 1 to December 31.
- Chehalis River from January 1 to December 31 for four per day.
- Harrison River for four per day from September 1 to December 31.
- Nicomen Slough, Norrish Creek and the Stave River for four per day from January 1 to December 31 with only two over 35 cm .

During 2016, there were limited non-tidal openings for hatchery marked coho on the following systems which enter Boundary Bay:

- Little Campbell River, Nicomekl River and the Serpentine River one per day from September 1 to December 31.


### 10.5 Commercial Fisheries

### 10.5.1 Commercial (A-H Fisheries includes ATP)

In 2016, Southern B.C. commercial fisheries were regulated so that impacts on coho, in particular Interior Fraser coho stocks, were minimized. Retention of coho by-catch in most of these fisheries was not permitted, including the Fraser River, with the exception of a few terminal seine and gill net fisheries targeting chinook and sockeye where Interior Fraser River coho were not prevalent.

Area G troll AABM chinook fisheries were permitted to retain marked coho by-catch from September 15 until December 31, 2016.

For the 2015/2016 (October 1, 2015 to September 30, 2016) AABM chinook fishing periods, the estimated total coho retained was 3601 and releases during this period were estimated at 3,244 coho salmon.

## WCVI Terminal Area Coho

In 2016, in Area 23 there were targeted coho Area D gillnet fisheries. There were also Area D gillnet t fisheries in Alberni Inlet targeting sockeye, and chinook terminal returns, that permitted coho by-catch retention. Retention of both hatchery and wild coho were permitted.

In 23-1 there were targeted Coho fisheries with chinook by catch authorized in September in upper Alberni inlet in Subarea 23-1. These fisheries were designed to target coho and chinook salmon using small mesh nets. The fisheries were restricted to 6 and $1 / 4$ inch mesh. The openings were 12 hours in duration and occurred Sept $15,16,19,20$, and 21 . The fisheries were not successful. The total coho catch was 742 pieces with a chinook bycatch of 781 pieces The sockeye and chinook fisheries in Area 23 bycatch of coho salmon was 66 pieces. Coho retention in other terminal WCVI commercial fisheries was not permitted in 2016.The total WCVI coho by-catch in commercial gillnet fisheries was 808 pieces retained.

### 10.6 Excess Salmon Spawning to Requirements (ESSR)

## WCVI ESSR Fisheries

The Tseshaht and Hupacasath First Nations were issued a joint ESSR Licence for coho at the Robertson Creek Hatchery facility. The total catch was 7,048 coho. The Ditidaht First Nation was issued an ESSR Licence for Nitinat Lake and the Nitinat Hatchery, but no harvest occurred. The total catch WCVI for the ESSR fisheries was 7,048 coho.

## Lower Fraser ESSR Fisheries

There were several ESSR fisheries in the Lower Fraser Area for First Nations. These were conducted at Capilano, Chilliwack, and Inch Creek Hatcheries for a total coho catch of 23,668 (total includes 1,230 jacks). Chehalis Hatchery reported no coho harvest for ESSR in 2016. Tenderfoot and Weaver Creek Hatcheries did not conduct ESSR fisheries in 2016.

## Strait of Georgia ESSR Fisheries

ESSR harvest at the Big Qualicum hatchery included catch of 7,688 coho (total includes 1852 jacks). ESSR harvest at Chapman Creek hatchery included 16 coho.

## Johnstone Strait ESSR Fisheries

Currently there are no ESSR opportunities on coho in Johnstone Strait.

## 11 JOHNSTONE STRAIT CHUM

### 11.1 OBJECTIVES AND OVERVIEW

The Johnstone Strait chum fisheries primarily target chum that spawn in Johnstone Strait, Strait of Georgia, and Fraser River areas. In order to improve the management of Johnstone Strait chum fisheries and to ensure sufficient escapements, a 20\% fixed exploitation rate strategy was implemented in 2002 in Johnstone Strait. Of the $20 \%$ exploitation rate, $15 \%$ is allocated to the commercial sector and the remaining $5 \%$ is set aside for test fisheries, First Nations FSC, sport harvesters, and to provide a buffer to commercial exploitation. Since the implementation of this management strategy, annual fisheries have been planned well in advance of the chum return.

The pre-season commercial fishing plan was developed based on expectation of effort, exploitation levels by gear group, and historical run timing (peak estimated as October 9). The fishing plan was developed to achieve the commercial allocation sharing guidelines of $77 \%$ for seine, $17 \%$ for gill net and $6 \%$ for troll. Adjustments to the fishing plan are made in-season, if warranted.

As outlined in Chapter 6 of the Pacific Salmon Treaty, commercial chum fisheries in Johnstone Strait are suspended when an abundance estimate of less than 1 million chum salmon migrating through Johnstone Strait is identified. This did not occur in 2016 and all fisheries proceeded as scheduled.

In 2016, the Area B (seine) and Area D (gill net) were competitive derby fisheries, and the Area $H$ (troll) fleet was managed using an effort-based individual transferable effort (ITE) demonstration fishery.

Chum catch and release information from all fisheries can be found in Appendix 7.

### 11.2 STOCK STATUS

## Mixed Stocks

The main components of the Inside South Coast (ISC) chum return were expected to be both Fraser and non-Fraser stocks. These stocks are typically dominated by four year old fish which were from an average 2012 brood return that out-migrated to the ocean in 2013. It was quite apparent that other salmon species that also out-migrated in 2013 encountered improved survival conditions (i.e. pink and coho returns in 2014). The pre-season expectation for ISC chum suggested near target returns to the area but was highly uncertain.
The Johnstone Strait test fishery, which ran from September $12^{\text {th }}$ through October $28^{\text {th }}$, provided timing and abundance information for the 2016 return, which is important in assessing the performance of the $20 \%$ fixed exploitation rate strategy. It also provided an index of abundance, used to determine the likelihood of the number of returning chum being over the 1.0 million critical level (requirement for commercial openings). Chum catch per unit effort in the test fishery was significantly higher than what was encountered in the low 2010 return and it was determined that the ISC index of abundance was likely above the 1.0 million critical level (Figure 11-1). The timing of the run also appeared to be later than average based on the peak

CPUE observed in the test fishery. As expected, the age composition derived from the test fishery and commercial samples was dominated by 4 year olds throughout the season.

Preliminary information on escapements and catches to date suggest returns were very strong and well above average to most Inner South Coast chum populations. In-season information is still being collected and analyzed regarding total stock size.


Figure 11-1: 2016 Johnstone Strait Chum Test Fishery Catch per Unit Effort (CPUE) comparison to 2010 (lowest chum return in recent years)

## Terminal returns

Preliminary information on the status of summer run chum in the Johnstone Strait area indicated varied returns. Assessments of terminal fall chum, such as the Nimpkish, have been hampered with high river flows during the fall and little information is available at this time on the status of those stocks.

### 11.3 FIRST NATIONS FISHERIES

First Nations fisheries for chum were not restricted. The preliminary estimated catch by First Nations in the Johnstone Strait area is 20,494 chum salmon.

### 11.4 Recreational Fisheries

### 11.4.1 Tidal Recreational Fisheries

The marine recreational daily limits for chum are four with a possession limit of eight salmon. Chum opportunities are typically opened at full limits in the Johnstone Strait area. Peak participation in the recreational chum fishery typically occurs over the Thanksgiving weekend in mid-October, and activity is usually driven by abundance. There was no Creel survey during the month of October in Areas 11 to 13, but recreational catches were reported as being excellent given the strong chum returns through Johnstone Strait. The majority of the sport chum salmon fishing effort occurs in Area 13 which is included in the Strait of Georgia catch estimate.

Incidentally caught coho salmon can be caught in this fishery. All wild coho must be released, but retention is permitted for 2 hatchery marked coho per day.

### 11.4.2 Non-Tidal Recreational Fisheries

There are no chum retention fisheries in non-tidal waters in the Johnstone Strait area.

### 11.5 Commercial Fisheries

### 11.5.1 Commercial (A-H includes ATP)

The commercial chum fisheries in Johnstone Strait were planned for September 28 to October 31, 2016. The total commercial chum catch from Johnstone Strait during chum directed fisheries is estimated at $1,333,478$ pieces. Area and gear restrictions, including the mandatory use of revival tanks, were in place for commercial chum fisheries. Catch monitoring included requirements for catch reporting and mandatory logbooks.

A description of each fishery is provided below.

## Area B Seine

In 2016, there were two commercial seine openings for chum salmon in portions of Areas 12 and 13. The first opening took place on October 3 for twelve hours. The second opening took place on October 17 for 10 hours and October 18 for 4 hours. The second opening was originally scheduled for ten hours but additional fishing time was granted during the second opening due to poor weather conditions that hampered fishing during the first opening.

The chum catches for the first and second openings were estimated at 179,063 pieces and 868,660 pieces respectively; for a total catch of $1,047,723$ chum. Additionally, there were estimated to be 1 sockeye, 176 coho, and 12 pink salmon kept during the first opening and 2 pink salmon kept during the second opening. The total releases from the fishery were estimated at 14 sockeye, 454 coho, 5 pink, 20 adult chinook, 3 jack chinook, and 9 steelhead.

## Area D Gill net

In 2016, there were three commercial gill net openings for chum salmon in portions of Areas 12 and 13. The first opening was for 41 hours from 16:00 hours on October 6 to 09:00 hours on October 8. The second opening was for 63 hours from 16:00 hours on October 10 to 09:00 hours on October 13. The third opening was for 41 hours from 16:00 hours on October 25 to 09:00 hours on October 27.

Pre-season, each Area D gill net opening was planned for 41 hours in duration but was subject to change based on in-season assessment information, weather constraints, and effort information. Additional fishing time was granted on the second opening due to poor weather conditions that hampered fishing on the first opening.
The estimated chum catches for the three Area D gill net fisheries were 76,260 pieces, 75,523 pieces and 68,962 pieces respectively; for a total estimated catch of 220,745 chum. Five pink salmon were estimated to be retained in all three openings.

Other species that were estimated to be released in all three openings combined were as follows: 377 coho, 11 pink, 28 chinook, and 22 steelhead.

## Area H Troll

In 2016, the Area H troll ITE demonstration fishery was divided into two fishing periods:
September 28 to October 11 (period 1) and October 13 to October 31 (period 2); with a one day closure between the two periods on October 12, and closures during the Area B seine fisheries on October 3 and 17 (except Subarea 13-3). Each licence was initially allocated three boat days during the first fishing period and two boat days during the second fishing period. Boat days could be transferred between vessels within each fishing period but not between fishing periods.

The catch for the first fishing period was 29,779 chum, and 35,231 chum for the second fishing period, for a total catch of 65,010 chum. Total effort for the Johnstone Strait fishery was 247 boat days; 137 in period 1 and 110 in period 2. No other species were reported as kept during the fishery, but there were an estimated 3 sockeye, 89 coho, 1 pink, 15 legal chinook, 27 sublegal chinook, and 35 chinook grilse released during the troll fishery.
Table 11-1: Johnstone Strait Commercial Catch and By Date and Gear Type

| Gear Type | Fishery Dates | Effort $^{\text {a }}$ | Catch |
| :--- | :--- | :--- | :--- |
| B - Seine | Oct 3 | 85 | 179,063 |
|  | Oct 17/18 | $83 / 75$ | 868,660 |
| D - Gill net | Oct 6-Oct 8 | 160 | 76,260 |
|  | Oct 10-Oct 13 | 171 | 75,523 |
|  | Oct 25-Oct 27 | 105 | 68,962 |
| H - Troll | Sep 28-Oct 11 | 137 | 29,779 |
|  | Oct 13-Oct 31 | 110 | 35,231 |

${ }^{\text {a }}$ Number of unique vessels for each seine and gill net opening, and boat days for troll by fishing period.

Table 11-2: Johnstone Strait Fisheries Catch and Allocation

| Gear Type | Total Catch | \% of catch | J.S. Allocation Plan |
| :--- | :--- | :--- | :--- |
| Area B | $1,047,723$ | $78.6 \%$ | $77 \%$ |
| Area D | 220,745 | $16.6 \%$ | $17 \%$ |
| Area H | 65,010 | $4.9 \%$ | $6 \%$ |
| Total Catch: | $\mathbf{1 , 3 3 3 , 4 7 8}$ |  |  |

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### 11.5.2 First Nations Commercial Harvest

There was no First Nations commercial harvest of Johnstone Strait chum in 2016.

### 11.6 ESSR

Currently there are no ESSR opportunities on chum in Johnstone Strait.

## 12 FRASER RIVER CHUM

### 12.1 ObJectives and Overview

Chum salmon return to the Fraser River from September through December, with the typical peak of migration through the lower river occurring from mid to late-October. Spawning locations are predominately located in the Fraser Valley downstream of Hope, B.C., with major spawning aggregations occurring within the Harrison River (including Weaver Creek and Chehalis River), the Stave River, and the Chilliwack River. No spawning locations have been identified upstream of Hells Gate.

The escapement objective for Fraser River chum is 800,000 . Since 2001, this objective has been achieved in all but two years. Escapements in 2009 and 2010 did not meet the escapement goal, with approximately 460,000 and 550,000 returning to spawn in those years, respectively.

Fraser River chum are typically harvested in Johnstone Strait, the Strait of Georgia, U.S. waters of Area 7 and 7A, and in the Fraser River.

Within the Fraser River, chum directed fisheries include: First Nations FSC fisheries; sport fisheries; and commercial fisheries. In recent years, significant conservation measures have been implemented in-river during the Fraser River chum migration period, in order to protect comigrating stocks of concern (including Interior Fraser coho and Interior Fraser steelhead). Depending on the fishery, these measures have included both time and area closures, as well as gear restrictions. These conservation measures have restricted Fraser River commercial chum fishing opportunities in recent years.

Catch data from all chum fisheries can be found in Appendix 7.

### 12.2 Stock Status

The number of adult chum returning to the Fraser River each fall is estimated in-season with a Bayesian model based on Albion test fishing catch.

The Fraser River chum test fishery at Albion operated every other day from September 1 until October 19, alternating days with the Albion chinook test fishery. From October 21 until November 15, the chum net fished every day, and then every other day from November 17 until November 23. In 2016, the total number of chum harvested during the Albion chum test fishery was 9,956 , and an additional 2,349 pieces were harvested during the the Albion chinook test fishery.

For fishery planning purposes, DFO provided a provisional in-season update on October 17 of 1.55 million chum. This estimate assumed that the peak date of the run was no later than October 17.

A subsequent estimate of Fraser River chum abundance was provided on October 26. The estimated terminal return on that date was 2.00 million ( $80 \%$ probability interval of 1.26 to 3.63 million), with a $50 \%$ migration date through the lower river of October 20th. This peak date is consistent with timing in recent years (average peak date from 1997-2012 is October 18).

Additional in-season estimates were not provided, as subsequent test fishing information was consistent with a run size of 2.00 million.

Fraser River chum salmon return to numerous spawning locations in the lower Fraser River and its tributaries. The escapement goal for Fraser Chum is 800K. Spawning escapement for Fraser River chum salmon is currently assessed for four of the six largest chum producing systems, as well as for a number of smaller tributaries. The largest observed escapement of Fraser River chum (greater than 3 million fish), was seen in 1998. However since 1998, Fraser Chum salmon escapement, for the annually assessed systems, trended downward to 2010. The escapement decline was halted and reversed with an estimated 1.1 million spawners reported in 2011. Spawning escapement has remained stable through 2015.

Current year escapement assessment programs are still ongoing, and preliminary estimates of escapement are not available. However, lower Fraser River harvest estimates and distribution and abundance observations of spawners to-date suggest terminal run size will approach the Oct.26, 2016 Albion-based in-season estimate of 2.0 million chum salmon.

### 12.3 First nations Fisheries

FSC gill net fisheries commenced October 8 (below Mission) and October 14 (above Mission), following closures to protect co-migrating Interior Fraser coho. The estimated kept catch from the chum directed FSC fishery below Sawmill Creek was 60,540 chum, 744 chinook, and 1,870 coho. The estimated released catch in this fishery was 10 sockeye, 1 chinook, and 26 coho. FSC fisheries targeting other species of salmon harvested 1,199 chum.

### 12.4 Recreational Fisheries

In 2016, only one of the major Fraser River watershed sport salmon fisheries impacting chum salmon was assessed, this was the significant salmon fishery occurring in the Chilliwack River (a tributary to the Fraser River in the lower Fraser Valley).

The lower Fraser River mainstem sport fishery was open to the retention of chum salmon from August 1 to August 11 and September 19 to December 31 (with a daily limit of two upstream and four downstream of Mission Bridge); the Fraser mainstem was closed to fishing for salmon prior to August 1 and from August 12 to September 18. In 2016, this mainstem fishery was assessed in the periods opened to the retention of chum until September 30. However, similar to 2014 and 2015, this assessment was truncated in October where past assessments have shown the majority of chum catch occurs (from 2007 through 2012, this sport fishery was assessed to October 15 in all years, and November 30 in 2007 and 2012). Preliminary estimates of kept and released chum salmon are not yet available. The Chilliwack River sport fishery was open to the retention of chum salmon from July 1 to December 31 (with a daily limit of one). This Chilliwack River fishery was assessed from September 15 to November 15 in 2016. Preliminary estimates of kept and released chum salmon are not yet available.

The Harrison River, Stave River and Nicomen Slough sport fisheries were open to the retention of chum salmon year round (daily limit of two). In 2016, no assessment was conducted on the Harrison River or Stave River fisheries; however, the Nicomen Slough fishery was assessed from October 7 to November 30. Preliminary estimates of kept and released chum salmon are not yet available.

### 12.5 Commercial Fisheries

### 12.5.1 Commercial (A-H Fisheries includes ATP)

## Area E

Commercial fisheries in the lower Fraser River (below Mission) remained closed during the Interior Fraser River coho window closure, and further closures were in place until later in October to meet the Interior Fraser steelhead management objectives. Two Area E Gill Net commercial openings took place in the Fraser River (Area 29) during the 2016 chum season, consisting of a ten hour fishery on October 24 and a ten hour fishery on October 27, for a total estimated harvest of 175,906 chum salmon retained and 11 chum released. Additionally, there were estimated to be 3 chinook and 179 coho salmon kept; releases from the two fisheries were estimated at 49 chinook, 919 coho, 21 steelhead and 62 sturgeon.

There were no Area E fisheries for Fraser sockeye in 2016 and therefore no by-catch retention of chum salmon to report.

## Area B

Area B seine was also provided a limited opportunity in Area 29 that took place on October 27 and 28 for a total estimated harvest of 472 chum salmon retained and 0 chum released and no reported by-catch

There were no Area B fisheries for Fraser sockeye in 2016 and therefore no by-catch retention of chum salmon to report.

## Area H

Area H was provided an opportunity in Area 29 that took place from October 24 to November 4 for a total estimated harvest of 0 chum retained and 0 chum released (no fishing activity occurred).

### 12.5.2 First Nations Commercial Harvest

Fraser River First Nations commercial chum fisheries for gill net and beach seine were conducted between October 22 and November 7. There were 132,848 chum, 4 chinook and 286 coho harvested in Economic Opportunity fisheries. There was 1 chum, 283 chinook, 414 coho, 52 sockeye, 3 pink, released in Economic Opportunity fisheries. Tsawwassen First Nation as part of their harvest agreement kept 13,672 chum, 2 chinook, and 17 coho salmon and released 17 chinook and 6 coho.

Musqueam and Tsawwassen First Nations Economic Opportunities consisted of two daylight only gill net opportunities with both First Nations fishing on October 26, Tsawwassen fishing October 29, and Musqueam fishing November 5th.

The First Nations above the Port Mann bridge (Sto:lo First Nations) Economic Opportunity fisheries were conducted with beach seines and gill nets. The beach seine fisheries were authorized for 3 days on October 20, November 4, and November 7. They also had a daylight only gill net opportunity on October 31.

The Harrison Fisheries Authority (Sts’ailes and Scowlitz First Nation) Economic Opportunity fishery was authorized for 4 days of beach seine fishing October 24, October 25, November 3 and November 8. They were not authorized any gillnet opportunities for their Economic Opportunity fishery.

### 12.6 Excess Salmon to Spawning Requirements (ESSR) Fisheries

There were several ESSR chum fisheries in the Lower Fraser Area for First Nations. These were conducted at Chehalis, Chilliwack, and Inch Creek Hatcheries for a total chum catch of 26,045. The Capilano Hatchery reported no chum harvest for ESSR in 2016. Tenderfoot and Weaver Creek Hatcheries did not conduct ESSR fisheries in 2016.

## 13 STRAIT OF GEORGIA CHUM

### 13.1 ObJectives and Overview

Strait of Georgia chum fisheries consist of terminal opportunities for chum returning to their natal spawning streams. Many of the potential terminal fishing areas have enhancement facilities and/or spawning channels associated with the rivers. Terminal fishery strategies consist of monitoring and assessing stocks (escapement and returning abundance), with the objective of ensuring adequate escapement and providing harvest opportunities where possible. Stock assessments may include test fisheries, escapement enumeration including swim surveys, stream walks, channel entry counts, fence counts, Sonar (DIDSON) counts and over flights. In some areas where stocks receive considerable enhancement or where stocks have above average productivity, limited fishing may occur prior to major escapement occurring.

A productivity analysis was conducted in 2014 in order to review escapement targets in the major chum systems of the Strait of Georgia. The results of this analysis have led to new interim escapement targets in Big Qualicum, Little Qualicum and Nanaimo Rivers.

## Commercial Overview

## Area 14

Chum returning to this area have been enhanced since the late 1960s and terminal fisheries have occurred in October and November since the 1970s. The returning Area 14 chum abundance is forecasted pre-season using brood escapement, average survival and age composition. In-season run strength is assessed from any early catches, visual observations at river estuaries and by escapement counts to the three major river systems.

This fishery is directed at the enhanced stocks of three systems: Puntledge, Qualicum and Little Qualicum Rivers. The Qualicum River is often referred to as the ‘Big’ Qualicum River, to better distinguish it from the Little Qualicum River. The interim escapement goals for the three river systems are 60,000 for Puntledge River, 85,000 for Little Qualicum River, and 85,000 for Qualicum River, adding up to an overall interim escapement goal of 230,000 chum, not including enhancement facility requirements (about 10,000 chum, bringing the total escapement goal to 240,000). Escapement goals on the Qualicum and Little Qualicum rivers were reduced in 2014 from 130,000 and 100,000 respectively, as a result of the productivity analysis conducted for chum systems in the Strait of Georgia.

The Area 14 fishery has a specific harvest strategy, implemented since 1981. The strategy consists of limited early harvest prior to escapement occurring. The allowable early chum harvest is calculated from $65 \%$ of the predicted surplus (terminal return run size minus escapement of 240,000 and buffer of 100,000 ). The buffer safeguards against errors in forecast stock abundance. The surplus within the 100,000 buffer and remaining $35 \%$ of the surplus may be harvested provided that escapement targets have been achieved. If there is no significant surplus identified in the pre-season forecast, potential fishing opportunities are determined inseason based on pre-set in-river escapement targets and run timing information.

In 2016, a surplus above the escapement target was observed in all Area 14 systems. An Area D Gill Net fishery open November 1and remained open until November 25. The Area B Seine

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fishery opened on November 5 and remained open until November 25. The Area H Troll fishery was open however there was no participation. The catches in the fisheries were 231,097 chum for Area B Seine and 38,193 for Area D Gill Net.

## Area 16

This fishery targets wild chum stocks returning to river systems in the Jervis Inlet area. The main systems are Tzoonie, Deserted and Skwawka Rivers. The overall escapement goal for Jervis/Narrows Inlet Rivers is 85,000 . These terminal fisheries occur when the individual or combined escapement goals have been assured. Fishing opportunities do not occur on a regular basis. There were no fisheries in Area 16 in 2016.

## Area 17

This fishery is a terminal fishery targeting Nanaimo River stocks. The Nanaimo River chum stocks are supplemented by the Nanaimo River hatchery (supplementation is on a sliding scale), where increased enhancement occurs during poor escapement years. Escapements fluctuate annually and fishery openings are planned in-season based on escapement estimates. The overall interim escapement goal for the Nanaimo River is 40,000.

Nanaimo River assessments include swims by Nanaimo River Hatchery staff, a sonar counting system (DIDSON) and spot counts or helicopter counts by DFO during the peak of the return when possible. The DIDSON was installed and operational on October 5 until November 21; due to heavy storms and debris the DIDSON was not operational from October 14 until October 19 when the water level decreased enough to remain operation. The Preliminary escapement estimate based on DIDSON data is approximately 100,000, although these data are very preliminary and will change upon further review.

In 2016 there were Area E Gill Net and Area B Seine openings for Nanaimo River chum. The Area E Gill Net fishery opened October 17 and the Area B Seine fishery opened on October 27; the Area E Gillnet fishery was on October 17, 18 and 21 and then daily from October 24 until November 17 and the Area B Seine fishery opened daily from October 27 until November 17. The fisheries closed for the season on November 17. The catches in the fisheries were 86,187 for gill nets and 61,600 for seines.

## Area 18

This fishery is directed primarily at Cowichan River stocks; however incidental catches of Goldstream bound chum are also harvested. Fishery openings in mid to late November are limited to Satellite Channel, in order to minimize impacts on Goldstream stocks. Chemainus River stocks could also be impacted if the fisheries are earlier in November, but likely to a lesser extent.

Fishery openings are planned in-season based on escapement estimates from a DIDSON counter and information from a test fishery. Management is also guided by advice from the Cowichan Fisheries Roundtable and the Mid Vancouver Island (MVI) Chum Subcommittee, and an inseason Chum Escapement Forecast Tool based on the DIDSON count and date. The overall escapement goal for the Cowichan River is currently 160,000 chum counted by the DIDSON counter.

The DIDSON was installed on October 11. The preliminary escapement estimate was 230,000 chum.

A weekly conference call was held with the Cowichan Fisheries Roundtable to discuss stock status and potential fishing opportunities in Area 18. In 2016, a commercial opportunity was triggered on October 25 when the Didson chum count was near $50 \%$ of the escapement target of 160,000 chum. The Cowichan Tribes Demo fishery began October 26 for approximately 13\% of the forecasted surplus for the week. The Cowichan Tribes Demonstration fishery was licenced to fish on October 26, October 29 to November 4, and from November 8 daily until November 30. The Preliminary Cowichan Tribes Commercial Demonstration catch is approximately 13,090 chum. The Area E Gill net fishery began in Area 18 on October 27. Area E Gillnets fished in Area 18 on October 27 and 28, October 31 and November 1 and then daily from November 4 until 29. The total Area E commercial chum catch is estimated to be approximately 198,000 chum. The Area B Seine fishery began on November 2. Area B commercial seine fisheries occurred daily from November 2 until November 22. The total Area B commercial chum catch is estimated to be approximately 91,000 chum.

## Area 19

This fishery is directed primarily at Goldstream River stocks, although some Cowichan River chum salmon are also harvested. Fishery openings set for mid to late November are limited to the portion of Saanich Inlet (Sub area 19-8) which is outside or to the north of Squally Reach. This area restriction is implemented to minimize impact on Goldstream chinook and coho stocks.

Fisheries are planned in-season based on escapement estimates. Area 19 falls under the same management regime as Area 18. The overall escapement goal for the Goldstream River is 15,000 . Weekly (or bi-weekly in 2016) stream walks are conducted on Goldstream River by Goldstream Hatchery staff to estimate chum escapement. In 2016, enumerations began on October 12. The preliminary escapement estimate is 12,400 .

There were no commercial chum fisheries in Area 19 in 2016.
Chum catch and release information from all fisheries can be found in Appendix 7.

### 13.2 STOCK STATUS

Historically, chum returns have been highly variable relative to brood year escapements. For 2016, the forecast for Jervis/Narrows Inlet chum abundance was for slightly below to above the target level, and the Mid-Vancouver Island systems were near or well above the target level. Nanaimo, Cowichan and Goldstream Rivers’ chum abundance were forecast to be above to well above the target levels. All of these forecasted expectations are highly uncertain and a review of the procedures and data used for forecasting these systems will be conducted in the near future.

Conditions for returning chum migration and spawning were marginal at the beginning of the migration period in October due to low water levels, but rain events in mid-October and throughout November increased water levels so that migration was unimpeded.

Monitoring spawning escapements of chum are mostly completed now and data are currently being compiled and reviewed. The 2016 data reported in Table 13-1 below are very preliminary and will change upon further review (especially the estimate for Nanaimo River). To date returns for the Jervis/Narrows Inlet aggregate (which includes Brittain River, Skwawka River, Deserted

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River, Vancouver River and Tzoonie River), the Mid-Vancouver Island systems, Nanaimo and Cowichan were at or above the expected range and reached the target escapements (Table 13-1). The Goldstream River chum abundance was well below the lower expected range and slightly below the target (Table 13-1).

Table 13-1: Strait of Georgia Chum Preliminary Spawning Escapements

|  | Target Escapement | 2016 forecast <br> Expected range | Preliminary 2016 <br> Escapement | \% of target |
| :--- | :---: | :---: | :---: | :---: |
| Jervis/Narrows <br> Inlet | 85 K | $73 \mathrm{~K}-109 \mathrm{~K}$ | 110 K | $129 \%$ |
| Mid-Vancouver <br> Island | 240 K | $219 \mathrm{~K}-328 \mathrm{~K}$ | 381 K | $159 \%$ |
| Puntledge | 60 K |  | 80 K | $134 \%$ |
| Little Qualicum | 85 K (interim) |  | $55 K^{*}$ | $65 \%^{*}$ |
| Big Qualicum | 85 K (interim) |  | 246 K | $289 \%$ |
| Nanaimo | 40 K (interim) | $67 \mathrm{~K}-100 \mathrm{~K}$ | 100 K | $250 \%$ |
| Cowichan | 160 K | $192 \mathrm{~K}-289 \mathrm{~K}$ | 230 K | $144 \%$ |
| Goldstream | 15 K | $38 \mathrm{~K}-56 \mathrm{~K}$ | 12 K | $83 \%$ |

- Little Qualicum preliminary 2016 escapement estimate includes spawning channel count only; river estimate is unavailable due to high water and unsafe survey conditions during migration. Spot check observations indicated a strong run with large numbers of chum spawning in the river.


### 13.3 First Nations Fisheries

The preliminary estimated FSC catch by First Nations in the Strait of Georgia is estimated to be approximately 4,622 chum.

### 13.4 Recreational Fisheries

### 13.4.1 Tidal Recreational Fisheries

Marine recreational chum fisheries are subject to the normal salmon daily and possession limits (limit of four per day and possession of eight), and are typically open throughout the area. The majority of the recreational effort directed at chum salmon in the Strait of Georgia occurs in the lower portions of the Discovery Passage area, particularly in the waters around Campbell River. The annual Brown's Bay Charity Chum Derby which took place on the weekend of October 15 and 16 is usually the most active chum recreational fishery in the area. Catches in the derby were reported to be excellent despite poor weather conditions. There was no Creel survey during the months of October and November in the Strait of Georgia, but recreational catches were reported as being excellent given the strong chum returns through Johnstone Strait and to local river systems throughout the Strait of Georgia.

Marine chum fisheries also occur in the approach waters of the Puntledge, Qualicum, Little Qualicum, Nanaimo and Cowichan Rivers on Vancouver Island, as well as in Howe Sound. Marine recreational catch for the Strait of Georgia Creel survey from March through September was estimated to be 1,475 chum (catch was from August and September). There was no Creel survey in the Strait of Georgia in October and November.

Incidentally caught coho and chinook can be caught during chum directed recreational fisheries in the Strait of Georgia.

### 13.4.2 Non-Tidal Recreational Fisheries

Chum retention fisheries in the Strait of Georgia took place in 2016 in the Cowichan, Nanaimo, Qualicum, Little Qualicum and the Puntledge Rivers on Vancouver Island. Recreational freshwater opportunities are typically based on escapement estimates from hatchery operations, and where escapement goals are expected to be met, opportunities are provided.

Annually, but subject to in-season assessment information, retention opportunities are provided pre-season in the following Strait of Georgia rivers:

- Nanaimo - November 1 to 30 - 2 chum per day
- Little Qualicum - October 1 to November 30-1 chum per day
- Qualicum River - October 1 to November $30-1$ chum per day
- Puntledge - October 1 to November 30 - 2 chum per day

In early November, surplus chum returns were identified at the Cowichan, Nanaimo, Qualicum, Little Qualicum and the Puntledge Rivers and from November 7 to December 31 the retention of four chum per day was permitted in these river systems (where open to fishing). Catch monitoring programs did not take place in 2016 on these systems. Chum catch and effort from these freshwater fisheries is expected to be minimal. Other salmon and trout species may be caught while recreationally targeting chum salmon in Strait of Georgia river systems.

### 13.5 Commercial Fisheries

### 13.5.1 Commercial (A-H Fisheries includes ATP)

Strait of Georgia commercial chum fisheries for troll, gill net and seine were conducted in Areas 14, 17 and 18 between October 17 and December 1. The total commercial chum catch from the Strait of Georgia is estimated at 704,992 pieces (see Table 13-2 below). This total captures catch estimates as up to November 25, 2016. The gillnet fishery in Area 18 is ongoing. A description of each fishery is provided in the following table.

Chum catch and release information from all fisheries can be found in Appendix 7.
Table 13-2: Strait of Georgia Commercial Chum Catch by Date and Gear Type

| Fishery Date | Gear type | Area | Effort (boat days) | Catch |
| :---: | :---: | :---: | :---: | :---: |
| Oct 17-Nov 17 | GN | 17 | 400 | 86,187* |
| Oct 27-Nov 17 | SN | 17 | 74 | 61,600* |
| Oct 27-Nov 24* | GN | 18 | 806 | 197,065* |
| Nov 2-Nov 24* | SN | 18 | 127 | 90,850* |
| Nov 1 to Nov 25 | GN | 14 | 266 | 38,193* |
| Nov 15 to Nov 25 | SN | 14 | 166 | 231,097* |

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### 13.5.2 First Nations Commercial Harvest

A weekly conference call was held with the Cowichan Fisheries Roundtable to discuss stock status and potential fishing opportunities in Area 18. In 2016, a commercial opportunity was triggered on October 25 when the Didson chum count was near $50 \%$ of the escapement target of 160,000 chum. The Cowichan Tribes Demonstration fishery began October 26 for the approximate $13 \%$ of the forecasted surplus for the week. The Cowichan Tribes Demonstration fishery was licenced to fish on October 26, October 29 to November 4, and from November 8 daily until November 30. The Preliminary Cowichan Tribes Commercial Demonstration catch is approximately 13,090 chum.

### 13.6 Excess Salmon Spawning to Requirements (ESSR)

The Cowichan Tribes First Nation had an ESSR harvest at the CEDP hatchery on the Cowichan River. The First Nation harvested 10,200 chum salmon.

The Qualicum First Nation was issued an ESSR Licence for chum, coho and chinook at the Big Qualicum River hatchery. Catch numbers were preliminary at the time of this report but were reported as 44,186 chum being harvested.

The Comox First Nation was issued an ESSR license for the harvest of chum at the Puntledge River Hatchery which resulted in the harvest of 20,398 chum.

## 14 WEST VANCOUVER ISLAND CHUM

### 14.1 OBJECTIVES AND OVERVIEW

Commercial chum salmon fisheries normally occur on the WCVI from late September to early November in years of chum abundance. The majority of chum fishing on WCVI takes place adjacent to Nitinat Lake (Area 21), in Nootka Sound, Tlupana and Esperanza Inlets (Area 25). In some recent years there have been limited-fleet gill net fisheries in Barkley Sound (Area 23), Clayoquot Sound (Area 24), Nootka Sound and Esperanza Inlet (Area 25).

Fisheries for WCVI chum employ a two-tiered strategy for controlling removals; either a constant harvest rate strategy or a surplus-to-escapement goal strategy.

Fixed Harvest Rate Strategy (fisheries targeting natural origin stocks, hatchery stocks at low abundance):

For those fisheries where a significant component of the target stock is from naturally spawning populations, a constant harvest rate strategy of $10-20 \%$ is implemented. The maximum harvest rate is set a precautionary level relative to stock-recruit derived optimal exploitation rates for WCVI chum; which are in the order of $30-40 \%$. This approach allows limited harvest while protecting the biodiversity of chum stocks and permitting rebuilding when the population is low. In areas of low quality data or only naturally spawning stocks, including Barkley (Area 23), Clayoquot (Area 24), Esperanza Inlet (Area 25) and Kyoquot Sound (Area 26), the maximum allowable harvest rate is 10 to $15 \%$. In Nootka Sound, up to $20 \%$ harvest is permitted given the prevalence of hatchery stock in the area. The harvest rate is controlled by limiting effort (i.e. number and duration of openings and, in some areas, the number of permitted vessels) and limiting fishing areas to approach areas only (i.e. to those areas where fish are migrating not holding).

Note: since 2013, a fixed harvest rate strategy has also been used to harvest Nitinat Hatchery chum when the stock abundance is considered above the lower fishery reference point but below the target fishery reference point. The maximum harvest rate for the Nitinat stock is $25 \%$ when it is below the target fishery reference point.

Surplus-to-Escapement Goal Strategy (fisheries targeting hatchery stocks at high abundance):
For fisheries that target primarily hatchery surpluses, the allowable harvest rate may be determined by the escapement goal when it is determined the stock is abundant (e.g. it is established that escapement is above the target reference point for fisheries). These fisheries occur only in 'terminal areas', defined as an area in close proximity to the origin watershed of the target stock where little or no interception of other stocks occurs. Surplus to escapement goal fisheries for Conuma Hatchery stock occur within the Tlupana Inlet portion of Area 25. Surplus to escapement goal fisheries for Nitinat Hatchery stock occur in Area 21 near the mouth of Nitinat Lake or in Area 22 in Nitinat Lake. All Nitinat (and Conuma) hatchery chum are thermally marked, which allows for assessment of the hatchery contribution to fisheries and spawning.

### 14.2 Stock Status

In many recent years, the stock status of WCVI has been low: naturally spawning populations have been below target abundance despite the precautionary harvest regime. In addition, hatchery production levels have declined in recent years partially as a result of low abundance (i.e. hatcheries have not been able to achieve brood-stock targets in some years.) Therefore, in recent years, overall catches have declined relative to historic levels. However, like other South Coast areas in 2016, there were relatively abundant returns of chum to most WCVI areas and hatcheries, such as Nootka Sound and Nitinat Hatchery. This abundance was not observed in all areas, although extensive chum assessment is relatively data deficient.

### 14.3 First Nations Fisheries

Somass First Nations FSC catch was 711 chum. Maa-nulth domestic harvest was reported as 262 chum. The remaining WCVI NTC First Nations harvest reported to date is 1927 chum. The total combined catch for the WCVI First Nations was 2900 chum.

### 14.4 RECREATIONAL FISHERIES

### 14.4.1 Non-Tidal Recreational Fisheries

Chum retention fisheries place in the Nitinat River on Vancouver Island (October 15-Dec 31). Recreational freshwater opportunities are typically based on escapement estimates from hatchery operations, and where escapement goals are expected to be met, opportunities are provided. Chum returns to the WCVI were generally excellent in most systems in 2016, and as a result many recreational freshwater opportunities were available. Daily and possession limits are typically half of those provided in marine waters, with daily limits on most rivers being 2 /day and 4 in possession. These limits were increased to $4 /$ day in some systems on November 7 due to very strong chum returns. Catch monitoring programs did not take place in 2016 in WCVI river systems. Chum catch and effort from this fishery is expected to be marginal.

### 14.4.2 Tidal Recreational Fisheries

The WCVI recreational fishery is open year-round with a daily limit of four and possession of 8 chum. Anglers are restricted to the use of barbless hooks and there is a minimum size limit of 30 cm . In both offshore and inshore areas of WCVI, sport catch of chum is very low (estimated at less than 200 for all areas combined).

### 14.5 Commercial Fisheries

### 14.5.1 Commercial (A-H Fisheries includes ATP)

Commercial fisheries on the WCVI targeted two chum stocks in 2016: Nitinat (Area 21/121 and Nootka (Area 25).

## Nitinat

In 2016, the preseason forecast of 475,000 allowed for full fleet fisheries for both gillnet and seine fisheries. These fisheries occurred from October $2^{\text {nd }}$ to November $11^{\text {th }}$. The return was steady at the beginning of October and grew stronger each week. The weekly escapement goals
were exceeded early in the season and allowed for both fleets to be open continuously until further notice to November $11^{\text {th }}$. Due to successful Johnstone Strait fisheries fleet sizes for both gear types were small from mid-October onward but catches were extremely good. The final forecast for Nitinat Chum was over 1 million. The catch by sector was Area B seine 269,000 and Area E gillnet 137,000 chum.

## Nootka

Based on pre-season forecasts, a limited effort gillnet chum fishery, opened in Nootka Sound on September 27, 2016. Effort was initially limited to a maximum of 4 vessels fishing 2 days per week. CPUE's from the first week suggested that the return size was larger than the pre-season forecast and greater than the target reference point allowing for a full fleet opening; however the maximum vessels participating at any one time was 7 . The gillnet fishery was open two days a week (daylight hours only) from September $27^{\text {th }}$ to October $19^{\text {th }}$. The total catch for the Area D gillnets was 13,336 chum retained with 59 coho and 7 chinook reported released.

### 14.5.2 First Nations Commercial Harvest

There were no First Nations commercial harvest fisheries for chum in 2016.

### 14.6 EXCESS SALMON TO SPAWNING REQUIREMENTS (ESSR) FISHERIES

The Ditidaht First Nation was issued an ESSR Licence for chum at Nitinat Lake and Nitinat hatchery. The catch by gillnet in the lake was 33,879 . There was also $82,347 \mathrm{swim}$ ins at the Nitinat Hatchery facility. The total was 116,226 chum. There were no other chum ESSR fisheries on the WCVI in 2016.

## 15 APPENDICES

Appendix 1: Catches in Canadian Treaty Limit Fisheries, 1996 to 2016 (Preliminary)

| Fisheries/Stocks | Species | 2016 | 2015 | 2014 | 2013 | 2012 | 2011 | 2010 | 2009 | 2008 | 2007 | 2006 | 2005 | 2004 | 2003 | 2002 | 2001 | 2000 | 1999 | 1998 | 1997 | 1996 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Stikine River (all gears) | Sockeye | 86,729 | 60,046 | 42,800 | 36,146 | 30,352 | 55,623 | 50,543 | 48,049 | 33,614 | 59,237 | 101,209 | 85,890 | 84,866 | 58,784 | 17,294 | 25,600 | 27,468 | 38,055 | 43,803 | 65,559 | 74,281 |
|  | Coho | 5,346 | 5,619 | 4,992 | 4,835 | 5,748 | 4,703 | 4,952 | 5,061 | 2,398 | 47 | 72 | 276 | 275 | 190 | 82 | 233 | 301 | 181 | 726 | 401 | 1,404 |
|  | Chinook-1g | 2,731 | 4,157 | 3,308 | 3,415 | 4,573 | 2,307 | 1,766 | 2,330 | 7,860 | 10,576 | 15,776 | 18,997 | 3,857 | 1,396 | 1,362 | 1,480 | 3,086 | 2,916 | 2,164 | 4,483 | 2,471 |
|  | Chinook-jk | 794 | 1,537 | 759 | 1,594 | 1,213 | 1,165 | 1,001 | 714 | 1,067 | 1,735 | 2,078 | 2,177 | 2,574 | 1,052 | 578 | 103 | 628 | 1,264 | 423 | 286 | 421 |
| Taku River(commercial gillnet) | Sockeye | 37,624 | 19,747 | 17,872 | 21,163 | 30,209 | 24,012 | 20,211 | 11,057 | 19,445 | 16,564 | 21,093 | 21,932 | 19,860 | 32,730 | 31,053 | 47,660 | 28,009 | 20,681 | 19,038 | 24,003 | 41,665 |
|  | Coho | 9,513 | 7,886 | 14,568 | 10,374 | 8,689 | 6,102 | 10,349 | 5,649 | 4,866 | 5,399 | 9,180 | 6,860 | 5,954 | 3,168 | 3,082 | 2,568 | 4,395 | 4,416 | 5,090 | 2,594 | 5,028 |
|  | Chinook-lg | 1,021 | 868 | 2,472 | 738 | 1,909 | 2,333 | 4,658 | 7,031 | 1,184 | 862 | 7,312 | 7,534 | 2,074 | 1,894 | 1,561 | 1,458 | 1,576 | 908 | 1,107 | 2,731 | 3,331 |
|  | Chinook-jk | 205 | 0 | 657 | N/A | 478 | 514 | 697 | 1,183 | 330 | 337 | 198 | 821 | 334 | 547 | 291 | 118 | 87 | 257 | 227 | 84 | 144 |
| Alsek River (all gear) | Sockeye | 815 | 1,084 | 1,140 | 508 | 1,786 | 2,110 | 1,716 | 717 | 0 | 1,340 | 1,327 | 594 | 2,122 | 2,795 | 2,255 | 1,177 | 745 | 554 | 585 | 520 | 1,361 |
|  | Coho | 0 | 0 | 0 | 29 | N/A | 29 | 7 | 3 | 34 | 1 | 0 | 71 | 127 | 192 | 289 | 99 | 52 | 28 | 112 | 5 | 65 |
|  | Chinook | 10 | 87 | 39 | 73 | 85 | 214 | 294 | 125 | 7 | 41 | 19 | 114 | 185 | 228 | 2,194 | 277 | 142 | 412 | 346 | 530 | 1,098 |
| Areas 3 (1-4)* (commercial net)**** | Pink | * | 80,266 | 450,671 | 1,249,570 | 118,164 | 160,757 | 30,686 | 404,460 | 8,330 | 1,740,270 | 228,378 | 878,552 | 402,459 | 667,103 | 876,631 | 473,318 | 127,000 | 2,162,280 | 61,000 | 329,000 | 987,000 |
| Area 1 (commercial troll)**** | Pink | * | 41,551 | 31,775 | 84,216 | 57,013 | 52,221 | 19,948 | 60,402 | 29,295 | 61,276 | 34,854 | 39,430 | 27,751 | 98,347 | 41,418 | 175,000 | 28,295 | 25,000 | 0 | 261,000 | 732,000 |
| $\begin{aligned} & \text { North Coast** } \\ & \text { (troll + sport) } \end{aligned}$ | Chinook | 190,180 | 158,903 | 221,001 | 115,914 | 120,305 | 122,660 | 136,613 | 109,470 | 95,647 | 144,235 | 215,985 | 243,606 | 241,508 | 191,657 | 150,137 | 43,500 | 32,048 | 70,701 | 144,650 | 145,568 | 26,900 |
|  |  | $\begin{aligned} & 147,381+ \\ & 42,800 \\ & \hline \end{aligned}$ | $\begin{array}{r} 106,703 \\ +52,200 \\ \hline \end{array}$ | $\begin{array}{\|r\|} \hline 172,001+ \\ 49,000 \\ \hline \end{array}$ | $\begin{array}{r} 69,264+ \\ 46650 \\ \hline \end{array}$ | $\begin{array}{r} 80,256+ \\ 40050 \\ \hline \end{array}$ | $\begin{array}{r} 74,660+ \\ 48000 \\ \hline \end{array}$ | $\begin{array}{r} 90,213+ \\ 46400 \\ \hline \end{array}$ | $\begin{array}{r} 75,470 \div \\ 34,000 \\ \hline \end{array}$ | $\begin{array}{r} 52,147+ \\ 43500 \\ \hline \end{array}$ | $\begin{array}{r} 83,235+ \\ 61000 \\ \hline \end{array}$ | $\begin{array}{r} 151,485- \\ 64500 \\ \hline \end{array}$ | $\begin{array}{r} 174,806+ \\ 68,800 \\ \hline \end{array}$ | $\begin{array}{r} 167,508- \\ 74,000 \end{array}$ | $\begin{array}{r} 137,357+ \\ 54,300 \\ \hline \end{array}$ | $\begin{array}{r} 103,037+ \\ 47,100 \\ \hline \end{array}$ |  |  |  |  |  |  |
| West Coast <br> Vancouver Island <br> (troll + sport + <br> FN) | Chinook | 48,374 | 113,293 | 178,558 | 108,710 | 130,719 | 206,569 | 137,660 | 125,488 | 143,817 | 139,150 | 145,970 | 195,791 | 210,875 | 179,706 | 165,824 | 102,266 | 89,139 | 28,540 | 10,855 | 59,796 | 3677 |
|  |  | $\begin{array}{\|c\|} 37,809+317 \\ +10,248 \\ \hline \end{array}$ | $\begin{array}{r} \hline 60,572+ \\ 48,775+ \\ 3,946 \\ \hline \end{array}$ | $\begin{array}{r} 127,177+ \\ 48,365+ \\ 3,655 \\ \hline \end{array}$ | $\begin{array}{r} 43,043+ \\ 61,712+ \\ 3955 \\ \hline \end{array}$ | $\begin{array}{r} 62,573+ \\ 61,822+ \\ 4300 \end{array}$ | $\begin{array}{r} 123,930+ \\ 78,350+ \\ 4289 \\ \hline \end{array}$ | $\begin{array}{r} 79,123+ \\ 52,698+ \\ 5839 \\ \hline \end{array}$ | $\begin{array}{r} 53,191+ \\ 68,775+ \\ 3381 \end{array}$ | $\begin{array}{r} 89,704+ \\ 50,319+ \\ 3794 \end{array}$ | $\begin{array}{r} 87,921+ \\ 46,229+ \\ 5,000 \end{array}$ | $\begin{array}{r} 103,978+ \\ 36,992+ \\ 5,000 \end{array}$ | $\left.\begin{array}{r} 143,614+ \\ 52,177 \end{array} \right\rvert\,$ | $\begin{array}{r} 168,837+ \\ 42,038 \end{array}$ | $\begin{array}{r} 152,677+ \\ 27,029 \end{array}$ | $\left.\begin{array}{r} 134,308+ \\ 31516 \end{array} \right\rvert\,$ | $\begin{array}{r} 78,302+ \\ 23964 \end{array}$ | $\begin{array}{r} 64,216+ \\ 24923 \end{array}$ | $\begin{array}{r} 6,906+ \\ 21634 \end{array}$ | $\begin{array}{r} 6,678+ \\ 4177 \end{array}$ | $\begin{array}{r} 53,396+ \\ 6400 \end{array}$ | $4+3673$ |
| Fraser River Canadian Commercial Catch | Sockeye | 0 | 0 | 7,945,474 | 2,124 | 0 | 443,000 | 9,305,104 | 0 | 16,942 | 0 | 4,633,623 | 137,000 | 1,993,800 | 1,042,986 | 2,182,700 | 295,000 | 953,000 | 54,000 | 1,295,000 | 8,737,000 | 1,019,000 |
|  | Pink | 0 | 452 | 0 | 2,855,441 | 0 | 4,751,800 | - | 1,442,840 | 0 | 333,300 | 68,325 | 338,000 | 0 | 1,149,189 | 0 | 579,000 | 0 | 3,000 | 0 | 3,660,000 | 0 |
| Fraser River <br> U.S. Commercial <br> Catch | Sockeye | 0 | 44,100 | 691,000 | 4,609 | 105,100 | 266,000 | 1,970,000 | 0 | 49,800 | 3,900 | 701,300 | 0 | 192,200 | 244,000 | 434,600 | 240,000 | 494,000 | 41,000 | 707,000 | 1,578,000 | 257,000 |
|  | Pink | 0 | 334,700 | 0 | 3,057,222 | 0 | 2,893,400 | 0 | 2,726,230 | 0 | 377,600 | 0 | 0 | 0 | 773,000 | 0 | 427,000 |  | 3,000 | 0 | 1,565,000 | 0 |
| West Coast <br> Vancouver Island <br> (commercial troll) | Coho | 774 | 18,126 | 32,992 | 5,499 | 1,988 | 0 | 458 | 0 | 369 | 1,424 | 2,399 | 5,989 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 761,000 |
| Johnstone Strait (commercial catch)*** | Chum | 1,333,478 | 492,841 | 318,984 | 597,003 | 391,324 | 751,560 | 62,510 | 510,708 | 298,931 | 494,944 | 800,363 | 787,226 | 1,089,100 | 1,026,029 | 700,000 | 236,000 | 161,000 | 41,411 | 1,820,000 | 104,593 | 101,971 |

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*AREA 5-11 CATCHES INCLUDED PRIOR TO 1995 AND EXCLUDED FROM 1995-1998 INCLUSIVE. NOT PART OF 1999 ANNEX IV PROVISIONS. ** NORTH COAST CATCH EXCLUDES TERMINAL EXCLUSION CATCHES OF 6,000 ('91), 6,100 ('92), 7,400 ('93), 6,400 ('94), 1,702 ('95), 16,000 ('96), 5,943 ('97), and 2,182 in 1998. NO TERMINAL EXCLUSION IN THE 1999 AGREEMENT - COVERED UNDER THE AABM ARRANGEMENT; CENTRAL COAST AREAS NOT PART OF 1999 ANNEX IV PROVISIONS.
*** CANADIAN CATCH INCLUDES COMMERCIAL, FSC AND TEST-FISH CATCHES IN AREAS 11-13 FOR 1991-94 INCLUSIVE, AND IN AREAS 12-13 FOR 1995 TO 2004 INCLUSIVE. 2002-PRESENT, CATCHES FROM FISHERIES MANAGED TO FIXED HARVEST RATE OF 20\%.
****ALL PINK CATCHES FOR ALL YEARS (1995-2012) IN AREAS 3(1-4) AND AREA 1 HAVE BEEN UPDATED TO REFLECT FINAL ESTIMATES. NOTE 1: WCVI CHINOOK CATCHES FROM 1995-1998 ARE REPORTED BY CALENDAR YEAR; CATCHES FROM 2008-1999 ARE REPORTED BY CHINOOK YEAR (OCT-SEPT)

NOTE 2: 1999 CATCHES ARE REPORTED ACCORDING TO FISHERIES/STOCKS UNDER THE 1999 ANNEX IV PROVISIONS.

Appendix 2: Preliminary 2016 South Coast AABM Chinook Catch by Fishery and Area

| PST Regime | Fishery | Month | Numbers |  |
| :---: | :---: | :---: | :---: | :---: |
|  |  |  | Kept | Released |
| WCVI-AABM | Area G Troll * | Oct-15 | 178 | 22 |
| Commercial |  | Nov-15 | 13 | 0 |
|  |  | Dec-15 | 1 | 7 |
|  |  | Jan-16 | 51 | 104 |
|  |  | Feb-16 | 342 | 167 |
|  |  | Mar-16 | 315 | 150 |
|  |  | Apr-16 | 6,456 | 566 |
|  |  | May-16 | 31,799 | 919 |
|  |  | Jun-16 | 0 | 0 |
|  |  | Jul-16 | 0 | 0 |
|  |  | Aug-16 | 7,574 | 298 |
|  |  | Sep-16 | 2,390 | 850 |
| First Nations Commercial Harvest | Taaq-wiihak | May - Sep | 6,049 | 1,688 |
| Total |  |  | 55,168 | 4,771 |
|  |  |  |  |  |
| Recreational | Sport | WCVI - Inshore (20W-27) | 3,557 | 5,326 |
|  | Sport | WCVI - Offshore (121-127) | 34,252 | 17,186 |
| Total |  |  | 37,809 | 22,512 |


| First Nations FSC and Treaty | Johnstone Strait | 0 | 0 |  |
| :--- | :--- | :---: | :---: | :---: |
|  | Strait of Georgia | 0 | 0 |  |
|  | WCVI Offshore | 2,346 | 0 |  |
|  | WCVI Inshore | 0 | 0 |  |
|  | Fraser River | $\mathbf{2 , 3 4 6}$ | $\mathbf{0}$ |  |
| Total |  |  |  |  |
| All Total |  |  |  |  |

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## Appendix 3: Preliminary 2016 South Coast ISBM Chinook Catch by Fishery and Area

| ISBM CHINOOK |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: |
| Fishery | Gear | Fishery (Area) | Numbers |  |
|  |  |  | Kept | Released |
| Commercial | Area G Troll | WCVI Chinook | 0 | 0 |
|  | Area H Troll | Fraser Sockeye (12,13) | 0 | 0 |
|  | Area H Troll | Fraser Sockeye (29) | 0 | 0 |
|  | Area H Troll | Fraser Pink (12, 13, 29) | 0 | 0 |
|  | Area H Troll | JST Chum $(12,13)$ | 0 | 77 |
|  | Area H Troll | Fraser Chum (29) |  |  |
|  | Area H Troll | MV1 Chum (14-19) | 0 | 0 |
|  | Area B Seine | Barkley Sockeye (23) | 0 | 451 |
|  | Area B Seine | Fraser Sockeye ( 12,13 ) | 0 | 0 |
|  | Area B Seine | Fraser Sockeye (16) | 0 | 0 |
|  | Area B Seine | Fraser Sockeye (29) | 0 | 0 |
|  | Area B Seine | Mainland Pink (12, 13, 16) | 0 | 0 |
|  | Area B Seine | Howe Sound Pink (28) | 0 | 0 |
|  | Area B Seine | Fraser Pink (12, 13, 29) | 0 | 0 |
|  | Area B Seine | Nitinat Chum $(21,121)$ | 0 | 1 |
|  | Area B Seine | JST Chum $(12,13)$ | 0 | 23 |
|  | Area B Seine | Fraser Chum (29) | 0 | 0 |
|  | Area B Seine | MVI Chum (14-19) | 0 | 0 |
|  | Area D Gillnet | Barkley Sockeye (23) | 116 | 39 |
|  | Area D Gillnet | Barkley Chum (23) | 0 | 0 |
|  | Area D Gillnet | Somass Chinook (23) | 1,555 | 0 |
|  | Area D Gillnet | Clayoquot Chum (24) | 0 | 0 |
|  | Area D Gillnet | Tlupana Chinook (25) | 3,451 | 0 |
|  | Area D Gillnet | Nootka Chum (25) | 0 | 7 |
|  | Area D Gillnet | Fraser Sockeye (11,12,13,14) | 0 | 0 |
|  | Area D Gillnet | JST Chum $(12,13)$ | 0 | 28 |
|  | Area D Gillnet | MVI Chum (14) | 0 | 0 |
|  | Area E Gillnet | Fraser Sockeye (29) | 0 | 0 |
|  | Area E Gillnet | Fraser Chum (29) | 3 | 49 |
|  | Area E Gillnet | Nitinat Chum ( 21,121 ) | 0 | 4 |
|  | Area E Gillnet | MV1 (Area 17-19) |  |  |
| Commercial Harvest Total |  |  | 5,125 | 679 |
| First Nations Commercial | T'aaq-wiihak HA | WCVI ISBM Chinook (25) | 317 | 0 |
|  | T'aaq-wiihak HA | WCVI AABM Chinook (24-26, 124-126) | n/a | n/a |
|  | Maa-nulth HA | Henderson Sockeye (23) |  |  |
|  | Harvest Agreement | Fraser River | 2 | 17 |
|  | EO | Johnstone Strait |  |  |
|  | EO | Strait of Georgia |  |  |
|  | EO | WCVI | 10,248 | 0 |
|  | EO | Fraser River | 4 | 283 |
|  | Demo | Johnstone Strait |  |  |
|  | Demo | Strait of Georgia |  |  |
|  | Demo | WCVI |  |  |
|  | Demo | Fraser River |  |  |
| First Nations Commercial Total |  |  | 10,571 | 300 |
| Total Combined Commercial Catch |  |  | 15,696 | 979 |
|  |  |  |  |  |
| Recreational | Sport | Juan de Fuca (19,20) | 22,866 | 23,886 |
|  | Sport | Strait of Georgia (13-19,28,29) | 27,443 | 55,474 |
|  | Sport | Johnstone Strait (11-12) | 8,349 | 7,146 |
|  | Sport | WCVI - Inshore (20W-27) | 33,574 | 37,098 |
|  | Sport | Fraser River | 1,968 | 126 |
| Total Recreational Catch |  |  | 94,200 | 123,730 |
| First Nations FSC and Treaty |  |  |  |  |
|  |  | Johnstone Strait | 347 |  |
|  |  | Strait of Georgia | 650 |  |
|  |  | WCVI | 3,526 | 0 |
|  |  | Fraser River | 9,639 | 56 |
| Total First Nations FSC Catch |  |  | 14,162 | 56 |
|  |  |  |  |  |
| ESSR |  | Johnstone Strait |  |  |
|  |  | Strait of Georgia* | 3,028 | 0 |
|  |  | WCVI | 37,322 |  |
|  |  | Fraser River | 6,712 | 0 |
| Total First Nations ESSR Catch |  |  | 47,062 | 0 |
| TOTAL - ALL FSHERIES |  |  | 171,120 | 124,765 |

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Appendix 4: Preliminary 2016 South Coast Sockeye Catch by Fishery and Area

| Fishery | Gear | Fishery (Area) | Numbers |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  | Non-Fraser Kept | Unknown Origin | Fraser Kept | All Stocks <br> Released |
| Commercial | Area G Troll | WCVI AABM Chinook (23-27, 123-127) | 0 | 0 | 0 | 0 |
|  | Area H Troll | Fraser Sockeye (12,13) | 0 | 0 | 0 | 0 |
|  | Area H Troll | Fraser Sockeye (29) | 0 | 0 | 0 | 0 |
|  | Area H Troll | Fraser Pink (12, 13, 29) | 0 | 0 | 0 | 0 |
|  | Area H Troll | JST Chum $(12,13)$ | 0 | 0 | 0 | 3 |
|  | Area H Troll | Fraser Chum (29) |  |  |  |  |
|  | Area H Troll | MVI Chum (14) | 0 | 0 | 0 | 0 |
|  | Area B Seine | Barkley Sockeye (23) | 228,329 | 0 | 0 | 7 |
|  | Area B Seine | Fraser Sockeye (12,13) | 0 | 0 | 0 | 0 |
|  | Area B Seine | Fraser Sockeye (16) | 0 | 0 | 0 | 0 |
|  | Area B Seine | Fraser Sockeye (29) | 0 | 0 | 0 | 0 |
|  | Area B Seine | Mainland Pink (12, 13,16) | 0 | 0 | 0 | 0 |
|  | Area B Seine | Howe Sound (28) | 0 | 0 | 0 | 0 |
|  | Area B Seine | Fraser Pink (12, 13, 29) | 0 | 0 | 0 | 0 |
|  | Area B Seine | Nitinat Chum ( 21,121 ) |  |  |  |  |
|  | Area B Seine | JST Chum $(12,13)$ | 0 | 1 | 0 | 14 |
|  | Area B Seine | Fraser Chum (29) | 0 | 0 | 0 | 0 |
|  | Area B Seine | MVI Chum (14-19) | 0 | 0 | 0 | 0 |
|  | Area D Gillnet | Barkley Sockeye (23) | 161,934 | 0 | 0 | 0 |
|  | Area D Gillnet | Barkley Chum (23) | 0 | 0 | 0 | 0 |
|  | Area D Gillnet | Somass Chinook (23) | 0 | 0 | 0 | 6 |
|  | Area D Gillnet | Clayoquot Chum (24) | 0 | 0 | 0 | 0 |
|  | Area D Gillnet | Tlupana Chinook (25) | 0 | 0 | 0 | 0 |
|  | Area D Gillnet | Nootka Chum (25) | 0 | 0 | 0 | 0 |
|  | Area D Gillnet | Fraser Sockeye (11,12,13,14) | 0 | 0 | 0 | 0 |
|  | Area D Gillnet | JST Chum $(12,13)$ | 0 | 0 | 0 | 0 |
|  | Area D Gillnet | MVI Chum (14) | 0 | 0 | 0 | 0 |
|  | Area E Gillnet | Fraser Sockeye (29) | 0 | 0 | 0 | 0 |
|  | Area E Gillnet | Fraser Chum (29) | 0 | 0 | 0 | 0 |
|  | Area E Gillnet | Nitinat Chum $(21,121)$ |  |  |  |  |
|  | Area E Gillnet | MVI Chum (Area 17-19) | 0 | 0 | 0 | 0 |
| Commercial Harvest Total |  |  |  |  |  |  |
| First Nations Commercial | T'aaq-wiihak HA | WCVI ISBM Chinook (25) | 0 | 0 | 0 | 0 |
|  | T'aaq-wiihak HA | WCVI AABM Chinook (24-26, 124-126) | 0 | 0 | 0 | 0 |
|  | Maa-nulth HA | Henderson Sockeye (23) | 1,015 | 0 | 0 | 0 |
|  | Harvest Agreement | Fraser River |  |  | 0 | 0 |
|  | EO | Johnstone Strait |  |  |  |  |
|  | EO | Strait of Georgia |  |  |  |  |
|  | EO | WCVI | 171,617 | 0 | 0 | 0 |
|  | EO | Fraser River |  |  |  |  |
|  | Demo | Johnstone Strait |  |  |  |  |
|  | Demo | Strait of Georgia |  |  |  |  |
|  | Demo | WCVI |  |  |  |  |
|  | Demo | Fraser River |  |  |  |  |
| First Nations Commercial Total |  |  | 172,632 | 0 | 0 | 0 |
| Total Combined Commercial Catch |  |  | 172,632 | 0 | 0 | 0 |
| Recreational |  |  |  |  |  |  |
|  | Sport | Juan de Fuca (19,20) |  |  | 7 | 186 |
|  | Sport | Strait of Georgia (13-19,28,29) |  |  | 0 | 360 |
|  | Sport | Johnstone Strait (11-12) |  |  | 61 | 47 |
|  | Sport | WCVI - Inshore (20W-27) | 53,647 | 0 | 0 | 0 |
|  | Sport | WCVI - Offshore (121-127) |  |  | 25 | 5 |
|  | Sport | Fraser River |  |  |  |  |
| Total Recreational Catch |  |  | 53,647 | 0 | 93 | 598 |
|  |  |  |  |  |  |  |
| First Nations FSC and Treaty |  | Johnstone Strait |  |  | 32,211 |  |
|  |  | Strait of Georgia |  |  | 660 |  |
|  |  | WCVI | 37,352 | 0 | 0 | 0 |
|  |  | Fraser River |  |  | 103,140 | 694 |
| Total First Nations FSC and Treaty Catch |  |  | 37,352 | 0 | 136,011 | 694 |
|  |  |  |  |  |  |  |
| ESSR |  | Johnstone Strait |  |  |  |  |
|  |  | Strait of Georgia |  |  |  |  |
|  |  | WCVI | 0 | 0 | 0 | 0 |
|  |  | Fraser River |  |  | 0 | 0 |
| ESSR Catch |  |  | 0 | 0 | 0 | 0 |
| TOTAL - ALL FSHERIES |  |  | 263,631 | 0 | 136,104 | 1,292 |

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## Appendix 5: Preliminary 2016 South Coast Pink Catch by Fishery and Area

| Fishery | Gear | Fishery (Area) | Numbers |  |
| :---: | :---: | :---: | :---: | :---: |
|  |  |  | Kept | Released |
| Commercial | Area G Troll | WCVI AABM Chinook (23-27, 123-127) | 5 | 1 |
|  | Area H Troll | Fraser Sockeye (12,13) | 0 | 0 |
|  | Area H Troll | Fraser Sockeye (29) | 0 | 0 |
|  | Area H Troll | Fraser Pink (12, 13, 29) | 0 | 0 |
|  | Area H Troll | JST Chum $(12,13)$ | 0 | 1 |
|  | Area H Troll | Fraser Chum (29) | 0 | 0 |
|  | Area H Troll | MVI Chum (14-19) | 0 | 0 |
|  | Area B Seine | Barkley Sockeye (23) | 2 | 0 |
|  | Area B Seine | Fraser Sockeye (12,13) | 0 | 0 |
|  | Area B Seine | Fraser Sockeye (16) | 0 | 0 |
|  | Area B Seine | Fraser Sockeye (29) | 0 | 0 |
|  | Area B Seine | Mainland Pink (12, 16) | 0 | 0 |
|  | Area B Seine | Howe Sound Pink (28) | 0 | 0 |
|  | Area B Seine | Fraser Pink (12, 13, 29) | 0 | 0 |
|  | Area B Seine | Nitinat Chum $(21,121)$ |  |  |
|  | Area B Seine | JST Chum $(12,13)$ | 14 | 5 |
|  | Area B Seine | Fraser Chum (29) | 0 | 0 |
|  | Area B Seine | MVI Chum (14-19) | 0 | 0 |
|  | Area D Gillnet | Barkley Sockeye (23) | 0 | 1 |
|  | Area D Gillnet | Barkley Chum (23) | 0 | 0 |
|  | Area D Gillnet | Somass Chinook (23) | 0 | 0 |
|  | Area D Gillnet | Clayoquot Chum (24) | 0 | 0 |
|  | Area D Gillnet | Tlupana Chinook (25) | 0 | 0 |
|  | Area D Gillnet | Nootka Chum (25) | 0 | 0 |
|  | Area D Gillnet | Fraser Sockeye (11,12,13,14) | 0 | 0 |
|  | Area D Gillnet | JST Chum $(12,13)$ | 5 | 11 |
|  | Area D Gillnet | MVI Chum (14) | 0 | 0 |
|  | Area E Gillnet | Fraser Sockeye (29) | 0 | 0 |
|  | Area E Gillnet | Fraser Chum (29) | 0 | 0 |
|  | Area E Gillnet | Nitinat Chum $(21,121)$ |  |  |
|  | Area E Gillnet | MVI Chum (Area 17-19) |  |  |
| Commercial Harvest Total |  |  | 26 | 19 |
| First Nation Commercial | T'aaq-wiihak | WCVI ISBM Chinook (25) | 0 | 0 |
|  | T'aaq-wiihak | WCVI AABM Chinook (24-26, 124-126) | 0 | 1 |
|  | Maa-nulth HA | WCVI |  |  |
|  | Harvest Agreement | Fraser River | 0 | 0 |
|  | EO | Johnstone Strait |  |  |
|  | EO | Strait of Georgia |  |  |
|  | EO | WCVI | 0 | 0 |
|  | EO | Fraser River | 0 | 3 |
|  | Demo | Johnstone Strait |  |  |
|  | Demo | Strait of Georgia |  |  |
|  | Demo | WCVI |  |  |
|  | Demo | Fraser River |  |  |
| Total First Nations EO Catch |  |  | 0 | 4 |
| Total Commercial Catch |  |  | 26 | 23 |


| Recreational | Sport | Juan de Fuca (19,20) | 154 | 69 |
| :--- | :--- | :--- | :---: | :---: |
|  | Sport | Strait of Georgia (13-19,28,29) | 1,946 | 1,064 |
|  | Sport | Johnstone Strait (11-12) | WCVI - Inshore (20W-27) | 2,451 |
|  | Sport |  |  |  |
|  | Sport |  |  |  |
|  | Sport | Fraser River | 96 | 122 |
|  |  | 36 | 170 |  |
| Total Recreational Catch |  | $\mathbf{4 , 6 8 3}$ | $\mathbf{3 , 4 9 1}$ |  |


| First Nations FSC and <br> Treaty | Johnstone Strait | 2,437 |  |  |
| :--- | :--- | :--- | :---: | :---: |
|  |  | Strait of Georgia | WCVI | 18 |


| ESSR | Johnstone Strait |  |  |
| :--- | :--- | :--- | :---: |
|  | Strait of Georgia |  |  |
|  | WCVI | 0 |  |
|  | Fraser River | 0 | 0 |
| Total First Nations ESSR Catch |  | 0 | 0 |
| TOTAL - ALL FSHERIES |  | $\mathbf{7 , 1 9 0}$ | $\mathbf{3 , 5 1 4}$ |

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## Appendix 6: Preliminary 2016 South Coast Coho Catch by Fishery and Area

| COHO |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: |
| Fishery | Gear | Fishery (Area) | Numbers |  |
|  |  |  | Kept | Released |
| Commercial | Area G Troll* | WCVI AABM Chinook (23-27, 123-127) | 360 | 3,244 |
|  | Area H Troll | Fraser Sockeye (12,13) | 0 | 0 |
|  | Area H Troll | Fraser Sockeye (29) | 0 | 0 |
|  | Area H Troll | Fraser Pink (12, 13, 29) | 0 | 0 |
|  | Area H Troll | JST Chum $(12,13)$ | 0 | 89 |
|  | Area H Troll | Fraser Chum (29) |  |  |
|  | Area H Troll | MVI Chum (14-19) | 0 | 0 |
|  | Area B Seine | Barkley Sockeye (23) | 0 | 80 |
|  | Area B Seine | Fraser Sockeye (12,13) | 0 | 0 |
|  | Area B Seine | Fraser Sockeye (16) | 0 | 0 |
|  | Area B Seine | Fraser Sockeye (29) | 0 | 0 |
|  | Area B Seine | Mainland Pink (12, 16) | 0 | 0 |
|  | Area B Seine | Howe Sound Pink (28) | 0 | 1 |
|  | Area B Seine | Fraser Pink (29) | 0 | 0 |
|  | Area B Seine | Nitinat Chum $(21,121)$ | 0 | 93 |
|  | Area B Seine | JST Chum ( 12,13 ) | 176 | 454 |
|  | Area B Seine | Fraser Chum (29) | 0 | 0 |
|  | Area B Seine | MVI Chum (14-19) | 0 | 149 |
|  | Area D Gillnet | Barkley Sockeye (23) | 0 | 218 |
|  | Area D Gillnet | Barkley Chum (23) | 0 | 0 |
|  | Area D Gillnet | Somass Chinook (23) | 800 | 0 |
|  | Area D Gillnet | Clayoquot Chum (24) | 0 | 0 |
|  | Area D Gillnet | Tlupana Chinook (25) | 0 | 1 |
|  | Area D Gillnet | Nootka Chum (25) | 0 | 59 |
|  | Area D Gillnet | Fraser Sockeye (11,12,13,14) | 0 | 0 |
|  | Area D Gillnet | JST Chum $(12,13)$ | 0 | 377 |
|  | Area D Gillnet | MVI Chum (14) | 0 | 5 |
|  | Area E Gillnet | Fraser Sockeye (29) | 0 | 0 |
|  | Area E Gillnet | Fraser Chum (29) | 179 | 919 |
|  | Area E Gillnet | Nitinat Chum $(21,121)$ | 0 | 93 |
|  | Area E Gillnet | MVI Chum (Area 17-19) | 0 | 131 |
| Commercial Harvest Total |  |  | 1,515 | 5,913 |
| First Nations Commercial | T'aaq-wiihak | WCVI ISBM Chinook (25) | 0 | 0 |
|  | T'aaq-wiihak | WCVI AABM Chinook (24-26, 124-126) | 414 | 417 |
|  | Maa-nulth HA | Henderson Sockeye (23) |  |  |
|  | Harvest Agreement | Fraser River | 17 | 6 |
|  | EO | Johnstone Strait |  |  |
|  | EO | Strait of Georgia |  |  |
|  | EO | WCVI | 2,764 |  |
|  | EO | Fraser River | 286 | 414 |
|  | Demo | Johnstone Strait |  |  |
|  | Demo | Strait of Georgia |  |  |
|  | Demo | WCVI |  |  |
|  | Demo | Fraser River |  |  |
| Total First Nations EO Catch |  |  | 3,481 | 837 |
| Total Commercial Catch |  |  | 4,996 | 6,750 |


| Recreational | Sport | Juan de Fuca (19,20) | 7,581 | 16,194 |
| :--- | :--- | :--- | :---: | :---: |
|  | Sport | Strait of Georgia (13-19,28,29) | 8,142 | 29,525 |
|  | Sport | Johnstone Strait (11-12) | 4,449 | 4,461 |
|  | Sport | WCVI - Inshore (20W-27) | 16,132 | 8,030 |
|  | Sport | WCVI - Offshore (121-127) | 5,692 | 9,000 |
| Sport | Fraser River | 8 | 0 |  |
| Total Recreational Catch |  |  |  |  |


| First Nations FSC and Treaty | Johnstone Strait | 701 |  |
| :---: | :---: | :---: | :---: |
|  | Strait of Georgia | 2,048 |  |
|  | WCVI | 6,699 |  |
|  | Fraser River | 2,094 | 771 |
| Total First Nations FSC Catch |  | 11,542 | 771 |
| ESSR | Johnstone Strait |  |  |
|  | Strait of Georgia | 7,688 |  |
|  | WCVI | 7,048 |  |
|  | Fraser River | 23,668 | 0 |
| Total First Nations ESSR Catch |  | 38,404 | 0 |
| TOTAL - ALL FSHERIES |  | 96,946 | 74,731 |

*Area G coho harvest estimate is based on the chinook year (Oct 1, 2015 to Sept 30, 2016). Total coho retained includes 107 from 2015 with the remainder in 2016 fisheries.

## Appendix 7: Preliminary 2016 South Coast Chum Catch by Fishery and Area

| Fishery | Gear | Fishery (Area) | Numbers |  |
| :---: | :---: | :---: | :---: | :---: |
|  |  |  | Kept | Released |
| Commercial | Area G Troll | WCVI AABM Chinook (23-27, 123-127) | 479 | 27 |
|  | Area H Troll | Fraser Sockeye (12,13) | 0 | 0 |
|  | Area H Troll | Fraser Sockeye (29) | 0 | 0 |
|  | Area H Troll | Fraser Pink (12, 13, 29) | 0 | 0 |
|  | Area H Troll | JST Chum $(12,13)$ | 65,010 | 0 |
|  | Area H Troll | Fraser Chum (29) | 0 | 0 |
|  | Area H Troll | MVI Chum (14-19) | 0 | 0 |
|  | Area B Seine | Barkley Sockeye (23) | 0 | 0 |
|  | Area B Seine | Fraser Sockeye (12,13) | 0 | 0 |
|  | Area B Seine | Fraser Sockeye (16) | 0 | 0 |
|  | Area B Seine | Fraser Sockeye (29) | 0 | 0 |
|  | Area B Seine | Mainland Pink ( 12,16 ) | 0 | 0 |
|  | Area B Seine | Howe Sound Pink (28) | 0 | 0 |
|  | Area B Seine | Fraser Pink (29) | 0 | 0 |
|  | Area B Seine | Nitinat Chum $(21,121)$ | 269,042 | 0 |
|  | Area B Seine | JST Chum $(12,13)$ | 1,047,723 | 0 |
|  | Area B Seine | Fraser Chum (29) | 472 | 0 |
|  | Area B Seine | MVI Chum (14-19) | 383,547 | 0 |
|  | Area D Gillnet | Barkley Sockeye (23) | 3 | 1 |
|  | Area D Gillnet | Barkley Chum (23) | 0 | 0 |
|  | Area D Gillnet | Somass Chinook (23) | 1 | 169 |
|  | Area D Gillnet | Clayoquot Chum (24) | 0 | 0 |
|  | Area D Gillnet | Tlupana Chinook (25) | 35 | 4 |
|  | Area D Gillnet | Nootka Chum (25) | 13,336 | 0 |
|  | Area D Gillnet | Fraser Sockeye (11,12,13,14) | 0 | 0 |
|  | Area D Gillnet | JST Chum $(12,13)$ | 220,745 | 3 |
|  | Area D Gillnet | MVI Chum (14) | 38,193 | 0 |
|  | Area E Gillnet | Fraser Sockeye (29) | 0 | 0 |
|  | Area E Gillnet | Fraser Chum (29) | 175,906 | 11 |
|  | Area E Gillnet | Nitinat Chum (21, 121) | 137,591 | 0 |
|  | Area E Gillnet | MVI Chum (Area 17-19) | 283,252 | 0 |
| Commercial Harvest Total |  |  | 2,635,335 | 215 |
| First Nations Commercial | T'aaq-wiihak | WCVI ISBM Chinook (25) | 0 | 0 |
|  | T'aaq-wiihak | WCVI AABM Chinook (24-26, 124-126) | 0 | 3 |
|  | Maa-nulth HA | Henderson Sockeye (23) |  |  |
|  | Harvest Agreement | Fraser River | 13,672 | 0 |
|  | EO | Johnstone Strait |  |  |
|  | EO | Strait of Georgia |  |  |
|  | EO | WCVI |  |  |
|  | EO | Fraser River | 132,848 | 1 |
|  | Demo | Johnstone Strait |  |  |
|  | Demo | Strait of Georgia | 13,090 |  |
|  | Demo | WCVI |  |  |
|  | Demo | Fraser River |  |  |
| Total First Nations EO Catch |  |  | 159,610 | 4 |
| Total Commercial Catch |  |  | 2,794,945 | 219 |
|  |  |  |  |  |
| Recreational | Sport | Juan de Fuca (19,20) | 11 | 16 |
|  | Sport | Strait of Georgia (13-19,28,29) | 1,475 | 37 |
|  | Sport | Johnstone Strait (11-12) | 555 | 51 |
|  | Sport | WCVI - Inshore (20W-27) | 128 | 6 |
|  | Sport | WCVI - Offs hore (121-127) | 51 | 0 |
|  | Sport | Fraser River |  |  |
| Total Recreational Catch |  |  | 2,220 | 110 |
|  |  |  |  |  |
| First Nations FSC and Treaty |  | Johnstone Strait | 20,494 |  |
|  |  | Strait of Georgia | 4,622 |  |
|  |  | WCVI | 2,900 | 0 |
|  |  | Fraser River | 61,739 | 115 |
| Total First Nations FSC Catch |  |  | 89,755 | 115 |
|  |  |  |  |  |
| First Nations ESSR |  | Johnstone Strait |  |  |
|  |  | Strait of Georgia | 74,784 | 0 |
|  |  | WCVI | 116,226 | 0 |
|  |  | Fraser River | 26,045 | 0 |
| Total First Nations ESSR Catch |  |  | 217,055 | 0 |
| TOTAL - ALL FSHERIES |  |  | 3,103,975 | 444 |

Appendix 8: Preliminary 2016 Southern B.C. Commercial Catch Totals by Gear and Area

| License Group | Fishing Area | Adult Sockeye Kept | Sockeye Released | Coho Kept | Coho <br> Released | Pink Kept | Pink <br> Released | Chum Kept | Chum <br> Released | Chinook Kept | Chinook <br> Released |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Area G Troll* | WCVI AABM Chinook (23-27,123-127) | 0 | 0 | 360 | 3,244 | 5 | 1 | 479 | 27 | 55,168 | 4,771 |
| Area H Troll | Fraser Sockeye (12,13) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Area H Troll | Fraser Sockeye (29) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Area H Troll | Fraser Sockeye (12, 13, 29) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Area H Troll | JST Chum ( 12,13 ) | 0 | 3 | 0 | 89 | 0 | 1 | 65,010 | 0 | 0 | 77 |
| Area H Troll | Fraser Chum (29) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Area H Troll | MVI Chum (14) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Area B Seine | Barkley Sockeye (23) | 228,329 | 7 | 0 | 80 | 2 | 0 | 0 | 0 | 0 | 451 |
| Area B Seine | Fraser Sockeye ( 12,13 ) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Area B Seine | Fraser Sockeye (16) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Area B Seine | Fraser Sockeye (29) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Area B Seine | Mainland Pinks (12, 13, 16) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Area B Seine | Howe Sound Pink (28) | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Area B Seine | Fraser Pink (12, 13, 29) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Area B Seine | Nitinat Chum (21, 121) | 0 | 0 | 0 | 93 | 0 | 0 | 269,042 | 0 | 0 | 1 |
| Area B Seine | JST Chum $(12,13)$ | 0 | 14 | 176 | 454 | 14 | 5 | 1,047,723 | 0 | 0 | 23 |
| Area B Seine | Fraser Chum (29) | 0 | 0 | 0 | 0 | 0 | 0 | 472 | 0 | 0 | 0 |
| Area B Seine | MVI Chum (14-19) | 0 | 0 | 0 | 149 | 0 | 0 | 383,547 | 0 | 0 | 0 |
| Area D Gillnet | Barkley Sockeye (23) | 161,934 | 0 | 0 | 218 | 0 | 1 | 3 | 1 | 116 | 39 |
| Area D Gillnet | Barkley Chum (23) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Area D Gillnet | Somass Chinook (23) | 0 | 6 | 800 | 0 | 0 | 0 | 1 | 169 | 1,555 | 0 |
| Area D Gillnet | Clayoquot Chum (24) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Area D Gillnet | Tlupana Chinook (25) | 0 | 0 | 0 | 1 | 0 | 0 | 35 | 4 | 3,451 | 0 |
| Area D Gillnet | Nootka Chum (25) | 0 | 0 | 0 | 59 | 0 | 0 | 13,336 | 0 | 0 | 7 |
| Area D Gillnet | Fraser Sockeye (11, 12, 13,14) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Area D Gillnet | JST Chum $(12,13)$ | 0 | 0 | 0 | 377 | 5 | 11 | 220,745 | 3 | 0 | 28 |
| Area D Gillnet | MVI Chum (14) | 0 | 0 | 0 | 5 | 0 | 0 | 38,193 | 0 | 0 | 0 |
| Area E Gillnet | Fraser Sockeye (29) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Area E Gillnet | Fraser Chum (29) | 0 | 0 | 179 | 919 | 0 | 0 | 175,906 | 11 | 3 | 49 |
| Area E Gillnet | Nitinat Chum (21, 121) | 0 | 0 | 0 | 93 | 0 | 0 | 137,591 | 0 | 0 | 4 |
| Area E Gillnet | MVI Chum (Area 14-19) | 0 | 0 | 0 | 131 | 0 | 0 | 283,252 | 0 | 0 | 0 |
| T'aaq-wiihak Demo | WCVI AABM Chinook (24-26,124-126) | 0 | 0 | 414 | 417 | 0 | 1 | 0 | 3 | 6,049 | 1,688 |
| T'aaq-wiihak Demo | WCVI ISBM Chinook (25) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 317 | 0 |
| Maa-nulth HA | Henderson Sockeye (23) | 1,015 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Harvest Agreement | Fraser | 0 | 0 | 17 | 6 | 0 | 0 | 13,672 | 0 | 2 | 17 |
| EO | Johnstone Strait | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| EO | Strait of Georgia | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| EO | WCVI | 171,617 | 0 | 2,764 | 0 | 0 | 0 | 0 | 0 | 10,248 | 0 |
| EO | Fraser River | 0 | 0 | 286 | 414 | 0 | 3 | 132,848 | 1 | 4 | 283 |
| Demo | Johnstone Strait | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Demo | Strait of Georgia | 0 | 0 | 0 | 0 | 0 | 0 | 13,090 | 0 | 0 | 0 |
| Demo | WCVI | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Demo | Fraser River | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TOTALS |  | 562,89 | 30 | 4,99 | 6,750 | 26 | 23 | 2,794,945 | 219 | 76,913 | 7,438 |

*Area G coho harvest estimate is based on the chinook year (Oct 1, 2015 to Sept 30, 2016). Total coho retained includes 107 from 2015 with the remainder in 2016 fisheries.

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Appendix 9: Preliminary 2016 Southern B.C. Recreational Catch Totals by Area

| Fishing Area | Sockeye Kept | Sockeye <br> Released | Coho <br> Kept | Coho <br> Released | Pink <br> Kept | Pink <br> Released | Chum Kept | Chum Released | $\begin{array}{\|c\|} \hline \text { Chinook } \\ \hline \text { ISBM } \\ \text { Kept } \end{array}$ | Chinook ISBM <br> Released | Chinook AABM Kept | $\begin{array}{\|c\|} \hline \text { Chinook } \\ \text { AABM } \\ \text { Released } \end{array}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Juan de Fuca (19,20) | 7 | 186 | 7,581 | 16,194 | 154 | 69 | 11 | 16 | 22,866 | 23,886 |  |  |
| Strait of Georgia (13-19,28,29) | - | 360 | 8,142 | 29,525 | 1,946 | 1,064 | 1,475 | 37 | 27,443 | 55,474 |  |  |
| Johnstone Strait (11-12) | 61 | 47 | 4,449 | 4,461 | 2,451 | 2,066 | 555 | 51 | 8,349 | 7,146 |  |  |
| WCVI - Inshore (20W-27) | 53,647 | - | 16,132 | 8,030 | 96 | 122 | 128 | 6 | 33,574 | 37,098 | 3,557 | 5,326 |
| WCVI - Offshore (121-127) | 25 | 5 | 5,692 | 9,000 | 36 | 170 | 51 | - | - | 126 | 34,252 | 17,186 |
| Fraser River | 0 | - | 8 | - | - | - | - | - | 1,968 | 126 |  |  |
| TOTAL | 53,740 | 598 | 42,004 | 67,210 | 4,683 | 3,491 | 2,220 | 110 | 94,200 | 123,856 | 37,809 | 22,512 |

All totals are preliminary.
SOG includes a portion of Area 19 (19 GS).
JDF includes a portion of 19 and a portion of Area 20 (20 JDF)
WCVI Inshore contains a portion of 20W (West of Sherringham)
-estimates not yet available for some lower Fraser River recreational fisheries

Appendix 10: Preliminary 2016 Southern B.C. First Nations (FSC and Treaty) and ESSR Catch Estimates by Area

| Fishery type | Fishing Area | Sockeye Kept | Sockeye <br> Released | Coho Kept | Coho <br> Released | Pink <br> Kept | Pink <br> Released | Chum Kept | Chum <br> Released | $\begin{array}{\|c\|} \hline \text { Chinook } \\ \text { ISBM } \\ \text { Kept } \\ \hline \end{array}$ | Chinook ISBM <br> Released | Chinook <br> AABM Kept | $\begin{gathered} \hline \text { Chinook } \\ \text { AABM } \\ \text { Released } \end{gathered}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| First Nations FSC and Treaty | Johnstone Strait | 32,211 | 0 | 701 | 0 | 2,437 | 0 | 20,494 | 0 | 347 | 0 | 0 | 0 |
|  | Strait of Georgia | 660 | 0 | 2,048 | 0 | 18 | 0 | 4,622 | 0 | 650 | 0 | 0 | 0 |
|  | WCVI | 37,352 | 0 | 6,699 | 0 | 25 | 0 | 2,900 | 0 | 3,526 | 0 | 2,346 | 0 |
|  | Fraser River | 103,140 | 694 | 2,094 | 771 | 1 | 0 | 61,739 | 115 | 9,639 | 56 | 0 | 0 |
| TOTAL |  | 173,363 | 694 | 11,542 | 771 | 2,481 | 0 | 89,755 | 115 | 14,162 | 56 | 2,346 | 0 |


| Fishery type | Fishing Area | Sockeye Kept | Sockeye Released | Coho Kept | Coho Released | Pink <br> Kept | Pink <br> Released | Chum Kept | Chum Released | Chinook ISBM Kept | Chinook ISBM <br> Released | Chinook AABM Kept | Chinook AABM <br> Released |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| ESSR | Johnstone Strait | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
|  | Strait of Georgia | 0 | 0 | 7,688 | 0 | 0 | 0 | 74,784 | 0 | 3,028 | 0 | 0 | 0 |
|  | WCVI | 0 | 0 | 7,048 | 0 | 0 | 0 | 116,226 | 0 | 37,322 | 0 | 0 | 0 |
|  | Fraser River | 0 | 0 | 23,668 | 414 | 0 | 0 | 26,045 | 0 | 6,712 | 0 | 0 | 0 |
| TOTAL |  | 0 | 0 | 38,404 | 414 | 0 | 0 | 217,055 | 0 | 47,062 | 0 | 0 | 0 |

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## Appendix 11: Preliminary 2016 South Coast Test Fishery Catches

| Test-Fisheries | Start Date | End Date | Boat Days | Sockeye kept | Sockeye released | Coho kept | Coho released | Pink <br> kept | Pink released | Chum kept | Chum released | Chinook kept | Chinook released | GRAND TOTAL |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Albion Chinook Gillnet | 24-Apr-16 | 20-Oct-16 | 155 | 805 | 0 | 37 | 0 | 0 | 0 | 2,349 | 0 | 1,219 | 0 | 4,410 |
| Albion Chum Gillnet | 1-Sep-16 | 23-Nov-16 | 53 | 11 | 1 | 209 | 0 | 0 | 0 | 9,956 | 0 | 241 | 0 | 10,418 |
| Mquqwin / Brooks Chinook Troll | 12-Jul-16 | 3-Aug-16 | 14 | 0 | 0 | 91 | 198 | 0 | 0 | 0 | 0 | 354 | 83 | 726 |
| Juan De Fuca Chum Seine | 27-Sep-16 | 30-Oct-16 | 20 | 0 | 0 | 0 | 174 | 0 | 0 | 1,024 | 447 | 0 | 25 | 1,670 |
| Area 12 Chum Seine | 12-Sep-16 | 28-Oct-16 | 66 | 0 | 67 | 0 | 405 | 0 | 43 | 40,974 | 131,412 | 0 | 41 | 172,942 |
| Naka Creek Sockeye Gillnet ** | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | 0 |
| Area 13 Sockeye Seine ** | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | 0 |
| Area 23 Sockeye Seine | 6-Jun-16 | 2-Aug-16 | 21 | 10,054 | 3,698 | 0 | 15 | 0 | 1 | 0 | 2 | 0 | 423 | 14,193 |
| Blinkhorn Sockeye Seine | 21-Jul-16 | 12-Aug-16 | 22 | 2,037 | 4,490 | 0 | 143 | 31 | 5,341 | 0 | 1,244 | 0 | 204 | 13,490 |
| Round Island Sockeye Gillnet * | 11-Jul-16 | 9-Aug-16 | 30 | 615 | 1 | 241 | 223 | 798 | 3 | 24 | 0 | 22 | 20 | 1,947 |
| San Juan Sockeye Seine | 22-Jul-16 | 12-Aug-16 | 22 | 1,853 | 525 | 0 | 789 | 0 | 16 | 0 | 78 | 0 | 1,154 | 4,415 |
| San Juan Sockeye Gillnet | 11-Jul-16 | 3-Aug-16 | 25 | 2,055 | 2 | 27 | 27 | 33 | 0 | 11 | 1 | 3 | 83 | 2,242 |
| Whonnock Gillnet | 30-Jun-16 | 11-Sep-16 | 72 | 1,005 | 22 | 80 | 10 | 0 | 0 | 3 | 0 | 464 | 23 | 1,607 |
| Cottonwood Gillnet | 7-Jul-16 | 23-Aug-16 | 47 | 807 | 24 | 0 | 1 | 0 | 0 | 0 | 0 | 52 | 18 | 902 |
| Qualark Gillnet | 1-Jul-16 | 2-Sep-16 | 64 | 1,069 | 2 | 3 | 4 | 0 | 0 | 0 | 0 | 315 | 30 | 1,423 |
| Grand Total |  |  |  | 20,311 | 8,832 | 688 | 1,989 | 862 | 5,404 | 54,341 | 133,184 | 2,670 | 2,104 | 230,385 |

* coho given to local First Nations

All test fish catches include assessment and non-assessment sets
** Did not operate in 2016
Note: Jacks included in the above test fishing catches if encountered

Revisions to the Post-Season Report For 2016 Canadian Treaty Limit Fisheries (Dec. 20, 2016) on January 20, 2017

1) Page 86 - Appendix 9: WCVI offshore entry for ISBM chinook is currently a repeat of what is entered in the Fraser Row, it should actually be zero. The new total for this column is 94,200 instead of 96,168.
2) Page 52: Clarification - The paragraph describing Black Creek has been revised to:

## Black Creek

The 2016 Black Creek adult project is on-going; escapement to date has been below average. The majority of adult Coho moved past the fence during rain events of Oct $5^{\text {th }}$-Oct $14^{\text {th }}$; the fence was breached shortly thereafter during the high water that followed. As the carcass recovery portion of the program is on-going, the escapement estimate for this population is not yet available, but will likely be similar to last year's return of approximately 3,500 adults. The smolt production contributing to the 2016 return (from the 2013 parental brood of 10,378 adults) was the lowest juvenile migration recorded since 1996, possibly due to the drought conditions of 2014. The 2016 adult return may have also been impacted by poor marine conditions existing during the 2015-2016 marine residence of Strait of Georgia coho salmon.
3) Page 24: Clarification - under Area G Summary - section has been revised to include:

Area G did not fish until August 6 and then the fishery stayed open until Sept 30.
4) Page 34: Clarification - Paragraph has been revised to:
" In 2016 marine sport fisheries were monitored by creel surveys in three main areas; 1) Juan de Fuca including Victoria (south of Cadboro Point) and Juan de Fuca Strait through Subareas 20-1; 2) Portions of the Strait of Georgia including Areas 14 through 18, that portion of Area 19 north of Cadboro Point, Areas 28 and 29; and 3) Johnstone Strait including Areas 11 to 13. Monitoring of the Strait of Georgia sport fishery took place from June-October (not all areas were surveyed every month), and Juan de Fuca Strait sport fishery (March to October) has been fairly consistent from year to year using an access point (landing site) survey for collecting catch, CPUE, and biological information combined with an aerial survey for effort counts. In addition, logbook programs, directed at estimating the sport catch by fishing guides during guided trips, were conducted in the Campbell River and Victoria Areas in 2016. The Johnstone Strait creel survey commenced in Area 13 in May and continued through until the end of September, and from June through August to included Areas 11 and 12."
5) Page 27: Clarification - Paragraph on Cowichan chinook has been revised to:

Despite strong returns in 2016 relative to expectations, this population continues to be a stock of concern. There are continuing improvements to the returns to Cowichan River, to the point of getting near the escapement target, however it continues to be a stock of concern until such time that the run can be considered to be no longer at risk. Three generations would be the time frame (9 years).
6) Page 50 - Clarification - IFR coho. Paragraph 4 states "in 2016 an ER of 3-5\% was permitted in Canadian fisheries" yet in paragraph 6 it states that "Based on an analysis etc. .... a decision was made to increase the ER from $3 \%$ to a maximum of $10 \%$ for Canadian fisheries in SBC." And then on page 54, paragraph 1, the report states "In 2016 DFO returned to a 3\% ER on IFR coho."

Clarification - Paragraph below has been added to this section:
In 2016, Canada did not articulate an ER objective for IFR coho domestically given that the models for assessing fisheries impacts were under review and could not measure compliance with an ER objective. Instead, the objective articulated domestically was "to manage Canadian fisheries in a highly precautionary manner with fisheries management measures similar to those in place prior to 2014".
7) Page 60 - Section 11.4.1 Tidal Recreational Fisheries, the section below was deleted from this sentence. Chum opportunities are typically opened at full limits in the Johnstone Strait area., but may be reduced based on rum-size estimates of Fraser River chum, which compose the majority of the chum caught in this area.
8) Page 75: The text for sections 14.4.1 and 14.4.2 (tidal/non-tidal) were reversed.

# 2016 POST SEASON REPORT UNITED STATES SALMON FISHERIES OF RELEVANCE TO THE PACIFIC SALMON TREATY 

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## POST SEASON REPORT

## I. PRELIMINARY 2016 SOUTHEAST ALASKA FISHERIES

## NORTHERN BOUNDARY AREA FISHERIES

District 104 Purse Seine Fishery

The 2009 Pacific Salmon Treaty (PST) Agreement calls for abundance based management of the District 104 purse seine fishery. The agreement allows the District 104 purse seine fishery to harvest 2.45 percent of the Annual Allowable Harvest (AAH) of Nass and Skeena sockeye salmon prior to Alaska Department of Fish and Game (ADFG) statistical week 31 (referred to as the treaty period). The AAH is calculated as the total run of Nass and Skeena sockeye salmon minus either the escapement requirement of 1.1 million (200,000 Nass and 900,000 Skeena) or the actual in-river escapement, whichever is less.

The District 104 purse seine fishery opens by regulation on the first Sunday in July. In 2016, the initial opening was July 3 (week 28). The pre-week 31 fishing plan for District 104 was based on the preseason Canadian Department of Fisheries and Oceans (DFO) forecast returns of approximately $1,959,000$ Nass and Skeena sockeye salmon. Using this forecast, the 2016 preweek 31 AAH was approximately 21,000 Nass and Skeena sockeye salmon in the District 104 purse seine fishery. In the 2016 Treaty period (Alaska statistical weeks 28-30), 110,346 sockeye were harvested during a 15 and 12-hour opening in Week 28; two 12-hour opening in Week 29, and one 6-hour opening in week 30 (Table 1). A total of 106 purse seine vessels fished at some time in the district during the Treaty period. In past years $60 \%$ to $80 \%$ of Treaty-period sockeye salmon have been of Nass and Skeena origin, therefore we would anticipate between 66,200 and 88,200 Nass and Skeena sockeye may have been harvested in the District 104 purse seine fishery during the 2016 Treaty period. The final number of Nass and Skeena sockeye salmon harvested, and the actual harvest by stock, will not be available until harvest, escapement, and stock composition estimates are finalized for the year.

In 2016, a total of $3,659,894$ pink salmon, 405,989 sockeye salmon, 348,647 chum salmon, 123,696 coho salmon, and 12,206 Chinook salmon were harvested in the District 104 purse seine fishery (Table 1). The number of days that the fishery was open was well below the 1985-2015 average (Figure 1). The number of boats fishing was above average during the first two weeks of the season and then dropped below average for the remainder of the fishery (Figure 2). Chinook salmon harvests were well above average in most weeks of the fishery, and the harvest of 12,206 fish was $180 \%$ of the 1985-2015 average (Figure 3). Sockeye salmon harvests were above average early in the season (Figure 4) and the treaty period (week 28-30) harvest of 110,346 was $110 \%$ of the 1985-2015 average. The total sockeye salmon harvest of 405,989 was $84 \%$ of the 1985-2015 average of 482,000 fish. Harvests of coho salmon were far above average in weeks 28 and 29 and then dropped below average for the remainder of the season (Figures 5) and the overall harvest was close to the long-term average. Pink salmon harvests started off strong, but were well below average during the normal peak weeks of the fishery-the overall harvest was only $43 \%$ of the long-term average (Figure 6). Chum salmon harvests also started off very strong in weeks 28 and 29, but were below average through the remainder of the season (Figure 7).

Since the Pacific Salmon Treaty was signed in 1985, the number of hours open, boats fishing and boat-days fished in the pre-Week 31 annex period in District 104 are down 55\%, 61\% and 84\% respectively compared to the averages in the pre-treaty 1980-1984 period (Table 2). The total pre-week 31 Treaty-period sockeye salmon harvest is also down $47 \%$. The seine fleet moves freely between districts as various species are harvested, so seining opportunities elsewhere affect the effort and catch in District 104.

Table 1.-Catch and effort in the Alaska District 104 purse seine fishery, 2016.

| Week/ Opening | Start <br> Date | Chinook | Sockeye | Coho | Pink | Chum | Boats | Hours |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 28 | 7/3 | 578 | 11,917 | 3,905 | 61,938 | 45,480 | 14 | 15 |
| 28B | 7/7 | 918 | 16,034 | 16,380 | 250,125 | 60,300 | 82 | 12 |
| 29 | 7/10 | 1,348 | 26,127 | 22,224 | 424,441 | 66,254 | 77 | 12 |
| 29B | 7/14 | 1,112 | 45,554 | 27,394 | 734,522 | 52,747 | 71 | 12 |
| 30 | 7/17 | 174 | 10,714 | 4,054 | 99,457 | 7,229 | 37 | 6 |
| 31 | 7/24 | 237 | 17,571 | 5,005 | 164,401 | 8,371 | 42 | 15 |
| 31B | 7/28 | 1,196 | 53,211 | 12,281 | 408,116 | 20,049 | 49 | 15 |
| 32 | 7/31 | 2,256 | 120,948 | 13,988 | 671,348 | 32,590 | 69 | 39 |
| 32B | 8/4 | 1,556 | 56,500 | 6,641 | 402,943 | 22,242 | 62 | 39 |
| 33 | 8/8 | 743 | 20,791 | 4,538 | 190,863 | 13,058 | 46 | 39 |
| 33B | 8/12 | 1,303 | 11,896 | 3,166 | 94,133 | 7,185 | 48 | 15 |
| 34 | 8/15 | 327 | 7,642 | 1,841 | 91,256 | 6,603 | 41 | 15 |
| 34B | 8/18 | 458 | 7,084 | 2,279 | 66,351 | 6,539 | 32 | 15 |
|  |  |  |  |  |  | Permits |  |  |
|  |  |  |  |  |  | Fished |  |  |
| Weeks 28-30 |  | 4,130 | 110,346 | 73,957 | 1,570,483 | 232,010 | 106 | 57 |
| Weeks 31-35 |  | 8,076 | 295,643 | 49,739 | 2,089,411 | 116,637 | 101 | 192 |
| Total |  | 12,206 | 405,989 | 123,696 | 3,659,894 | 348,647 | 134 | 249 |

Table 2.-Fishing opportunity, effort, and sockeye salmon harvest prior to week 31 in the District 104 purse seine fishery, 1980-2016.

| Year | Hours <br> Fished | Individual Permits Fished | $\begin{gathered} \text { Days } \\ \text { Fished } \\ (1 \mathrm{~d}=15 \mathrm{hrs}) \\ \hline \end{gathered}$ | Approximate Boat-Days | Sockeye <br> Harvest | Sockeye <br> Catch per <br> Boat-Day |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |
| 1980 | 207 | 244 | 13.8 | 2,877 | 266,273 | 93 |
| 1981 | 132 | 212 | 8.8 | 1,108 | 185,188 | 167 |
| 1982 | 117 | 255 | 7.8 | 1,435 | 213,150 | 149 |
| 1983 | 108 | 241 | 7.2 | 1,211 | 170,306 | 141 |
| 1984 | 132 | 174 | 8.8 | 805 | 103,319 | 128 |
| 1985 | 84 | 141 | 5.6 | 502 | 100,590 | 200 |
| 1986 | 108 | 194 | 7.2 | 968 | 91,320 | 94 |
| 1987 | 90 | 134 | 6 | 457 | 72,385 | 158 |
| 1988 | 108 | 210 | 7.2 | 994 | 248,789 | 250 |
| 1989 | 84 | 135 | 5.6 | 438 | 157,566 | 360 |
| 1990 | 42 | 171 | 2.8 | 276 | 169,943 | 615 |
| 1991 | 41 | 134 | 2.7 | 243 | 98,583 | 406 |
| 1992 | 29 | 108 | 1.9 | 142 | 79,643 | 561 |
| 1993 | 45 | 171 | 3 | 343 | 163,189 | 476 |
| 1994 | 55 | 84 | 3.7 | 202 | 158,524 | 783 |
| 1995 | 58 | 109 | 3.9 | 218 | 71,376 | 328 |
| 1996 | 31 | 113 | 2.1 | 128 | 215,144 | 1,684 |
| 1997 | 56 | 159 | 3.7 | 409 | 572,942 | 1,402 |
| 1998 | 32 | 78 | 2.1 | 89 | 17,394 | 196 |
| 1999 | 30 | 38 | 2 | 44 | 7,664 | 174 |
| 2000 | 81 | 66 | 5.4 | 192 | 48,969 | 255 |
| 2001 | 50 | 95 | 3.3 | 182 | 203,090 | 1,115 |
| 2002 | 72 | 44 | 4.8 | 124 | 26,554 | 215 |
| 2003 | 52 | 40 | 3.5 | 97 | 84,742 | 875 |
| 2004 | 107 | 24 | 7.1 | 102 | 30,758 | 302 |
| 2005 | 68 | 38 | 4.5 | 93 | 35,690 | 382 |
| 2006 | 95 | 39 | 6.3 | 117 | 89,615 | 766 |
| 2007 | 50 | 68 | 3.3 | 136 | 112,135 | 824 |
| 2008 | 33 | 17 | 2.2 | 22 | 6,262 | 281 |
| 2009 | 72 | 38 | 4.8 | 95 | 15,971 | 168 |
| 2010 | 55 | 21 | 3.7 | 39 | 4,617 | 118 |
| 2011 | 84 | 29 | 5.6 | 77 | 25,280 | 329 |
| 2012 | 75 | 30 | 5.0 | 93 | 18,300 | 196 |
| 2013 | 46 | 36 | 3.1 | 59 | 13,102 | 222 |
| 2014 | 60 | 101 | 4 | 260 | 115,015 | 442 |
| 2015 | 70 | 39 | 4.7 | 100 | 43,873 | 439 |
| 2016 | 57 | 106 | 3.8 | 313 | 110,346 | 353 |
| Avg. 80-84 | 139 | 225 | 9 | 1,487 | 187,647 | 136 |
| Avg. 85-15 | 63 | 88 | 4 | 236 | 100,293 | 468 |
| \% Change | -55\% | -61\% | -55\% | -84\% | -47\% | 245\% |



Figure 1.-Days open by week in the District 104 purse seine fishery, 2016.


Figure 2.-Number of boats fishing by week in the District 104 purse seine fishery, 2016.


Figure 3.-Chinook salmon harvest by week in the District 104 purse seine fishery, 2016.


Figure 4.-Sockeye salmon harvest by week in the District 104 purse seine fishery, 2016.


Figure 5.-Coho salmon harvest by week in the District 104 purse seine fishery, 2016.


Figure 6.-Pink salmon harvest by week in the District 104 purse seine fishery, 2016.


Figure 7.-Chum salmon harvest by week in the District 104 purse seine fishery, 2016.

## District 101 Drift Gillnet Fishery

The 2009 PST agreement calls for abundance based management of the District 101 (Tree Point) drift gillnet fishery. The agreement specifies a harvest of 13.8 percent of the AAH of the Nass River sockeye run. The AAH is calculated as the total run of Nass sockeye salmon minus either the escapement requirement of 200,000 or the actual in-river escapement, whichever is less. The return of Nass sockeye salmon was forecast at 679,000 in 2016 which, minus an escapement goal of 200,000, would result in an AAH of about 479,000. Using this forecast, the 2016 allowable harvest in the District 101 drift gillnet fishery was approximately 66,102 Nass River sockeye salmon.

The District 101 drift gillnet fishery opens by regulation on the third Sunday in June, which was June 19 in 2016. During the early weeks of the fishery, management is based on the run strength of Alaska wild stock chum and sockeye salmon and on the run strength of Nass River sockeye salmon. Beginning in the third week of July, when pink salmon stocks begin to enter the fishery in large numbers, management emphasis shifts by regulation to that species. By regulation, the District 101 Pink Salmon Management Plan begins the third Sunday in July and sets gillnet fishing time in this district in relation to the District 101 purse seine fishing time. Beginning in Week 35 (August 21) management was based on the strength of wild stock fall chum and coho salmon.

The District 101 drift gillnet fishery opened Sunday June 19 (week 26) in 2016. The number of days the fishery was open was near average all season (Figure 8), but the number of boats fishing during weekly openings was below average throughout the season (Figure 9). The total number of individual boats fishing during the season was 75 , which was $69 \%$ of the 1985-2015 average of 109 boats. A total of 39,912 sockeye salmon were harvested, which was only $33 \%$ of the 1985-2015 average of 119,957 fish and was the third lowest harvest since the inception of the Pacific Salmon Treaty (Table 3). Harvests of sockeye salmon were below treaty period averages until late in the season (Figure 10). The cumulative sockeye salmon harvest prior to the initiation of the PSMP in Week 30 was 14,686 fish, or about $38 \%$ of the season's total sockeye salmon harvest. The final number of Nass River sockeye harvested at Tree Point will not be available until catch, escapement, and stock composition estimates are finalized for the 2016 season. In
past years approximately 65\% of the District 101 gillnet sockeye harvest has been of Nass River origin, therefore we would anticipate that approximately 25,900 Nass River sockeye may have been harvested in the District 101 gillnet fishery in 2016.

Coho salmon harvests were near average for most weeks of the season and the total harvest of 46,393 fish was $94 \%$ of the treaty period average (Figure 11). Pink salmon harvests were near or above average all season and the total harvest of 561,021 fish was $110 \%$ of average (Figure 12). Chum salmon harvests were near or below average in most weeks of the fishery and the total harvest of 273,608 fish was $90 \%$ of average (Figure 13). Chinook salmon harvests were near average throughout the season (Figure 14).

Table 3.-Weekly harvest and effort in the Alaska District 101 commercial drift gillnet fishery, 2016.

|  | Start |  |  |  |  |  |  |  |
| ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
| Week | Date | Chinook | Sockeye | Coho | Pink | Chum | Boats | Hours |
| 26 | $6 / 19$ | 336 | 3,882 | 481 | 162 | 19,767 | 42 | 96 |
| 27 | $6 / 26$ | 311 | 4,138 | 783 | 10,312 | 26,722 | 45 | 96 |
| 28 | $7 / 3$ | 153 | 3,286 | 2,121 | 34,097 | 35,428 | 57 | 96 |
| 29 | $7 / 10$ | 103 | 3,380 | 1,390 | 48,067 | 24,022 | 48 | 96 |
| 30 | $7 / 17$ | 36 | 3,200 | 629 | 84,243 | 15,050 | 40 | 96 |
| 31 | $7 / 24$ | 11 | 3,945 | 995 | 83,336 | 22,811 | 44 | 96 |
| 32 | $7 / 31$ | 24 | 2,581 | 1,248 | 69,669 | 10,590 | 43 | 120 |
| 33 | $8 / 7$ | 37 | 7,257 | 1,896 | 100,799 | 9,805 | 41 | 120 |
| 34 | $8 / 14$ | 29 | 4,199 | 2,247 | 76,026 | 7,572 | 43 | 96 |
| 35 | $8 / 21$ | 96 | 2,210 | 4,258 | 43,931 | 17,347 | 41 | 96 |
| 36 | $8 / 28$ | 25 | 810 | 5,857 | 8,919 | 20,430 | 39 | 96 |
| 37 | $9 / 4$ | 16 | 899 | 10,416 | 1,356 | 24,924 | 44 | 96 |
| 38 | $9 / 11$ | 6 | 109 | 6,532 | 101 | 21,585 | 42 | 96 |
| 39 | $9 / 18$ | 7 | 10 | 4,786 | 3 | 12,248 | 32 | 96 |
| 40 | $9 / 25$ | 1 | 6 | 2,754 | 0 | 5,307 | 22 | 96 |
| Total |  | 1,191 | 39,912 | 46,393 | 561,021 | 273,608 | 75 | 1,488 |
| $1985-2015$ Avg. | 1,495 | 119,958 | 49,580 | 508,481 | 305,000 | 110 | 1,364 |  |

Table 4.-Sockeye salmon harvest in the Alaska District 101 gillnet fishery, 1985 to 2016, and comparison of harvest and effort (boats, hours, and boat-hours) between weeks 26 and 35 when sockeye salmon are most abundant in this district.

| Year |  | Total <br> Sockeye <br> Harvest | Catch and Effort between Weeks 26-35 |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  | Sockeye <br> Harvest | Individual <br> Permits Fished | Total <br> Hours Open | Boat- <br> Hours ${ }^{1}$ |
|  |  |  |  |  |  |  |
|  | 1985 | 173,100 | 159,021 | 155 | 1,032 | 106,209 |
|  | 1986 | 145,699 | 143,286 | 201 | 960 | 109,490 |
|  | 1987 | 107,503 | 106,638 | 178 | 615 | 64,104 |
|  | 1988 | 116,115 | 115,888 | 192 | 756 | 93,072 |
|  | 1989 | 144,936 | 130,024 | 178 | 1,023 | 117,465 |
|  | 1990 | 85,691 | 78,131 | 159 | 840 | 70,421 |
|  | 1991 | 131,492 | 123,508 | 136 | 984 | 80,064 |
|  | 1992 | 244,649 | 243,878 | 118 | 1,080 | 94,159 |
|  | 1993 | 394,098 | 390,299 | 149 | 1,032 | 102,814 |
|  | 1994 | 100,377 | 98,725 | 144 | 984 | 74,408 |
|  | 1995 | 164,294 | 151,131 | 140 | 1,008 | 82,512 |
|  | 1996 | 212,403 | 175,569 | 130 | 1,104 | 86,108 |
|  | 1997 | 169,474 | 152,662 | 138 | 1,008 | 81,672 |
|  | 1998 | 160,506 | 159,307 | 124 | 1,044 | 87,358 |
|  | 1999 | 160,028 | 158,268 | 118 | 1,032 | 80,424 |
|  | 2000 | 94,651 | 94,399 | 95 | 912 | 49,488 |
|  | 2001 | 80,041 | 62,129 | 76 | 1,020 | 46,874 |
|  | 2002 | 120,353 | 106,360 | 76 | 1,008 | 42,528 |
|  | 2003 | 105,263 | 96,921 | 71 | 1,104 | 44,008 |
|  | 2004 | 142,357 | 141,395 | 61 | 1,104 | 42,400 |
|  | 2005 | 79,725 | 75,875 | 70 | 1,104 | 40,864 |
|  | 2006 | 62,770 | 53,048 | 48 | 840 | 28,265 |
|  | 2007 | 66,822 | 50,642 | 56 | 1,032 | 33,713 |
|  | 2008 | 34,113 | 30,672 | 54 | 936 | 31,961 |
|  | 2009 | 69,859 | 69,325 | 65 | 1,080 | 43,432 |
|  | 2010 | 62,680 | 61,987 | 68 | 1,008 | 45,135 |
|  | 2011 | 88,618 | 87,744 | 87 | 840 | 47,627 |
|  | 2012 | 62,506 | 40,518 | 85 | 1,008 | 43,695 |
|  | 2013 | 54,575 | 45,413 | 92 | 1,104 | 59,437 |
|  | 2014 | 55,828 | 49,722 | 73 | 1,095 | 44,551 |
|  | 2015 | 28,155 | 27,365 | 71 | 912 | 35,946 |
|  | 2016 | 39,912 | 38,078 | 71 | 1,008 | 44,640 |
| Average 1985-2015 |  | 119,957 | 112,253 | 110 | 987 | 64,845 |

${ }^{1}$ Boat-hours equals the sum of all weekly estimates of boat-hours: boats fished multiplied by open hours. Boat-hours does not equal individual permits fished multiplied by total open hours.


Figure 8.-Days open by week in the District 101 drift gillnet fishery, 2016.


Figure 9.-Number of boats fishing by week in the District 101 drift gillnet fishery, 2016.


Figure 10.-Sockeye salmon harvest by week in the District 101 drift gillnet fishery, 2016.


Figure 11.-Coho salmon harvest by week in the District 101 drift gillnet fishery, 2016.


Figure 12.-Pink salmon harvest by week in the District 101 drift gillnet fishery, 2016.


Figure 13.-Chum salmon harvest by week in the District 101 drift gillnet fishery, 2016.


Figure 14.-Chinook salmon harvest by week in the District 101 drift gillnet fishery, 2016.

## Pink, Sockeye, and Chum Salmon Escapements

Escapements of pink salmon were generally strong throughout southern Southeast Alaska, but were below average throughout much of northern Southeast Alaska inside waters. The total 2016 Southeast Alaska pink salmon escapement index of 10.08 million index fish ranked $27^{\text {th }}$ since 1960. Biological escapement goals were met in the Southern Southeast and Northern Southeast Outside subregions, but escapements in the Northern Southeast Inside Subregion were below goal in 2016 (Table 5). On a finer scale, escapements met or exceeded management targets for 8 of 15 districts in the region and for 30 of the 46 pink salmon stock groups in Southeast Alaska. The Southern Southeast Subregion includes all of the area from Sumner Strait south to Dixon Entrance (Districts 101-108). The escapement index value of 6.6 million was within the escapement goal range of 3.0 to 8.0 million index fish. The pink salmon harvest of 16.3 million in the Southern Southeast Subregion was $75 \%$ of the recent 10 -year average. The overall Southeast Alaska pink salmon harvest of 18.4 million fish was approximately $50 \%$ of the 20062015 average of 38.1 million.

Table 5.-Southeast Alaska 2016 pink salmon escapement indices and biological escapement goals by subregion (in millions).

|  |  | 2016 Pink |  |  |  |
| :--- | :---: | :---: | :---: | :---: | :---: |
|  |  |  | Biological Escapement Goal |  |  |
| Subregion |  |  | Salmon Index |  |  |
|  | Lower Bound | Upper Bound |  |  |  |

Sockeye salmon returns throughout Southeast Alaska were mixed in 2016, and escapement targets were met for 11 of the 13 sockeye salmon systems with formal escapement goals. The Hugh Smith Lake adult sockeye salmon escapement was 12,900 , which was within the optimal escapement goal range of 8,000 to 18,000 adult sockeye salmon. Based on the expanded peak foot survey count, the escapement of sockeye salmon into McDonald Lake was estimated to be 15,600 fish, which was far below the sustainable escapement goal range of 55,000 to 120,000.

For summer-run chum salmon, lower bound sustainable escapement goals were met for two of the three subregions in Southeast Alaska. In Southeast Alaska, runs are broken into summer and fall runs. The Southern Southeast summer-run chum salmon stock group is composed of an aggregate of 15 summer-run chum salmon streams on the inner islands and mainland of southern Southeast Alaska, from Sumner Strait south to Dixon entrance, with a sustainable escapement goal of 62,000 index spawners (based on the aggregate peak survey to all 15 streams). Summer chum salmon escapements were above average at most index streams in southern Southeast Alaska, and the index of 90,000 in 2016 was well above goal (Figure 15).

Cholmondeley Sound is the only area in southern Southeast Alaska with a formal escapement goal for fall chum salmon. Fall chum salmon runs are monitored in Cholmondeley Sound through aerial surveys at Disappearance and Lagoon creeks. The escapement index of 30,000 just reached the lower bound of the sustainable escapement goal range of 30,000 to 48,000 index spawners (based on the aggregate peak survey to both streams; Figure 16).


Figure 15.-Observed escapement index value by year (solid circles) and the sustainable escapement goal threshold of 62,000 index spawners (horizontal line) for wild summerrun chum salmon in the Southern Southeast Subregion, 1980-2016.


Figure 16.-Observed escapement index value by year (solid circles) and the sustainable escapement goal range of 30,000 to 48,000 index spawners (shaded area) for Cholmondeley Sound fall-run chum salmon, 1980-2016.

## TRANSBOUNDARY AREA FISHERIES

## Stikine River Area Fisheries

The initial preseason forecast for large Chinook salmon returning to the Stikine River was approximately 33,900 fish, which allowed for directed Chinook salmon fisheries in District 108. Since terminal Chinook salmon run projections were not available early in the season, the management of District 108 commercial fisheries was based on the preseason forecast and then performance in marine and inriver fisheries. The postseason run reconstruction for large Chinook salmon returning to the Stikine River was 15,287 fish, with an escapement of 10,343 fish, which was below the goal range of 14,000 to 28,000 fish.

The 2016 preseason forecast for sockeye salmon returning to the Stikine River was 223,000 fish, which was well above the recent 10-year average of 172,000 fish. The 2016 forecast included approximately 87,000 wild Tahltan (39\%), 42,000 enhanced Tahltan (19\%), 38,000 enhanced Tuya ( $17 \%$ ), and 56,000 mainstem ( $25 \%$ ) sockeye salmon. Due to the near identical return timing of the Tahltan Lake and Tuya Lake stocks, any open fishing periods in District 108, and to a lesser extent in District 106, are determined by the inseason abundance estimate of the Tahltan Lake return. Typically, the Tahltan Lake and Tuya Lake sockeye salmon run timing peaks in statistical week 27 (June 26-July 2) through the Districts 106 and 108 fisheries. During an average Tahltan Lake run significant numbers of sockeye salmon could be present as early as statistical week 25 (June 12-18) and as late as statistical week 31 (July 24-30). The 2016 returns of local area sockeye salmon stocks were expected to be average.

Directed commercial fishing for Stikine River Chinook salmon occurred during the first three weeks of May in District 108. The directed drift gillnet fishery began May 2 for a 24 hour fishing period and continued for one day a week for the following two weeks. Effort was generally low and harvests were poor each opening. The District 108 directed troll fishery is linked to drift gillnet fishery. As a result the troll fishery was open three days a week for the first three weeks of May. Effort and harvest in the troll fishery were variable from week to week. Due to the poor performance of both inriver and marine catches, directed commercial fishing was closed until the beginning of the sockeye salmon fishery.

The District 106 and 108 drift gillnet sockeye salmon fisheries opened Monday, June 13 (week 25). The initial opening in both districts was limited to two days and area was limited in District 108 for Stikine River Chinook salmon conservation. The following week, both districts were opened for an initial three days and again area was limited in District 108. A two day midweek occurred in District 108 as it was apparent from both inriver catches and marine catches that the Stikine River sockeye run was developing as forecasted if not better. Beginning in week 27, area restrictions were relaxed in District 108 and fishing time was again extensive with 5 days as it was apparent that the Tahltan River component of the run was higher than the preseason forecast. District 106 open time remained at three days a week. Open time in District 106 was three to four days a week for the remainder of the sockeye salmon fishery and open time in District 108 was three to five days a week as sockeye salmon abundance estimates continued to increase (Tables 6 and 7). The preliminary postseason assessment for Stikine River sockeye salmon was 253,275 fish and included 104,504 wild Tahltan (41\%), 50,661 enhanced Tahltan (20\%), 35,271 Tuya (14\%), and 62,666 Mainstem (25\%) fish.

Districts 106 and 108 were managed based on pink salmon abundance during the month of August. Three day openings occurred in weeks 32 through 34 and the final opening for pink salmon management was for two days in week 35 (Figures 17 and 24). In early September, management focus switched to coho salmon and the fisheries continued to be open for two or three days weekly through the remainder of the fisheries.

The number of permits participating in the District 106 weekly openings was above average in many weeks (Figure 18), but the seasonal number of permits fished was $91 \%$ of average (Table 6). The number of permits participating in the District 108 fishery was well below average during the directed Chinook salmon fishery in May, but was above average in many weeks of the sockeye salmon fishery; the seasonal number of permits fished was right at the recent 10-year average of 141 permits (Figure 25; Table 7).

During the 2016 season, 358,309 pink salmon, 106,649 sockeye salmon, 130,236 chum salmon, 122,101 coho salmon, and 2,094 Chinook salmon were harvested in the District 106 drift gillnet fishery (Table 6). Chinook salmon harvests were generally above average from late June through mid-July (Figure 19) and were comprised of $35 \%$ Alaska hatchery origin fish. Sockeye salmon harvests were below average in the first three weeks of the season, but then increased to above average from early July until mid-August (Figure 20). The total sockeye salmon harvest of 106,649 fish was $124 \%$ of the recent 10 -year average and 21,598 were estimated to be of Stikine River origin. Harvests of coho salmon were below average in most weeks until mid-September. The overall harvest of 122,101 coho salmon was $85 \%$ of the recent 10 -year average of 143,509 fish (Figure 21). Pink salmon harvests were above average from the second week of July through early August (Figure 22), and the overall harvest of 358,309 fish was $135 \%$ of the recent 10 -year average. Chum salmon harvests were below average in most weeks and the overall harvest was $74 \%$ of average (Figure 23).

During the 2016 season, 35,250 pink salmon, 70,143 sockeye salmon, 200,653 chum salmon, 22,146 coho salmon, and 10,024 Chinook salmon were harvested in the District 108 drift gillnet fishery (Table 7). Only 118 Chinook salmon were harvested in the directed fishery in May, but the harvest was above average in most weeks from mid-June to late July and was comprised of 50\% Alaska hatchery origin fish for the season (Figure 26). An estimated 1,707 Stikine River large Chinook salmon were harvested in District 108 from weeks 18 through 29 by subsistence, sport, troll, and drift gillnet fisheries. Sockeye salmon harvests were well above average during the peak weeks of the season (Figure 27) and the total sockeye salmon harvest of 70,143 fish was $188 \%$ of the recent 10 -year average. An estimated 59,613 fish, or $85 \%$ of the harvest, were estimated to be Stikine River sockeye salmon. The overall coho salmon harvest of 22,146 fish was below the recent 10-year average of 30,725 fish (Table 7, Figure 28). Pink salmon harvests were near or below average most of the season and the overall harvest was $75 \%$ of the recent 10 year average (Figure 29). Chum salmon harvests were near or above average throughout the season and the overall harvest of 200,653 fish was $127 \%$ of the recent 10 -year average (Figure 30).

Table 6.-Weekly salmon harvest in the Alaskan District 106 commercial drift gillnet fisheries, 2016. Harvests do not include Blind Slough terminal area harvests.

|  |  |  |  |  |  |  |  | Boat |  |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
| Week | Start Date | Chinook | Sockeye | Coho | Pink | Chum | Boats | Days | Days |
| 25 | 13-Jun | 191 | 1,235 | 512 | 44 | 2,203 | 31 | 2 | 62 |
| 26 | 20-Jun | 178 | 5,836 | 2,509 | 238 | 2,185 | 45 | 3 | 135 |
| 27 | 26-Jun | 338 | 9,536 | 4,497 | 2,610 | 6,501 | 54 | 3 | 162 |
| 28 | 3-Jul | 301 | 16,025 | 6,831 | 12,314 | 11,576 | 55 | 3 | 165 |
| 29 | 10-Jul | 209 | 14,842 | 6,317 | 38,366 | 26,171 | 56 | 4 | 224 |
| 30 | 17-Jul | 170 | 16,951 | 5,639 | 62,332 | 13,377 | 64 | 4 | 256 |
| 31 | 24-Jul | 115 | 14,196 | 4,212 | 76,520 | 16,777 | 64 | 3 | 192 |
| 32 | 31-Jul | 214 | 15,539 | 6,130 | 90,697 | 17,910 | 76 | 3 | 228 |
| 33 | 7-Aug | 174 | 5,700 | 3,503 | 37,148 | 5,017 | 52 | 3 | 156 |
| 34 | 14-Aug | 29 | 4,039 | 6,856 | 22,866 | 5,006 | 66 | 3 | 198 |
| 35 | 21-Aug | 73 | 1,809 | 5,586 | 8,510 | 3,036 | 73 | 2 | 146 |
| 36 | 28-Aug | 13 | 592 | 6,732 | 5,100 | 3,806 | 55 | 2 | 110 |
| 37 | 4-Sep | 1 | 286 | 7,945 | 1,364 | 4,240 | 61 | 2 | 122 |
| 38 | 11-Sep | 12 | 53 | 21,468 | 191 | 5,561 | 69 | 2 | 138 |
| 39 | 18-Sep | 26 | 10 | 19,451 | 9 | 4,614 | 74 | 3 | 222 |
| 40 | 25-Sep | 27 | 0 | 10,239 | 0 | 1,954 | 32 | 3 | 96 |
| 41 | 2-Oct | 23 | 0 | 3,674 | 0 | 302 | 15 | 2 | 30 |
| Total |  | 2,094 | 106,649 | 122,101 | 358,309 | 130,236 | 138 | 47 | 2,641 |
|  |  |  |  |  |  |  |  |  |  |
| $2006-2015$ | Average | 2,220 | 86,054 | 143,510 | 265,844 | 174,986 | 151 | 48 | 2,692 |
|  |  |  |  |  |  |  |  |  |  |
| 2016 as \% of Average | $94 \%$ | $124 \%$ | $85 \%$ | $135 \%$ | $74 \%$ | $91 \%$ | $98 \%$ | $98 \%$ |  |



Figure 17.- Days open by week in the District 106 drift gillnet fishery, 2016.


Figure 18.-Number of boats fishing by week in the District 106 drift gillnet fishery, 2016.


Figure 19.-Chinook salmon harvest by week in the District 106 drift gillnet fishery, 2016.


Figure 20.-Sockeye salmon harvest by week in the District 106 drift gillnet fishery, 2016.


Figure 21.-Coho salmon harvest by week in the District 106 drift gillnet fishery, 2016.


Figure 22.-Pink salmon harvest by week in the District 106 drift gillnet fishery, 2016.


Figure 23.-Chum salmon harvest by week in the District 106 drift gillnet fishery, 2016.

Table 7.-Weekly salmon harvest and effort in the Alaskan District 108 traditional commercial drift gillnet fishery, 2016a.

|  |  |  |  |  |  |  |  |  |  |
| ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
| Week | Start Date | Chinook | Sockeye | Coho | Pink | Chum | Boats | Days | Days |
| 19 | 2-May | 8 | 0 | 0 | 0 | 0 | 4 | 1 | 4 |
| 20 | 9-May | 33 | 0 | 0 | 0 | 0 | 11 | 1 | 11 |
| 21 | 16-May | 77 | 0 | 0 | 0 | 0 | 12 | 1 | 12 |
| 25 | 13-Jun | 1,495 | 444 | 33 | 3 | 364 | 50 | 2 | 100 |
| 26 | 20-Jun | 2,581 | 11389 | 469 | 43 | 3103 | 74 | 5 | 250 |
| 27 | 26-Jun | 2,544 | 22,283 | 961 | 245 | 5,902 | 85 | 5 | 347 |
| 28 | 3-Jul | 1,460 | 17,655 | 752 | 1,544 | 30,463 | 76 | 5 | 297 |
| 29 | 10-Jul | 858 | 8,382 | 509 | 4,463 | 27,325 | 58 | 5 | 230 |
| 30 | 17-Jul | 576 | 5,146 | 609 | 7,650 | 38,166 | 68 | 4 | 272 |
| 31 | 24-Jul | 139 | 1,654 | 626 | 7,547 | 40,069 | 63 | 3 | 189 |
| 32 | 31-Jul | 138 | 1,817 | 947 | 6,196 | 38,325 | 59 | 3 | 183 |
| 33 | 7-Aug | 63 | 587 | 787 | 5,228 | 11,179 | 38 | 3 | 114 |
| 34 | 14-Aug | 23 | 524 | 1,810 | 1,733 | 3,697 | 36 | 3 | 111 |
| 35 | 21-Aug | 2 | 161 | 1,163 | 519 | 1,158 | 22 | 2 | 44 |
| 36 | 28-Aug | 5 | 62 | 2,167 | 73 | 250 | 24 | 2 | 48 |
| 37 | 4-Sep | 3 | 22 | 1,579 | 6 | 121 | 17 | 2 | 34 |
| 38 | 11-Sep | 10 | 16 | 3,083 | 0 | 204 | 19 | 2 | 38 |
| 39 | 18-Sep | 2 | 1 | 2,141 | 0 | 63 | 12 | 3 | 30 |
| 40 | 25-Sep | 6 | 0 | 3,065 | 0 | 236 | 12 | 3 | 36 |
| 41 | 2-Oct | 1 | 0 | 1,445 | 0 | 28 | 7 | 2 | 14 |
| Total |  | 10,024 | 70,143 | 22,146 | 35,250 | 200,653 | 141 | 58 | 2,364 |
| $2006-2015$ Average | 11,332 | 37,376 | 30,724 | 46,758 | 158,200 | 141 | 53 | 2,160 |  |
| 2016 as $\%$ of Average | $88 \%$ | $188 \%$ | $72 \%$ | $75 \%$ | $127 \%$ | $100 \%$ | $109 \%$ | $109 \%$ |  |



Figure 24.-Days open by week in the District 108 drift gillnet fishery, 2016.


Figure 25.-Number of boats fishing by week in the District 108 drift gillnet fishery, 2016.


Figure 26.-Chinook salmon harvest by week in the District 108 drift gillnet fishery, 2016.


Figure 27.-Sockeye salmon harvest by week in the District 108 drift gillnet fishery, 2016.


Figure 28.-Coho salmon harvest by week in the District 108 drift gillnet fishery, 2016.


Figure 29.-Pink salmon harvest by week in the District 108 drift gillnet fishery, 2016.


Figure 30.-Chum salmon harvest by week in the District 108 drift gillnet fishery, 2016.

## Taku River Area Fisheries

The traditional drift gillnet fishery in District 111 targets salmon stocks bound for the transboundary Taku River. This fishery is managed for Chinook salmon from week 18 to week 25 when there are sufficient fish surplus to escapement to provide for a fishery. From week 26 to week 33 the fishery is managed for Taku River sockeye salmon, and from week 34 to week 42 for Taku River coho salmon. Also harvested in this fishery are salmon bound for Stephens

Passage and Port Snettisham streams as well as enhanced Chinook, sockeye, coho and chum salmon from Douglas Island Pink and Chum, Inc. (DIPAC) hatchery releases. The traditional fishery does not include harvests from the Speel Arm Special Harvest Area (SHA) inside Port Snettisham.

The escapement goal range for Taku River large Chinook salmon is 19,000 to 36,000 fish with a point goal of 25,500 fish. In years of high abundance, directed Chinook salmon fisheries can be implemented to harvest runs in excess of escapement needs. The 2016 preseason terminal run forecast for the Taku River of 29,200 large Chinook salmon did not allow for any directed Chinook salmon fisheries in District 111.

The escapement goal range for Taku River sockeye salmon is 71,000 to 80,000 fish, with a point goal of 75,000 fish. The 2016 Taku River sockeye salmon forecast was for an above average 210,000 fish, based on the average of Canadian stock-recruit and sibling forecasts. DIPAC forecast 254,000 enhanced sockeye salmon returning through District 111 waters to Port Snettisham.

An escapement goal range of 50,000 to 90,000 Taku River coho salmon with a point goal of 70,000 fish was adopted in early 2015. The U.S. management intent in 2016 was to pass a minimum of 75,000 coho salmon above the border, providing for escapement and a 5,000 fish Canadian assessment fishery. The preseason forecast was for an average inriver run of 127,000 coho salmon in the Taku River, and DIPAC forecast a return of 81,000 enhanced coho salmon from releases in Gastineau Channel. For 2016, DIPAC forecast returns totaling 893,000 enhanced chum salmon to Gastineau Channel and Limestone Inlet, which was below the recent average.

The traditional drift gillnet fishery in District 111 began on Sunday, June 19, 2016 (week 26). The initial drift gillnet opening of the season in District 111 was for two days, with a significant area restriction intended to minimize harvest of Taku River Chinook salmon abundance. Effort for the opening was 29 boats, which was well below the ten-year average of 51 boats. The sockeye salmon harvest was approximately half of the recent ten-year average and the chum salmon harvest was only $17 \%$ of the recent ten-year average (Figures 34 and 37). A total of 134 Chinook salmon were harvested, which was well below average for the week (Figure 33).

From early July through early August (weeks 27-32) effort in the District 111 drift gillnet fishery was generally below average, with a peak of 103 boats fishing in week 30 (Figure 32). Harvests of sockeye salmon were below average through mid-July, but then improved and the peak weekly catch of 47,511 in week 32 was nearly three times average for the week. Sockeye salmon harvests remained above average through week 36 (Figure 34). Weekly chum salmon catches were generally below average and approximately 446,000 fish were harvested from late June to mid-August (Figure 37). Most of the summer-run chum salmon harvest in District 111 consists of DIPAC hatchery fish returning to release sites in Gastineau Channel and Limestone Inlet. Chinook salmon harvests were below average through the tail end of the run and few fish were caught after mid-July (Figure 33). Pink salmon harvests were well below average through early August (Figure 36).

For the remainder of August and September (weeks 33-41), overall effort in the fishery was above or near average in most weeks and the fishery was open for three or four days of fishing weekly (Figure 31). The weekly number of boats fishing was near or above average from midAugust through late September (Figure 32). Harvests of coho salmon were below average from mid-August to late September (Figure 35). Pink salmon harvests were below average in all but week 33 (Figure 36). Chum salmon harvests were below the recent ten-year average from week 34 through 38. Although the chum salmon harvests were small in the final two weeks of the fishery, they were well above average for the statistical weeks (Figure 37).

A number of Chinook salmon stocks are known to contribute to the Juneau area sport fishery, including those from the Taku, Chilkat, and King Salmon rivers, and local hatchery stocks, but the major contributor of mature wild fish is believed to be the Taku River. Preliminary estimates indicate that approximately 635 of the Chinook salmon harvested in the Juneau sport fishery from weeks 16 through 28 were of Taku River origin (based on genetic stock identification analysis). The preliminary District 111 harvest of Taku River large Chinook salmon during the accounting period was 159 fish in the drift gillnet fishery, 635 in the sport fishery, and an estimated 30 in the personal use fishery, for a total of 824 . Harvests of Taku River large Chinook salmon in these fisheries from week 29 onwards were minimal and resulted in a total catch well below the U.S. base level catch of 3,500 fish. The preliminary escapement estimate of Taku River large Chinook salmon is 12,381 fish, which was well below the escapement goal range.

The 2016 traditional District 111 sockeye salmon harvest of 148,317 fish was $146 \%$ of the recent ten-year average. Peak catches of sockeye salmon occurred in weeks 32 and 33 (early-to-mid August; Figure 34). The Speel Arm SHA was opened continuously from the second week of August to mid-September to harvest enhanced DIPAC sockeye salmon returning to the Snettisham Hatchery. The lower bound of the Speel Lake sustainable escapement goal range of 4,000 to 9,000 fish was reached on August 14 and the final weir count was 5,571 sockeye salmon. The peak harvest in the Speel Arm SHA occurred in week 33, when 80 boats harvested 37,813 sockeye salmon and smaller numbers of other species of salmon. A total of 66,732 sockeye salmon were caught in the SHA in 2016. The preliminary escapement estimate of Taku River sockeye salmon is 174,000 fish, which was above the escapement goal range.

The 2016 traditional District 111 coho salmon harvest of 34,445 fish was $87 \%$ of the recent tenyear average (Figure 35). Approximately 76\% of the coho salmon were harvested in Taku Inlet, which was below the ten-year average of $83 \%$, and $23 \%$ were harvested from Stephens Passage and Port Snettisham. Coho salmon stocks harvested in District 111 include runs to the Taku River, Port Snettisham, Stephens Passage, and local Juneau area streams as well as Alaskan hatcheries. This was the second year of full production for DIPAC's revitalized enhanced coho salmon program. DIPAC enhanced coho salmon first appeared in the District 111 harvest in week 36 and comprised $21 \%$ to $72 \%$ of the harvest each remaining week of the fishery. DIPAC enhanced coho salmon contributed $21 \%$ of the 2016 District 111 traditional drift gillnet harvest. The preliminary escapement estimate of Taku River coho salmon is 87,700 fish, which was near the upper end of the escapement goal range.

The 2016 District 111 traditional pink salmon harvest of 44,668 fish was only 29\% of the tenyear average (Figure 36). The 2016 pink salmon escapement to the Taku River was unknown;
however, the number of pink salmon passing through the fish wheels at Canyon Island is used as an index of escapement. The 2016 Canyon Island pink salmon fish wheel catch of 1,369 fish (not including new $3^{\text {rd }}$ fish wheel catch) was only $13 \%$ of the 1996-2014 odd-year average, and was the lowest fish wheel catch since the program began in 1985.

The 2016 District 111 traditional fishery chum salmon harvest of 447,616 fish was $76 \%$ of the recent ten-year average, and was comprised almost entirely of summer run fish (Figure 37). The summer chum salmon run continues through mid-August (week 33) and is comprised mostly of domestic hatchery fish and small numbers of wild stocks. Chum salmon returning to DIPAC release sites in Gastineau Channel and Limestone Inlet contributed a major portion of the harvest, but quantitative contribution estimates are not available. Approximately $77 \%$ of the District 111 chum harvest was taken in Taku Inlet, and 21\% in Stephens Passage. The harvest of 1,885 fall-run chum salmon (i.e. chum salmon caught after week 33) was only $45 \%$ of the recent ten-year average. Most of these fall-run chum salmon are probably of wild Taku and Whiting River origin. Chum salmon escapement numbers to the Taku River are unknown; however, the numbers of fall chum passing through the fish wheels at Canyon Island is used as an index of escapement. The Canyon Island fish wheel project ceased operations on September 27, 2016, and the index of 66 chum salmon (not including new $3^{\text {rd }}$ fish wheel catch) was the lowest since the inception of the project.

Table 8.-Weekly salmon harvest in the Alaskan District 111 traditional commercial drift gillnet fishery, 2016 ${ }^{\text {a }}$.

|  |  |  |  |  |  |  |  | Boat |  |
| :---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
| Week | Start Date | Chinook | Sockeye | Coho | Pink | Chum | Boats | Days | Days |
| 26 | 19-Jun | 134 | 1,721 | 59 | 1 | 4,950 | 29 | 2 | 58 |
| 27 | 26-Jun | 163 | 3,471 | 246 | 116 | 30,075 | 47 | 3 | 141 |
| 28 | 3-Jul | 72 | 3,963 | 398 | 822 | 41,038 | 54 | 3 | 162 |
| 29 | 10-Jul | 46 | 5,387 | 1,538 | 3,098 | 155,756 | 70 | 4 | 280 |
| 30 | 17-Jul | 95 | 23,160 | 1,710 | 7,721 | 150,860 | 103 | 4 | 412 |
| 31 | 24-Jul | 27 | 14,382 | 982 | 5,049 | 26,758 | 76 | 4 | 304 |
| 32 | 31-Jul | 14 | 47,511 | 1,879 | 5,880 | 29,270 | 69 | 4 | 276 |
| 33 | 7-Aug | 8 | 27,605 | 2,287 | 21,116 | 7,024 | 114 | 4 | 456 |
| 34 | 15-Aug | 15 | 11,362 | 2,400 | 652 | 743 | 52 | 3 | 156 |
| 35 | 21-Aug | 2 | 8,340 | 5,118 | 206 | 550 | 54 | 3 | 162 |
| 36 | 28-Aug | 3 | 1,258 | 6,760 | 7 | 297 | 43 | 3 | 129 |
| 37 | 4-Sep | 2 | 135 | 4,831 | 0 | 135 | 34 | 3 | 102 |
| 38 | 11-Sep | 0 | 18 | 3,454 | 0 | 59 | 27 | 4 | 108 |
| 39 | 18-Sep | 1 | 4 | 1,863 | 0 | 77 | 15 | 4 | 60 |
| 40-41 | 25-Sep | 0 | 0 | 920 | 0 | 24 | 11 | 8 | 44 |
| Total |  | 582 | 148,317 | 34,445 | 44,668 | 447,616 | 170 | 56 | 2,850 |
| $2006-2015$ | Average | 1,581 | 101,680 | 39,730 | 153,665 | 587,805 | 185 | 56 | 2,983 |
| 2016 as \% of Average | $37 \%$ | $146 \%$ | $87 \%$ | $29 \%$ | $76 \%$ | $92 \%$ | $100 \%$ | $96 \%$ |  |

${ }^{\text {a }}$ The 2016 District 111 drift gillnet harvest and effort, as well as the 2006-2015 averages, are for the directed sockeye and coho salmon portions of the fishery only. There was no directed fishery for Chinook salmon in District 111 in 2016 due to a low Taku River preseason abundance forecast.


Figure 31.-Days open by week in the District 111 drift gillnet fishery, 2016.


Figure 32.-Number of boats fishing by week in the District 111 drift gillnet fishery, 2016.


Figure 33.-Chinook salmon harvest by week in the District 111 drift gillnet fishery, 2016.


Figure 34.-Sockeye salmon harvest by week in the District 111 drift gillnet fishery, 2016.


Figure 35.-Coho salmon harvest by week in the District 111 drift gillnet fishery, 2016.


Figure 36.-Pink salmon harvest by week in the District 111 drift gillnet fishery, 2016.


Figure 37.-Chum salmon harvest by week in the District 111 drift gillnet fishery, 2016.

## Transboundary River Joint Enhancement

The transport of sockeye salmon fry from the Snettisham Hatchery facility back to the Canadian lakes was complete on May 27, 2016. Approximately 3.9 million fry were released in Tahltan, King Salmon, and Tatsamenie lakes in Canada. The overall green egg to fry survival of $74 \%$ for
brood year (BY) 2015 releases (Table 9) was above the previous five-year average survival of 58.3\% (BY09-BY13) for Tatsamenie and Tahltan fry. Fry from one Tatsamenie stock incubator tested positive this year for IHNV, accounting for a loss of approximately 89,100 fry prior to transport/back-planting. After transporting BY15 fry back to their respective lakes, all TBR modules, incubators, and short-term fry rearing containers were broken down, cleaned, and disinfected prior to setting up to receive green eggs from BY16 egg-takes.

Brood year 2016 egg-takes were initiated on September 2 at Tahltan Lake, September 13 at Tatsamenie Lake, and September 9 at Trapper Lake. An estimated total of 7.8 million green eggs were collected from the three donor lakes. Tahltan Lake egg-takes were completed on September 23, and an estimated 5.3 million eggs in 11 egg lots were taken. Due to poor weather conditions, the receipt of six lots of Tahltan eggs was delayed by one or two days. Tatsamenie Lake egg-takes were completed on September 24th and 2.2 million eggs were collected in 4 lots. Due to poor weather conditions, the receipt of three lots of Tatsamenie eggs was delayed by one to three days. A single Trapper Lake egg-take occurred on September 9th. This one lot, estimated at 277,200 green eggs, was received at Snettisham Hatchery on September 10th and was delayed one day, due again to poor weather conditions. Adult sockeye salmon tissues were collected on the spawning grounds by contractors for DFO and shipped to the ADF\&G Juneau Fish Pathology laboratory via Snettisham Hatchery as per treaty agreement.

Table 9.-Summary of numbers and survival rates of brood year 2015 sockeye salmon fry released May 2016. Fish were raised at Snettisham Hatchery as part of the Transboundary River Salmon Enhancement Project.

| Brood stock | Release site | Number of <br> trips | Survival rate <br> to eyed stage | Survival rate <br> to release | Number <br> released |
| :--- | :---: | :---: | :---: | :---: | :---: |
| Tahltan | Tahltan Lk | 7 | $83.8 \%$ | $75.4 \%$ | $3,399,600$ |
| Tatsamenie | Upper Tats Lk | 1 | $77.9 \%$ | $73.4 \%$ | 384,300 |
| Tatsamenie | Upper Tats Lk, <br> Extended Rearing | 1 | $85.8 \%$ | $41.7 \%$ | 86,200 |
|  | Average/Totals | 9 | $83.3 \%$ | $73.9 \%$ | $3,870,100$ |

During the 2016 season, the ADF\&G Thermal Mark Lab processed 19,106 sockeye salmon otoliths collected by ADF\&G and DFO staff as part of the U.S./Canada fry-planting evaluation program. These collections came from commercial and test fisheries in both U.S. and Canadian waters on the Taku and Stikine Rivers over a 12-week period. The laboratory provided estimates on hatchery contributions for 93 distinct sample collections. Estimates of the percentage of hatchery fish contributed to commercial fishery catches were provided to ADF\&G and DFO fishery managers 24 to 48 hours after samples arrived at the lab.

## Alsek River Area Fisheries

Although harvest sharing arrangements of Alsek salmon stocks between Canada and the U.S. have not been specified, Annex IV of the Pacific Salmon Treaty calls for the development and implementation of cooperative abundance-based management plans and programs for Alsek River Chinook and sockeye salmon. Escapement goals are in place for Chinook and sockeye salmon stocks spawning at the Klukshu River, a tributary that flows into the Tatshenshini River, approximately 80 km northeast of its junction with the Alsek River. The principal escapement-
monitoring tool for Chinook, sockeye, and coho salmon stocks on the Alsek River is the Klukshu River weir, operated by Fisheries and Oceans Canada in cooperation with the ChampagneAishihik First Nation since 1976. In 2013, Canadian and U.S. biologists adopted a new biological escapement goal range of 7,500 to 11,000 sockeye salmon through the Klukshu River weir. The current biological escapement goal range for Klukshu River Chinook salmon, adopted in February 2013, is a range of 800 to 1,200 fish.

The Department of Fish and Game manages the Alsek River commercial set gillnet fishery to achieve the agreed upon escapement goal ranges. Time and area openings are adjusted by monitoring fishery performance data and comparing it to historical CPUE. The duration of weekly fishing periods is based on fishery performance data (CPUE) and Klukshu River weir data. Historically, gillnets have often been restricted to a maximum mesh size of 6 inches through July 1 to minimize Chinook salmon harvest. The mesh restriction was lifted in 2013 and 2014, but was reintroduced in 2015 and implemented again in 2016.

Preseason expectations were for above average runs in 2016 for both sockeye and Chinook salmon. The overall Alsek drainage sockeye salmon run was expected to be approximately 83,000 fish, which would have been above the recent ten-year average of 68,000 fish. The outlook for 2016 was based on a predicted run of 19,000 Klukshu River sockeye salmon, derived from the latest Klukshu River stock-recruitment data, a Klukshu River contribution rate of 23\% to the total run (based on mark-recapture results; 2000-04), and run size estimates using GSI (2005-06, 2011). Principal contributing brood years for the 2016 return were 2011 and 2012. The Klukshu River escapement in 2011 was approximately 21,400 sockeye salmon; well above the ten-year average of 15,600 fish. The sockeye salmon escapement in 2012 was 17,694, which was also above average. Based on the primary brood year escapements, the outlook for Klukshu River Chinook salmon in 2016 was for a return of 1,900 fish; slightly above the ten-year average of 1,400 fish.

The 2016 Alsek River set gillnet fishery opened Sunday June 5 (week 24). The total number of individual permits fishing during the season was 18, which was equal to the 2006-2015 average. The number of boats fishing during weekly openings was slightly above the recent ten-year average. The commercial fishery was opened for a total of 65.5 days which was twice the tenyear average of 32 days. The overall effort in boat-days was $277 \%$ of average (Table 10). Harvests of Chinook salmon through late June were below the recent ten-year average (Table 10). Harvests of sockeye salmon were below average in most weeks of the fishery and the total harvest of 6,709 fish was $43 \%$ of the $2006-2015$ average of 15,770 fish (Table 10). There was little effort after early August. In the past several years there has been reduced fishing effort during coho salmon season due to economic struggles and lack of pilots to transport fish to town. In 2016, only 652 coho salmon were harvested (Table 10).

The Klukshu River weir count of 7,584 sockeye salmon met the lower bound of the 7,500 to 11,000 fish escapement goal range. The count of 1,405 early run sockeye salmon (count through August 15) and the late run count of 6,179 were both below average. The 651 Chinook salmon counted through the Klukshu River weir fell below the established goal range of 800 to 1,200 Chinook salmon.

Table 10.-Weekly fishing effort and salmon harvest for Alsek River, 2016.

| Statistical Week | Start <br> Date | Catch |  |  |  |  | Effort |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  |  |  |  |  | Boats | Days | Boat Days |
|  |  | Chinook | Sockeye | Coho | Pink | Chum |  |  |  |
| 24 | 5-Jun | 28 | 136 | 0 | 0 | 0 | 11 | 1 | 11 |
| 25 | 12-Jun | 22 | 799 | 0 | 0 | 0 | 16 | 1 | 16 |
| 26 | 19-Jun | 21 | 1,067 | 0 | 0 | 0 | 15 | 1 | 15 |
| 27 | 26-Jun | 3 | 809 | 0 | 0 | 0 | 12 | 1 | 12 |
| 28 | 3-Jul | 5 | 1,196 | 0 | 0 | 0 | 12 | 1 | 12 |
| 29 | 10-Jul | 53 | 1,161 | 0 | 0 | 0 | 11 | 1 | 11 |
| 30 | 17-Jul | 0 | 365 | 0 | 0 | 1 | 8 | 1 | 8 |
| 31 | 24-Jul | 0 | 684 | 0 | 0 | 0 | 9 | 2 | 18 |
| 32 | 31-Jul | 0 | 284 | 0 | 0 | 0 | 7 | 1 | 7 |
| 33-35 ${ }^{\text {a }}$ | 7-Aug | 0 | 105 | 25 | 0 | 1 | 7 | 6 | 42 |
| $36^{\text {b }}$ | 28-Aug |  |  |  |  |  |  | 3 |  |
| $37-44^{\text {ac }}$ | 10-Sep | 0 | 2 | 630 | 0 | 2 | 8 | 46.5 | 372 |
| Total |  | 132 | 6,709 | 655 | 0 | 4 | 18 | 65.5 | 524 |
| 2006-2015 |  | 478 | 15,770 | 1,102 | 0 | 6 | 18 | 32 | 189 |
| 2016 as \% | Avg. | 28\% | 43\% | 59\% |  | 67\% | 100\% | 205\% | 277\% |

${ }^{\mathrm{a}}$ Includes weeks with fewer than three permits, confidential information so data combined in catch table.
${ }^{\mathrm{b}}$ Number of days the fishery was opened but not fished.
${ }^{\text {c }}$ Weeks 39-42 \& 44 were opened to fishing but not fished.

## SOUTHEAST ALASKA CHINOOK SALMON FISHERY

## All Gear Harvest

The 2016 SEAK Chinook salmon management programs were configured around an assumed draft abundance index (AI) of 2.06 for the 2016 fishing season (Table 1).

This was the eighth year that the Annex IV, Chapter 3 provisions of the 2009 PST Agreement were implemented. Therefore, the harvest limit for SEAK reflects a $15 \%$ reduction in allowable catch (AC) from that allowed under the 1999 PST Agreement. The preliminary total Chinook salmon harvest by all SEAK commercial fisheries was 318,730 fish, and the preliminary sport fish harvest was 70,000, for an all-gear harvest of 388,730 (Table 11). The preliminary all-gear PST harvest was 353,264 fish (Table 12).

Table 11.-Preliminary estimated all-gear Chinook salmon harvests in 2016.

| Gear | Total Harvest | AK <br> Hatchery <br> Harvest | Wild <br> Terminal <br> Exclusion | Alaska <br> Hatchery <br> Addon | Treaty <br> Harvest | Quota | O/U | \% O/U |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Troll | 276,432 | 13,780 | 405 | 10,362 | 265,666 |  |  |  |
| Sport | 70,000 | 10,300 | 0 | 8,269 | 61,731 |  |  |  |
| Drift Gillnet | 13,825 | 9,547 | 0 | 8,511 | 5,314 |  |  |  |
| Purse Seine | 28,244 | 8,256 | 0 | 7,921 | 20,323 <br> 0 | 0 |  |  |
| Set Gillnet | 230 | 0 | 0 | 0 | 230 |  |  |  |
| Total Net | 42,298 | 17,803 | 0 | 16,431 | 25,867 |  |  |  |
|  |  |  |  |  |  |  |  |  |
| Total All Gear | $\mathbf{3 8 8 , 7 3 0}$ | $\mathbf{4 1 , 8 8 3}$ | $\mathbf{4 0 5}$ | $\mathbf{3 5 , 0 6 2}$ | $\mathbf{3 5 3 , 2 6 4}$ |  |  |  |

Note: Annette Island and terminal area harvests are included.
Table 12.-Chinook all-gear harvests in Southeast Alaska, 1987 to 2016, and deviation from the ceiling for years in which there were ceilings. Harvests are in thousands.

| Year | Total Harvest | Add-on and Exclusion Harvest | Target Treaty <br> Harvest | Treaty Harvest | Deviation Number | Deviation Percent |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 1987 | 282.4 | 17.1 | 263 | 265.3 | 2.3 | 0.9\% |
| 1988 | 279.3 | 22.5 | 263 | 256.8 | -7.8 | -3.0\% |
| 1989 | 291.0 | 21.5 | 263 | 269.5 | 6.5 | 2.5\% |
| 1990 | 366.9 | 45.9 | 302 | 321.0 | 19.0 | 6.3\% |
| 1991 | 359.5 | 61.5 | 273 | 298.0 | 25.0 | 9.2\% |
| 1992 | 258.8 | 36.8 | 227.4 | 222.0 | -5.4 | -2.4\% |
| 1993 | 304.1 | 32.9 | 263 | 271.2 | 8.2 | 3.1\% |
| 1994 | 264.4 | 29.2 | 240 | 235.2 | -4.8 | -2.0\% |
| 1995 | 235.7 | 58.8 |  | 176.9 |  |  |
| 1996 | 236.3 | 81.3 |  | 155.0 |  |  |
| 1997 | 343.0 | 56.3 |  | 286.7 |  |  |
| 1998 | 270.6 | 27.4 | 260 | 243.2 | -16.8 | -6.5\% |
| 1999 | 251.0 | 52.2 | 184.2 | 198.8 | 14.6 | 7.9\% |
| 2000 | 263.3 | 76.8 | 178.5 | 186.5 | 8.0 | 4.5\% |
| 2001 | 265.7 | 78.8 | 250.3 | 186.9 | -63.4 | -25.3\% |
| 2002 | 426.5 | 69.4 | 371.9 | 357.1 | -14.8 | -4.0\% |
| 2003 | 439.4 | 59.3 | 439.6 | 380.2 | -59.4 | -13.5\% |
| 2004 | 499.3 | 82.2 | 418.3 | 417.0 | -1.3 | -0.3\% |
| 2005 | 493.1 | 104.5 | 387.4 | 388.6 | 1.2 | 0.3\% |
| 2006 | 435.5 | 75.4 | 354.5 | 360.1 | 5.6 | 1.6\% |
| 2007 | 404.6 | 76.4 | 259.2 | 328.2 | 69.0 | 26.6\% |
| 2008 | 244.2 | 71.4 | 152.9 | 172.8 | 19.9 | 13.0\% |
| 2009 | 293.7 | 65.6 | 176.0 | 228.0 | 52.0 | 29.6\% |
| 2010 | 284.7 | 53.9 | 215.8 | 230.8 | 15.0 | 6.9\% |
| 2011 | 357.0 | 66.3 | 283.3 | 290.7 | 7.4 | 2.6\% |
| 2012 | 295.0 | 52.5 | 205.1 | 242.5 | 37.4 | 18.3\% |
| 2013 | 257.3 | 65.6 | 176 | 191.4 | 15.4 | 8.8\% |
| 2014 | 492.5 | 56.6 | 378.6 | 435.2 | 56.6 | 14.9\% |
| 2015 ${ }^{1,2}$ | 405.3 | 67.3 | 337.5 | 337.8 | 0.3 | 0.1\% |
| $2016{ }^{2}$ | 388.7 | 35.1 |  | 353.3 |  |  |

${ }^{1}$ Preliminary.
${ }^{2}$ The actual all-gear harvest limit and deviation cannot be calculated until the CTC completes the postseason calibration.

## Troll Fishery

The accounting of treaty Chinook salmon harvested by trollers begins with the winter fishery and ends with the summer fishery. The winter troll fishery is managed for a guideline harvest level (GHL) of 45,000 non-Alaska hatchery-produced Chinook salmon, with a guideline harvest range of 43,000-47,000 non-Alaska hatchery-produced fish, plus the number of Alaska hatcheryproduced Chinook salmon harvested during the winter fishery. The 2015-2016 winter troll fishery was open from October 11, 2015 through March 8, 2016 and harvested a total of 52,291 Chinook salmon. Of these, 2,642 (5\%) were of Alaska hatchery origin, of which 1,980 counted toward the Alaska hatchery add-on, resulting in a treaty catch of 50,311 (Table 13).

The spring troll fisheries target Alaskan hatchery-produced Chinook salmon and are conducted along migration routes or close to hatchery release sites. Terminal area fisheries, which begin during the spring, occur directly in front of hatcheries or at remote release sites. While there is no ceiling on the number of Chinook salmon harvested in the spring fisheries, the take of PST Chinook salmon is limited according to the percentage of the Alaskan hatchery fish taken in the fishery. Non-Alaska hatchery fish are counted towards the annual PST quota of Chinook salmon, while most of the Alaska hatchery fish are not.

In 2016, spring troll fisheries were conducted from April 15-June 30 in a total of 36 spring areas and six terminal area fisheries. A total of 42,227 Chinook salmon were harvested in spring and terminal troll areas combined, of which 8,974 (21\%) were of Alaska hatchery origin and 6,761 counted toward the Alaska hatchery add-on. Trollers harvested a total of 562 large Chinook during the nine days of directed Chinook salmon fishing in District 108. Of those, 405 counted as wild terminal exclusion fish, resulting in a PST harvest of 35,623 fish (Table 13).

The 2016 summer troll fishery included two Chinook salmon retention periods, from July 1-5 and August 13-September 3. In addition to the traditional summer retentions periods, an experimental mark-selective fishery was conducted from September 4-30 (459 Chinook retained). A total of 181,352 Chinook salmon were harvested, of which 2,163 (11\%) were of Alaskan hatchery origin and 1,621 counted toward the Alaska hatchery add-on. The resulting PST catch was 179,731 fish. The total harvest for all troll fisheries in the 2016 accounting year was 276,432 Chinook salmon, of which 265,666 counted as PST harvest.

Table 13.-Preliminary 2016 troll fishery Chinook salmon harvest by season.

| Gear/Fishery | Total Harvest | Alaska Hatchery Harvest | Alaska <br> Hatchery <br> Add-on | Total |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  |  | Terminal Exclusion Harvest | Term. <br> Exclusion/ Alaska Hatchery Add-on | Treaty Harvest |
| Winter Troll | 52,291 | 2,642 | 1,980 | 0 | 1,980 | 50,311 |
| Spring Troll ${ }^{\text {a }}$ | 42,789 | 8,974 | 6,761 | 405 | 7,166 | 35,623 |
| Summer Troll |  |  |  |  |  |  |
| First Period ${ }^{\text {b }}$ | 106,653 | 1,197 | 897 | 0 | 897 | 105,756 |
| Second Period | 74,240 | 954 | 715 | 0 | 715 | 73,525 |
| MSF ${ }^{\text {c }}$ | 459 | 12 | 9 |  | 9 | 450 |
| Total Summer | 181,352 | 2,163 | 1,621 | 0 | 1,621 | 179,731 |
| Total Traditional Troll | 276,432 | 13,780 | 10,362 | 405 | 10,766 | 265,666 |
| Annette Is. Troll | 0 | 0 | 0 | 0 | 0 | 0 |
| Total Troll Harvest | 276,432 | 13,780 | 10,362 | 405 | 10,766 | 265,666 |

${ }^{2}$ Spring troll harvest includes all terminal and Wild Terminal Exclusion harvests for year.
${ }^{\mathrm{b}}$ Total summer harvest includes confiscated harvest for year.
${ }^{\text {c }}$ The mark-selective fishery occurred during the second Chinook Non-Retention coho-directed fishery.

## Net Fisheries

A total of 13,825 Chinook salmon were harvested in the drift gillnet fisheries in 2016, of which 9,547 (69\%) were of Alaska hatchery origin and 8,511 counted toward the Alaska hatchery addon, resulting in a PST harvest of 5,314 fish (Table 11). A total of 28,244 Chinook salmon were harvested in the purse seine fisheries, of which 8,256 (29\%) were of Alaska hatchery origin and 7,921 counted toward the Alaska hatchery add-on, resulting in a PST harvest of 20,323 fish. A total of 230 Chinook salmon were harvested in the set gillnet fisheries, none of which were of Alaska hatchery origin, resulting in a PST harvest of 230 fish (Table 11).

With the exception of directed gillnet harvests of Chinook salmon in SEAK terminal area regulatory Districts 108 and 111, as provided in the Transboundary River agreement (Chapter 1), harvests of Chinook salmon in the net fisheries are primarily incidental to the harvest of other species and only constituted a small fraction ( $<1.0 \%$ ) of the total net harvest of all species. In 2016, the initial preseason forecast for large Chinook salmon returning to the Stikine River was large enough to allow for directed Chinook salmon fisheries in District 108. The drift gillnet fleet harvested an estimated 118 large Chinook salmon during the three days of fishing that occurred between May 2 and May 16 (Table 7).

## Recreational Fisheries

The Southeast Alaska king salmon sport fishery is managed under provisions of the Southeast Alaska King Salmon Management Plan (5 AAC 47.055). This plan prescribes management measures based upon the preseason abundance index determined by the Chinook Technical Committee of the Pacific Salmon Commission. The preseason abundance index generated for the SEAK AABM fishery in 2016 was 2.06, resulting in a preseason sport allocation of 65,799 treaty Chinook salmon under the harvest management plan adopted by Alaska Board of Fisheries. Based on this preseason AI and the SEAK King Salmon Management Plan, a resident sport fish angler was allowed to use two rods from October through March, and the bag and possession limit was three king salmon 28 inches or greater in length. The nonresident annual harvest limit was six king salmon 28 inches or greater in length; daily bag and possession limits were one king
salmon 28 inches or greater in length except during May and June, when the bag and possession limit was two fish 28 inches or greater in length. The 2016 recreational fishery had an estimated preliminary total harvest of 70,000 Chinook salmon, of which 61,731 counted as treaty harvest. The final total and treaty harvest in the sport fishery for 2016 will be available in late fall of 2017.

## SOUTHEAST ALASKA COHO SALMON FISHERIES

Attachment B of the June 30, 1999 U.S.-Canada Agreement relating to the Pacific Salmon Treaty specifies provisions for inseason conservation and information sharing for northern boundary coho salmon. In 2016, troll CPUE in Area 6 in the early weeks of the fishery averaged 40 coho/day, which was well above the highest boundary area conservation trigger of 22 coho/day. The mid-July projection of region-wide total commercial harvest of 2.13 million was greater than the 1.1 million trigger for an early region-wide troll closure, specified in Alaska Board of Fisheries regulation and the PST conservation agreement.

The 2016 region-wide summer troll coho fishery began by regulation on June 1. The mid-season closure occurred from August 9-12, and the fishery was extended for 10 days past the normal September 20 ending date. The 2016 all-gear catch of coho salmon totaled 2.37 million fish, of which 2.10 million (88\%) were taken in commercial fisheries (Table 14). The troll catch of 1.39 million fish was $10 \%$ below the 10 -year average of 1.54 million fish and accounted for $66 \%$ of the commercial catch. Power troll wild coho CPUEs were above the 10 -year average during the third and fifth statistical weeks of July and below average for the rest of the season. The overall wild stock abundance (wild troll catch divided by an index of the troll exploitation rate) was estimated at 4.82 million, and was $22 \%$ above the 20 -year average. The purse seine harvest of 267,200 fish was $10 \%$ below the 10-year average while the drift gillnet harvest of 299,600 fish was $20 \%$ below the 10 -year average. The set gillnet harvest of 144,000 fish in the Yakutat area was $12 \%$ above the 10 -year average, with $90 \%$ of the catch taken in the Situk-Ahrnklin Lagoon and $8 \%$ in the Tsiu River system. A very preliminary estimate of the Southeast Alaska sport catch $(273,700)$ is $9 \%$ above the 10-year average $(252,100$ fish $)$.

Wild production accounted for 1.65 million fish (79\%) in the commercial catch compared with a recent 10 -year average of 1.80 million fish ( $78 \%$ wild). The hatchery percentage of the commercial catch (21.3\%) was the lowest since 2010, and well below the recent range of 24$28 \%$ during 2011-2015. Of the estimated hatchery contribution of 448,700 fish, over $99 \%$ originated from facilities in Southeast Alaska. Klawock Hatchery dominated the hatchery component, contributing $47 \%$ of the hatchery troll harvest and $40 \%$ of the total commercial harvest of hatchery-reared fish, while accounting for an estimated $11.5 \%$ of the combined troll harvest of wild and hatchery stocks.

Escapement counts and estimates were within or above goal in most cases. The total escapement of 944 coho salmon to Hugh Smith Lake was within the biological escapement goal (500-1,600 spawners) for the second consecutive year, after consistently exceeding the goal during the prior seven years. The estimated total run size of 2,583 adults was $38 \%$ below the long-term (19822015) average of 4,154 adults. Escapements were within respective goal ranges for four northern Southeast inside stocks (Auke Creek, Berners River, Taku River, Montana Creek) while falling under goal for two streams in that area (Chilkat River, Peterson Creek). The combined peak
count of 13,420 coho salmon in the 14 surveyed streams in the Ketchikan area was well-above the 1987-2015 average of 8,666 spawners, and the goal of 4,250-8,500 spawners. The combined peak count of spawners in five streams in the Sitka area was the highest on record.

Marine survival was well-below average (6.6\% versus 12.8\%) for the Hugh Smith Lake population southeast of Ketchikan, and reached record lows in the northern inside area where marine survival rates of $4.1 \%$ for Auke Creek and $6.4 \%$ for the Berners River where far below historical averages of $19 \%$ and $16 \%$, respectively. Coho salmon returns appeared to be proportionately much stronger in outer coastal systems from southern Southeast to Yakutat, compared with inside area streams.

Total exploitation rate estimates were low to moderate for wild indicator stocks, ranging from $25 \%$ for Auke Creek and $28 \%$ for Berners River to $63 \%$ for Hugh Smith Lake. The estimated allgear exploitation rate on the Hugh Smith Lake stock of $63 \%$ was the highest since 2004, while falling approximately midway between averages of $75 \%$ for the 1990s and $53 \%$ during 20002015. The Alaska troll fishery exploitation rate on the Hugh Smith Lake stock (30\%) was below the historical (1982-2015) average of 33\% but was the highest Alaska troll exploitation rate since 2005. Alaska troll fishery exploitation rates on northern inside stocks were the lowest on record at $7-8 \%$ for both Auke Creek and the Berners River compared with a long-term average for Auke Creek of $28 \%$, and a peak 10-year (1989-1998) average of $33 \%$.

Table 14.-Coho salmon harvest in Southeast Alaska in 2016 by gear type (preliminary).

| Gear Type | Harvest |
| :--- | :---: |
| Troll | $1,386,600$ |
| Purse Seine | 267,200 |
| Drift Gillnet | 299,600 |
| Set Gillnet | 144,000 |
| Sport (marine and freshwater) | 273,700 |
| Total | $2,371,100$ |

## II. PRELIMINARY 2016 CHINOOK AND COHO SALMON FISHERIES IN WASHINGTON AND OREGON

## INTRODUCTION

This report describes the conduct of United States (U.S.) fisheries of interest to the Pacific Salmon Commission (PSC) that occurred during 2016 in the area north of Cape Falcon, Oregon and south of the U.S./Canada border. These fisheries were conducted under pre-season management plans that were consistent with Annex IV of the Pacific Salmon Treaty (PST 2008) including obligations defined within Chapter 3 for Chinook individual stock based management regimes (ISBM) and Chapter 5 for Southern Coho Management.

An overview of the Chinook (Oncorhynchus tshawytscha) and Coho (Oncorhynchus kisutch) salmon conservation challenges facing managers during the 2016 pre-season planning process in this region is provided. The conduct of major fisheries is described, and estimates of landed catch, where available, are compared to pre-season catch limits or expectations for Chinook (Table 15) and Coho (Table 16). For perspective, landed catches for those fisheries since 2011 are also presented. Where available, preliminary estimates of the number of Chinook or Coho salmon released by anglers in 2016 mark-selective fisheries are also presented (Table 17). All estimates for the 2016 fisheries are preliminary and subject to change. Estimates of spawning escapements and abundance of Coho and Chinook stocks are not available at this time.

## PRE-SEASON PLANNING

Pre-season planning for southern U.S. fisheries of interest to the PSC is a coordinated activity involving Tribal, State and Federal management entities, with the involvement of conservation and fishing interests. The Pacific Fishery Management Council (PFMC) conducted a series of public meetings to consider options for ocean fishery season structures while the Tribes and States conducted government-to-government and public, open meetings throughout the region to develop and analyze alternative season structures for fisheries in the inside waters of the Columbia River, coastal Washington and Puget Sound. Participants in these various planning sessions evaluated the biological and socio-economic consequences of the alternative season structures for the outside (ocean) and inside (marine and freshwater) fisheries (Figure 38) including the anticipated impacts on U.S. southern origin stocks in fisheries conducted under the PST in Canada and Southeast Alaska. Agreement was reached on season structures expected to achieve conservation goals, domestic fishery objectives and legal obligations, including the PST, assuming fisheries are conducted as planned and pre-season abundance estimates are accurate.


Figure 38. Map of Western Washington marine catch areas of the Washington coast (Areas 1 through 4) and Puget Sound (Areas 5 through 13) (WAC 220-22-030). Inside (Columbia River) fisheries reported in this document extend beyond the scope of this map.

## Chinook Salmon Management

Under the 2008 Pacific Salmon Treaty Agreement, southern U.S. fisheries are subject to the Individual Stock Based Management provisions of Annex IV, Chapter 3. These provisions require the non-ceiling index for aggregated Southern U.S. fisheries on Chinook stocks not achieving their management objectives to be no greater than $60 \%$ of the levels estimated for the 1979-1982 base period.

Conservation obligations associated with the U.S. Endangered Species Act (ESA) for threatened and endangered Chinook salmon stocks originating from Puget Sound and the Columbia River have been more constraining to southern U.S. fisheries than PST obligations. Catch quotas for the 2016 U.S. ocean fisheries in the area north of Cape Falcon, Oregon, were defined by the impact limits on ESA-listed lower Columbia River natural tule fall Chinook stocks, ESA-listed

Puget Sound Chinook stocks, and the abundance of other healthy, harvestable Chinook salmon stocks contributing to fisheries in this area. Puget Sound fishing seasons were structured to provide fishing opportunity on healthy salmon species or stocks within the impact limits defined for ESA-listed Puget Sound Chinook.

## Coho Salmon Management

During the pre-season fishery planning process of 2016, Canadian fishery managers informed the U.S. that the Interior Fraser management unit was again expected to be in the low categorical abundance status, and U.S. fisheries were constrained to ensure that the exploitation rate on this management unit did not exceed $10.0 \%$ as defined by the PST Southern Coho Management Plan. All U.S. natural spawning Coho management units specified by the PST Southern Coho Management Plan were forecasted to be in low status except Hood Canal natural Coho were at moderate status.

The impact on natural Coho stocks, seasons and catch limits adopted for southern U.S. fisheries were predicted using the Fisheries Regulation Assessment Model (FRAM). The total exploitation rate on the Interior Fraser management unit was predicted to be 3.7\% in Southern U.S. fisheries. Seasons and Coho quota levels for U.S. ocean fisheries were closed or severely constrained by the management objectives of Washington coastal and Puget Sound natural Coho and ESA-listed lower Columbia River natural Coho, and limits to fisheries in marine areas within northern Puget Sound and the Strait of Juan de Fuca were likewise constrained by management objectives reflecting very low forecasted returns for Puget Sound natural Coho stocks.

## NORTH OF CAPE FALCON OCEAN FISHERIES

Details regarding North of Cape Falcon ocean salmon fishing plans were reported in Preseason Report III, published by the Pacific Fishery Management Council in April 2016. http://www.pcouncil.org/salmon/stock-assessment-and-fishery-evaluation-safe-documents/preseason-reports/2016-preseason-report-iii/

Fisheries in this area are managed to meet conservation objectives for ESA listed stocks, natural stocks and brood stock goals for hatchery stocks. Within these stock management objectives, ocean fishing seasons are defined that meet legal requirements of Tribal treaties and allocations between Non-Tribal troll and sport fisheries. Ocean fishery seasons are also constructed to ensure a balance of opportunity for harvest with the inside fisheries. Lower Columbia River hatchery Coho and Columbia River fall Chinook have historically been the major stocks contributing to catches of ocean fisheries in the North of Cape Falcon area.

Chinook and Coho salmon catch quotas were established for the 2016 ocean Tribal, Non-Tribal troll and sport fisheries. Ocean fishery quotas for Chinook salmon were defined by exploitation rate limits on several ESA-listed Puget Sound Chinook stocks as well as the total exploitation rate limit of $41 \%$ on ESA-listed lower Columbia River natural tule fall Chinook stocks in all fisheries. Due to conservation concerns, retention of coho was not allowed except for a 18,900 marked coho selective recreational fishery off the Columbia River mouth. .

## Non-Tribal Troll Fishery

Pre-season quota levels for the non-Tribal troll fisheries were 35,000 Chinook with no Coho retention. The preliminary estimate of non-Tribal harvest in the 2016 North of Falcon troll fishery is 19,500 Chinook ( $55 \%$ of the coast-wide quota). Trollers harvested 12,700 Chinook in the May 1 - June 30 fishery, and the remaining 6,800 Chinook were harvested in the summer fishery between July 8 and August 23.

## Tribal Troll Fishery

The Tribal troll ocean fishery (also known as the Treaty troll fishery) quotas were defined by conservation concerns for ESA listed Chinook and Coho stocks, as well as very low forecasted returns of Washington coastal and Puget Sound Coho stocks. For Chinook salmon quotas Lower Columbia River Tule Chinook salmon and Lower Columbia River Wild Chinook salmon were the stocks that established the Chinook quota at 40,000. Coho retention was not allowed due to constraints by Washington coastal Coho salmon as well as Puget Sound Coho. The Tribal troll fishery takes place in ocean areas 2, 3, 4 and 4B. The season was comprised of a May/June Chinook-directed fishery and a July 1 through August 31 fishery which normally targets all species (Chinook and Coho) but was truncated and closed to Coho this year. The Chinook quota was split 50:50 between the two fisheries. The Chinook-directed fishery ran through all of May and closed on June 30 and caught 16,947 of the 20,000 Chinook sub-quota or $84.7 \%$. The Tribal trollers made 391 landings during this fishery. The second half of the fishery opened on July 1 with the same Chinook sub-quota as the first fishery. That fishery closed on August 31 taking $29 \%$ of the Chinook sub-quota. The season concluded with a total catch of 22,741 Chinook salmon (56.9\% of the overall quota). The Tribes made 604 landings during the ocean Tribal troll season.

## Sport Fisheries

Pre-season quotas for the sport fishery were 35,000 Chinook and 18,900 Coho with a clipped adipose fin, hereinafter referred to as marked. Preliminary total catch estimates for the ocean sport fisheries north of Cape Falcon were 18,000 Chinook ( $51 \%$ of the coast-wide quota) and 18,600 Coho ( $99 \%$ of the coast-wide quota). A description of the resulting season structure and catches by management area follows.

Columbia Ocean Area (including Oregon)
All-species salmon sport fishing opened in Ocean Area 1 (Columbia Ocean Area) on July 1 with a pre-season quota of 18,900 marked Coho and a guideline of 10,200 Chinook. The fishery closed upon attainment of the Coho quota on August 27. The catch estimates for Area 1 are 6,000 Chinook ( $59 \%$ of the guideline) and 18,600 Coho ( $98 \%$ of the quota). ( 62 additional Coho were landed in the sport fishery north of Cape Falcon, and retained illegally in Ocean Areas 2, 3, and 4.) The Chinook minimum size limit was 24 inches, with a sub-area closure in the Columbia Control Zone.

Preliminary estimates of Coho encounters (retained and released), and mark rate in the Area 1 Coho mark-selective sport fishery, July 1 - August 27, 2016.

| Coho retained | Coho released | Total encounters | Mark \% |
| :---: | :---: | :---: | :---: |
| 18,600 | 14,100 | 32,700 | $64 \%$ |

## Westport, Washington

Ocean Area 2 (Westport, WA) opened for all-species salmon sport fishing on July 1 with a preseason guideline of 16,600 Chinook; Coho retention was not allowed. The fishery closed as scheduled on August 21. The catch estimate for Area 2 is 8,400 Chinook ( $51 \%$ of the guideline). The Chinook minimum size limit was 24 inches.

Preliminary estimates of Coho encounters (retained and released), in the Area 2 Coho nonretention sport fishery, July 1 - August 21, 2016.

| Coho retained | Coho released | Total encounters | Mark \% |
| :---: | :---: | :---: | :---: |
| 0 | 7,600 | 7,600 | NA |

## La Push, Washington

Ocean Area 3 (La Push, WA) opened for all-species salmon sport fishing on July 1 with a preseason guideline of 2,000 Chinook; Coho retention was not allowed. The fishery closed on its automatic closure date, August 21. The catch estimate for Area 3 is 300 Chinook ( $13 \%$ of the guideline). The Chinook minimum size limit was 24 inches.

Preliminary estimates of Coho encounters (retained and released), in the Area 3 Coho nonretention sport fishery, July 1 - August 21, 2016.

| Coho retained | Coho released | Total encounters | Mark \% |
| :---: | :---: | :---: | :---: |
| 0 | 1,100 | 1,100 | NA |

Neah Bay, Washington
Ocean Area 4 (Neah Bay, WA) opened for all-species salmon sport fishing on July 1 with a preseason guideline of 6,200 Chinook; Coho retention was not allowed. The fishery closed on its automatic closure date, August 21. The catch estimate for Area 4 is 3,300 Chinook ( $53 \%$ of the guideline). The Chinook minimum size limit was 24 inches.

| Preliminary estimates of Coho encounters (retained and released), in the Area 4 Coho non- |  |  |  |
| :---: | :---: | :---: | :---: |
| retention sport fishery, July 1 - August 21, 2016. |  |  |  |
| Coho retained | Coho released | Total encounters | Mark \% |
| 100 | 4,300 | 4,400 | NA |

## NORTH OF CAPE FALCON INSIDE FISHERIES

## WASHINGTON COASTAL RIVER FISHERIES

## North Washington Coastal Rivers

Net and sport fisheries directed at salmon in this region were implemented based upon preseason, Tribal-State agreements and subject to in-season adjustments. The 2016 north coastal rivers net harvest (all by Tribal fisheries that are non-selective) includes catch from the Sooes, Quillayute system, Hoh, Queets, and Quinault Rivers. The 2016 commercial Tribal net fisheries in north coastal rivers have harvested an estimated 8,800 Chinook salmon and 49,800 Coho salmon through November 15, 2016.

Recreational fisheries conducted in the Quillayute, Hoh and Queets River systems included mark-selective fisheries for hatchery Chinook and hatchery summer and fall coho salmon. Harvest or impact estimates for these fisheries are unavailable at this time.

## Grays Harbor, Washington

Harvest for Grays Harbor, WA includes catch from both the Humptulips and Chehalis Rivers through November 15, 2016. The non-selective Tribal net fisheries in Grays Harbor, and including fisheries in the Humptulips and Chehalis Rivers, harvested an estimated 2,100 Chinook salmon and 1,800 Coho salmon. The non-Tribal commercial fishery in the northern portion of Grays Harbor near the Humptulips River (Area 2C), was non-selective and harvested 18 Chinook and 28 Coho. There were 8 Chinook salmon (mark-selective) and 204 Coho harvested in the Non-Tribal commercial gillnet fishery in Areas 2A and 2D. Sport fisheries conducted in the Chehalis and Humptulips Rivers included mark-selective components for Chinook and Coho salmon. Harvest data for these fisheries are not available at this time.

## COLUMBIA RIVER FISHERIES

Tribal and Non-Tribal net and sport salmon fisheries in 2016 occurred during the winter/spring (January - June 15), summer (June 16 - July) and fall (August - October) periods. All fisheries were constrained by impacts on ESA listed stocks. Winter/spring fisheries were primarily constrained by impacts on ESA listed upper Columbia River spring Chinook, Snake River spring/summer Chinook and wild winter Steelhead. Summer fisheries were constrained by impacts to ESA listed Snake River Sockeye. Fall fisheries were mainly constrained by impacts to ESA listed Snake River wild fall Chinook, wild lower Columbia tule fall Chinook and Group B Steelhead which are part of the Snake River Steelhead distinct population segment (DPS). Wild lower Columbia River Coho can be a constraint to fall season fisheries, but impacts to other listed stocks generally limit fisheries first.

Columbia River salmon fisheries are developed and regulated to meet conservation standards. Fisheries are managed to operate within the impact limits set for ESA listed stocks, meet the objectives for healthy Columbia River natural stocks, and ensure brood stock needs are met for hatchery salmon. Mainstem Columbia River fisheries are also developed and managed to remain within the requirements of the 2008-2017 US v. Oregon Management Agreement which include Tribal/Non-Tribal sharing agreements. All 2016 data is preliminary and subject to change. This section includes harvest from Columbia River fisheries that are considered to be of the interest to PSC; therefore the data may not match other reports that include total harvest.

## Winter-Spring Fisheries

## Non-Tribal Net

The mainstem Winter/Spring commercial fishery has operated under mark-selective fishery regulations since 2002. In 2016, the winter/spring salmon season consisted of six fishing periods ( 65 hours total) between March 29 and June 8. The fishery occurred downstream of Bonneville Dam, with time, area, and gear restrictions in place. Landings included 3,300 hatchery adult spring Chinook kept (1,900 non-adipose fin clipped released). Additional
fisheries occur in off-channel areas (Select Areas) in the Columbia River estuary and from Wanapum tribal fisheries upstream of Priest Rapids Dam but are not reported in this document.

| Preliminary adult Spring Chinook handle in the |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 2016 Winter/Spring Commercial non-Tribal drift-net mark-selective fishery. |  |  |  |  |  |
| System | Area | Chinook <br> Kept | Chinook <br> Released | Total <br> Handle | \% Kept |
| Columbia River | Below BON (LCR) | 3,300 | 1,900 | 5,200 | $63 \%$ |

## Sport

Mainstem Columbia River mark-selective sport fisheries began in 2001. The area below Bonneville Dam was open January 1 - April 9, May 13-15, May 20-22, May 27-30 and June 315 for hatchery Chinook retention. Catch estimates include 12,700 hatchery adult spring Chinook (3,800 non-adipose fin clipped released). The area from Bonneville Dam upstream to the Oregon/Washington border (17 miles upstream of McNary Dam) was open March 16 - May 8 and May 13-15. Catch estimates for this area total 1,500 hatchery adult spring Chinook (300 non-adipose fin clipped released). The Snake River fishery structure included three specific catch areas open on a days-per-week rotation. The fishery opened in late April and continued into late May. One area re-opened for two days June. Catch in the Snake River fishery totaled 1,300 hatchery adult spring Chinook ( 300 non-adipose fin clipped released). Fisheries also occur in tributaries but are not reported in this document.

| Preliminary adult Spring Chinook handle in the |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 2016 Winter/Spring sport mark-selective fishery. |  |  |  |  |  |
| System | Area | Chinook <br> Kept | Chinook <br> Released | Total <br> Handle | $\%$ Kept |
| Columbia River | Below BON (LCR) | 12,700 | 3,800 | 16,500 | $77 \%$ |
| Columbia River | BON to WA-OR S/L | 1,500 | 300 | 1,800 | $83 \%$ |
| Snake River | Washington Waters | 1,300 | 300 | 1,600 | $81 \%$ |

## Tribal

Tribal mainstem winter/spring fisheries occur from January 1 through June 15. Tribal mainstem fisheries are not mark-selective. Tribal fisheries are conducted in the mainstem Columbia River from just downstream of Bonneville Dam upstream to McNary Dam (Zone 6). Spring season fisheries include three fishery sectors, a ceremonial permit gillnet fishery, a platform and hook and line fishery and a commercial gillnet fishery. The platform and hook and line fishery was open for for subistence throughout the winter/spring period and for commercial use in the later part of the spring. Harvest estimates from the combined ceremonial, subsistence and commercial fisheries totaled 17,059 upriver spring Chinook. Fisheries are also conducted in Zone 6 tributaries. and in Columbia and Snake River tributaries upstream from McNary Dam. Tributary harvest (including Snake Basin harvest) is not reported in this document.

## Summer Fisheries

## Non-Tribal Net

Summer season commercial fisheries are not mark-selective. A total of two fishing periods (16 hours total) occurred, one on June 16 and the other on June 11 in the area below Bonneville Dam. Time, area, and gear restrictions were in place for all summer season commercial fisheries. Landings are estimated at 3,000 upper Columbia summer Chinook.

## Sport

Summer season fisheries occurred from June 16-July 31 from the Astoria-Megler Bridge near the mouth of the Columbia River upstream to Priest Rapids Dam (PRD). The fishery was markselective the entire season. Catch estimates below Bonneville Dam (BON) total 3,100 adult Chinook kept (4,200 non-adipose fin clipped released. Catch estimates from Bonneville Dam upstream to Priest Rapids Dam total 500 adult Chinook kept (600 non-adipose fin clipped released). The majority of harvest occurs in fisheries upstream of Priest Rapids Dam and in tributaries, which are not reported in this document.

| Preliminary adult Summer Chinook handle in the <br> 2016 sport mark-selective fishery. |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
| System | Area | Chinook <br> Kept | Chinook <br> Released | Total <br> Handle | \% Kept |
| Columbia River | Below BON (LCR) | 3,100 | 4,200 | 7,300 | $42 \%$ |
| Columbia River | BON to PRD | 500 | 600 | 1,100 | $45 \%$ |

## Tribal

Summer season fisheries occurred from June 16 through July 31. Treaty Tribal mainstem fisheries are not mark-selective. Treaty Tribal fisheries are conducted in the mainstem Columbia River from just downstream of Bonneville Dam upstream to McNary Dam (Zone 6). Seven weekly commercial gillnet fishing periods were conducted June 16 - July 31. Platform and hook and line fisheries also occurred throughout the season, and fish were sold commercially or retained for subsistence use. Harvest estimates total 20,519 adult upper Columbia summer Chinook from mainstem fisheries. Minor summer season fisheries were also conducted in some Zone 6 tributaries and in tributaries upstream of McNary Dam. Tributary harvest is not reported in this document. The Colville and Wanapum tribes conduct C\&S fisheries upstream of Priest Rapids Dam, but harvest is not reported in this document.

## Fall Fisheries

## Non-Tribal Net

Fall season mainstem fisheries are typically categorized into early and late fall seasons. The early fall season generally encompasses the month of August, whereas the late fall season generally begins in mid-September and continues through October. Time, area, and gear restrictions were in place for all fall season commercial fisheries. In 2016 the early fall season consisted of 2-3 periods per week during August 7 - 31. The late fall season was brief due to ESA constraints, consisting of only two periods in September (September 18 and September 22).

A small mostly mark-selective seine fishery (only two days were non mark-selective) also occurred during August 22 - September 30. Harvest estimates total 58,900 fall Chinook (100 non-adipose fin clipped released) for the entire season (all gear types).

| Preliminary adult Fall Chinook handle in the |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 2016 Commercial non-tribal seine net mark-selective fishery. |  |  |  |  |  |  |
|  | Area is Below <br> BON. Gear type is: | Chinook <br> Kept | Chinook <br> Released | Total <br> Handle | \% Kept |  |
| Columbia River | Beach Seine | 1 | 0 | 1 | $100 \%$ |  |
| Columbia River | Purse Seine | 1,000 | 100 | 1,100 | $91 \%$ |  |

## Sport

Fall season fisheries are mark-selective for Coho and in recent years have included a brief markselective period for Chinook in the Buoy 10 area and in an 80-mile stretch in the lower Columbia River from the Tongue Point line upstream to Warrior Rock, which is near the mouth of the Columbia River. The Buoy 10 fishery was open August 1- December 31; Chinook retention was allowed the entire season with mark-selective regulations in place intermittently in August and September. Regulations at Buoy 10 include minimum size limits for Chinook (24inches) and Coho (16-inches). Released fish would include adult and jack hatchery and wild fish that did not meet the size requirement, adult and jack fish requiring released under any markselective regulations and adult and jack fish requiring release under non-retention regulations. Buoy 10 catch estimates include 17,800 Chinook kept and 9,000 hatchery Coho kept. Released fish (hatchery, wild, adults and jacks) include 7,500 Chinook and 4,600 Coho. The lower Columbia River (LCR) mainstem sport fishery from the Rocky Point - Tongue Point line upstream to Bonneville Dam was open August 1 - December 31, except for a brief closure in late October. In the area from the Rocky Point - Tongue Point line upstream to the Lewis River, mark-selective rules for Chinook were in effect September 10-30. Catch estimates for the LCR sport fishery include 25,100 adult Chinook. The mainstem sport fishery from Bonneville Dam to the Highway 395 Bridge (near Pasco, Washington) was open August 1 - December 31. Catch estimates for this area total 5,600 adult fall Chinook. Additional fisheries occur on the Columbia River in the Hanford Reach area (downstream of Priest Rapids Dam), in tributaries and in the Snake River but are not reported in this document.

| Preliminary adult Fall Chinook handle in the <br> 2016 sport mark-selective fishery. |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
| System | Area | Chinook <br> Kept | Chinook <br> Released | Total <br> Handle | \% Kept |
| Columbia River | Buoy 10 | 17,800 | 7,500 | 25,300 | $70 \%$ |
| Columbia River | LCR Sport | 700 | 1,800 | 2,500 | $28 \%$ |
| System | Area | Coho <br> Kept | Coho <br> Released | Total <br> Handle | \% Kept |
| Columbia River | Buoy 10 | 9,000 | 4,600 | 13,600 | $66 \%$ |

## Tribal

Fall season fisheries occur from August 1 through December 31. Tribal fisheries are not markselective. Tribal fisheries are conducted in the mainstem Columbia River from just downstream of Bonneville Dam upstream to McNary Dam (Zone 6). Platform and hook and line fisheries were open and allowed commercial sales through Dec 31. The commercial gillnet fishery consisted of nine weekly fishing periods August 22 - October 21. Preliminary harvest estimates for all fall season fisheries total 153,440 adult fall Chinook and 6,027 adult coho. Fisheries are also conducted in some Zone 6 tributaries and in the Snake and Clearwater Rivers. Harvest of Chinook in tributary fisheries is not reported in this document.

## PUGET SOUND FISHERIES

In 2016, Puget Sound marine fisheries of interest to the Pacific Salmon Commission were regulated to meet conservation and allocation objectives for Chinook, Coho, Chum, and Sockeye salmon stocks, per Tribal-State agreement. For Puget Sound Chinook listed under the ESA, fisheries were managed according to the Puget Sound Chinook Harvest Management Plan (PSIT and WDFW 2010). This management plan defines limits to total exploitation rates for natural stocks and was determined by the National Marine Fisheries Service (NMFS) to be consistent with requirements specified under the ESA 4(d) Rule.

Release requirements were applied to many sport and net fisheries for Chinook, Coho, and Chum salmon, the latter to protect ESA-listed Hood Canal and Strait of Juan de Fuca summer Chum.

Puget Sound marine fisheries were constrained by the need to meet management objectives for ESA listed Puget Sound Chinook, including Nisqually, Skokomish, and Puyallup River Chinook. Skagit, Stillaguamish, and Snohomish Coho, were the primary Coho management units of concern for managing fisheries in the Strait of Juan de Fuca, San Juan Islands, and Puget Sound.

## Strait of Juan de Fuca Sport

Selective Chinook retention was allowed for sport fishing in salmon management Area 5 from February 16 - April 10 and Area 6 from December 1, 2015 - March 18, 2016. Sport fishing regulations allowed retention of marked Chinook July 1 through August 15 in Areas 5 and 6. Coho retention was not permitted except within Dungeness Bay for hatchery Coho during October. An additional mark-selective fishery for Chinook is open from December 1- 31, 2016 in Area 6. The preliminary estimate for Area 5 Chinook retained for the entire open fishing period July 1 - August 15 was 3,395 fish.

Preliminary estimates of Chinook retained, released (legal and sub-legal size), and the legalsize mark rate in the Area 5 sport mark-selective fishery, July 1 - August 15, 2016.

| Chinook retained | Chinook released | Total encounters | Mark \% (legal size) |
| :---: | :---: | :---: | :---: |
| 3,395 | 21,424 | 24,819 | $73 \%$ |

A detailed report of this summer period sport fishery, including catch, effort and results of sampling and monitoring programs, will be available from the Washington Department of Fish and Wildlife in early 2016.

## Strait of Juan de Fuca Tribal Troll (Area 4B, 5, and 6C)

During the winter Tribal troll fishery in Areas 4B, 5, and 6C (November 1, 2015 - April 15, 2016), 300 Chinook were caught. In the summer Tribal troll fishery in Areas 5 and 6C only (June 1 - September 30, 2016), 100 Chinook and zero Coho were caught. The Tribal catch estimates from this area do not include catch from Area 4B during the May-September PFMC management period, which have been included in the North of Cape Falcon Tribal ocean troll summary.

## Strait of Juan de Fuca Tribal Net

Preliminary estimates of the 2016 catch in the Strait of Juan de Fuca Tribal net fisheries are 300 Chinook and 400 Coho salmon.

## San Juan Islands Net (Areas 6, 7, and 7A)

Preliminary estimates of the 2016 catch in the San Juan Island net fishery directed at Sockeye or Chum salmon total and 500 Coho salmon for the Non-Tribal fishery. Tribal fishery landings from this area for all gear types total 100 Chinook and 3,400 Coho.

## San Juan Islands (Area 7) Sport

Marked Chinook retention was allowed in the entire area for the period December 1, 2015 March 13, 2016. The numbers of Chinook retained and released by anglers during this fishery were estimated by an intensive sampling program and are presented in the table below. A detailed report of this fishery, including catch, effort and results of sampling and monitoring programs, is available from the Washington Department of Fish and Wildlife. The southern and southeastern (Rosario Strait) portions of this catch area were closed August 1 - September 30 to protect Puget Sound Chinook salmon. Chinook retention was allowed July 1 - October 31, with unmarked Chinook released during the months of July and October. Additional sub area closures are described in the Washington State Sport Fishing Rules Pamphlet. Catch estimates and sampling information for this area for the period August 1 - October 31 are not available at this time.

| Estimated Chinook retained, released (legal and sub-legal size) and the legal size mark rate in <br> the Area 7 sport mark-selective fishery, December 1, 2015 - March 13, 2016. |  |  |  |
| :---: | :---: | :---: | :---: |
| Chinook retained | Chinook released | Total encounters | Mark \% (legal size) |
| 2,591 | 10,552 | 13,143 | $58 \%$ |

Estimated Chinook retained, released (legal and sub-legal size) and the legal size mark rate in the Area 7 sport mark-selective fishery, July 1-31, 2016.

| Chinook retained | Chinook released | Total encounters | Mark \% (legal size) |
| :---: | :---: | :---: | :---: |
| 1,184 | 4,805 | 5,989 | $42 \%$ |

Inside Puget Sound (Areas 8-13) Sport
Mark-selective sport fisheries directed at hatchery Chinook were conducted in Area 8.1 (Skagit Bay \& Saratoga Passage), Area 8.2 (Port Susan \& Port Gardner), Area 9 (Admiralty Inlet), Area 10 (Seattle - Bremerton), Area 11 (Tacoma), and Area 12 (Hood Canal) during the winter
(October, 2015 - April, 2016) period, and in Areas 9, 10, 11, 12, and 13 (South Puget Sound) during the summer (May - September, 2016) period, as well as Area 8-2 (Tulalip Bubble).

Detailed reports of these fisheries, including retained and released encounters, effort and mark rates from sampling and monitoring programs, will be available from the Washington Department of Fish and Wildlife in the spring of 2017.
Mark-selective sport fisheries directed at hatchery Coho were conducted in Area 8-2 (Tulalip Bubble) Saturdays and Sundays only from September 17-25, 2016, Area 10 (Sinclair Inlet) July 1 - September 30, 2016, and Area 13 October 1 - December 31, 2016.

| Puget Sound Chinook mark-selective sport fisheries conducted in marine areas during the <br> period October 1, 2015 through December 31, 2016. |  |
| :---: | :--- |
| Areas | Season |
| 8.1 \& 8.2 | November 1, 2015 - April 3, 2016; Tulalip Bubble only: Fridays, Saturdays, <br> Sundays and Mondays June 24 - September 5, 2016; Tulalip Bubble only: <br> Saturdays and Sundays September 10- 25, 2016 |
| 9 | January 16 - April 10, 2016; July 16 - August 4, 2016; November 1-30, 2016 |
| 10 | October 1-18, 2015; July 16 - August 15, 2016; November 1 - December 31, <br> 2016; Sinclair Inlet: July 1 - September 30, 2016 |
| 11 | February 1 - April 30, 2016; June 24 - August 19, 2016 |
| 12 | February 1 - April 30, 2016; July 1 - December 31, 2016 |
| 13 | January 1 - April 30, 2016, June 24 - August 31, 2016; October 1 - December <br> 31, 2016 |

Puget Sound Marine Net (Areas 8-13 \& 7B-D)
To achieve conservation objectives for natural Puget Sound Chinook and Coho, limited marine net fishing opportunities directed at returns of hatchery Chinook and Coho were planned for 2016. Many Puget Sound Coho stocks returned in significantly larger numbers than was forecast pre-season. Chinook and Coho were also intercepted in fisheries directed at Chum salmon. A total of 43,200 Chinook and 188,500 Coho were landed in Tribal Puget Sound marine net fisheries (Areas 8-13 \& 7B-D) during 2016. Non-Tribal net fishery landings from these areas total 6,600 Chinook and 13,900 Coho.

## Puget Sound Rivers Fisheries

Tribal net and non-Tribal sport fisheries directed at salmon in this region were implemented based upon pre-season, Tribal-State agreements and subject in part to in-season adjustment. Due to unexpectedly strong returns of many Puget Sound Coho stocks, a number of terminal freshwater fisheries for Coho were implemented in 2016 where none had been planned preseason. The Net harvest (in Puget Sound Rivers by Tribal fisheries) included catch from river systems in the Strait of Juan de Fuca, Hood Canal, and Puget Sound. A total of 27,600 Chinook and 69,700 Coho were landed in Puget Sound River net fisheries during 2016.

Mark-selective fisheries directed at Chinook salmon were also conducted in the following Puget Sound Rivers with PSC Chinook coded wire tag (CWT) exploitation rate indicator stocks or double index tag (DIT) groups:

| Chinook mark-selective sport fisheries conducted in Puget Sound Rivers, 2016. |  |
| :--- | :--- |
| River | Season |
| Nooksack River | September 1-30 |
| Cascade River (Skagit) | June 24 - July 15 |
| Skagit River | June 24 - July 15 |
| Skykomish River | June 24 - July 31 |
| Nisqually River | January 1 - 5; July 1 - August 31 |
| Carbon River | September 10 - 24 |

A Coho mark-selective fishery occurred on the Skagit River and Cascade River from September 28 - November 30, 2016. During 2016, no other mark-selective sport fisheries were conducted in any Puget Sound Rivers with PSC Coho CWT exploitation rate indicator stocks or DIT groups.

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Puget Sound Indian Tribes and Washington Department of Fish \& Wildlife (PSIT and WDFW). 2010. Comprehensive Management Plan for Puget Sound Chinook: Harvest Management Component. Northwest Indian Fisheries Commission, Olympia, Washington. 237 p.

Pacific Fishery Management Council (PFMC). 2008. Fishery Regulation Assessment Model (FRAM): An Overview for Coho and Chinook v3.0. Pacific Fishery Management Council, Portland, Oregon. 43 p.

Table 15. Preliminary 2016 Landed Chinook Catch for Washington and Oregon Fisheries of Interest to the Pacific Salmon Commission.
Values are presented in number of fish rounded to the nearest 100. ${ }^{9 /}$

|  | 2016 |  |  | 2015 | 2014 | anded | 2012 | 2011 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Preseason ${ }^{5 /}$ |  |  |  |  |  |  |  |
| Fisheries | Total Mortality ${ }^{1 /}$ | Landed ${ }^{2 /}$ | Preliminary Landed |  |  | 2013 |  |  |
| OCEAN FISHERIES |  |  |  |  |  |  |  |  |
| Commercial Troll |  |  |  |  |  |  |  |  |
| Neah Bay and La Push (areas 3,4,4B) ${ }^{3 /}$ | 58,500 | 51,500 | 28,100 | 73,600 | 77,000 | 63,200 | 78,800 | 42,800 |
| Columbia Ocean Area and Westport (area 1,2) ${ }^{\text {// }}$ | 37,500 | 23,500 | 14,400 | 51,400 | 39,400 | 28,300 | 21,000 | 18,300 |
| Sport (see text for quota information) |  |  |  |  |  |  |  |  |
| Neah Bay (area 4) | 7,000 | 6,200 | 3,300 | 8,500 | 5,900 | 6,200 | 5,600 | 3,000 |
| La Push (area 3) | 2,300 | 2,000 | 300 | 2,400 | 1,600 | 2,400 | 1,300 | 1,500 |
| Westport (area 2) | 18,600 | 16,600 | 8,400 | 19,100 | 23,500 | 13,700 | 19,500 | 19,100 |
| Columbia Ocean Area (area 1) | 13,700 | 10,200 | 6,000 | 12,200 | 11,300 | 8,500 | 9,100 | 7,200 |
| INSIDE FISHERIES |  |  |  |  |  |  |  |  |
| Sport ${ }^{10 /}$ |  |  |  |  |  |  |  |  |
| Strait of Juan de Fuca (area 5,6) | 17,500 | 11,100 | na | 11,800 | 11,100 | 14,900 | 13,900 | 9,500 |
| San Juan Islands (area 7) | 9,800 | 7,300 | na | 8,600 | 9,200 | 9,500 | 5,800 | 6,500 |
| Puget Sound Marine (area 8-13) | 16,400 | 10,000 | na | 9,000 | 12,100 | 16,600 | 22,000 | 11,600 |
| Puget Sound Rivers ${ }^{12 /}$ | 8,700 | 8,600 | na | 11,100 | 11,800 | 19,600 | 23,200 | 18,200 |
| North WA Coastal Rivers | na | na | na | 2,100 | 1,100 | 2,900 | 1,600 | 2,300 |


| Grays Harbor ${ }^{7 /}$ | na | na | na | 3,800 | 1,200 | 3,800 | 4,600 | 3,400 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Columbia River (Spring) ${ }^{6 /}$ | na | na | 15,500 | 23,100 | 21,400 | 8,400 | 17,000 | 16,100 |
| Columbia River (Summer) ${ }^{6 /}$ | na | na | 3,600 | 6,700 | 2,300 | 2,100 | 3,200 | 5,500 |
| Columbia River (Fall) (incl. Buoy 10) ${ }^{\text {6/ }}$ | na | na | 48,600 | 91,300 | 63,000 | 74,500 | 47,000 | 44,300 |
| Commercial ${ }^{11 /}$ |  |  |  |  |  |  |  |  |
| Strait of Juan de Fuca net and troll (area 4B,5,6C) | 8,900 | 6,000 | 700 | 5,900 | 6,100 | 4,100 | 3,900 | 4,200 |
| San Juan Islands (area 6,7, 7A) | 6,400 | 6,300 | 100 | 4,700 | 6,900 | 4,000 | 400 | 5,700 |
| Puget Sound Marine (8-13,7B-D) | 34,200 | 33,500 | 49,800 | 33,100 | 28,400 | 70,100 | 75,700 | 63,200 |
| Puget Sound Rivers ${ }^{12 /}$ | 29,500 | 29,500 | 27,600 | 23,400 | 21,900 | 34,400 | 38,300 | 37,400 |
| North WA Coastal Rivers | na | na | 8,800 | 17,300 | 20,200 | 14,400 | 12,800 | 11,800 |
| Grays Harbor (area 2A-2D) ${ }^{7 /}$ | na | na | 2,100 | 10,600 | 5,100 | 2,900 | 5,300 | 8,300 |
| Columbia River Net (Winter/Spring) ${ }^{8 /}$ | na | na | 20,400 | 37,600 | 28,200 | 11,200 | 23,800 | 20,100 |
| Columbia River Net (Summer) ${ }^{8 /}$ | na | na | 23,500 | 41,700 | 22,200 | 15,300 | 9,500 | 25,600 |
| Columbia River Net (Fall) ${ }^{\text {8/ }}$ | na | na | na | 343,900 | 365,900 | 312,500 | 119,800 | 183,600 |

Table 1 Footnotes:
${ }^{1 /}$ Estimates of total mortality (not adjusted for adult equivalents) include non-retention mortality. Total Mortality is estimated by Fishery Regulation Assessment Model (FRAM) as catch + incidental mortality, where incidental mortality = drop off + non-retention mortality (PFMC 2008).
${ }^{2 /}$ For the ocean fisheries, this column shows the Chinook troll and recreational quotas used for 2016 pre-season fishery planning as distributed by ocean area (Landing Quotas = Landed). See text for any in-season adjustments.
${ }^{3 /}$ Includes Area 4B catch during the PFMC management period (May 1 - September 15); Area 4B Treaty troll catch outside PFMC period included under Strait of Juan de Fuca net and troll (October-April).
${ }^{4 /}$ Includes Oregon troll catch in Area 1
${ }^{5 /}$ FRAM modeled pre-season fishery impacts cover the current fishery planning year, for Chinook defined as May 1 through April 30.
${ }^{6 /}$ Mainstem retained sport catch only (upstream to McNary Dam for spring, Priest Rapids Dam for summer and to Hwy 395 for fall). See tables 10, 22-23 in the current Joint Staff Report regarding spring and summer Chinook and tables 25-27 in the annual fall report. http://wdfw.wa.gov/fishing/crc/staff_reports.html.
${ }^{7 /}$ Includes Grays Harbor catch, as well as catch from the Chehalis and Humptulips Rivers and their tributaries for sport and Chehalis and Humptulips Rivers for net estimates.
${ }^{8 /}$ Mainstem retained catch only, includes tribal C\&S and Commercial from all gear types and non-tribal (Columbia River mouth upstream to McNary Dam). Catch data from annual Joint Staff Reports. Winter and spring catch Tables 7 (Tribal) and T18 (non-Tribal). Summer catch is in Table10. Fall catch from annual fall report T21, 23 and 29. http://wdfw.wa.gov/fishing/crc/staff_reports.html.
${ }^{9 /}$ Includes catch from mark-selective fisheries as shown in table 3.
${ }^{10 /}$ Sport data after March 2015 are preliminary. All data subject to change.
${ }^{11 /}$ Includes non-tribal \& tribal commercial, as well as tribal C\&S for all gear types.
${ }^{12 /}$ Chinook fisheries in Puget Sound Rivers are modeled using the Terminal Area Management Module (TAMM), based upon FRAM output of terminal run sizes. Total Mortality is estimated in TAMM as catch + non-retention mortality (PFMC 2008).

Table 16. Preliminary 2016 Landed Coho Catch for Washington and Oregon Fisheries of Interest to the Pacific Salmon Commission.
Values are presented in number of fish rounded to the nearest 100. ${ }^{6 /}$

|  | 2016 |  |  | Landed |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Preseason ${ }^{9 /}$ |  |  |  |  |  |  |  |
| Fisheries | Total Mortality ${ }^{1 /}$ | Landed ${ }^{2 /}$ | Preliminary Landed | 2015 | 2014 | 2013 | 2012 | 2011 |
| OCEAN FISHERIES |  |  |  |  |  |  |  |  |
| Commercial Troll |  |  |  |  |  |  |  |  |
| Neah Bay and La Push (area 3,4,4B) ${ }^{3 /}$ | 1,000 | - | - | 4,100 | 59,600 | 48,800 | 38,300 | 14,100 |
| Columbia Ocean Area and Westport (area 1,2) ${ }^{\text {10/ }}$ | 3,200 | - | - | 4,800 | 19,000 | 5,300 | 2,700 | 2,900 |
| Sport (see text for quota information) |  |  |  |  |  |  |  |  |
| Neah Bay (area 4) | 1,700 | - | 100 | 7,800 | 5,600 | 6,500 | 7,500 | 3,100 |
| La Push (area 3) | 700 | - | - | 600 | 4,600 | 2,800 | 2,200 | 2,100 |
| Westport (area 2) | 6,200 | - | - | 30,700 | 54,500 | 20,400 | 11,900 | 13,800 |
| Columbia Ocean Area (area 1) | 21,800 | 18,900 | 18,600 | 44,600 | 75,100 | 20,500 | 11,400 | 26,700 |
| INSIDE FISHERIES |  |  |  |  |  |  |  |  |
| Sport ${ }^{7 /}$ |  |  |  |  |  |  |  |  |
| Strait of Juan de Fuca (area 5,6) | 700 | - | na | 62,900 | 63,000 | 41,300 | 76,200 | 21,400 |
| San Juan Islands (area 7) | 400 | - | na | 3,700 | 2,000 | 2,600 | 2,200 | 900 |
| Puget Sound Marine (area 8-13) | 5,800 | 4,000 | na | 77,200 | 59,200 | 72,100 | 91,300 | 34,500 |
| Puget Sound Rivers | 4,500 | 4,200 | na | 18,600 | 17,900 | 70,000 | 43,500 | 40,300 |
| North WA Coastal Rivers | 200 | 200 | na | 3,700 | 8,900 | 8,000 | 3,400 | 7,900 |


| Grays Harbor ${ }^{5 /}$ | 3,100 | 3,000 | na | 8,200 | 27,300 | 21,200 | 18,300 | 14,600 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Columbia River Buoy 10 $0^{4,11 /}$ | 23,800 | 20,000 | 9,000 | 36,900 | 57,700 | 7,600 | 7,400 | 7,600 |
| Commercial ${ }^{8 /}$ |  |  |  |  |  |  |  |  |
| Strait of Juan de Fuca net and troll (area 4B,5,6C) | 1,200 | 1,100 | 400 | 1,700 | 2,300 | 2,700 | 3,500 | 2,700 |
| San Juan Islands (area 6,7,7A) | 4,100 | 3,500 | 4,000 | 4,000 | 19,800 | 19,700 | 10,500 | 11,300 |
| Puget Sound Marine (area 8-13,7B-D) | 67,800 | 66,300 | 202,400 | 28,800 | 108,400 | 168,500 | 236,300 | 136,500 |
| Puget Sound Rivers | 13,400 | 13,100 | 69,700 | 17,300 | 73,700 | 136,600 | 123,600 | 89,000 |
| North WA Coastal Rivers | 29,600 | 29,000 | 49,800 | 18,300 | 101,100 | 44,000 | 39,500 | 82,800 |
| Grays Harbor (area 2A-2D) ${ }^{5 /}$ | 5,400 | 5,300 | 1,800 | 12,600 | 67,200 | 30,400 | 44,000 | 32,300 |

## Table 2 Footnotes:

${ }^{1 /}$ Estimates of total mortality include non-retention mortality. Total Mortality is estimated by Fishery Regulation Assessment Model (FRAM) as catch + incidental mortality, where incidental mortality = drop off + non-retention mortality (PFMC 2008).
${ }^{2 /}$ For ocean fisheries this column shows the Coho troll and recreational quotas used for 2016 pre-season fishery planning as distributed by ocean area (Landing Quotas = Landed). See text for any in-season adjustments.
${ }^{3 /}$ Includes area 4B catch during the PFMC management period (May 1 - September 15); area 4B Treaty troll catch outside the PFMC period included under Strait Juan de Fuca net and troll (October-April).
${ }^{4 /}$ Retained catch only. See table 26 in the current Fall Joint Staff report available on line at http://wdfw.wa.gov/fishing/crc/staff_reports.html.
${ }^{5 /}$ Includes Grays Harbor catch, as well as catch from the Chehalis and Humptulips Rivers; their tributaries are included in sport estimates only.
${ }^{6 /}$ Includes catch from mark-selective fisheries where estimates are available.
${ }^{7 /}$ Sport data for the most recent two years are preliminary. All data subject to change.
${ }^{8 /}$ Includes Non-Tribal and Tribal commercial and take home, as well as Tribal ceremonial and subsistence (C\&S) for all gear types. Starting in 2012, the Copalis, Moclips, and Ozette Rivers have been removed from landed catch.
${ }^{9 /}$ FRAM modeled pre-season fishery impacts cover the current fishery planning year, for Coho defined as January 1 through December 31.
${ }^{10 /}$ Includes Oregon troll catch in Area 1
${ }^{11 /}$ Sport data after March 2013 are preliminary. For Buoy 10, see tables 25 in the annual fall report.

Table 17. Mark-Selective Chinook and Coho Fisheries by Area and Year. "Yes" denotes that a mark-selective fishery occurred, even if it only occurred in a subset of the fishing area, season, gear type, or user group.

| Selective Coho | 2016 | 2015 | 2014 | 2013 | 2012 | 2011 | 2010 | 2009 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Ocean Troll |  |  |  |  |  |  |  |  |
| Cape Flattery \& Quillayute (Areas 3/4) | no | yes | yes | yes | yes | yes | yes | yes |
| Columbia R \& Grays Harbor (Areas 1 \& 2) | no | yes | yes | yes | yes | yes | yes | yes |
| Ocean Sport |  |  |  |  |  |  |  |  |
| Neah Bay (Area 4) | no | yes | yes | yes | yes | yes | yes | yes |
| LaPush (Area 3) | no | yes | yes | yes | yes | yes | yes | yes |
| Grays Harbor (Area 2) | no | yes | yes | yes | yes | yes | yes | yes |
| Col. R. (Leadbetter Pt. to Cape Falcon) | yes | yes | yes | yes | yes | yes | yes | yes |
| Inside Fisheries |  |  |  |  |  |  |  |  |
| Sport |  |  |  |  |  |  |  |  |
| Juan de Fuca (Areas 5 \& 6) | yes | yes | yes | yes | yes | yes | yes | yes |
| San Juan Islands (7) | no | yes | yes | yes | yes | yes | yes | yes |
| Puget Sound Sport (Areas 8-13 all year) | yes | yes | yes | yes | yes | yes | yes | yes |
| Puget Sound Rivers | yes | yes | yes | yes | yes | yes | yes | yes |
| North WA Coastal Rivers | yes | yes | yes | yes | yes | yes | yes | yes |
| Grays Harbor (Areas 2-2) | yes | yes | yes | yes | yes | no | yes | yes |
| Willapa Bay (Area 2-1) | no | yes | no | no | no | no | yes | no |
| Columbia River Buoy 10 | yes | yes | yes | yes | yes | yes | yes | yes |
| Commercial |  |  |  |  |  |  |  |  |
| North WA Coastal Rivers | no | no | no | no | no | no | no | no |
| Grays Harbor (Areas 2A-2D) | yes | yes | yes | no | no | yes | yes | yes |
| Willapa Bay (Area 2-1) | no | no | no | no | no | no | yes | no |
| Columbia River Net/ - Fall | no | yes | yes | yes | no | no | no | no |
| Strait of Juan de Fuca (Areas 4B/5/6C) Net \& Troll | no | no | no | no | no | no | no | no |
| San Juan Islands (Areas 6, 7 \& 7A) | yes | yes | yes | yes | yes | yes | yes | yes |
| Puget Sound Marine (Areas 8-13) | yes | no | no | no | no | no | yes | no |


| Puget Sound Rivers | no | no | no | no | no | no | no | no |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Selective Chinook | 2016 | 2015 | 2014 | 2013 | 2012 | 2011 | 2010 | 2009 |
| Ocean Troll <br> Cape Flattery \& Quillayute (Areas 3/4/4B) <br> Columbia. R \& Grays Harbor (Areas 1\&2) |  |  |  |  |  |  |  |  |
|  | no | no | no | no | no | no | no | no |
|  | no | no | no | no | no | no | no | no |
| Ocean Sport |  |  |  |  |  |  |  |  |
| Neah Bay (Area 4) | no | yes | yes | yes | yes | yes | yes | no |
| La Push (Area 3) | no | yes | yes | yes | yes | yes | yes | no |
| Grays Harbor/Westport (Area 2) | no | yes | yes | yes | yes | yes | yes | no |
| Col. R./Ilwaco (Leadbetter Pt. to Cape Falcon) | no | yes | yes | yes | yes | yes | yes | no |
| Inside Fisheries |  |  |  |  |  |  |  |  |
| Sport |  |  |  |  |  |  |  |  |
| Juan de Fuca (Area 5\&6) | yes | yes | yes | yes | yes | yes | yes | yes |
| San Juan Islands (Area 7) | yes | yes | yes | yes | yes | yes | yes | yes |
| Puget Sound Sport (Areas 8-13) | yes | yes | yes | yes | yes | yes | yes | yes |
| Puget Sound Rivers | yes | yes | yes | yes | yes | yes | yes | yes |
| North WA Coastal Rivers | yes | yes | yes | yes | yes | yes | yes | yes |
| Grays Harbor (Areas 2-2) | yes | yes | yes | yes | yes | no | no | no |
| Columbia River Sport - Winter/Spring | yes | yes | yes | yes | yes | yes | yes | yes |
| Columbia River Sport - Summer | yes | yes | yes | yes | yes | yes | yes | no |
| Columbia River Sport - Fall | yes | yes | yes | yes | yes | no | no | no |
| Willapa Bay (Area 2-1) | yes | yes | yes | yes | yes | yes | yes | yes |
| Commercial |  |  |  |  |  |  |  |  |
| North WA Coastal Rivers | no | no | no | no | no | no | no | no |
| Grays Harbor (Areas 2A-2D) | yes | yes | yes | yes | yes | no | no | no |
| Willapa Bay (Area 2-1) | yes | yes | yes | yes | yes | yes | yes | yes |
| Columbia River Net-Winter/Spring | yes | yes | yes | yes | yes | yes | yes | yes |
| Columbia River Net - Summer | no | no | no | no | no | no | no | no |
| Columbia River Net - Fall | yes | yes | yes | yes | no | no | no | no |


| Strait of Juan de Fuca(4B/5/6C) Net \& | no | no | no | no | no | no | no |
| :--- | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Troll |  |  | no |  |  |  |  |
| San Juan Islands (Areas 6, 7 \& 7A) | yes | yes | yes | yes | yes | yes | yes |
| Puget Sound Marine (Areas 8-13) | no | yes | no | no | no | yes | yes |
| Puget Sound Rivers | no | yes | yes | yes | yes | yes | no |

## III. PRELIMINARY REVIEW OF THE 2016 WASHINGTON CHUM SALMON FISHERIES OF INTEREST TO THE PACIFIC SALMON COMMISSION

This summary report provides a preliminary review of the 2016 U.S. Chum salmon (Oncorhynchus keta) fisheries conducted by Puget Sound salmon co-managers (Puget Sound Treaty fishing tribes and the State of Washington) in the Strait of Juan de Fuca (Salmon Management and Catch Reporting Areas 4B, 5 and 6C), the San Juan Islands and the Point Roberts area (Areas 7 and 7A) (Figure 39), conducted in compliance with provisions of Chapter 6 of Annex IV of the Pacific Salmon Treaty (PST 2008). The harvest and abundance information provided are based on preliminary data reported through November 15, 2016 and is subject to correction and revision as additional information becomes available.

Figure 39. Puget Sound Salmon Management and Catch Reporting Areas with Chum salmon fisheries of interest to the Pacific Salmon Commission.


## MIXED STOCK FISHERIES

Areas 4B, 5 and 6C
As in previous years, the Chum salmon fishery in Areas 4B, 5 and 6C was restricted to Treaty Indian fishers using gillnets. The fall Chum-directed salmon fishery opened the week of October 9 , with a schedule of six days per week and continued through November 12. Effort was higher
than in recent years with a total of 25,550 Chum salmon harvested (Table 18). During the fall Chum fisheries in Areas 4B, 5, and 6C, there was a reported by-catch of 338 Coho, 53 Chinook, and zero Steelhead.

Table 18. Preliminary 2016 Chum salmon harvest report for Washington Salmon Catch Reporting Areas 4b, 5, 6c.

| Areas 4B, 5, 6C |  |
| :---: | ---: |
| Treaty Indian, Gill Net Only |  |
| Time Periods | GN |
| Through 9/17 | 0 |
| $9 / 18-9 / 24$ | 0 |
| $9 / 25-10 / 1$ | 0 |
| $10 / 2-10 / 8$ | 0 |
| $10 / 9-10 / 15$ | 238 |
| $10 / 16-10 / 22$ | 3,366 |
| $10 / 23-10 / 29$ | 15,588 |
| $10 / 30-11 / 5$ | 4,081 |
| $11 / 6-11 / 12$ | 2,277 |
| Total | 25,550 |

## Areas 7 and 7A

Chum salmon fisheries in Areas 7 and 7A are regulated to comply with a base harvest ceiling of 130,000 Chum salmon, unless a critically low level of abundance is identified for those stocks migrating through Johnstone Strait ("Inside Southern Chum salmon") (PST 2008). Chapter 6 of Annex IV specifies that U.S. commercial fisheries for Chum salmon in Areas 7 and 7A will not occur prior to October 10. Paragraph 10 (a-b) specifies run sizes below 1.0 million as critical (estimated by Canada). For run sizes below the critical threshold, the U.S. catch of Chum salmon in Areas 7 and 7A will be limited to those taken incidentally to other species and in other minor fisheries, and shall not exceed 20,000. During 2016, following Chapter 6 requirements and preseason domestic fishery plans, U.S. commercial Chum fisheries were initiated on October 10 and continued through October 26.

Paragraph 10 (d) states that Canada will provide an in-season estimate of Fraser River Chum salmon run size no later than October 22. If that estimate is below 900,000, then the U.S. will limit its fishery to not exceed a catch of 20,000 additional Chum salmon from the day following notification. An estimated Fraser River Chum salmon run size of 1,550,000 was provided by Canada on October 19. Paragraph 10(d) further states that the total catch is not to exceed 130,000 Chum Salmon. Therefore, to ensure that the U.S. chum fishery stayed within its share while paying back the remaining Chum owed to Canada (Table 19), fishery managers tracked catches daily relative to share, and the fishery continued through October 26. Total U.S. catch between October 10 and October 26 in Areas 7 and 7A was 118,049 Chum salmon (Table 19). The NonTreaty gillnet and purse seine fleets were open daily October 10, 12, 13, 17, 19, and 21. The

Treaty Indian gillnet and purse seine fisheries were opened on October 10 and ran continuously through October 20, then reopened for one day with limited effort on October 26.

Non-Indian reef net fisheries targeting adipose-marked Coho salmon were conducted from the end of Fraser Panel control in Area 7 (September 3) until September 30, with Chum salmon retention prohibited. From October 1 through October 21, reef nets were open daily with Chum salmon retention allowed. Total Chum salmon catch in the reef net fishery was 2,334 fish.

The total 2016 Chum salmon catch by all gears in Areas 6, 7, and 7A, reported through October 26, was 118,926 (Table 20). Catch distribution, between Areas 7 and 7A, was $63 \%$ and $36 \%$ respectively. However, it should be noted that these catch reports may be incomplete as of the date of this report. Due to the low returns of Fraser River Sockeye, no Sockeye directed fisheries took place and thus no chum were harvested prior to the October fisheries. During the fall Chum salmon-directed fisheries in Areas 6, 7 and 7A, there was a reported by-catch of 3,465 Coho, 3 Chinook, and zero Steelhead (Table 20).

By the conclusion of the 2016 chum fishing season in Areas 7/7A, the U.S. had paid back in full the Chum owed to Canada as a result of the U.S. overage that occurred in 2014. In 2014, for the first time under the 2008 PST Chum agreement, the U.S. landed the full share of 130,000 Chum salmon allowed to be caught in Area 7/7A in a non-critical year under the current Chapter 6 of the Pacific Salmon Treaty (PST) (Table 19). Additionally, during the 2014 season the U.S. exceeded its 130,000 share by 16,571 Chum. Chapter 6.10 (h) of the PST provides guidance for overage calculations, as follows: "Catches in excess of 135,000 Chum shall result in an overage being calculated by subtracting 130,000 from the total Chum catch. Overages will be accounted for by reducing the U.S. annual catch ceilings in up to two subsequent non-critical Inside Southern Chum salmon years." As shown in Table 2, the total U.S. catch (tribal and non-tribal) in Area 7/7A during 2016 was 118,049 Chum, with a payback to Canada of 11,951 Chum. Thus, during the 2015 and 2016 Chum fisheries, the U.S. paid back in full the 2014 overage of 16,571 during the subsequent two non-critical years. Further, in 2016 the U.S. did not catch 533 chum of its share, providing additional savings (Table 19).

Table 19. U.S. 7/7A Chum Catches, 2009-2016.

| Year | Total <br> U.S. <br> catch | Total <br> U.S. <br> Share | Uncaught <br> share | Overage <br> vs. <br> $\mathbf{1 3 0 K}$ <br> share | Number <br> Paid <br> Back ${ }^{\text {a/ }}$ | Remaining <br> Number <br> Owed to <br> Canada |
| :---: | :---: | :---: | ---: | :---: | :---: | :---: |
| 2009 | 24,073 | 130,000 | 105,927 | 0 |  |  |
| 2010 | 23,404 | 130,000 | 106,596 | 0 |  |  |
| 2011 | 60,485 | 130,000 | 69,515 | 0 |  |  |
| 2012 | 72,866 | 130,000 | 57,134 | 0 |  |  |
| 2013 | 79,650 | 130,000 | 50,350 | 0 |  |  |
| 2014 | 146,571 | 130,000 | 0 | 16,571 |  |  |
| 2015 | 124,847 | 130,000 | 0 | 0 | 5,153 | 11,418 |
| 2016 | 118,049 | 130,000 | 533 | 0 | 11,951 | 0 |

${ }^{\text {a/ }}$ (U.S. share of 130,000 ) - (Total U.S. actual catch) $=$ Chum paid back to Canada in 2015 and 2016.
${ }^{\text {b/ }}$ Remaining Chum owed to Canada in the next non-critical year: (Overage in 2014 at 16,571) - (Amount paid back in 2015 and 2016) = Remaining amount of 0 .

Table 20. Preliminary 2016 Chum salmon harvest report for Washington Salmon Catch Reporting Areas 6, 7, 7A.

|  | Area 6 | Area 7 |  |  |  | Area 7A |  |  | Area 6,7,7A |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Time Periods | GN | PS | GN | RN | Area Total | PS | GN | Area Total | Total |
| Through 9/24 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| $9 / 25-10 / 1$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| $10 / 2-10 / 8$ | 0 | 0 | 0 | 581 | 581 | 0 | 0 | 0 | 581 |
| $10 / 9-10 / 15$ | 57 | 20,742 | 3,924 | 1,753 | 26,419 | 10,283 | 13,051 | 23,334 | 49,810 |
| $10 / 16-10 / 22$ | 820 | 44,843 | 2,420 | 0 | 47,263 | 3,463 | 16,313 | 19,776 | 67,859 |
| $10 / 23-10 / 29$ | 0 | 600 | 0 | 0 | 600 | 0 | 76 | 76 | 676 |
| $10 / 30-11 / 5$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 877 | 66,185 | 6,344 | 2,334 | 74,863 | 13,746 | 29,440 | 43,186 | 118,926 |
| Gear Type Abbreviations: GN=Gill Net; PS=Purse Seine; RN=Reef Net |  |  |  |  |  |  |  |  |  |
| 10/10- 11/5 <br> By-catch | Coho: 3,465 | Chinook: 3 |  |  |  |  |  |  | Steelhead: 0 |

## puget sound terminal area fisheries and run strength

Pre-season forecasts for Chum salmon returns to Puget Sound predicted a fall Chum run size totaling approximately $1,183,300$ fish, with 489,698 Chum predicted to return to Hood Canal and 526,060 predicted to return to South Puget Sound. As of the date of this report, in-season estimates indicate that Chum returns to Puget Sound are generally at or above forecast with some exceptions. In-season run size updates from the 2016 fall Chum fisheries in Hood Canal and South Puget Sound indicate that the Hood Canal run is above forecast at 625,900 Chum while the South Puget Sound run is below forecast at 380,000 Chum. Some Puget Sound Chum fisheries are still underway and additional in-season estimates of abundance may occur. As of the
date of this report, spawning escapement surveys are in progress for most Puget Sound stocks and therefore escapement estimates are not yet available. Early indications from these surveys do, however, suggest that nearly all stocks will meet escapement goals; although, some central Puget Sound Fall Chum stocks appear to be below escapement again this year.

## REFERENCES

Pacific Salmon Treaty (PST) Act of 1985. 2008 Agreement. U.S.-Canada. Public Law 99-5, 16 U.S.C. 3631.

## IV.PRELIMINARY REVIEW OF 2016 UNITED STATES FRASER RIVER SOCKEYE AND PINK SALMON

## INTRODUCTION

The 2016 Fraser River Panel fishing season was implemented under Annex IV of the Pacific Salmon Treaty (PST), and guidelines provided by the Pacific Salmon Commission to the Fraser River Panel. The treaty establishes a bilateral (U.S. and Canada) Fraser River Panel (Panel) that develops a pre-season management plan and approves in-season fisheries within Panel Area waters directed at sockeye and pink salmon bound for the Fraser River (Figure 40). In partial fulfillment of Article IV, paragraph 1 of the PST, this document provides a season review of the 2016 U.S. Fraser River salmon fisheries as authorized by the Panel. Catch and abundance information presented is considered preliminary.


Figure 40. British Columbia and State of Washington Fishery Management Areas, 2016. The shaded area in the figure represents the marine waters managed by the Fraser River Panel.

## PRESEASON EXPECTATIONS AND PLANS

## Forecasts and Escapement Goals

Pre-season run size forecasts and escapement goals by run timing group (run) at various probability levels were provided to the Panel by the Department of Fisheries and Oceans, Canada (DFO). Table 21 shows the 2016 pre-season sockeye forecasts based on the 50 percent probability level, which represent the mid-point of the range of possible run sizes for all runs. Table 21 also provides the escapement goals for the sockeye run timing groups based on the preseason forecasted abundance. The escapement goals for all runs can change in-season as the run size estimates are updated.

Table 21. 2016 pre-season Fraser River sockeye forecasts and escapement goals by run timing group.

|  | Early Stuart | Early Summer | Summer | Lates | Total |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Forecast of <br> Abundance | 36,000 | 447,000 | $1,677,000$ | 111,000 | $2,271,000$ |
| Escapement <br> Goal | 36,000 | 178,800 | 722,000 | 111,000 | $1,047,800$ |

## Northern Diversion Rate

Northern diversion rate is defined as the percentage of Fraser sockeye migrating through Johnstone Strait (rather than the Strait of Juan de Fuca) in their approach to the Fraser River. The preseason forecast for diversion was $75 \%$ which is above the 1990-2015 median diversion of 63\%.

## Management Adjustments (MA) and Environmental Conditions

Management adjustments (MA) for sockeye salmon reflect the anticipated difference between escapement estimates at Mission (minus catch above Mission) and actual spawning escapements. Adjustments adopted by the Panel are added to the gross escapement goal, effectively increasing the spawner escapement goal for that run timing group. MAs are modeled using forecasts of environmental conditions and return timing or median historical differences between estimates. Table 22 provides the pre-season projected MAs that were used for planning fisheries in 2016. In-season management adjustments use MA models that are based on both measured and forecasted temperatures and discharges or, for Late-run sockeye, upstream migration timing.

Table 22. 2016 pre-season proportional management adjustment (pMA) and corresponding proportional difference between estimates $\left(\mathrm{pDBE}^{1}\right)$ for each run timing group.

| Early Stuart |  | Early Summer |  | Summer |  | Lates |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| pMA | pDBE | pMA | pDBE | pMA | pDBE | pMA | pDBE |
| 0.69 | $-41 \%$ | 0.59 | $-37 \%$ | 0.11 | $-10 \%$ | 0.47 | $-32 \%$ |

${ }^{1}$ The aggregate Early Summer, Summer, and Late-Run pDBE is calculated using the component pDBEs weighted by the p50 run size forecasts. The median pDBE for Chilliwack is calculated using dominant/subdominant years, while the median pDBE for Late-run, excluding Birkenhead/Big Silver, uses 2016 cycle line years. The median pDBE for all other component groups is based on all years of historic data.

## Run Timing

Run timing is temporal information about the presence of a salmon stock in a specific time and area. Run timing is an important variable when planning fisheries and predicting run size inseason. The following Area $2050 \%$ dates (the dates when $50 \%$ of the run is forecasted to have passed through Area 20) were predicted pre-season for the major Fraser River sockeye run groups (Table 23).

Table 23. 2016 Area 20 historic 50\% run timing dates and updated pre-season timing forecasts in June.

| Run Timing <br> Group | Area 20 50\% Run Timing <br> Historic Date | Area 20 50\% Run <br> Timing (June) |
| :---: | :---: | :---: |
| Early Stuart | July 4 | July 2 |
| Early Summer | July 29 | July 19 |
| Summer | August 8 | August 3 |
| Lates | August 20 | August 12 |

## U.S. Total Allowable Catch (TAC)

Pre-season, the US TAC was established at 106,000 sockeye. The TAC available by sockeye run timing group is shown in Table 24.

Table 24. 2016 total U.S. total allowable catch (TAC) by run timing group ${ }^{1}$.

| Run Timing Group | Pre-season U.S. TAC |
| :---: | ---: |
| Early Stuart | 0 |
| Early Summer | 13,000 |
| Summer | 93,000 |
| Lates | 0 |
| Total | 106,000 |

${ }^{1}$ Based on Panel-approved final pre-season model run on July 19, 2016.

## Preseason Management Plans

During the pre-season planning process the Panel evaluates and adopts management approaches for Fraser sockeye that address conservation and harvest objectives for each major run timing group. The Panel develops fishing plans and in-season decision rules with the objective of meeting management goals. Managing Fraser River sockeye salmon involves a trade-off between catching abundant runs and meeting escapement objectives for less abundant run groups.

In 2016, the pre-season forecast of $\sim 2.3$ million sockeye resulted in available US TAC in the Early Summer and Summer run timing groups (Table 23) with the majority of TAC ( $\sim 88 \%$ ) in the Summer run group. While planning pre-season fishing schedules, the lack of TAC in Early Stuart and Late run sockeye left a narrow window for the U.S. to prosecute fisheries and minimize the impact to Early Stuart and Late run sockeye. U.S. fisheries were planned to
commence in late July right before the peak of Summer run sockeye and prior to Late run sockeye showing up in abundance.

## IN-SEASON MANAGEMENT

In-season, the Pacific Salmon Commission staff analyzes a variety of information to produce best estimates of northern diversion, management adjustments, timing, abundance, and harvest by run timing group. Stock identification information (both genetic data and scales), age data, test fishing data, escapement counts past Mission, harvest data, and environmental information are all used to provide these in-season estimates that are critical to Fraser Panel management.

## Run Assessment

The final in-season total abundance estimate for sockeye in 2016 (Table 25) was 855,000, which was $38 \%$ of the pre-season forecast. This represents the lowest sockeye return to the Fraser River since record keeping began in 1893. Across the four run timing groups, all groups returned well below their preseason forecasts. Early Stuart and Early Summer run sockeye performed similarly with respective in-season run size estimates at $50 \%$ and $54 \%$ of their pre-season forecasts. The return of Summer-run sockeye was only $31 \%$ of the preseason forecast while Late-run sockeye performed the strongest, but still at $63 \%$ of forecast.

The 2016 Fraser sockeye run timing varied across run timing groups with both Summer run and Late run sockeye arriving 3 and 4 days early (July 31 and Aug. 8 respectively; Table 26). Both Early Stuart and Early Summer run sockeye were one day later relative to preseason expectations.

Table 25. Comparison of 2016 pre-season vs. in-season abundance estimates for Fraser River sockeye salmon by run timing group.

| Run Timing Group | Pre-Season <br> 50\% Probability <br> Forecast | In-Season <br> Run Size <br> Estimate | Comparison: <br> In-Season / <br> Pre-Season Forecast |
| :--- | :---: | :---: | :---: |
| Early Stuart | 36,000 | 18,000 | $50 \%$ |
| Early Summer | 447,000 | 240,000 | $54 \%$ |
| Summer | $1,677,000$ | 527,000 | $31 \%$ |
| Lates | 111,000 | 70,000 | $63 \%$ |
| Total Sockeye | $2,271,000$ | 855,000 | $38 \%$ |

${ }^{1}$ As of September 19, 2016.

Table 26. Comparison of 2016 preliminary 50\% run timing dates through Area 20 to inseason estimates.

| Run Timing Group | Pre-season 50\% Run <br> Timing Date | In-season 50\% Run <br> Timing Date |
| :---: | :---: | :---: |
| Early Stuart | July 2 | July 3 |
| Early Summer | July 19 | July 20 |
| Summer | August 3 | July 31 |
| Lates | August 12 | August 8 |

## Season Description

The Fraser Panel met on every Tuesday and Friday between July 8 and August 26 to receive updates on the abundance and timing of the sockeye return from PSC staff and to review migration conditions in the Fraser River watershed. In-season abundance estimates did not match pre-season expectations so U.S. fisheries were extremely limited. In-river environmental conditions were not a major factor affecting management decisions in 2016. The following summarizes the major decisions related to U.S. fishing during the 2016 season.

## July 22, 2016:

The first Panel approved U.S. commercial fishery was scheduled for July 23 to July 27 for Treaty fishers in areas 4B, 5, and 6C. Early Summer and Summer run abundances leading up to the approved fishery were tracking slightly below the preseason forecasts, however, marine area abundances appeared to be increasing based on test fishery catches. There was not enough information to update either the Early Summer or Summer run sizes.

The Panel extended the Treaty fishery in areas 4B, 5, and 6C through July 30 on July 26 and through August 3 on July 29. Sockeye catches in this fishery were small (less than 1,000 fish cumulative total).

## August 2, 2016:

The Early Summer run size was downgraded to 300,000 with an associated marine area timing of July 22, three days later than the preseason forecast. Effort and sockeye catch by the Treaty Indian fishery in areas 4B, 5, and 6C remained low and the fishery was extended to August 6.

## August 5, 2016:

Based on test fishery catches and numbers of sockeye passing Mission that remained well below preseason expectations, the Summer run size was downgraded to the p25 forecast level of 992,000 sockeye with an associated timing of August 6 (three days later than the preseason forecast). The Early Summer run size remained unchanged at 300,000. The lowering of the Summer run size, along with the prior change to the Early Summer run size, eliminated fish available for U.S. TAC. The Treaty Indian fishery in areas 4B, 5, and 6C was scheduled to close August 6 and no further U.S. fisheries were planned.
U.S. fisheries remained closed for the remainder of the season. Table 27 summarizes changes to run sizes made by the Fraser Panel during the 2016 season.

Table 27. Summary of changes to Fraser River sockeye run size estimates made by the Fraser Panel during the 2016 season.

| Meeting Date | Run Timing Group | Change Made |
| :--- | :--- | :--- |
| July 19, 2016 | Early Stuart | decreased to 22,000 |
| August 2, 2016 | Early Summer | decreased to 300,000 |
| August 5, 2016 | Early Stuart <br> Summer | decreased to 18,000 <br> decreased to 992,000 |
|  | Early Summer | decreased to 250,000 |
|  | Summer | decreased to 700,000 |
| August 12, 2016 | Summer | decreased to 600,000 |
| August 19, 2016 | Early Summer | decreased to 240,000 |
|  | Summer | decreased to 520,000 |
|  | Lates | decreased to 75,000 |

## HARVEST

U.S. harvest opportunities in 2016 were expected to be limited going into the season and inseason abundances estimates were continually downgraded from preseason expectations throughout the season with no sockeye available for U.S. TAC after the decreases to the run sizes that the Panel adopted at the August 5 meeting. The limited harvest that occurred was in Treaty ceremonial and subsistence (C\&S) fisheries and Treaty commercial fisheries in areas 4B, 5, and 6C (Table 28). Treaty commercial fisheries were open for 15 days in areas 4B, 5, and 6C. There were no All Citizens fishery openings in 2016.

Table 28. Preliminary estimate of 2016 U.S. catches of Fraser River sockeye salmon in Panel area waters.

|  | Treaty Indian | All Citizens |
| :--- | :---: | :---: |
| Ceremonial and <br> Subsistence (all areas) | 842 | 0 |
| Commercial Catch in <br> Areas 4B/5/6C | 828 | 0 |
| Commercial Catch in <br> Areas 6/7/7A | 0 | 0 |
| Total Catch | 1,670 | 0 |
| \% of U.S. Catch | $100.0 \%$ | 0 |

## SEAK MSF Fishery 2016 Postseason Summary



PSC Postseason Meeting
January 9-13, 2017


## 2016 AK Proposed MSF

- Experimental fishery
- Coho-directed troll fishery
- July to September
- Up to 10,000 Chinook
- Regulations:
- Areas of high Chinook abundance closed
- Applies to marked Chinook > 28 inches



## MSF Proposal Amended

- February 2016 U.S. Section meeting
- Alaska proposes that the MSF fishery will occur inside of Table 1 limits.
- All other facets of the fishery to remain the same as proposed



## 2016 MSF Fishery Implementation

- September 4 - 30
- Coho-directed fishery
- Inside Table 1 limits
- Areas of high Chinook abundance closed
- Poor weather/ fishing conditions


## High Chinook abundance closure areas



## 2016 MSF Fishery Information

- 459 landed Chinook salmon
- 450 Treaty fish
- 9 Alaska Hatchery Add-on
- 452 permits fished, 150 permits landed Chinook
- Equates to ~3 Chinook per vessel for the 27 day fishery.
- Concern that fishermen would target Chinook unsubstantiated.


## 2016 Sampling Information

- 35\% sampled ( $\mathrm{N}=159$ )
- CWT, ASL, and tissues collected
- $48 \%$ No Tags ( $\mathrm{n}=77$ )
- 52\% CWT (n=82)


## 2016 CWT Recoveries



Other= Snootli Creek, Philips River, and Dexter Ponds

## 2016 Postseason Considerations

- Experimental fishery has learning curve
- Educated fleet, buyers, processors, \& samplers
- Amended databases to accommodate data
- No interviews with fishermen occurred to collect release/encounter data
- Apply release mortality rates used in the CTC exploitation rate analysis and PSC Chinook Model
- Catches low during September
- Consider opening fishery earlier


## 2017 MSF Proposal/ Plans

## 2016 Reporting

- Final postseason report submitted to PSC

2017 Proposal

- Similar to 2016 proposal
- Inside Table 1 limits


## 2017 Planning

- Continue experimental fishery
- Conduct fishery earlier in the summer
- Interview fishermen to get release/encounter information


# Revised process to provide PSC Guidance on Very High Priority Chinook Projects for 2017 

and 2018

## Introduction:

The following revised process is proposed to replace the Commission's process adopted February 11, 2016, titled "Process to Provide PSC Guidance on Very High Priority Chinook Projects for 2017 and 2018."

## Revised process for providing advice to the Northern and Southern Fund Committees on Very High Chinook Projects in 2016, 2017 and 2018:

## April 2016:

Task 1: The CTC will provide advice to the Commission at the conclusion of their April 2016 meeting. The CTC's advice will cover very high priority chinook issues to help inform the development of requests for proposals for 2017 projects at the level of detail consistent with the April 18, 2016 memo (Attch 1).

Task 2: The Commission chairs will consider the CTC advice and provide the Commission's views to the JFC in advance of 2016 RFPs (Attch 2).

January 2017, at Post-Season Meeting: Commission requests the results of the JFC technical review of 2017 proposals be provided to the Commission for its review and consideration of the funding recommendations list, including VHPC recommendations (technical review scheduled to occur January 8, 2017).

## February 2017, at Annual Meeting:

Task 1: The Parties to the Commission discuss with their CTC representatives the JFC's ranked list of projects, and specifically consider whether any of the VHPC project recommendations may impact the Parties' ability to meet their Treaty obligations (i.e., where the recommendation is not to fund, the project is unlikely to be funded elsewhere, and without the project the Parties fail to meet a Treaty obligation).

Task 2: The Commission Chairs decide if any communication to the JFC is necessary, for example, to highlight any impact on the Commission's ability to meet its Treaty obligations.

Task 3: As necessary, the Commission Chairs provide the Commission's views on the JFC's funding recommendations and list of projects regarding requests and justifications for adjustments to recommendations of specific VHPC projects for the 2017 calendar year. The Commission's views would be transmitted to the JFC before the end of the Annual Meeting.

February 2017, following Annual Meeting: The JFC considers the Commission's views, as
available, and its funding recommendations for projects, and decides which projects to fund in 2017.

May 2017:
Task 1: The CTC will provide advice to the Commission at the conclusion of their May 2017 meeting consistent with the level of detail provided in their April 2016 memo. The CTC's advice will cover very high priority chinook issues to help inform the development of requests for proposals for 2018 projects (i.e., as occurred April 2016).

Task 2: The Commission chairs will consider the CTC advice and provide the Commission's views to the JFC in advance of 2017 RFPs.

January 2018, at Post Season Meeting: Commission requests the results of the JFC technical review of 2018 proposals be provided to the Commission for its review and consideration of the funding recommendations list, including VHPC recommendations.

## February 2018, at Annual Meeting:

Task 1: The Parties to the Commission discuss with their CTC representatives the JFC's funding recommendations and list of projects, and specifically consider whether any of the VHPC project recommendations may impact the Parties' ability to meet their Treaty obligations (i.e., where the recommendation is not to fund, the project is unlikely to be funded elsewhere, and without the project the Parties fail to meet a Treaty obligation).

Task 2: The Commission Chairs decides if any communication to the JFC is necessary, for example, to highlight any impact on the Commission's ability to meet its Treaty obligations.

Task 3: As necessary, the Commission Chairs provide the Commission's views on the JFC's funding recommendations for projects regarding requests and justifications for adjustments to recommendations of specific VHPC projects for the 2018 calendar year. The Commission's views would be transmitted to the JFC by the end of the Annual Meeting.

## February 2018, following Annual Meeting:

The JFC considers the Commission's views, as available, and its funding recommendations for projects, and decides which projects to fund in 2018.

## Implementation:

If the Commission agrees on a revised process as proposed, the PSC Secretariat will apprise the appropriate groups of the process adopted by the Commission to address very high priority chinook projects. Per this plan, the PSC Secretariat will request and relay the results of the JFC's technical review to the Commission, as available. The changes proposed from the process previously adopted are summarized below.

- Limiting the role of the CTC to advising the Commission on VHPC issues regarding
development of RFPs consistent with the thematic advice provided in April 2016 and advising on the JFC's technical review.
- Identifying a lead role for Commission Chairs regarding the need for and development of communications to the JFC.
- Requesting Commission review of the JFC's funding recommendations resulting from their technical review.
- Changing the timing of the Commission's communication to the JFC from January $31^{\text {st }}$ to the end of the Annual Meeting.


## Attachment 1. CTC Advice to Commission, April 2016



TO: PSC Commissioners
CC: John Field, PSC Executive Secretary
FROM: John Carlile, Robert Kope and Gayle Brown (CTC co-chairs)
DATE: April 18, 2016
SUBJECT: CTC response to the assignment to provide strategic advice regarding 2017 high priority Chinook project priorities

The CTC was tasked by the PSC Commissioners on Feb. $11^{\text {th }}$ to complete the following task by April 15, 2016:
On an interim basis for 2016, the CTC will provide strategic advice to the Commission in its April 2016 meeting on very high priority chinook issues to help inform the development of requests for proposals for 2017 projects.

The Commission chairs will consider the CTC advice and provide its views to the JFC in advance of 2016 RFPs.

John Field conveyed his interpretation of this direction in emails to the CTC on Feb 19 and April 12. The specific wording provided to the CTC in his most recent email (but consistent with the first), was:

1. Summarize categories of research, fishery monitoring, or other data needs that are priorities for 2017 implementation of Annex IV, Chapter 3.
2. Where possible, provide specific research projects or funding needs in those categories. Where it's not possible to identify specific projects or funding needs, the category itself will be sufficient strategic advice.

There is disagreement within the CTC as to whether item 2 in the direction from John Field
accurately reflects the task description as discussed bilaterally among the PSC Commissioners. Furthermore, some CTC members question whether this is a desirable way to proceed. The following response from the CTC reflects these differing viewpoints.

In response to this assignment, the CTC reached agreement on a list of priority activities to support the 2017 implementation of Annex IV, Chapter 3. The CTC recommends use of the following project themes to guide development of requests for proposals for high priority Chinook projects by the Endowment Fund committees:

- Sampling in fisheries and escapements, lab processing, and data reporting to support the recovery of adequate numbers of Coded-Wire-Tags to support estimation of precise statistics produced by the cohort analysis procedure
- $\quad$ Coded Wire Tagging of CTC exploitation rate indicator stocks (single index tagging and double index tagging) designed to improve the quality and quantity of CWT data identified in PSC CWT guidelines.
- Continued or improved estimates of catch, terminal returns, and escapements to meet CTC data standards.
- Development of additional escapement goals and stock-specific exploitation rate management objectives needed to implement the Chinook management regime
- PSC Coast Wide Chinook model and Exploitation Rate Analysis improvements
- Improvement of methods for stock and fishery assessments (e.g., estimation of spatial/temporal stock-age distribution, projection of maturation rates for incomplete broods, systematic evaluation of current analytical methods using the Data Generation Model)

Existing fiscal constraints and funding pressures threaten to impact Canada’s ability to implement Chapter 3, thus Canadian CTC members worked to prepare a list of Canadian high priority projects to provide to the PSC Commissioners for their consideration. However, these projects have not yet been discussed by the bilateral CTC. The list consists of 1) VHPCPs that received PSC Endowment funding in 2014 and 2015, 2) projects that had received former CWTIT or SSP funding, and 3) additional core escapement and CWT indicator programs considered to be at high risk of funding loss in 2017. This list of projects and associated costs is available for consideration.

The US CTC members have not yet assembled a list of high priority projects for discussion by the bilateral CTC. The reasons include incomplete knowledge at this time of the year regarding funding gaps expected in 2017. In addition, the US has not yet had the opportunity to make decisions regarding the distribution of continuing CWTIT funds (\$1.5M) and US Abundance Based Management (LOA) funds for US projects in 2017.

Without a list that includes both Canadian and US projects, it has not been possible for the CTC to discuss and recommend any specific projects with bilateral endorsement at this time.

The timing of the need for strategic advice on 2017 high priority Chinook projects to support the meeting schedule and decision process of the PSC Joint Fund Committee occurs prior to when there is complete understanding of all 2017 agency budgets. Consideration of a process to identify high priority projects for 2017 at a later time this year could provide a solution to this dilemma.

## Attachment 2. Commission Advice to JFC, April 2016

(Was on PSC letter head, below is the text of the memo)

## Memorandum

From: Phil Anderson and Susan Farlinger, PSC Chair and Vice-Chair
To: Joint Fund Committee
Date: April 22, 2016
Subject: VHPC recommendations for 2017
The purpose of this memorandum is to provide Pacific Salmon Commission (PSC) advice to the Joint Fund Committee (JFC) on Very High Priority Chinook (VHPC) projects, for 2017.

In February 2016, the PSC adopted the Chinook Interface Group's proposed process to provide strategic advice to the Joint Fund Committee on VHPC for 2016, 2017 and 2018. (Attachment\#1). As part of this process, the PSC requested the Chinook Technical Committee (CTC) provide it with strategic advice to help inform the development of the JFC requests for proposals for 2017 projects.

The PSC recommends that the JFC consider using the following project themes to guide the development of its requests for proposals for Very High Priority Chinook projects as priorities for 2017 implementation of Annex IV, Chapter 3.

## Recommended Project Themes for VHPC Projects in 2017:

- Sampling in fisheries and escapements, lab processing, and data reporting to support the recovery of adequate numbers of Coded-Wire-Tags to support estimation of precise statistics produced by the cohort analysis procedure
- Coded Wire Tagging of CTC exploitation rate indicator stocks (single index tagging and double index tagging) designed to improve the quality and quantity of CWT data identified in PSC CWT guidelines.
- Continued or improved estimates of catch, terminal returns, and escapements to meet CTC data standards.
- Development of additional escapement goals and stock-specific exploitation rate management objectives needed to implement the Chinook management regime
- PSC Coast Wide Chinook model and Exploitation Rate Analysis improvements
- Improvement of methods for stock and fishery assessments (e.g., estimation of spatial/temporal stock-age distribution, projection of maturation rates for incomplete broods, systematic evaluation of current analytical methods using the

Data Generation Model).
The CTC has not yet bilaterally vetted a specific list of projects. However please note that funding needs to implement Annex IV, Chapter 3 from Canada's perspective include the list of VHPC projects that received PSC endowment funding in 2014 and 2015, projects that had received former Coded-Wire Tag Improvement Team or Sentinel Stocks Program funding, and additional core escapement and CWT indicator programs considered at risk of funding shortfall in 2017 (Attachment \#2). As the U.S. gains more information regarding its 2017 funding and any shortfall thereof to implement Annex IV, Chapter 3, the U.S. will be in a position to identify more specific funding needs from the U.S. perspective.

The PSC will receive a CTC vetted and prioritized list of project proposals in December 2016. The PSC will then provide the JFC with its bilateral priorities of specific VHPC projects and costs by January 31, 2017, in advance of the JFC funding decisions for 2017. Thank you for considering the PSC's advice on the VHPC projects in your deliberations. Please do not hesitate to contact us should you have any questions or concerns about the memorandum or its attachments.

## Attachments:

1. Process to provide PSC Guidance on Very High Priority Chinook Projects
2. Canadian list of projects

Cc:
U.S. Commissioners and Alternates,

Canadian Commissioners and Alternates, Angus Mackay,
John Field, Alison Agness,
Kirsten Ruecker

## Proposed List of Priority Tasks, CTC Work Plan

The CTC work plan tasks presented below are suggested with the following understanding:

- The time period for this CTC work plan is January through December 2017.
- All CTC work plan tasks identified bilaterally are important and should be completed over time.
- Given limited CTC capacity and resources, only tasks that are essential: (a) for planning 2017 Chinook fisheries and (b) to inform negotiations of a renewed Chinook chapter should be undertaken in 2017.
- The CTC will manage the work plan task list such that all bilaterally-agreed tasks will be completed in 2017. This will likely require controlling the effort dedicated to each task ensuring that a balanced approach to each task is applied.
- The CTC should provide periodic updates to the PSC Chair and Vice-Chair on the status of their work progress (April, June and September) enabling the Commission to provide further direction on CTC task priorities, as required. In addition, the CTC should identify any project that has been more difficult and time consuming than anticipated, including an assessment of the impact on the completion of other projects.

1. Annual Analyses

- 2017 Chinook exploitation rate analysis
- 2017 Chinook Model Calibration

2. Annual Reports

- 2017 Catch and Escapement report
- 2017 Calibration and Exploitation Rate Analysis report


## 3. Ad-hoc Reports

- Chapter Three Performance Review errata
- 2015/2016 Exploitation Rate Analysis output data notebook
- Phase 2 of the base period recalibration of the PSC Chinook Model


## 4. Ad-hoc Analyses

- Investigation and implementation of mark-selective fishery algorithms in the annual exploitation rate analysis
- Escapement goals presented for review and acceptance will be evaluated by the CTC

Agenda Item 7. CIG report on proposed work plan priorities Bilateral CIG agreement for the Commission January 12, 2017

- Feasibility assessment of the expert panel's final report of forecast methodologies
- Testing and validation of the DGM
- Modify Chinook model, test, and implement stock specific growth functions and agency estimates of shakers

Proposed List of CTC Work Plan Tasks for 2018 and Beyond

- 2015 Calibration and Exploitation Rate Analysis Report
- 2016 Calibration and Exploitation Rate Analysis Report
- Testing and validation of ForecastR
- Testing and validation of CIS
- Review of Attachments I-V
- Phase III Model Improvements

Implementation of MSF capability in the Chinook Model and related stratification of stocks and fisheries, time periods; modify Chinook Model to use forecasts of cohort abundances; etc.

- Scope the representativeness of coded-wire-tag indicator stocks in relation to other wild/hatchery stocks they are intended to represent



## PACIFIC SALMON COMMISSION WORK PLAN <br> 2016-2017

## Panel / Committee:

The Chinook Technical Committee reports to the Pacific Salmon Commission.

Date: PSC Fall Session - October 3-7, 2016

## Update on Bi-lateral Tasks Assigned Under the Current PSC Agreement:

## 1. Annual Reports

Progress This Past Cycle: The CTC typically produces two annual reports each year: the Catch and Escapement (C\&E) report and the Calibration and Exploitation Rate (CLB\&ER) report. The CTC has not yet published the 2015 or 2016 CLB\&ER reports. As per instructions from the bilateral CIG, finalizing the 2015 document will require separate reports, one on the exploitation rate analysis portion prepared by the bilateral CTC and one on the 2015 PSC Chinook Model calibration portion prepared by individuals that wish to participate. Work on both the 2015 and 2016 CLB\&ER reports was negatively impacted during this cycle by the need for the Analytical Work Group (AWG) to focus attention on the base period recalibration of the PSC Chinook Model and to complete other assignments from the Commission. The 2016 C\&E report was finalized in July of 2016.

Anticipated Progress this Cycle: The 2017 C\&E (data through 2016) and 2015, 2016 and 2017 CLB\&ER reports are anticipated to be completed in 2017.

## 2. Model Improvements

Progress This Past Cycle: Progress was made on five specific Model Improvement initiatives:

1) Base period calibration of the Chinook Model: The AWG began work on the base period calibration of the PSC Chinook Model in 2009 and this work continued this cycle based on the February $10^{\text {th }}$ Model Action Plan developed bilaterally by the Chinook Interface Group (CIG).

Preliminary base period calibrations in 2014, 2015 and 2016 expanded the number of stocks (Phase I) and the number of fisheries (Phase II) to more accurately reflect AABM and ISBM management. At the PSC Fall meeting, the CTC will report progress on the Phase I and II work, and present preliminary results of the new base period Model calibration.

Work on four key model improvement projects occurred during this cycle and will be completed either during this cycle or early in the next one. These are:
2) DGM (Data Generation Model): Work on this tool, which can be used to evaluate various fisheries metrics and alternative management models, is nearing completion by the contractor. Testing and validation by the CTC will be necessary.
3) ForecastR: ForecastR is a computer program developed to facilitate forecasting of Chinook returns and provide a statistical evaluation and decision-making framework for forecast model selection. Model improvement funds were used to develop most of the forecasting framework and a graphical user interface (GUI) is currently being developed using Southern Endowment Funds. The GUI will make Forecast R immediately accessible to forecasters. ForecastR will be available for agency use in 2017.
4) CIS (Chinook Integrated System): CIS is a Microsoft Access-based approach for storing all inputs and outputs for the annual exploitation rate analysis and Chinook Model calibration. The CIS is expected to improve speed and efficiency of many annual routine tasks. Further development of CIS is occurring this cycle using Chinook Abundance Based Management Implementation funds. CIS will be completed early in the next cycle. Testing and validation by the CTC will be necessary.
5) Maturation Rate and EV Investigation: The CTC-AWG was asked to evaluate the assumptions made for maturation rates and EVs used in the Chinook Model's forecasting procedure. The resulting investigation was submitted in a report (TCCHINOOK16-1) to the Commission in February. The recommendation to use a 9-year average for maturation rates and a 1-year EV was adopted by the Commission and implemented in the 2016 Model calibration procedure.

Anticipated Progress This Cycle: Several model improvements will be addressed this cycle.

1) Phase II of the base period calibration (BPC) is scheduled to be completed prior to the October 2016 PSC Fall meeting. A Chinook Model Calibration using this new BPC will be evaluated and, if it is deemed acceptable, will be used to translate the new time series of AIs into a new Table 1. A preliminary report on the BPC will be presented at the 2016 PSC Fall meeting and a final report including the translation of Table 1 is scheduled to be completed and presented to the Commissioners by June of 2017. A preliminary plan for Phase III of the BPC has been developed, including modeling mark selective fisheries, further stratification of time periods within a year, dividing fisheries into components when size limits differ, incorporating empirical estimates of legal and sub-legal Chinook releases, and enabling the use of pre-fishery ocean abundance forecasts in the model calibration procedure. The timing of work on Phase III will depend on Commission priorities, other CTC tasks relating to the renegotiation of Chapter 3 and available personnel and monetary resources.
2) DGM: The DGM should be completed this cycle. Testing and validation by the CTC will be necessary. The design specification for the next phase, which will include a model evaluation framework, is being developed. However, no Model Improvement funds remain. A new funding source will need to be identified if this work is to continue.
3) ForecastR: The stock forecasting tool will be completed and available for use in 2017.
4) CIS: Chinook Abundance Based Management Implementation Funding will be used to improve current functionality and introduce new functionality.
5) Maturation Rate and EV Investigation: No further work on this task is anticipated this cycle.

## 3. Bilateral Data Standards

Progress to Date: No progress was made on bilateral data standards during the 2015-2016 cycle.
Anticipated Progress This Cycle: Work on this assignment will occur at the direction of the Commission.

## 4. Individual Stock Based Management Index

Progress to Date: No progress on evaluating alternative ISBM indices was made during the 2015-2016 cycle. This task can be advanced when the DGM is completed and validated.

Anticipated Progress This Cycle: Progress on this task depends on two inputs. First, the CTC is waiting for guidance from the CIG regarding policy issues identified in memos to the CIG during January 2012 and February 2012. Second, the DGM is needed to perform quantitative evaluations of the metrics identified in TCCHINOOK(11)-4. The CTC will continue evaluating ISBM fisheries, per paragraph 13(d) and 13(e) and reporting the results in the annual CTC CLB\&ER report. This evaluation was initiated in 2013.

## 5. Escapement Goal Reviews

Progress This Past Cycle: No escapement goals were presented to or adopted by the CTC during the 2015-2016 cycle.

Anticipated Progress This Cycle: Any escapement goals presented for review and acceptance will be evaluated by the CTC.

## 6. Five Year Review (Chapter 3 Performance Review)

Progress This Past Cycle: The Chapter 3 Performance Evaluation (C3PE) Report (TCCHINOOK16-2) was completed in May of 2016.

Anticipated Progress This Cycle: Errors in some of the data presented in the C3PE report have been identified and corrected information will be forthcoming.

## 7. Attachments I-V

Progress This Past Cycle: The review of Attachments I-V has not yet been addressed.
Anticipated Progress This Cycle: Like the Five Year Review, this task was assigned a completion year of 2014 in the current Agreement. The CTC could use information from the base-period calibration, CWT data, and available escapement indicator stocks to proceed on this task. Conceptual development of this task could proceed at the direction of the Commission in advance of completing the new base period calibration. The required analytical work could then proceed once data from the new BPC are available. The Commission may need to decide how to prioritize this task with other CTC tasks.

## 8. Total Mortality (TM) Regimes

Progress This Past Cycle: No work on implementing a Total Mortality regime occurred in the 2015-2016 cycle. The CTC is waiting for the Commission's instructions regarding when and how to proceed with implementation of a total mortality regime.

Anticipated Progress This Cycle: The CTC is waiting for direction and guidance from the Commission before proceeding on further TM work.

## 9. Framework for Precautionary Management (PM)

Progress to Date: No work on implementing a framework for Precautionary Management occurred in the 2015-2016 cycle. The annotated PM draft report was presented to the Commissioners at the October 2013 Fall Session and no further instructions have been received.

Anticipated Progress This Cycle: No further work by the PM Workgroup or the CTC is anticipated during this cycle.

## 10. Recommended Research Projects

Progress This Past Cycle: The CTC has not recommended, developed or reviewed project proposals, aside from those associated with Model Improvements. The Sentinel Stocks Program and the Coded Wire Tag Improvement Program have expired although some of the work funded by these programs is now being funded by the Northern and Southern Endowment Funds. Projects for 2017 are currently being evaluated for possible funding by the Endowment Fund committees.

Anticipated Progress This Cycle: The CTC will provide input to the Joint Fund Committees as directed by the PSC.

## 11. Alternative Fishery Regulatory Measures

Progress This Past Cycle: The differential impacts of mark-selective fisheries on marked and unmarked Chinook DIT stocks were again evaluated and will be reported in the CLB\&ER report. A small subgroup of the CTC and others was also tasked with providing a review and recommendations concerning an alternative approach proposed by Alaska for managing the SEAK AABM fisheries (the CPUE-based winter troll fishery model). This task was completed during the February PSC Annual meeting.

Anticipated Progress This Cycle: The CTC will continue to evaluate and report on impacts of mark-selective fisheries in its future annual reports. CTC members will also continue to work on mark selective fishery issues with the Selective Fishery Evaluation Committee. Analytical methods have been, and will continue to be, discussed and developed in anticipation of incorporating mark selective fisheries in the CTC Exploitation Rate Analysis and the PSC Chinook Model calibration. Methods for modeling MSF impacts will be developed during Phase III of the base period calibration.

## Obstacles to Completing above Bi-lateral Tasks:

## Time Constraints

As in previous years, the primary obstacle is the amount of time and effort required to complete the large number of tasks assigned to the CTC under the 2009 agreement and the technical complexity of those tasks. Although the formation of smaller CTC workgroups to address individual assignments creates some efficiency, the necessity of assigning CTC members to multiple workgroups creates bottlenecks. There will undoubtedly be scheduling conflicts for workgroup meetings and CTC members will have to prioritize their workloads among the workgroups to which they belong. In the coming year, there will also be additional demands on CTC members to provide data and analyses in support of renegotiation of the Chinook chapter of the Treaty. It is difficult to predict the number and complexity of these assignments and additional bilateral CTC meetings beyond those detailed in this memo could be required.

## Funding Constraints

The MI funds paid for a large portion of AWG travel during the past six years. However, the funds were exhausted during 2016 and funds available for CTC travel may be limited due to budget constraints in both the Canadian and US sections. Meeting costs have the potential to significantly impact the CTC's ability to complete the ERA, PSC Chinook Model calibration, MI tasks, and annual reporting.

## Policy Issues

Progress could be hindered by policy issues that arise in the workgroups, and subsequent lack of resolution by the Commission.

Outline of Other Panel / Committee Tasks or Emerging Issues:

None.

## Potential Issues for Commissioners:

## CWT Sampling Programs

The viability of the coastwide CWT program depends on stable funding for tagging, sampling and reporting programs. A funding source needs to be identified to maintain the integrity of the coastwide CWT program. The CWT program remains the only tool that provides the coastwide data required for implementation of the current PST Chinook agreement. The CTC requests that the Commission carefully consider the possible ramifications before Commission funds are used to explore alternative technologies such as PBT. This may have the unintended consequence of eroding and undermining the viability of the CWT program.

## Transition Planning

During the past several years the CTC has lost three AWG members, and is anticipating the loss of additional AWG members in the near future. Succession planning is needed in order to provide continued capacity to implement and evaluate the requirements of Chapter 3 of the PST Agreement. Of particular concern is the loss of key programmers.

## Chinook Model Improvements

As mentioned earlier, any modifications or improvements to the PSC Chinook Model, including the BPC, have the potential to alter the time series of AIs and the historical relationship between AIs and landed catches. When the historic estimates of these indices change the CTC will need guidance from the PSC in order to maintain the historic relation between catch and the abundance indices as specified under the current Agreement.

## Chinook Model Improvement Funds

The CTC has exhausted all of the MI funds. Future MI work that cannot be accomplished during the CTC's usual course of business will need to rely on the US Chinook Abundance Based Management Implementation Funding, Northern or Southern Endowment Funds, or some new funding source.

## Potential Issues for Committee on Scientific Cooperation:

None.

## Proposed Meeting Dates and Draft Agendas:

Meeting Locations: The CTC proposes to hold all meetings in Seattle, Portland or Vancouver (PSC office) to reduce travel costs, with the exception of one meeting in Juneau, AK. The meeting schedule proposed for 2016-2017 includes seven full bilateral CTC meetings and three additional CTC-AWG meetings. The schedule also includes a US Chinook Abundance Based

Management Implementation Funding meeting. One of the proposed bilateral CTC meetings is designated for work on tasks that may result from renegotiation of the PST or other Commission assignments. However, additional CTC meetings may be required, depending on the number and scope of additional tasks assigned to the CTC.

October 31-November 4, 2016. The bilateral CTC will meet in Seattle, WA to review the base period recalibration of the PSC Chinook Model.

December 1-2, 2016. The U.S. CTC will meet in Portland, OR for the annual U.S. Chinook Abundance Based Management Implementation workshop. The U.S. CTC will review continuing and completed projects, and will develop a request for proposals for the 2017 Abundance Based Management funds.

January 9-13, 2017. The bilateral CTC will meet during the PSC Post-season meeting in Vancouver, BC. The CTC will work on outstanding annual reports, begin work on the 2017 C\&E report and will work on other workgroup assignments as time permits. The AWG will begin work on the ERA through 2015.

February 13-17, 2017. The bilateral CTC will meet during the $32{ }^{\text {nd }}$ PSC Annual meeting in Portland, OR. The AWG will continue work on the ERA and begin work on the 2017 PSC Chinook Model calibration. The CTC will work on outstanding annual reports, begin work on the 2017 C\&E report and will work on other workgroup assignments as time permits. The U.S. CTC will reach consensus on its LOA funding recommendations for 2017.

February 27-March 3, 2017. The bilateral CTC AWG will meet in Vancouver, BC to complete the annual Chinook ERA and continue work on the 2017 PSC Chinook Model calibration.

March 13-17, 2017. The bilateral CTC AWG will meet in Portland, OR to continue work on the PSC Chinook Model calibration and produce a final calibration. The CTC will report the 2017 preseason AIs and allowable catch targets for the AABM fisheries to the PSC Commissioners by April 1.

April 24-28, 2017. The bilateral CTC will meet in Seattle, WA to work on the C\&E report and to work on outstanding CTC assignments. The AWG will work on the outputs for the CLB\&ER report. The C\&E report will be completed by June.

May 13-14, 2017. The bilateral CTC AWG will meet in Seattle, WA to get up to speed on the improvement to the CIS and to recreate the annual model calibration in CIS.

May 15-19, 2017. The bilateral CTC will meet in Seattle, WA to finish work on base period recalibration tasks and work on any tasks assigned by the PSC Commissioners related to the PST renegotiation.

June 5-9, 2017. The bilateral CTC will meet in Juneau, AK to finalize the C\&E report and draft the CLB\&ER report and continue work on outstanding CTC assignments. The CTC will also review progress on workgroup assignments to date and assign tasks for the summer.

September 18-22, 2017. The bilateral CTC will meet in Vancouver, BC to work on CTC assignments and complete the 2017 CLB\&ER report.

## Status of Technical or Annual Reports:

The 2016 C\&E report is complete. The 2015 and 2016 CLB\&ER reports will be completed in 2017 and the 2017 C\&E and 2017 CLB\&ER reports will be completed in 2017.

## Comments:

The CTC has no additional comments at this time.


PSC Chinook Technical Committee

TO: PSC Commissioners
FROM: John Carlile, Robert Kope and Gayle Brown (CTC co-chairs)
DATE: January 13, 2017
SUBJECT: Prioritization of CTC Tasks for the 2016-2017 Work Cycle
This memo serves to inform the PSC Commissioners that the CTC co-chairs consider the document entitled "CIG report on proposed work plan priorities, Bilateral CIG agreement for the Commission, January 12, 2017" (see Attachment 1) to be the de facto CTC workplan for the 2016-2017 cycle.

The CTC will also adhere to the meeting schedule through September of 2017 (presented below) as previously approved by the Commission during the October 5-7, 2016 Executive Session. However the tasks to be accomplished during each meeting were modified to correspond to the work plan priorities as described in the attachment. Attachment 2 contains a condensed version of the CTC schedule for the 2017 calendar year.

## Proposed Meeting Dates and Draft Agendas:

Meeting Locations: The CTC proposes to hold all meetings in Seattle, Portland or Vancouver (PSC office) to reduce travel costs, with the exception of one meeting in Juneau, AK. The meeting schedule proposed for 2016-2017 includes seven full bilateral CTC meetings and three additional CTC-AWG meetings. The schedule also includes a US Chinook Abundance Based Management Implementation Funding meeting.

October 31-November 4, 2016. The bilateral CTC will meet in Seattle, WA to review the base period recalibration of the PSC Chinook Model.

December 1-2, 2016. The U.S. CTC will meet in Portland, OR for the annual U.S. Chinook Abundance Based Management Implementation workshop. The U.S. CTC will review continuing and completed projects, and will develop a request for proposals for the 2017 Abundance Based Management funds.

January 9-13, 2017. The bilateral CTC will meet during the PSC Post-season meeting in Vancouver, BC. The CTC will work on its review of the Forecast Review Panel recommendations, the 2015-2016 ERA data notebook and Phase II of the base period calibration. The AWG will begin work on the ERA through 2015.

February 13-17, 2017. The bilateral CTC will meet during the $32^{\text {nd }}$ PSC Annual meeting in Portland, OR. The AWG will continue work on the ERA and begin work on the 2017 PSC Chinook Model calibration. The CTC will begin work on the 2017 C\&E report, the 2015-2016 ERA data notebook, Phase 2 of the base period calibration, review algorithms for implementing Mark Selective Fishing (MSF) in the ERA, and begin work on evaluating the Data Generation Model (DGM). The U.S. CTC will reach consensus on its LOA funding recommendations for 2017.

February 27-March 3, 2017. The bilateral CTC AWG will meet in Vancouver, BC to complete the annual Chinook ERA and continue work on the 2017 PSC Chinook Model calibration.

March 13-17, 2017. The bilateral CTC AWG will meet in Portland, OR to continue work on the PSC Chinook Model calibration and produce a final calibration. The CTC will report the 2017 preseason AIs and allowable catch targets for the AABM fisheries to the PSC Commissioners by April 1.

April 24-28, 2017. The bilateral CTC will meet in Seattle, WA to work on the 2017 C\&E report, Phase 2 of the base period calibration and growth functions and shaker function implementation in the PSC Chinook Model. The AWG will work on the outputs for the CLB\&ER report. The C\&E report will be completed by June.

May 13-14, 2017. The bilateral CTC AWG will meet in Seattle, WA to get up to speed on the improvement to the CIS and to recreate the annual model calibration in CIS.

May 15-19, 2017. The bilateral CTC will meet in Seattle, WA to finish work on 2017 C\&E report, Phase 2 of the base period calibration and also work on growth functions and shaker function implementation in the PSC Chinook Model. The CTC will also discuss VHPC project priorities and provide advice to the Commission at the conclusion of this meeting.

June 5-9, 2017. The bilateral CTC will meet in Juneau, AK to draft the 2017 CLB\&ER report, and implement changes to the cohort analysis code to implement MSF in the ERA. The CTC will also review progress on workgroup assignments to date and assign tasks for the summer.

September 18-22, 2017. The bilateral CTC will meet in Vancouver, BC to work on any outstanding CTC assignments, review escapement goals and complete the 2017 CLB\&ER report.

## Proposed List of Priority Tasks, CTC Work Plan

The CTC work plan tasks presented below are suggested with the following understanding:

- The time period for this CTC work plan is January through December 2017.
- All CTC work plan tasks identified bilaterally are important and should be completed over time.
- Given limited CTC capacity and resources, only tasks that are essential: (a) for planning 2017 Chinook fisheries and (b) to inform negotiations of a renewed Chinook chapter should be undertaken in 2017.
- The CTC will manage the work plan task list such that all bilaterally-agreed tasks will be completed in 2017. This will likely require controlling the effort dedicated to each task ensuring that a balanced approach to each task is applied.
- The CTC should provide periodic updates to the PSC Chair and Vice-Chair on the status of their work progress (April, June and September) enabling the Commission to provide further direction on CTC task priorities, as required. In addition, the CTC should identify any project that has been more difficult and time consuming than anticipated, including an assessment of the impact on the completion of other projects.

1. Annual Analyses

- 2017 Chinook exploitation rate analysis
- 2017 Chinook Model Calibration

2. Annual Reports

- 2017 Catch and Escapement report
- 2017 Calibration and Exploitation Rate Analysis report

3. Ad-hoc Reports

- Chapter Three Performance Review errata
- 2015/2016 Exploitation Rate Analysis output data notebook
- Phase 2 of the base period recalibration of the PSC Chinook Model


## 4. Ad-hoc Analyses

- Investigation and implementation of mark-selective fishery algorithms in the annual exploitation rate analysis
- Escapement goals presented for review and acceptance will be evaluated by the CTC
- Feasibility assessment of the expert panel's final report of forecast methodologies
- Testing and validation of the DGM
- Modify Chinook model, test, and implement stock specific growth functions and agency estimates of shakers

Proposed List of CTC Work Plan Tasks for 2018 and Beyond

- 2015 Calibration and Exploitation Rate Analysis Report
- 2016 Calibration and Exploitation Rate Analysis Report
- Testing and validation of ForecastR
- Testing and validation of CIS
- Review of Attachments I-V
- Phase III Model Improvements

Implementation of MSF capability in the Chinook Model and related stratification of stocks and fisheries, time periods; modify Chinook Model to use forecasts of cohort abundances; etc.

- Scope the representativeness of coded-wire-tag indicator stocks in relation to other wild/hatchery stocks they are intended to represent


## Attachment 2

The CTC 2017 meeting schedule and Priorities tasks

| Month | Meeting | Dates | Location |  |
| :---: | :--- | :--- | :--- | :--- |
| Jan | PSC Post-season (\& CTC) | Jan 9-13 | Vancouver | Phase II BPC; Data Notebook; Feasibility assessment; Plan ERA |
| Feb | PSC Annual (\& CTC) | Feb 13-17 | Portland | Phase II BPC; Data Notebook; ERA; Plan MSF; Test DGM |
| Feb | CTC-AWG ERA | Feb 27-Mar 3 | Vancouver | ERA |
| Mar | CTC-AWG Model Calibration | Mar 13-17 | Portland | Calibration |
| Apr | CTC Bilateral Meeting | Apr 24-27 | Seattle | Phase II BPC; Growth functions/Shaker functions; C\&E |
| Apr | CTC reports to Commission |  |  |  |
| May | Bilateral Chinook Negotiation | May 8-12 | Vancouver | Chap 3 negotiation |
| May | CTC-AWG CIS Validation | May 13-14 | Seattle | Test CIS |
| May | CTC Bilateral Meeting | May 15-19 | Seattle | Phase II BPC; Growth functions/Shaker functions; C\&E; VHPCP advice to PSC |
| Jun | CTC Bilateral Meeting | Jun 5-9 | Juneau | C\&E; Code MSF algorithms |
| Jun | CTC reports to Commission |  |  |  |
| Jul | No meeting |  |  | Clb\&ER report; Test MSF algorithms; Test DGM |
| Aug | No meeting |  | Clb\&ER report; Test MSF algorithms; |  |
| Sep | CTC Bilateral Meeting | Sep 18-22 | Vancouver | Clb\&ER report; Escapement Goal Review |
| Sep | CTC reports to Commission |  |  |  |
| Sep | Bilateral Chinook Negotiation | Sep 25-29 | Portland | Chap 3 negotiation |
| Oct | PSC Fall Session | Oct 23-27 | Suquamish | PST/Chp 3 negotiation |
| Nov | Tentative CTC meeting | Nov |  | Test MSF algorithms; Escapement Goal Review |

## CSC Progress Report January 13, 2017

1. Radio Frequency Identification (RFID) tags feasibility evaluation.
2. Documenting Anomalies
3. Identification of 2015 anomalies
4. PSC strategy for on-going consideration of annual environmental variation
5. International Year of the Salmon.

## Radio Frequency Identification (RFID) Tags

- RFID tags identified by CWT Expert Panel (PSC 2005) as potential improvement to CWTs
- Allows non-lethal sampling, potential for mass-screening
- RFID tags have been used to tag bees, ants, and spiders
- RFID chips as small as $0.15 \mathrm{~mm} \times 0.15 \mathrm{~mm} \times 0.01 \mathrm{~mm}$ CWTs: Standard size $1.1 \mathrm{~mm} \times 0.25 \mathrm{~mm}$ PIT: "Small" tags are $8.0 \mathrm{~mm} \times 1.25 \mathrm{~mm}$


RFID Passive Integrated Transponder (PIT) Tags


## Feasibility of Radio-Frequency Identification Tags for Marking Juvenile Salmon for Pacific Salmon Commission Management Applications

- Northern Fund Proposal Approved in 2016 25K
- Competitive bid process, LGL selected as contractor
- Draft report submitted by LGL to CSC in January


## Project Objectives

1. Review application of RFID tags for animal identification and management.
2. Compare tag sizes and costs of RFID tags (including PIT tags) with those of CWTs.
3. Review detection capabilities of RFID tags.
4. Evaluate the feasibility for mass screening for detection and reading of RFID tags in landings of Pacific salmon.
5. Evaluate the feasibility and cost of incorporating RFID tags to replace CWT in marking juvenile salmon for coastwide Coho and Chinook salmon management.

## Preliminary Results

1. RFID microchips are not suitable for use marking salmon as a replacement for CWTs due to constraints on detection distances (its all about the physics).
2. RFID PIT tags could potentially be used to provide enhanced information for PSC management, but application must be considered in context of costs, tag loss, and survival relative to CWTs.

## Next Steps

1. CSC reviews comments to contractor by January 14, 2017.
2. Review by Coho Technical Committee (CoTC).
3. Final report and presentation by contractor to PSC Science Community at February 2017 Annual Meeting.
4. CSC recommendations, incorporating comments by CoTC, to be presented in the CSC Annual Report at February meeting.

## Progress on 2015 Anomalies Identification:

-Review project background.
-Overview of contractor's report on the 2015 anomalies.
-Next steps in completion of the contract and CSC assignment.

## Background

- January 2016: Commission requested "... a proposal for annual collation of data on the environment, run size, fish condition, and other metrics that may reveal anomalies in salmon survival ."
- February 2016: CSC proposed a two-stage approach
- Document 2015 anomalies.
- Develop a PSC strategy for ongoing consideration.
- The Commission directed the CSC to proceed with Stage 1 and return for direction on Stage 2.


## 2015 Anomalies Contract

- A contract funded jointly by the Pacific Salmon Foundation and DFO was let in the fall of 2016 to Dr. Skip McKinnell.
- Part A of this contract is to identify anomalies and extrema in indices of environmental variability and salmon population characteristics occurring in 2015 and, where feasible, 2016.


## Part A: Approach

- Approximately 60 environmental and biological indices relevant to Pacific salmon were considered.
- Values in 2015 (and 2016 where available) were compared with historical values to identify 'anomalies'.
- Anomalies were identified and categorized as extrema (maximum or minimum) or strong (exceeding +/-two standard deviations from mean of time series).



## Part A: Overview of Results Examples of Environmental Anomalies

> Sea surface temperatures (SST) over much of the NE Pacific have been at unprecedented highs, peaking in September 2014 and persisting at high levels in 2015 and 2016.
> The timing of fall chlorophyll blooms in 2016 in coastal, shelf, and offshore areas was the latest observed over the 15 -year data series.

## Part A: Overview of Results Examples of Environmental Anomalies

> Temporal shifts in zooplankton abundance, biomass and body size in the eastern Gulf of Alaska in 2016 indicate a substantial change in its community composition.
> The high abundance of subtropical zooplankton off the Oregon coast in 2015 was unprecedented in nearly 50 years of sampling.

## Part A: Overview of Results Examples of Salmon Anomalies

- Alaska/Yukon
> Chinook salmon count in Yukon R (at Eagle AK) in 2015 was the highest since 2005.
> Latest run timing on record for 2015 Bristol Bay sockeye.
> Pink salmon harvest in Prince William Sound was highest on record in 2015 but lowest in 20 years in 2016.


## Part A: Overview of Results Examples of Salmon Anomalies

- British Columbia
> Abundances of Nass R Chinook and sockeye salmon were anomalously low in 2015, and Nass R sockeye salmon size at age was extremely small in 2015.
> Total return of sockeye salmon to the Fraser R in 2016 was lowest in the 100+ year data record.
> Fraser R pink salmon in 2015 returned was low, far below forecast, and had the smallest body size on record.


## Part A: Overview of Results

## Examples of Salmon Anomalies

- Washington/Oregon/Idaho
> Run size of large Chinook salmon to the Columbia $R$ in 2015 was highest in the historical record.
> Columbia R sockeye salmon abundance was anomalously high in 2015.
> Skagit R Baker Lake sockeye salmon returns in 2015 were the highest in the historical record.


## Part A: Overview of Results

In summary, 2015 and 2016 were noteworthy for the number and magnitude of anomalies in environmental and salmon population indices in the Northeastern Pacific.

## 2015 Anomalies Contract Part B: Objectives

- Determine whether the salmon anomalies are associated with local, regional, or basin-scale environmental anomalies.
- Consider implications of anomalies for future salmon production, management, forecasting, and other Commission interests.
- Identify approaches to monitoring of anomalies, storage of related data, and communication of information to the PSC Community.


## 2015 Anomalies Contract Part B : Schedule

- Final report including Part B due at February Annual Meeting.
- Presentation by contractor of Part A and Part B to PSC Community scheduled for February Annual Meeting.
- This will complete the CSC Stage 1 assignment.


## Stage 2: Draft PSC Strategy Elements

- Information sharing within the Commission to support future reporting of environmental variation and impacts
- Use of environmental data in forecasting and managing PSC fisheries.
- Information sharing with other international organizations.
- Informing the Commission annually on observations of changing environmental conditions and their relation to salmon production.


## Stage 2: Draft PSC Strategy Status

- October 2016 Commission directive to present strategy at February Annual Meeting.
- CSC plans to revise the February 2016 draft in light of the Stage 1 results and to present a proposed Stage 2 Strategy to the Commission for consideration at February Annual Meeting.


## The International Year of the Salmon (IYS)

- The Commission has directed the Executive Secretary to participate in the February 28 - March 2 meeting of the North Pacific IYS Steering Committee and report about possible involvement of the PSC.
- As per the CSC Work Plan, the CSC is prepared to assist the Commission in assessing the potential costs and benefits of engaging in the IYS.
- Canadian CSC members will also be participating in this meeting as CDFO and NPAFC representatives.


## Environmental anomalies in the Northeast Pacific Ocean and

 their influence on Pacific salmon run timing, abundance, growth, and survival in 2015 and 2016Skip McKinnell, Ph.D.


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## 1. Highlights

### 1.1 Approach

One of the major findings of the 2010 PICES report on the state of marine ecosystems of the North Pacific was a trend toward increasing variability (McKinnell \& Dagg 2010) compared to what had been reported during the five year period prior to that (PICES 2005). If an update was to be written now, the same observation would likely be made. Since 2013, environmental variability has been ratcheted up another notch, with what appears to be variable consequences for North American Pacific salmon. The present report focuses on environmental and biological extrema of 2015 (and 2016 where data are available) in the salmosphere ${ }^{1}$. In most cases, new indices of environmental variability were developed in order to focus on the environmental variability occurring within the salmosphere, or a portion thereof. This section entitled "Highlights" provides a brief written description of what was found when 2015 and 2016 years were compared with available historical records. Atmospheric, oceanic, and biological properties that did not reach extreme values are not included in the highlights but are discussed occasionally.

### 1.2 Environmental extrema

### 1.2.1 Air Temperature

The focus of recent analyses of environmental anomalies in the ocean has generally been on the development and duration of sea surface temperature anomalies (SSTa), a.k.a. The Blob, but the development of warm SST was preceded by warmer air temperatures in the salmosphere. There was an abrupt increase in surface air temperatures (SAT) in the salmosphere between May and June of 2013. Principal component analysis of SAT anomalies (SATa) found, not unexpectedly, that the dominant mode of monthly average air temperature variability in the North Pacific salmosphere was closely associated with variation in the Pacific Decadal Oscillation with maximum correspondence ( $\mathrm{r}=0.77$ ) occurring in May. The only extremum recently in SATa-PC1 (since 1948) occurred in April 2016. On the other hand, the subdominant mode (SATa-PC2) had positive extrema in February and October 2015, and also in July and August 2016.

### 1.2.2 Sea Temperature

a) Surface - There is no precedent in the historical instrumental record of observations of the magnitude and persistence of high sea surface temperatures (SST) in the salmosphere. The abrupt increase in SAT that occurred in June of 2013 and was followed by an abrupt shift in SST during the last two weeks of July of 2013. Apart from a brief cooling in the fall of 2013, SST anomalies (SSTa) have generally exceeded +1 s.d. through to the writing of this report. The maximum extremum observed during this period occurred in September 2014.
b) Subsurface - Salmon do not live at the very surface of the ocean where the satellites are measuring SST. Their habitat is beneath the surface where the uppermost measurements by Project Argo profiling floats are typically recorded ( $4-5 \mathrm{~m}$ ). Because they are so few, a relatively coarse grid is required to accumulate monthly spatial statistics. Using a $2^{\circ}$ latitude by $5^{\circ}$ longitude grid, there are about 7 observations per grid point per year, from which means and anomalies can be computed from 2003. The most extreme anomalies $\left(> \pm 4^{\circ} \mathrm{C}\right)$ at 5 m depth in the eastern salmosphere (eastward of $180^{\circ}$ longitude) occurred at its southern fringe (negative) and near the Aleutian archipelago (positive). All of the most extreme

1 The current and future domain of Oncorhynchus and Salmo in the northern hemisphere.
temperature anomalies were south of $49^{\circ}$ latitude.
c) Coastal temperature (bigh resolution) - A similar analysis was conducted using higher resolution data (daily, $1 / 4^{\circ}$ grid) on the continental shelf ( $<1000 \mathrm{~m}$ ) since 1981. The dominant pattern (PC1) is coastwide positive covariation (PC1) throughout the entire Gulf of Alaska. The most extreme of the positive PC1 scores on the shelf occurred in 2016 rather than in 2015. Strong coastal anomalies are typical for an el Niño (McKinnell \& Crawford 2007). The three highest positive PC1 scores ( $>3.6$ s.d.) occurred over a 3-day period, May 14-16, 2016. The next 6 highest scores occurred in 2004 and in 2005. In 2015, the rank of the strongest positive score that year occurred on July 12 and it was 19st in the entire record. The strongest positive score in 2014 ( $50^{\text {th }}$ highest) occurred on December 27. The contrast between pre-2014 average SST and 2014-2016 average SST on the continental shelf is not as great in offshore waters. There is little to no evidence of an overall linear trend in PC1 prior to 2014. PC1 is significantly correlated with survival of Chilko Lake sockeye salmon postsmolts; colder years are associated with higher survival. It has not been cold lately. Daily data collected at Kains Island (NW Vancouver Island) indicated that 2015 was the spicest (warm-salty) year on record (since 1934).

### 1.2.3 Sea Level Pressure (SLP)

Due to an atmospheric teleconnection, there is a close correspondence between SLP in the western tropical Pacific in winter and air and sea temperatures along the North American coast in the following months. SLP at Darwin, Australia (the western pole of the Southern Oscillation Index) had the highest average January SLP in 2016, in a record that dates back to the 19th century. SLP extrema were found across the entire salmosphere in the North Pacific during January and February of 2016. Although strong (negative) pressure anomalies in the Subarctic are a regular feature of major el Niños, many of the anomalies that occurred in 2016 were extrema. An Aleutian Low index, restricted to the salmosphere was developed and 2016 was only the $3^{\text {rd }}$ strongest in the record, behind 1983 and 1998.

### 1.2.4 Nutrients

At all stations along Line-P from the west coast to the middle of the Gulf of Alaska, the winter nutrient supply in 2015 was the lowest observed by DFO scientists in the past seven years.

### 1.2.5 Chlorophyll

a) Offshore - the most noteworthy feature of the record from 2003 was the extreme timing (late) of the fall bloom in 2016.
b) Shelf - the late timing of the fall bloom in 2016 was an extremum.
c) Coastal - the late timing of the fall bloom in 2016 was an extremum.

### 1.2.6 Zooplankton

a) Offshore - in the eastern Gulf of Alaska, there were no extrema of abundance, biomass, or average size of zooplankton in 2015 measured by the Continuous Plankton Recorder (CPR). This is a standard sampling device that is towed behind commercial ships as they transit the World Oceans including the North Pacific since the late 1990s. CPR data for 2016 (preliminary) had extremes of abundance in May (low), June (low), and July (high) and an extreme of biomass (April), and extremes in average size in April through June (high), shifting to July (low). Near-average biomass combined with an inverse relationship between abundances and average sizes suggests a dynamic shift in the community composition in 2016, moreso than in other years. The disappearance of large copepods from surface waters (where the CPR operates) in summer is part of the ontogeny of most of the large copepods in the Gulf of Alaska.
b) Coastal - Extrema were numerous off the coast of Oregon in 2015, mostly due to the appearance of numerous taxa of subtropical origin that had not previously been observed in nearly 50 years of sampling. Zooplankton biomass extrema also occurred in 2015 and were stronger off northwest Vancouver Island than southwest Vancouver Is. This pattern suggests a more extreme intrusion of subtropical water than has been observed before.

### 1.3 Salmon extrema

It was thought desirable to have a standard (comparable) approach to identifying coastwide extrema in salmonid biology. The most common form of salmon data for understanding timing/abundance are the daily counts past observation points. Preferred sites are located before fisheries occur, but these are more rare than sites located after fisheries have occurred. Where fishing is relatively heavy, the resulting observations will no doubt be affected by it. While the tools used to make salmon observations may differ (weirs, test fisheries, sonar), the data generated are suitable for fitting to a common abundance/timing model framework. The migration model developed by Schnute and Sibert (1983) was used because of its flexibility to capture various aspects of a migration. Where complex migrations were clearly evident (e.g. chinook salmon at Bonneville Dam), the data were fit to a complex migration model (McKinnell, unpublished) that allows for mixtures of populations (timing groups) to be identified in a time series. Salmon runs are often a composite of multiple pulses of fish going to one location or multiple populations going to different locations, perhaps each also with multiple pulses of abundance. The parameters estimated for each component include: abundance (A), skewness $(\mathrm{S})$, compression ( C ), and peak date ( P ). Abundance is the cumulative total abundance or CPUE (catch-per-unit-effort), skewness measures the degree to which a run deviates from symmetry about an estimate of the peak date, compression measures the fraction of the run passing on the peak date (i.e. related to kurtosis). Peak date is estimated by the model based on the fit of the model to the curve so may differ slightly from the observed peak date. The model was fit to each species in each year to understand the historical interannual variability of each parameter for each run component. The results were placed in rank order to determine if any of the parameters were extrema in 2015 or 2016.
To provide a graphical overview (at the end of Highlights section) of the overall results values of each parameter were classified as high (red) or low (blue) if they were historical extrema in 2015 or 2016. If not, strong anomalies were defined as high (orange) or low (cyan) anomalies if the anomaly exceeded 2 standard deviations from the long-term mean", or "normal" within 2 s.d. of the long-term mean. Note that an extremum need not exceed $\pm 2$ s.d. Mean size-at-age data, where available, were also ranked to determine if 2015 or 2016 were extrema, strong anomalies or normal using the same criteria. For the most part, environmental extrema are discussed only if they occurred in 2015 or 2016.

### 1.3.1 Bering Sea

a) Yukon River

- 2015 - highest chinook salmon count at Eagle (near the Alaska - Yukon border).
- 2016 - earliest peak date of chinook salmon and latest peak date of fall chum salmon at Eagle. Latest peak date of pink salmon and least compressed run of summer chum salmon on the Anvik River (tributary 300 mi upstream of estuary)

2 Variable lengths of time series.
b) Bristol Bay

- 2015 - latest migration timing of sockeye salmon return timing ever observed at the Port Moller test fishery.
- 2016 - average weight of sockeye salmon was the smallest observed in 20 years ( 2.4 kg ).
1.3.2 Northern Gulf of Alaska
a) Kodiak.
- 2015 - highest count of early-run sockeye salmon and skewed (slow rise to peak) migration of laterun sockeye to Karluk R.
- 2016 - highest count of late-run sockeye salmon and most skewed and compressed returns of pink salmon (early pulse) to the Karluk R.


## b) Prince William Sound

- 2015 - Prince William Sound had the largest pink salmon catch on record. Kodiak pink salmon harvest was a strong anomaly (high). There was a strong anomaly (high) in the abundance of earlyrun Copper River sockeye salmon.
- 2016 - Prince William Sound had the lowest pink salmon catch in 20 years. Russian River - Earlyrun sockeye salmon was most compressed, and the chinook salmon migration was most skewed and earliest peak date.


### 1.3.3 Southeast Alaska

- 2015 - There were no harvest abundance extrema in northern or southern SEAK, althought harvest was below average in SSEAK but second highest in the past 20 years in NSEAK (outside), and average in NSEAK (inside). Considering body size, of 10 age/population combinations of sockeye salmon examined, only Chilkoot (age 1.3) had a mean length extremum (small) in 2015. This same population/age-class was also small in 2016.
- 2016 - Pink salmon harvest in NSEAK (inside) was the lowest in the past 20 years, and NSEAK (outside) was the second lowest. SSEAK was below average but not an extreme.
- Coho - No mean size extrema in 2015 nor in 2016 (including data from 2016 troll fishery).
- Chum - 2015 - Chilkat R. only - age 0.3 females were smallest, no extrema for age 0.3 males or age 0.4 males and females.
- Chinook - troll fishery - mean dressed weights in 2015 of age 1.3 and age 0.4 fish were extrema (small) but not for age 0.3 or age 1.4. The dominant feature in these data, across all age-classes, is the declining trend in mean weight over the past 35 years.


### 1.3.4 British Columbia

The DFO State of the Pacific Ocean report for 2016 (Chandler et al. 2016) provides a good starting point for the present study as it commented on what was known to have occurred in 2015 and what might be expected as a consequence of the environmental conditions that were expected to play out in 2016. Based on what is currently understood about the salmo-environmental linkage, the worst effects of 2015-2016, at least for those in the southern part of the salmosphere, are yet to come.

The 2014-2015 anomalously warm water conditions in the North Pacific Ocean did not induce widespread salmon
recruitment failures in 2015 due to common ocean effects as some feared but, did influence return timing, straying rates and size-at-age traits of many salmon populations originating from eastern Pacific waters from south-central Alaska, through B.C., Washington and Oregon. The impacts of a warmer than average ocean in 2014-2015 followed by the El Niño in spring 2016 suggest survival unfavourable conditions for juvenile salmon making sea entry from the B.C. central to south coast in those years so significant reductions in returns to many populations (Okanagan-Columbia River salmon; Barkley and west coast Vancouver Island salmon) may be expected in 2016-2018.

## a) Nass River (fish wheel)

The data are escapement abundances from 1994. Chinook salmon and sockeye salmon were modelled as having early and late timing components. Coho salmon were modelled as a single pulse as only the first part of the migration is observed before the wheel is shut down for the season.

- 2015 - No timing/abundance extrema in early or late sockeye and chinook salmon, or coho salmon, but the abundances of sockeye and chinook salmon were strong anomalies (low). Sockeye mean size-at-age was an extremum (small) in 2015 in 3 of four age-classes, more extreme for fish that had spent 3 winters at sea.
- 2016 - Early and late-run sockeye salmon and chinook salmon abundances were extrema (high). Early run sockeye and late run chinook had extreme peak dates (late) and for the case of late run chinook salmon, the most compressed run. Coho salmon abundance (till the shutdown) was lowest, most compressed, with the earliest peak date). Mean size-at-age of $4_{2}$ and $5_{3}$ sockeye was small from 2014-2016, but only age $5_{3}$ of the 4 major age-classes had an extremum in 2016 .
b) Skeena River (Tyee test fishery)
- 2015 - No timing/abundance extrema occurred in sockeye, coho, pink, and chum salmon and steelhead trout. Chinook salmon had late and compressed timing extrema.
- 2016 - Sockeye salmon migration timing at Tyee was the latest with no other abundance/timing extrema.


## c) Docee River (fence count)

- 2015 - no abundance/timing extrema in sockeye salmon.
- 2016 - earliest peak date of migration of sockeye salmon.


## d) Fraser River (test fisheries)

The data are pre-fishery abundances (test fisheries) from 2002 to present. Gillnet test fisheries precede seine test fisheries with variable numbers of days of overlap. For simplicity, each time series for each species in each year was modelled as a single pulse of migration. The complexity of decomposing runs of all species, particularly sockeye salmon with different migration timing among cycle years, was beyond the scope of this project.

- 2015 - Of the 60 parameters examined (4 for each time series) in the Johnstone Strait (Round Is. and Blinkhorn) test fisheries, 13 were either extrema or large anomalies. Steelhead trout in the Blinkhorn seine test fishery was the only abundance extremum (high). Pink salmon were early and extremely skewed (sharp drop after an early peak) at Blinkhorn but there were no extrema for pink salmon in the Round Is. gillnet test fishery. Runs of age large sockeye salmon and steelhead trout past Blinkhorn and steelhead trout and coho salmon past Round Is. were the least compressed of all years. Although they were few, timing of age $3_{2}$ sockeye salmon was late at Blinkhorn. Because of their small size, they are rarely caught in gillnet test fisheries. Large chinook salmon were late at

Blinkhorn but not at Round Is. yet both locations had compressed runs.
In the Juan de Fuca test fisheries (gillnet and seine), 16 of 60 parameters examined had extrema or large anomalies. High extrema occurred in the seine fishery (abundances of large and small chinook salmon, and chum salmon) while low extrema occurred in the gillnet fishery (abundances of large sockeye, small and large chinook salmon, and chum salmon). Given that the gillnet fishery starts prior to the seine fishery, this pattern suggests that chinook and chum salmon arrived later than normal, although none were extrema. As in Johnstone St., pink salmon in the gillnet test fisheries at Juan de Fuca did not indicate extrema (except for a skewed migration - slow increase) but the seine fishery did. Pink salmon in the seine test fishery had an early peak and declined more rapidly than in other years. The only other timing extremum was the late peak of coho salmon in the gillnet fishery. The most consistent extrema were found in the compression parameter; most were low values indicating more drawn out migrations. The average weight of Fraser River pink salmon was the smallest ever observed. Total abundance of pink salmon at the Fraser R. was low, much lower than expected, but not an extremum.

- 2016 - The highlight of 2016 was a report by the PSC of the lowest total return of sockeye salmon to the Fraser River since the start of records (late $19^{\text {th }}$ century). Of 52 timing/abundance parameters examined in Johnstone Strait, 14 had extrema or large anomalies. All abundance extrema featured low abundance in seine test fisheries but not gillnet test fisheries (small sockeye, large chinook, and coho salmon at Blinkhorn and large sockeye, small sockeye, large chinook, and steelhead trout in Juan de Fuca). Large sockeye salmon had the earliest peak date in both Juan de Fuca and Blinkhorn test fisheries. At Blinkhorn, the sockeye run was also skewed and compressed (sharp peak). Indeed, all but one (Round Is. chum) of the 13 compression extrema had sharp peaks in 2016. It would be useful to explore the implication for 2017 of low abundances of age $3_{2}$ sockeye salmon in both seine test fisheries in 2016. Extrema in peak dates were few (5) and all but one (steelhead trout at Round Is.) were early.


### 1.3.6 U.S. Mainland

a) Baker Lake

Data are reconstructed pre-fishery abundances on the Skagit River from 1992.

- 2015 - total returns of sockeye salmon were the highest in the record.
- 2016 - no abundance/timing extrema.


## b) Lake Washington (Ballard Locks counts)

The daily sockeye salmon counts at the Ballard Locks were examined.

- 2015 - no abundance/timing extrema
- 2016 - no abundance/timing extrema


## c) Columbia River (Bonneville Dam)

Escapement (counts at Bonneville Dam since 1980). Species analyzed included sockeye, large and small chinook, large and small coho, and steelhead trout. Returns of chinook salmon were modelled as 3 pulses, coho salmon as 2 pulses and all other species as single pulses. Data for 2016 included counts to October 21, 2015 except chinook salmon where the counts were re-run later in the season to include data into late November.

- 2015 - The largest total return of large chinook salmon occurred as a result of Summer and Fall Run extrema added to a high abundance of the Spring run. There were no other extrema in this
year although sockeye salmon abundance had a strong anomaly (high). Spring and summer small chinook salmon were extremely skewed (peaks in the first part of the run). Small Spring run chinook and large late run coho had compression extrema (low). The only peak date extremum (early) was large early run coho salmon. Although not an extremum of interest to this report, the 2014 ocean entry year produced remarkably few large coho salmon spawners in 2015, considering the sibling relationship that has persisted through the 21 st century (see below).
- 2016 - Of 48 parameters examined only 1 was an extremum or strong anomaly and that was the skewed run of steelhead trout (slow rise to a peak).


## Body size extrema



Figure 1: Anomalies and extrema in mean size at age in 2015 and 2016; most are mean length but mean weight is indicated by (wt) in the label. SX-sockeye, PK-pink, CK-chinook, CO-coho, CM-chum, SH-steelhead. Age-at-maturity indicated as two numerals $x$.y where $x$-number of freshwater annuli and $y$-number of ocean annuli.
Total age is their sum +1 as there is no annulus formed during the first winter in freshwater (as an egg).

Timing and abundance extrema


Figure 2: Determination of extrema and strong anomalies in: $A=$ abundance, $S=$ skewness (bigh [low] values have an abrupt [slow] rise to a peake followed by a long [abrupt] decline), $C=$ compression (bigh [low] values have a larger percentage of the run passing near the peak date), $P=$ peak date.(bigh [low] values are late [early]]. Lg= large adults, $S m=$ small adults, $E=$ early run, $L=$ late run, $S p r=$ spring, $S u m=$ summer, Fal= autumn. SX-sockeye, PK-pink, CK-chinook, CO-coho, CM-chum, SH-steelhead. Other location codes are SJ= San Juan, BON=Bonneville Dam.

## Introduction

The Northeast Pacific has been experiencing a heat-wave for the last few years (di Lorenzo and Mantua 2016). For marine fish species, the responses to various environmental phenomena, el Niño for example, are often unpredictable (Bailey et al. 1995). Throughout history, outcomes for Pacific salmon arising from an intermittently warmer ocean have varied by species and location. Certainly in the southern extremes of the salmosphere, surface ocean warmth is never considered as a sign of high survival or abundance when juvenile salmon are exposed to it (Mueter et al. 2005). On the other hand, some of the largest adult sockeye salmon returns to the Fraser River have occurred in years when the Gulf of Alaska was much warmer than average, e.g. 1958, 1997 (McKinnell et al. 2012).
At their January 2016 annual meeting, the Pacific Salmon Commission directed the CSC to collaborate with appropriate experts to develop a proposal for annual collation of data on the environment, run size, fish condition, and other metrics that may reveal anomalies in salmon survival. In response, the CSC recommended a two stage approach, the first documenting the 2015 anomalies and the second developing a PSC strategy for ongoing consideration of annual environmental variability and its impact on salmon production and management. The Commissioners directed the CSC to proceed on the first stage of this approach, documenting anomalies in environmental conditions and characteristics of salmon runs in 2015.
A Statement of Work was developed for the author to document 2015 anomalies along with preliminary observations for 2016 where available. The first part was to compile a list of anomalous characteristics of salmon runs in the NE Pacific and potentially linked environmental anomalies in 2015, and similar information for 2016 if available. The CSC will facilitate contacts within State or Federal agencies that can assist with the provision of knowledge and data. The second part, which will form part of the final report, was to conduct a comprehensive evaluation of the identified anomalies which will include:

- Assessment of each anomaly in context of the historical time series, if available.
- Implications of each anomaly to future salmon production, management, forecasting or other Commission interests.
- Recommendations regarding monitoring of each anomaly including consideration of data gaps.


## Mapping the salmosphere

In general, existing knowledge of the distribution of salmon in the North Pacific Ocean beyond the continental shelf (excluding the Bering Sea) comes from an intensive period of research that was conducted by Canada, Japan, and the United States during the 1950s and 1960s under the auspices of the International North Pacific Fisheries Commission (INPFC). The Commission was interested in the oceanic distributions of salmon produced by different countries and the extent of their intermingling. Commercial and research catches of salmon on the high seas, primarily using gillnets, provided an understanding of the distributions of each species, whereas floating longline surveys by fisheries research agencies during the 1960s augmented that information with an understanding of the nature of species distributions from different regions. Longline gear was preferred because salmon could be captured alive on the high seas, allowing a tag to be attached to a fish then recovered at some later date by coastal fisheries along the coast during spawning migrations to natal streams. Less often, seine nets were used for the same purpose.
For the present study, the salmosphere in the North Pacific was defined on a $1^{\circ}$ grid of latitude/longitude using salmon release locations in the historical high seas tag database (NPAFC 2008), and augmented in the Gulf of Alaska by the locations of longline catches made by Canada from 1961 to 1967, from which many of the tagged salmon were released. A grid point was included in the salmosphere if a salmon of any
species had been caught and/or released anywhere within the $1^{\circ}$ cell in any year. For the Gulf of Alaska, the merging of longline catches with the historical tag release data created a relatively contiguous region where salmon of any species were caught with few obvious gaps from undersampling (see below). Likewise, grid points in the western North Pacific and parts of the Bering Sea were relatively contiguous, but the central North Pacific had a higher frequency of gaps.

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To fill many of the gaps, a median filter was applied to the data. This filter replaces each grid point by the median value of the surrounding cells. Thereafter, any cell that was obviously missed by the filter was edited manually to create a contiguous domain. Although they form part of the salmosphere, the marginal seas in the northwestern North Pacific were excluded from this analysis. Of course, this approach misses some locations were salmon catches did not occur in these databases which could be improved with additional effort to find them, but for the most part researchers will recognize this domain as that of Pacific salmon. A more rigorous approach would involve defining seasonal salmospheres, perhaps for each species, but that is beyond the scope of the present study. The final grid was used to determine locations where environmental data should be selected to develop salmo-relevant indices of variability.

## An Example of the Challenge

The predictability of outcomes for salmon as a consequence of environmental variation in any given year can be relatively poor because mechanistic understanding of cause and effect is not well developed. For example, at the onset of one of the largest el Niños of the $20^{\text {th }}$ century in 1982, a relatively large abundance of age $2_{2}$ coho salmon off the coast of Washington and Oregon that summer was followed one year later by a relatively low abundance (and small mean size) of age $3_{2}$ coho salmon of the same cohort. The dearth of spawners in 1983 was attributed to exceptional mortality at sea during the el Niño (Pearcy et al. 1985). If the el Niño was indeed the cause, one might expect similar kinds of over-winter mortality during other el Niños if the local oceanographic responses to them were similar. The 1997/98 el Niño was a major climatic event (McPhaden 1999) that exhibited most of the classical oceanic and atmospheric responses in the Northeast Pacific. It did not, however, appear to cause unusual over-winter mortality in Washington/Oregon coho salmon when measured as the ratio of the counts of age $3_{2}$ coho at Bonneville in 1998 to age $2_{2}$ counts in 1997. Indeed, the returns of age $3_{2}$ coho salmon to Bonneville Dam in both 1983 and 1998 were about what would have been expected from the sibling relationship of that era (but not of the recent era)(Figure 3). If there had been anomalously atypical over-winter mortality in 1983, a
strong outlier might have been expected in 1998, but it did not occur. So it seems rather difficult to reach


Figure 3: [left] Counts of age $3_{2}$ coho salmon (ordinate) versus counts of age $2_{2}$ coho salmon of the same cohort (abscissa). Plot point labels indicate ocean entry year of the cohort. Years are linked in sequence by blacke lines. [right] Data from the panel on the left expressed as proportion of age 32 spawners in each cohort. The 2013 ocean entry year produced the greatest number of total cobo salmon spawners in the record. The 2014 ocean entry year (blue dot), while having relatively large numbers of age $2_{2}$ spawners saw remarkably few age $3_{2}$ spawners of the same cohort the following year; a ratio that had not seen since the 1980s. Despite some of the bighest juvenile growth rates ever observed, the 2015 ocean entry year (red dot) produced fen spawners.
the general conclusion that el Niños kill coho salmon. What is more apparent is the division of the time series into two stanzas around the mid-1990s.

Two possible causes for a fundamental change come to mind. The first is that since the late 1990 s, a greater proportion of a cohort of coho salmon (those ascending above Bonneville Dam) have delayed maturity until after one full year at sea (Figure 3, right) rather than ascending the river to spawn after one summer at sea. Likewise, the apparent change in maturity schedule could arise if late-stage mortality was more prevalent prior to the late 1990s. Generally, however, smolt to adult survival of coho salmon was greater before the 1990s than after, which tends to support the idea of a fundamental shift in the maturity schedule of these fish. Delaying maturity is one of the responses by salmon to reduced growth. On average, older maturing salmon tend to exhibit slower growth throughout their lives (Bilton 1971, McKinnell 1995). As age-at-maturity in coho salmon may be determined in freshwater prior to seaward migration, the maturity schedule is not likely determined solely in the ocean. As most coho salmon above Bonneville Dam are from hatcheries, perhaps there was a change in some aspect of feeding that led to the change in maturity schedule.

The return of age $3_{2}$ coho salmon to Bonneville Dam in 2014 was a recent extremum (high). Likewise, the return of age $2_{2}$ was the $4^{\text {th }}$ largest since the 1980s (Figure 3). The 2015 return year (2014 OEY) of age $3_{2}$ coho salmon failed to match the abundance of that cohort seen the previous year. Indeed, that return in 2015 was what might have been expected under the sibling relationship that existed during the $20^{\text {th }}$ century when high age $2_{2}$ abundances were associated with much lower returns of siblings the following year. Juvenile coho salmon growth off Washington and Oregon was high in 2014 (B. Beckman, NOAA/Seattle, pers. comm.) and highest in a 20 year record off the West coast of Vancouver Island (Chandler et al. 2016). Therefore, the low abundances of age $3_{2}$ coho salmon at Bonneville in 2015 are more likely due to latestage mortality, than a change in the maturity schedule, all else held constant.

## Environmental extrema

The primary focus of this study is extrema that occurred in 2015 and 2016, yet the dominant cause of environmental variation in the salmosphere is the seasonal (annual) cycle of warming and cooling associated with the Earth's orbit around the sun. The general practice for studying unusual events is to begin by removing the effect of the seasonal cycle from the data by subtracting off seasonal average values. For example, the monthly average temperature in June 1977 at some location is transformed into a temperature "anomaly" at that location by subtracting the long-term average for the month of June from the June 1977 value. With daily data, the long-term daily average would be removed. Anomalies can be either positive or negative and the larger they are, the more extreme is the non-seasonal anomaly. The largest of these, of either sign, is what is sought in this study.

1. Surface air temperature (SAT)

Di Lorenzo and Mantua (2016) describe a marine heatwave in the Gulf of Alaska in 2014-2015 but it seems that there is evidence in the atmosphere for it starting in June of 2013, and that it continued well into 2016. Using the U.S. NCEP/NCAR Re-analysis 1 data (Kalnay et al. 1996), restricted to the Pacific salmosphere, SAT extrema (maxima) at individual grid points ( $2.5^{\circ} \times 2.5^{\circ}$ latitude/longitude) are far more numerous from 2014 to 2016 than in other years (Figure 7). The greatest number of SAT extrema (maxima) observed in any one month since 1948 in the salmosphere occurred in August 2016 ( $31 \%$ of the entire Pacific salmosphere). The greatest number of extrema (maxima) observed in any month in 2015 was of similar geographic scale, but they occurred in the month of February. The range of latitudes of SAT maxima was more widespread in February 2015 than in August 2016 (Figure 5).


Figure 4: Number of surface air temperature minima (left) and maxima (right) by year in the salmosphere since 1948 to 2016 (September). Data source: NOAA/NCAR Re-analysis.


Figure 5: Surface air temperature (SAT) extrema by latitude (across longitudes) in the Gulf of Alaska (east of $165^{\circ} \mathrm{W}$ ) in months when extrema were most frequent. The single horizontal bar at $42.5^{\circ} \mathrm{N}$ indicates that only one longitude at that latitude bad an extreme $\mathrm{S} A T$.

Principal Component (PC) analysis of monthly SAT anomalies (SATa) in the North Pacific salmosphere since 1948 suggests that SATa variation is associated with two independent forces of nearly equal weight ( $27.6 \%$ for PC1 and $23.5 \%$ for PC2). The spatial pattern of PC1 (Figure 4) is an east-west dipole (seesaw) with an alternation between warm in the West and cool in the East and vice versa, i.e. like the subarctic portion of the Pacific Decadal Oscillation of SSTa (hereafter the SalmoDO, see Figure 16 below) but in the atmosphere. The correlation between SATa-PC1 and the SalmoDO was maximum (0.77) in May. PC2, on the other hand, is a salmosphere-wide phenomenon that is associated with the Victoria Pattern of SSTa variation (also related to the NPGO-North Pacific Gyre Oscillation). It was the Victoria Pattern that shifted abruptly to positive between May and June of 2013 and the change has persisted to at least October 2016 (Figure 6). The average increase in PC2 after June 2013 was +1.9 s.d. higher than the average of the 65 year period that preceded it. This analysis found that only April 2016 was an extremum of PC1 in any month. In the months of January and February, only 1977 exceeded 2016 in magnitude of PC1 scores. There were no extrema of PC1 in 2015. PC2, on the other hand, had extrema in February and October of 2015 and July and August of 2016.


Figure 6: Principal components 1 (above) and 2 (below) of SAT anomalies in the salmosphere from 1948 to September 2016.
2. Sea level pressure (SLP)

Storms in the salmosphere and elsewhere are recognized as depressions in the sea level pressure field. Strong storms are associated with stronger, larger depressions. Integrating the pressures within these depressions over some sensible period of time generates an index of storminess during that period. Although various indices of winter storm intensity exist (North Pacific Index - Trenberth and Hurrell 1995), Aleutian Low Pressure Index (McFarlane and Beamish 1992), they have spatial domains that extend well into the subtropics. The Aleutian Low Integral Index (ALII - McKinnell 2016) was modified to compute an index of average winter (DJF) storminess in the salmosphere alone. The result was an index with high interannual variability and no trend after the 1976/77 climate regime shift. Neither the winters of 2015 nor 2016 were remarkable across the entire domain (Figure 8), but if the spatial domain is restricted to the eastern portion of the Pacific salmosphere (east of $180^{\circ}$ longitude), the winter of 2016 was the $3^{\text {rd }}$ highest in the time series, lagging only the 1983 and 1998 el Niños. The "knock-on" effects of a stormy winter are discussed in the section on mixed layer depth.


Figure 7: Spatial patterns of PC1 (above) and PC2(below) of monthy surface air temperature anomalies in the salmosphere from 1948 to 2016.


Figure 8: Aleutian Low Integral Index (ALII) is the integral of monthly sea level pressures $<1008.5$ hPa, in this case restricted to locations lying within the Pacific salmosphere. This figure indicates the winter (DJF) average values to 2016.
3. Sea surface temperature (SST)

Separate analyses were conducted to examine the two dominant phases of the oceanic life of salmon. Juveniles are generally restricted to the continental shelf during their early life history (Hartt and Dell, 1986; Grimes et al. 2007), whereas older immature salmon and maturing salmon, particularly the planktivores, occupy the deeper waters. Perhaps a more appropriate approach would be to further subdivide the salmosphere into a cohosphere, etc. as oceanic distributions vary by species, however, that level of detail was beyond the scope of this project. To capture finer scale variability on the narrow continental shelf, defined as depths $<1500 \mathrm{~m}$, daily SST data on a $1_{4}{ }^{\circ}$ grid were used rather than monthly average $1^{\circ}$ grid used for the oceanic region.

### 3.1. Continental shelf

SST measured daily at one lighthouse on Kains Island (Northwest Vancouver Island) reflects the SST variation that is occurring across a broad range of latitudes along the coast and even into the Gulf of Alaska (McKinnell et al. 1999). The nature of this coastwide (defined here as depths $<1500 \mathrm{~m}$ ) covariation was studied using principal components analysis by computing daily SSTa measured by satellite on a spatial grid from California to Alaska. The dominant component of non-seasonal SST variability (PC1) had loadings of the same sign extending from Cape Mendocino, CA to Prince William Sound, AK with the maximum located in central Queen Charlotte Sound, BC (Figure 6). PC1 accounted for $55 \%$ of SSTa covariation and its loadings tended to increase away from land, likely because of local SST variability added by buoyancy-driven coastal currents (e.g. Alaska Coastal Current versus the large-scale circulation of the Alaska Current) and coastal upwelling, primarily along the U.S. West coast. The lowest correlation of SSTa with PC1 at any location on the shelf was $r=+0.4$ indicating that the entire coast is correlated with this pattern suggesting that non-seasonal SSTa variation on the continental shelf is due to large-scale environmental forcing.


Figure 9: Correlations (loadings) between daily sea surface temperature anomaly variation $\left(0.25^{\circ}\right.$ spatial grid) and SST-PC1 are shaded in


Figure 10: Daily temporal variation of SSTa-PC1 on the continental shelf to the end of October, 2016.
Considering temporal variation in coastal SSTs, a number of interesting features are evident. PC1 scores were generally negative (cool) for an extended period from 2006 to mid-June of 2013 when there was an abrupt warming that abated briefly in August 2013 before returning to strongly positive (warm) scores in September that persisted through the fall of 2013 before returning to negative (Figure 9). Thereafter, PC1 scores continued at relatively neutral values until the beginning of May 2014 when they became strongly positive for a few weeks. This warm spell abated briefly in mid-June then shifted to positive scores for the longest uninterrupted period since 1982. Apart from two days (August 22 and 23, 2016), PC1 has been continuously positive since June 27, 2014 (to Dec. 29, 2016), a period of 956 days. The previous record of continuously positive PC1 values was 428 days during the last major el Niño in 1997/98. Of note, the latter featured values of PC1 that were comparable with those observed since 2014 (Figure 10). Periods of unusually high surface temperatures along the North American coast occur with some regularity at bidecadal intervals and this event was not unexpected (McKinnell and Crawford 2007).


Figure 11: Continental shelf variation in PC1 of SSTa covariation from California to Alaska; only years 2013-2016 are shown, along with 1997 when the last blob bit the $B C$ coast.

The three highest positive PC1 scores (>3.6 s.d.) occurred over a 3-day period, May 14-16, 2016 (Figure 10). The next 6 highest scores occurred in 2004 and in 2005. In 2015, the rank of the strongest positive score that year occurred on July $12^{\text {th }}$ and it was $19^{\text {th }}$ highest in the entire record, from 1981. The strongest positive score in 2014 ( $50^{\text {th }}$ highest) occurred on December 27. There is little evidence of an overall linear trend in this PC1 time series. If the recent stanza of strong PC1 scores from 2014 is excluded, there is no statistically significant linear trend in PC1 from 1982 to 2013.


Figure 12: SST anomalies at Kains Island (NW Vancouver Island) by year from 2011.


Figure 13: Bivariate ellipses indicate the location of the annual bivariate average of temperature and salinity anomalies at Kains Island. 2014-2016 are in the top right quadrant with 2015 the most extreme in the 82 year history.

Returning to Kains Island to gauge the local effect, SST and SSS have been recorded daily almost
continuously since 1934. The coastwide pattern of high values of SST-PC1 that occurred throughout 2014 did not begin at Kains Island until the beginning of May of that year (Figure 11). These strong positive anomalies were also accompanied by positive salinity anomalies rather than the normal negative anomalies (Thomson and Hourston 2010). By 2015, the combination of high SST and high SSS, sometimes called spicy water, was the highest observed bivariate annual average and it has persisted at least to August 2016 (Figure 12). As the salinity gradient away from Kains Island is increasing seaward, the appearance of spicy water suggests and offshore and perhaps southerly origin.
a) Chilko L. sockeye marine survival and coastal SST

There is a single timeseries of annual postsmolt survivals for Chilko Lake sockeye salmon that dates to the 1950s. If annual survival is compared with values of PC1 during ocean entry, from 1982 to 2014, the result confirms traditional scientific knowledge that warmer coastal SSTs are never good for survival of Fraser River sockeye salmon. Negative correlations between survival and PC1 scores were largest during a period between the summer solstice and the fall equinox (Figure 13).


Figure 14 Correlations, calculated daily, between PC1 scores and annual postsmolt survival for Cbilko Lake sockeye salmon. The vertical dashed line indicates the date of the summer solstice (June 21). At best, PC1 accounts for about 25\% of annual variation in survival during the period from the summer solstice to the autumnal equinox, a period when the salmon are assumed to be on the continental shelf.

So the coastal environment is generally uncorrelated with Chilko Lake sockeye salmon postsmolt survival during winter when the fish are still in the lake. Through the spring the negative correlations gradually strengthen until an abrupt decrease occurs near the solstice, the time when these postsmolts are leaving inside waters. By November and December the correlation returns toward zero. This pattern suggests that there is no reason to expect that average to good survival will arise from the 2014-2016 ocean entry years, adult returns largely in 2016-2018.

### 3.2. Offshore SST

Monthly SSTa variability in the salmosphere offshore is dominated by an east-west dipole (seesaw) with centres of action in the Gulf of Alaska to the east and a widespread region associated with the Kuroshio-Oyashio mixing region in the western North Pacific (Figure 16). This pattern (SalmoDO - Salmosphere Decadal Oscillation) accounts for $34 \%$ of the covariance of SSTa in the Pacific salmosphere. As might be expected, the SalmoDO is correlated with PC1 of SATa
 ( $\mathrm{r}=0.5$ ) but it is slightly more correlated with PC2 of SATa. The central North Pacific, southr of the Aleutian archipelago varies from weakly correlated to uncorrelated with the SalmoDO pattern as its location lies between the two extremes of the dipole. The most extreme positive value of PC 1 occurred in September 2014 (Figure 14) and 17 of the top 25 extreme values of the SalmoDO occurred from January 2014-August, 2016. Only 1997 (July to September) had more than one extremum in the top 25 . Some may recall that the summer of 1997 was the year of the widespread straying sockeye salmon phenomenon that affected, primarily, Fraser R. populations (McKinnell 2000). Many sockeye salmon abandoned their migration to spawn in


Figure 15: Temporal variation in PC1 (above) and PC2 (below) of monthly sea surface temperature anomalies in the salmosphere from November 1981 to October 2016. rivers along the migration route because they had begun to develop secondary sexual characteristics maturing while still at sea. The $4^{\text {th }}$ highest value in the PC1 time series occurred in November 1986 but it did not appear to lead to noteworthy biological phenomena. Apart from a one month excursion into the negative in October 2013, the SalmoDO has had strong positive values since July 2013. Comparing the SalmoDO with the PDO finds that only half of the variation in the SalmoDO is associated with the PDO. The correlation between the SalmoDO and the PDO is strongest ( $\mathrm{r}>0.8$ ) from November to April and weakest in summer (August $\mathrm{r}=0.5$ ). PC2, the subdominant pattern ( $24 \%$ of covariation), primarily captures SSTa variations in the western North Pacific so it will not be discussed further. It is highly correlated with PC2 of SATa, but only in the summer months.

### 3.3. Offshore (Project Argo)

The advantage of using satellites to measure SST is broad spatial coverage, but these measurements will tend to over-estimate the temperatures experienced by salmon because oceanic habitat lies beneath the surface where temperatures are generally cooler during the warm season. Project Argo (http://www-argo.ucsd.edu/) has populated the World Ocean beyond continental shelves with >3000


Figure 16: Spatial distribution of PC1 (above) and PC2 (below) of monthly sea surface temperature anomalies in the salmosphere, 1981 to present. The spacing between contours, indicated by difference colours, is 0.1.
profiling floats that measure temperature and salinity at depth and transmit the results via satellite to centres that distribute the data globally without charge. The Argo data allow water properties to be examined to a depth of 2000 m . For the present study, temperatures at 5 m depth were examined initially and compared with satellite based SST at or near (within) the float location to determine whether the temperature extrema in the Northeast Pacific were simply a very near surface effect, and if not, to determine the extent of the extrema with depth.
3.4. Temperature at 5 m depth

As the uppermost depths of the measurements made by the profiling floats are commonly near 5 m , all temperature and salinity readings found in the range $4-5.5 \mathrm{~m}$ in the salmosphere were selected for further analysis. See Appendix 1 for discussion of computing anomalies. A box and whisker plot (Figure 14) of all anomalies shows the range of variation found each year. Outliers in the range of $\pm 3^{\circ} \mathrm{C}$ are common in the eastern salmosphere but most of the anomalies every year, as indicated by the box are $< \pm 1^{\circ} \mathrm{C}$. There are clearly more extrema in 2016 than in any other year, although the median anomaly in 2015 was slightly higher than all other years. The highest positive anomalies occurred between $48^{\circ}-50^{\circ} \mathrm{N}$


Figure 17: Box and whisker plots of monthly average temperature anomalies at 5 m depth in $2 \times 5$ latitude/ longitude blocks in the salmosphere (east of 180 longitude).
(south of the Aleutian archipelago) while the most negative anomalies at about the same longitudes, were in the south $40^{\circ}-42^{\circ} \mathrm{N}$ (Figure 15). The strongest anomalies in 2016 occurred between $180^{\circ}$ and $170^{\circ} \mathrm{W}$ which is beyond the historical range of migration of many salmon populations in the eastern Gulf of Alaska.
3.5. Salinity at 5 m depth

In broad terms, salinity anomalies in the eastern salmosphere corresponded with, and likely contributed to the temperature anomalies. While the temperature anomalies were generally warm from 2003-2005, there was a sustained cool period thereafter that lasted until 2013. The salinity anomalies were generally fresh then salty, then fresh again during the heat-wave (Figure 20). Like the temperature anomalies, the largest salinity anomalies occurred in 2016 and were located near


Figure 18: Temperature anomalies by latitude in the salmosphere in 2016.
the international date line, although there were one or two strong anomalies adjacent to the North American coast. The inverse relationship between SST and SSS anomalies was described by Thomson \& Hourston (2010).

### 3.6. Salmon and the Blob

Although the Blob covered much of the surface of the northeastern North Pacific, its centre of mass at least in its earliest stages was not in the subarctic (Figure 19) and coastal SSTs during to the end of April 2014 at Kains Is. were normal (Figure 11). Based on weekly SST data on a since 1981 there have been 11,244 weekly anomalies somewhere in the North Pacific (north of $20^{\circ} \mathrm{N}$ ) that have exceeded +3 s.d. above the long-term mean for any particular time and location. From 2014 to 2016, the total number of these strong SST anomalies exceeded all other years. Most of these extremes occurred beyond the salmosphere, but that maybe simply from greater opportunity to exhibit a strong anomaly; there are many more grid points in the subtropics because the continents diverge with decreasing latitude.

Most of the large positive SST anomalies in 2014 occurred in January and February between $40^{\circ} \mathrm{N}$ to $50^{\circ} \mathrm{N}, 160^{\circ} \mathrm{W}$ to $140^{\circ} \mathrm{W}$ in the central Gulf of Alaska (Figure 17). That location places the strongest influence of this winter blob on the southern fringe of the salmosphere, although lesser positive anomalies certainly extended northward. While the range of salmons extend south of $50^{\circ} \mathrm{N}$, they are not very abundant at these latitudes except in the western Pacific.

By examining all Argo profiles within the "blob domain" of early 2014, it is clear that it penetrated to about 90 m depth which is approximately the depth of the mixed layer in winter. The maximum depth of the 2014 anomaly was determined by taking slices of 10


Figure 19: The Blob - an SST anomaly pattern in the Northeast Pacific (January - June 2014 average shown here).
m from the surface to depth and computing the average of all observations in each layer. Since 2002, the year 2014 had the highest average temperature in all layers down to 90 m , according to an ANCOVA (to control for the effect of latitude). At greater depths, 2015 had the highest average temperatures in all 10 m layers down to 150 m . In 2015, most of the strong positive SST anomalies occurred off Canada and the U.S. West coast in a zone that essentially highlighted the California Current region from its source near Queen Charlotte Sound to its recirculation into the subtropical North Pacific. This eastern blob in 2015 had a similar temperature vs. depth structure to the one found further offshore in 2014. Average temperature by 10 m layer in the eastern blob was highest in 2015 for all layers down to 100 m , and thereafter 2016 temperatures became


Figure 20: Box and whisker plot of salinity anomalies at 5 m depth in the eastern salmosphere. higher than 2015. Although most of the discussion is about the magnitude of anomalies, it is perhaps more important to consider the absolute values of the SSTs at locations where there were strong departures from average as the SSTs may or may not be physiologically stressful.
4. Mixed Layer Depth (MLD)

The salmosphere has a strong vertical density gradient with lighter water sitting on top of heavier water, primarily caused by a vertical salinity gradient (fresh water floats on salty water) (Favorite et al. 1976). This gradient is enhanced seasonally during summer because the sea surface is warmed by solar radiation which increases the gradient, as does melting sea ice where it exists. The combination of a stronger gradient and lighter winds in summer limits the depth of vertical ocean mixing in summer approximately to the upper 25 m . Nutrients beneath the depth of the mixed layer are not available to support phytoplankton growth. Energy, primarily from stronger winds, is needed to break down the gradient in the fall and recycle nutrients back into the surface layer. In the Gulf of Alaska the mixed layer depth (MLD) is of the order of $80-125 \mathrm{~m}$ in winter. The exact depths depend to a certain degree on how the depth of the layer is calculated and in this report, MLD was calculated as the depth of a surface layer of uniform density. Despite a relatively stormy winter of 2014/2015, the January-April MLD anomalies of 2015 were the most extreme (shallow) anomaly in the record. This suggests that the vertical stability that had built up during the heat wave of 2014 was not destabilized by the stronger than average winds that occurred in the winter of $2014 / 2015$. One expected result of a shallow winter MLD is low nutrient concentrations in the surface layer and this is exactly what was found on DFO's Line-P cruises in 2015 (Figure 21) where the winter nutrient (nitrate) supply in the winter of 2015 (Figure 21, top right) was the lowest observed on Line-P in the past seven years.


Figure 21: Location of sampling stations, chlorophyll-a ( $\mathrm{mg} / \mathrm{m}^{3}$ ) and nitrate ( $\mathrm{mmol} / \mathrm{m}^{3}$ ) in surface waters along Line P in winter, spring and summer of 2015 (red symbols) and 2008-2014 (blue symbols). Source: Chandler et al. (2016).
5. Sea level pressure (SLP)

Storms crossing the salmosphere tend to move as large-scale cyclones (counterclockwise) that travel from west to east. The intensity of a storm is related to the magnitude of the depression in atmospheric pressure at the sea surface. The effect on the ocean is generally strongest in fall and winter and the overall annual effect will depend on the frequency of storms, their intensity, location, timing, etc. during the winter. There are various methods of quantifying storminess and most of them are calculated from a monthly average sea level pressure grid derived from some type of global analysis such as the NOAA NCEP/NCAR Reanalysis that covers the period from 1948present (Kalnay et al,. 1996). Neither 2015 nor 2016 winters (December-February) were extrema, but 2016 was the $3^{\text {rd }}$ largest since 1948, which is not unexpected as winters during major el Niño events are generally among the most stormy (Emery and Hamilton 1985). During 2015, SLP extrema were both high and low. There were no low SLP extrema during the winter of 2015, but there were many during the summer and fall months (Figure 22). The low pressure extrema


Figure 22: Number of $2.5^{\circ}$ by $2.5^{\circ}$ latitude/ longitude grid points where sea level pressure extrema occurred in 2015 in the salmosphere.
were part of a widespread region in the subtropical North Pacific, centred approximately at Hawaii but extending northeastward to British Columbia and westward past the International Date Line (Figure 23). The few high SLP anomalies during this period were in the Bering Sea. As the mean SLP gradient in the North Pacific has a trend from high in the southeastern region to low in the northwest in summer, the summer and fall of 2015 featured a much reduced gradient which tends to reduce winds. The high SLP extrema in 2015 occurred primarily in November (Figure 23). The extrema were part of a widespread pattern of high SLP anomalies across the southern salmosphere (Figure 24). There were no SAT anomalies associated with this pattern.


Figure 23: Average SLP anomalies from July to October, 2015.


Figure 24: SLP anomalies during the month of November, 2015.
6. Chlorophyll

Phytoplankton are single celled organisms in the sea that combine energy from the sun (light) and nutrients drawn from seawater to store that energy in chemical bonds via photosynthesis. This energy is made available to animals if they consume and digest the phytoplankton. The quantities of light and nutrients determine how much energy is captured and stored at the base of the food web. Various factors influence the availability of sunlight and nutrients to phytoplankton, thereby affecting the availability of energy to herbivores and omnivores. As all have evolved together, strategies have developed among consumers to take advantage of this stored energy when and where it is available. Occasionally, the norm is substantially disrupted, and depending upon the nature of the disruption, can lead to the benefit or the detriment of consumers. One of the major disruptions involves variations in seasonal timing (Hjort 1914) and the study of this variation is known as


Figure 25: Sea level pressure (bectopascals) at Darwin, Australia during the month of January from 1882-2016. The highest SLP occurred in 2016, 1992, and 1983 (el Niño years) Source: bttp:// woww.cpc.ncep.noaa.gov/ data/indices/ phenology. This section of the report examines variations in the seasonal development of phytoplankton in the Northeast Pacific region of the salmosphere.
Chlorophyll concentrations in seawater are generally obtained by one of two methods: in situ water samples, or remotely via satellite measurements of ocean colour and generally, there is good correspondence between the two methods. In the Northeast Pacific, chlorophyll concentrations measured by ocean colour sensors on satellites (eg. SeaWiFS, MERIS, MODIS-A) indicate that the coastal zone has much higher chlorophyll concentrations than the deep water regions.

### 6.1. Shipboard sampling

Twice monthly in situ sampling at Station NH-15 in 2015 off the Oregon/Washington coast identified the onset and evolution of a widespread Pseudo-nitzschia algal bloom along the North American coast (Du et al. 2016). Its toxicity (they can produce a toxin; domoic acid) resulted the closure of the razor clam fishery and and first ever closure in the region of the Dungeness crab harvest. Domoic acid was transferred via the food web (sardine/anchovy) to higher trophic levels with deathly consequences for seabirds and marine mammals (Du et al. 2016). In British Columbia, high chlorophyll a concentrations were observed during sampling off the west coast of Vancouver Island in July 2015 (Chandler et al. 2016). Pseudo-nitzschia fraudulenta, a potential source of domoic acid represented $32 \%$ of all diatoms sampled and fishery closures were far fewer than in Washington/Oregon.


Figure 26: Annual cycle of numbers of nonvisible pixels (clouds or insufficient light) in the salmosphere (East of $165^{\circ} \mathrm{W}$ based on counts of missing pixels in the MODIS-A ocean colour satellite (2002-present) summarized to an 8-day $9 \mathrm{k} \mathrm{m}^{2}$ grid. Late winter and the fall equinox provide the clearest viens.


Figure 27: Cluster analysis of cblorophyll concentration time series (2002-2016) reveals coastal (yellow), shelf (light gray) and offshore (dark grey regions. Differences in seasonal cycles between regions are portrayed in Figure 28.

### 6.2. Satellite chlorophyll

The ability to measure chlorophyll from satellites relies on sunlight and cloudless skies and their frequency of occurrence varies seasonally (Figure 26). To distinguish the regions, individual pixels (each representing $9 \mathrm{~km}^{2}$ of ocean) were assigned group membership solely on the basis of their similarity to all other pixels during the period 2002-2016, regardless of where they were located. Similarity between pixels was based on sum-of-squared differences of the 8 -daily concentrations across all years. The groups formed by cluster analysis created an intuitive division into what appear to be coastal, shelf, and offshore zones (Figure 27). The coastal zone includes what is often called the Inside Passage, including also the West coast of Vancouver Is. and the east side of Bristol Bay.
The shelf zone extends beyond the continental shelf and forms a transition region between offshore and coastal zones except in the northern Gulf of Alaska and the Alaska Peninsula (both sides) where it extends to the land. The offshore region is clearly situated over the deep waters of the Gulf of Alaska. Zones can be distinguished by their average levels, by their variance, and by the relative magnitudes of their seasonal peaks (Figure 28).
a) Coastal

The coastal zone has a prominent spring bloom with a relatively weak fall bloom (Figure 28) and generally higher chlorophyll concentrations throughout the year than the other zones. In 2015, extrema in chlorophyll concentration occurred during a 7 week period from midFebruary to the end of March and again in June (Figure 30). A bloom occurring in winter was unusual in this record when compared to other years (Figure 29). See Figure 31 and Figure 32 for a comparison of high and low chlorophyll winters. The anomalous winter bloom in 205 also featured as a precursor to the Oregon/Washington bloom with the toxic alga, Pseudo-nitzschia (Du et al. 2016). By the end of summer in 2015, chlorophyll extrema in the other direction (low) appeared during a week ending in mid-September and two week period during October (Figure 30).


Figure 28: Average 8-daily cblorohbyll concentrations by region within the salmosphere. Regions (Figure 27) are coastal (yellow), shelf (gray), and offshore (black).

## b) Shelf

The shelf zone has lower average chlorophyll than the coastal zone and its seasonal characteristics are intermediate between that of the coastal zone and that found in the offshore (Figure 28). In 2015, it also exhibited atypically high chlorophyll concentrations in FebruaryMarch of 2015 (blue line on the left in Figure 30).
c) Offshore

The offshore region has much lower average chlorophyll concentrations than the coastal region and lacks a dominant spring bloom so the spring and fall blooms are of approximately the same magnitude (Figure 26). Analysis of offshore chlorophyll anomalies was restricted to satellite data for the eastern salmosphere in the North Pacific (east of $165^{\circ}$ W) which also includes a portion of the


Figure 29: By region and year, box and whisker plots of average chlorophyll concentrations during only the 8-day periods of extreme anomalies in 2015 (February -March). The median value was highest in 2015 in all 3 regions with the largest anomaly in the coastal zone adjacent to coastlines. Regions coloured as in Figure 28. southeastern Bering Sea. The seasonal cycle of chlorophyll concentrations is relatively weak (Thomas et al. 2012). Nevertheless, despite its low amplitude, an annual cycle with spring and fall peaks is evident. Higher average chlorophyll occurs during winter (January-April) and fall (October-November) and lower average chlorophyll during the summer (June-August) with rapid transitions between seasons in May and September. Low summer chlorophyll values are due to zooplankton grazing (McAllister et al. 1960) but summer is also a period of extensive cloud cover. The least cloud cover occurs just before the equinox in spring and at the equinox in fall (Figure 24).
As had occurred in the coastal region in 2015, lesser chlorophyll extrema also occurred in the offshore region in early February and through most of March (Figure 30). Unlike the coastal region, however, the offshore region had positive extrema in October 2015. A strong fall bloom may have occurred because of the oncoming of an el Niño winter when Gulf of Alaska winds tend to be stronger than average in the winter, but perhaps not as early as October. Following two years of a marine heat wave (di Lorenzo and Mantua 2016), the mixed layer was relatively shallow with high concentrations of nutrients stored beneath the mixed layer. The nutrients would be released (mixed to the surface waters) by vertical mixing when the autumnal winds arrived and because of the nutrient gradient with depth, more nutrients may be available if the winds are stronger than average.


Figure 30: Lowess smoother applied zone-wide average chlorophyll concentrations by year in 3 regions: Offshore, Shelf, Coastal. In each region, the line for 2015 (blue) begins above that for the other years. Higher than average cblorophyll offshore later in 2008 (top panel) is the Kasatochi volcano effect while the origin of the 2013 summer peak there is not known.


Figure 31: Cblorophyll concentration in the Northeast Pacific in winter (Jan-Apr) of 2015.


Figure 32: Cblorophyll concentration in the Northeast Pacific in winter (Jan-Apr) of 2007.

### 6.3. Chlorophyll phenology

Phenology in the eastern salmosphere was examined by evaluating the seasonal development of chlorophyll in each of 3 zones identified above. To increase the spatial coverage within each 8 -daily period and to fill in gaps found at individual pixels, average chlorophyll concentrations were calculated on a $1^{\circ} \times 1^{\circ}$ grid from the basic $9 \mathrm{~km}^{2}$ resolution, for each year and 8 -day period. If no data were available due to low light (December-January), the time series was shortened by a few weeks at each end. Timing was evaluated by fitting curves to the cumulative chlorophyll concentration at each grid point, seeking points of inflection during a year where chlorophyll was most rapidly increasing. Initially a single curve (single peak) was fit to each time series, but if there was a substantial improvement in the fit ( $\mathrm{R}^{2}$ increase $>5 \%$ ) by entertaining two seasonal peaks, spring and fall, then this result was adopted. The "fall" peak may be a misnomer here as the second peak found by the algorithm was typically in the fall (Figure 28) but may have occurred earlier.

## a) Offshore

Most of the grid points exhibited evidence (improvement in $\mathrm{R}^{2}$ ) of weak spring and fall chlorophyll peaks. The peak day of year of spring chlorophyll concentration in the offshore is highly variable, which is not too surprising given that it is a region known for little or no evidence of a bloom. Box and whisker plots were used to indicate, across the zone, where the peak dates were concentrated in each season (Figure 31). Within the zone, the timing peaks were more or less concentrated near a median date depending on year. There was no outstanding shift in median spring timing or extrema in 2015, however, there is an extremum (late) in median date of the fall bloom in 2016.


Figure 33: Box and whisker plots of peak spring (left) and peak fall (right) cblorophyll concentration offshore (east of $165^{\circ} \mathrm{W}$ estimated by curve fitting. Each dot represents 1 grid point in 1 year. The dates of the equinoxes and summer solstice are indicated as dashed lines to provide a seasonal timing reference.. * indicate timing that was an outlier (within that year).
b) Shelf


Figure 34: Box and whisker plots of peak spring (left) and peak fall (right) chlorophyll concentration in the shelf region (east of $165^{\circ} \mathrm{W}$ ) estimated by curve fitting. Each dot represents 1 grid point in 1 year. The dates of the equinoxes and summer solstice are indicated as dashed lines. * indicate timing that was an outlier (within that year) at a grid point.

As in the offshore region, median peak date of bloom timing in the shelf region was an extremum
(late) in 2016 in fall, but also had a late median date in spring (Figure 32). As this is somewhat of a transition between the nearshore and offshore, it is not too surprising that it picks up some of the characteristics of each. This region is expected to have additional variability because of the relatively greater influence of mesoscale eddy activity (Brickley and Thomas 2004; Crawford et al. 2005; Ladd 2007). To date, the role of eddies in salmon biology is not well known. For the most part, studies have focused on their role in affecting migration timing (Hamilton and Mysak 1986; Hamilton et al. 2000).


Figure 35: Box and whisker plots of peak spring (left) and peak fall (right) cblorophyll concentration offshore (east of $165^{\circ} \mathrm{W}$ ) estimated by curve fitting. Each dot represents 1 grid point in 1 year. The dates of the equinoxes and summer solstice are indicated as dashed lines. *indicate timing that was an outlier (within that year) at a grid point.

## c) Coastal

Median peak date in the coastal region was latest in 2003 and earliest in 2010 (Figure 33). The variability, measured by the lengths of whiskers, was greatest in 2016. The fall bloom was latest in 2016 and earliest in2008, a relatively cool year that was associated with an abundant return of Fraser River sockeye salmon but that may simply be a coincidence. Based on the previous analysis of coastal chlorophyll, there was an expectation that 2015 would have the earliest spring median date but that did not appear. There is a possibility that 2015 should have been modelled as a year of three peaks; a small but anomalous peak in winter, with normally timed spring and fall peaks. The early winter peak was probably swamped by the spring peak in a two-peak model.
6.4. Zooplankton
a) Coast/shelf

The current paradigm for juvenile salmon survival along the southeastern coast of the Gulf of Alaska is that survival is associated with the movement of different water masses along the North American coast making the environment more or less favourable for survival. A cooler (warmer) ocean in the south (north) is generally better (worse) for survival than a warmer (cooler) ocean (Mueter et al. 2002). Since the 1950s, dramatic changes in zooplankton communities have been observed regularly along the British Columbia, Washington, Oregon coastline (Beklemishev and Lybny-Gertsyk 1959; Frolander, 1962; Cross and Small 1967; Mackas 1984; Fulton and Lebrasseur 1985, Mackas et al. 2001, Mackas et al. 2007, Keister et al. 2010).


Figure 36: Schematic of variation of the copepod biomass in association with variation in ocean circulation. Source: Fulton and Lebrasseur (1985).

The taxonomic composition of the zooplankton community (primarily copepods) and its total biomass can change abruptly (Frolander 1962).

- Oregon

Regular and frequent sampling has shown the predominant role of low frequency variation in the coastal ocean since the late $20^{\text {th }}$ century (Figure 37). Peterson classified the major differences as southern and northern communities. Their phasing implies a strong association with large-scale oceanographic features involving currents, water masses. It is also a region of strong upwelling but the dominant pattern in these time series is not the seasonal scale. The southern community is dominated by copepod taxa that do not store lipids and reproduction is continuous providing that adequate food is available. The northern community is dominated by large lipid-storing copepods that enter diapause after the spring feeding season with sufficient energy stored to survive to reproduce the following spring. The current paradigm is that the latter provide an enriched food web for juvenile Pacific salmon. At Newport, the southern community has prevailed since mid-2014 with the largest anomaly occurring in 2015 (data for 2016 were not available). Qualitatively, these strength of these anomalies does not look particularly different from similar periods in the past (Figure 37).


Figure 37: (W.T. Peterson's) biweekly zooplank.ton community composition off Newport, OR indicates variation in biomass of boreal versus subtropical copepod species. Source: bttps:// wwww.nwfsc.noaa.gov/research/ divisions/fe/estuarine/ oeip/eb-copepod-anomalies.cfm\#NSC-01


Figure 38: Zooplankton species-group anomaly time series (vs climatological baseline) for southwestern Vancouver Is. (left) and nortbwestern Vancouver Is. (right) regions. Ordinate is annual $\log$ scale anomalies. R in Euphausiids represents: corrected for day/night tows. EUPpa: Euphausia pacifica; THYsp: Thysanoessa spinifera; CHAET; Chaetognaths divided into north/ south species group. Source: Cbandler et al. 2016.

- West Coast Vancouver Island

A sufficiently large-scale climate event can affect the zooplankton communities in a similar way along much of the North American coastline (Mackas et al. 2006). Extrema in 2015 were widespread among many taxa along the Vancouver Is. coastline but were more extreme along its northwestern coast (Figure 38). This effect could have arisen from a stronger or more prominent poleward circulation of southern waters, creating stronger anomalies in the north. Southern latitudes along Vancouver Is. experience zooplankton anomalies regularly, in association el Niños (Fulton and LeBrasseur 1985) so the appearance of southern taxa and diminished northern taxa is not as unusual. Adult salmon returns in southern British Columbia, following zooplankton anomalies such as these, will tend to be poorer rather than better.
a) Offshore

- Continuous Plankton Recorder

Data for the NE Oceanic Region (a CPR-defined region) were made available by the Director of CPR-Pacific as final results for 2015 and preliminary results for 2016 (to July). Preliminary results are based on $25 \%$ of a normal annual sample size for the program. 2015-no extrema were found in the zooplankton samples taken in the Oceanic Region (eastern Gulf of Alaska) during the CPR survey (Figure 39).


Figure 39: Indices of high seas plankton community based on Continuous Plankton Recorder data (courtesy of Dr. Sonia Batten, Director, CPR - Pacific). Statistics are based on 2000-2015 average monthly values. Colour legend for all panels appears in the top left panel. All ordinates are log-scale. Data for 2016 are available only to July.
Minimum, maximum and mean statistics are based on data from 2000-2015 so extrema in 2016 can exceed the minimum and maximum.

## Salmon Extrema

## Bering Sea

## Yukon River

- Eagle - Since 2005, the counts of chinook salmon at Eagle in 2015 was an extremum (high) and the return timing in 2016 was an extremum (early). In contrast to the early return of chinook salmon in 2016, the extrema (since 2006) for fall chum in 2016 was the most skewed return and latest peak.
- Anvik - The summer run of chum at Anvik R. (since 1980) was the most skewed (slow rise to a peak), but the date of the peak was not an extremum. Even year pink salmon had the latest peak date (since 1994) in 2016.


Figure 40: Total returns of sockeye salmon to east side rivers in Bristol Bay 2016 and forecast for 2017 (solid circle). Source: http:/ / wwww.adfg.alaska.gov/ static/ applications/dcfnewsrelease/ 756093217.pdf

Bristol Bay

- anomalies in the sockeye salmon return recently have been in timing rather than abundance. For example, 2015 was the latest return of sockeye salmon past the Port Moller test fishery, in contrast to 2013 which was the earliest return on record. An abundance extrema (positive) occurred in the

Alagnak R. in 2015 and the Ugashik R. in 2016 (Figure 40). No other total return extrema occurred in other rivers in either year. There were no abundance extrema in 2015 or 2016 in west side rivers (Figure 41).


Figure 41: Total returns of sockeye salmon to west side rivers in Bristol Bay 2016 and forecast for 2017 (solid circle). Source: http:/ / www.adfg.alaska.gov/ static/ applications/ dcfnewsrelease/ 756093217.pdf

## Northern Gulf of Alaska

## Copper River

- Coho salmon commercial harvest was the largest since 2004.
- Chinook and sockeye salmon runs in 2016 were bad and average, respectively.
- Mean size of sockeye salmon (without regard to age) was an extremum (small) in 2015 (Source: http://www.alaskajournal.com/2016-05-26/recent-trend-small-sockeye-continues-copper-river)
- The early-run sockeye salmon abundance was an extremum in 2015 but no other timing/abundance anomalies were found for this species.


## Kodiak

- In 2016, pink salmon harvest was the lowest since the 1970s. (Source:
http://www.adfg.alaska.gov/index.cfm?adfg=commercialbyfisherysalmon.bluesheetsummary). The pink salmon run to the Karluk R. was front loaded (most arriving early but without a peak date
extremum) with a protracted finish.
- The abundance of the early-run sockeye salmon to the Karluk River in 2015 was an extremum (high) as was the late-run abundance in 2016.


## Russian River (Cook Inlet)

- Sockeye salmon had no anomalies in 2015 but the return of early-run sockeye salmon in 2016 was the least compressed in the record.
- Chinook salmon had no extrema in 2015, but in 2016 was the earliest found and the run timing shape was front loaded.


## Southeast Alaska

Chinook summer troll fishery
Although the mean length of age 1.3 and age 0.4 chinook salmon in the summer (statistical weeks 27-29) troll fishery


Figure 42: Mean mid-eye to fork (MEF) length $(\mathrm{mm})$ of 4 age-classes of chinook salmon in the SEAK troll fishery during statistical weeks 27-29. Data courtesy of L. Shaul, ADFG. was the smallest in the record in 2015, the dominant feature of temporal change is the overall decline during the past 35 years (Figure 42). The rate of decrease increases with ocean age.

## Pink salmon

Forecasts of pink salmon harvests in Southeast Alaska based on juvenile pink salmon abundances in Icy Strait the previous year are relatively reliable in most years (Figure 43); 2015 and 2016 are noteworthy negative anomalies but not extrema. In 2016, harvests of pink salmon in Southeast Alaska were approximately 18 million whereas 30 million was the forecast based on a juvenile index value of 2.2 . Harvests in 2015 were well below forecast. The annual mean weight of pink salmon caught in northern SEAK and southern SEAK fisheries is highly correlated ( $r=0.9$ ) suggesting that they share common growing conditions in the Gulf of Alaska. There were no body size extrema in 2015 or 2016.

## Sockeye salmon

Time series of mean length of age 1.2 and age 1.3 sockeye salmon were available from Hugh Smith Lake, McDonald Lake, Ford Arm Lake, Situk Lake, and Chilkoot Lake. A principal component analysis of mean length of 10 age/population combinations indicated that they share only $43 \%$ of covariation in common but all load positively on the leading PC. The shared component is much lower than for SEAK pink salmon mean weight. The subdominant PC distinguished age 1.2 fish from age 1.3 fish. In northern BC sockeye populations, these two age-classes tend to occupy different locations in the Gulf of


Figure 43: Correlation of juvenile pink salmon peak CPUE in Icy Strait (June or July) and SEAK adult pink barvest the following year. The observed value of the abscissa in 2015 was 2.2, implying a harvest in 2016 of ~30 million. Source: Orsi et al. ( $N O A / A B L$ )

Alaska (McKinnell 1995). Only Chilkoot R. (age 1.3) had a mean length extremum (small) in 2015. Some sites (McDonald L.) was not sampled in 2015 and 2016, nor was Ford Arm Lake in 2016. Data for Situk L. for 2016 were not available at the time of writing but will be later, so mean length was interpolated (L. Shaul, ADFG, pers. comm.).

## Coho salmon

Average dressed weight data are available from the coho troll fishery from the 1970s. There were no extrema in mean weight in 2015 (2016 not available). The mean length of coho salmon spawners has declined generally over the past 35 years (Figure 44) although the past year or two has seen increases above the recent average in 3 of 4 of these populations. There were no extrema in mean length in 2015 or 2016 in these populations.


Figure 44: Mean length of coho salmon spawners (male and female average) at four locations in Southeast Alaska: Aukee Creek, Berners River, Ford Arm Lake, and Hugh Smith Lake. Data courtesy of L. Shaul, ADFG. The dashed vertical line indicates 2015.

## British Columbia

## Nass River

Data collected at a fish wheel in the lower river since 1994. Sockeye salmon and chinook salmon are better described by two pulses of migration.

- 2015 - the abundances of early and late running sockeye and early and late running chinook salmon
were extrema (low). There were no other extrema.
- 2016 - the abundances of early and late running sockeye and chinook salmon were extrema (high). The peak date of the early running sockeye salmon and the late running chinook salmon was an extremum (late) and the latter was very compressed (extremum). Coho salmon abundance was an extremum (low) and timing was early and brief (both extrema).


## Skeena River

Data are from the Tyee gillnet test fishery in the lower river since 1956. The later running species (chum, coho) continue migrating after the test fishery closes so the data will only reflect catch-per-unit-effort until that date. The abundance extremum (low) for sockeye salmon occurred in 2013.

- 2015 - the return of chinook salmon was late and compressed. There were other extrema for any species.
- 2016 - the sockeye salmon run was late. There were no extrema in abundances or timings for any species.


## Long Lake

The migration of sockeye salmon through Docee fence can, in most years, be described adequately by a single pulse of spawners passing through the fence. Infrequently, as in 2005, the migration has multiple pulses of spawners passing through the ladder and a single pulse model is inadequate. In 2016, the run was the earliest observed during the period from 1980. No other characteristics of the run were extreme in either 2015 or 2016, when the migration modelled as a single pulse.


Figure 45: [upper] Single pulse fits to cumulative timing at the Whonnock test fishery (Fraser R.) from 2013 to 2016. [lower] Two pulse fits to the same test fishery by 2015 cycle year.

## Strait of Georgia and WCVI

The marine survival of coho salmon in the Strait of Georgia declined abruptly after the 1980s (Figure 46). For the last two decades, it has remained low; less than half of what occurs on the West coast. The last two decades are one continuous extremum.

## Fraser River

The Fraser River approach route test fisheries for sockeye salmon and pink salmon in Johnstone Strait and the Strait of Juan de Fuca are both unique and valuable because they provide information on salmon timing, abundance, and size, prior to fishing, although years with later opening dates tend to miss the beginnings of early returning sockeye populations in the Upper Fraser, Baker Lake and Lake Washington. Other salmon species are caught as well although some are not on spawning migrations. For coho salmon and chum salmon these test fisheries are closed before spawning migrations of begin in earnest so catches
may not necessarily be well described by a model that anticipates migration peaks. Nevertheless, the shapes of cumulative abundance curves provide an opportunity for comparison among years.

As any biologist or manager can attest, the migration of Fraser River sockeye salmon is complicated. Since 2002, and likely before that, there have been relatively consistent differences in timing/abundance curves for the total return among cycle years. The 2016 cycle, for example, is distinguished from other cycles because of its earlier average timing (Figure 45, upper panel), which is caused for the most part by low average abundance in the late run populations. Therefore, in not dealing with stock-specific timing curves, anomalies should be calculated with respect to this four year cycle. However, with the available data, the number of years available to compute an average for any cycle year is only three or four. Furthermore, because there are so many populations, some of remarkable abundance, interannual variations in their relative abundances can easily affect the characteristics of any annual timing curve. Added to this source of variability are the effects of differences among test fisheries in their ability to detect the abundance signal, plus variable start and end dates.

Given the numbers of species $\times$ ages involved (8), the numbers of test fisheries (5), and variations in patterns among years, only single pulse models were fit to each, but there are clearly some years and species where multiple pulses would markedly improve the fit. In general, a single pulse model accounts for $>50 \%$ of the variation in CPUE (e.g. $>70 \%$ in the San Juan seine test fishery) but there are also some years and species with misfits ( $\mathrm{R}^{2}<10 \%$ ) but they do not occur often. Example of fitting multi-pulse models is seen in Figure 47 (sockeye) and Figure 49 (pink) compared to a single pulse in Figure 45.

The most remarkable migration timing anomaly in Fraser River sockeye salmon in recent memory occurred in 2005 ( 2013 cycle), a year of many remarkable environmental and biological extremes (see special issue on this event in Geophysical Research Letters Vol. 33) and subsequently low abundances of adult Fraser River sockeye salmon in 2007. Indeed, 2005 was so unusual that even greater timing extrema are almost unimaginable without digging into the distant past for a reminder. ${ }^{3}$

## Sockeye salmon

- 2015
- Regardless of whether a single pulse or multi-pulse migration model was used, the sockeye salmon return timing past the Whonnock test fishery (within the Fraser River) in 2015 had an intermediate timing when compared with four recent years, but it was generally earlier than the other years on that cycle (Figure 45). Early timing in a warm year is inconsistent with the "cold early-warm late" pattern that has been relatively consistent through the last half century (Blackburn 1987, McKinnell et al. 2012). In that sense, 2015 was an extremum because a later than average return would have been expected based on the coastal heatwave of that year. On the other hand, DFO had forecast an early return of Summer-run stocks (Fraser R. panel news release of 2015). Subsequent news releases noted the Early Summer and Summer runs were protracted as had occurred during the last heat-wave (McKinnell 2000).
- There were no timing/abundance extrema for large sockeye salmon in 2015 at the Round Is. (gillnet) test fishery but the Blinkhorn Is. (seine) test fishery was the least compressed (protracted), as was noted in the in-season Fraser River Panel reports. In contrast to the Round Is. test fishery, the abundance of large sockeye salmon in the gillnet test fishery at San Juan was an extremum (low) in 2015. There were no sockeye salmon extrema in the San Juan seine

3 Peak catch of sockeye salmon in 1926, a major el Niño year, occurred during the week of October 2 (Clemens \& Clemens 1927).
fishery in 2015.

- 2016
- large sockeye salmon in the Round Is. test fishery were the earliest observed, which coincided with an extremum in skewness (peak early). Large sockeye salmon in the Blinkhorn test fishery were the earliest in the record. The early timing in a warm year is inconsistent with historical norms.
- Small sockeye salmon (age $3_{2}$ ) are not caught in the gillnet test fisheries as they are too small. Their abundance in 2016 was an extremum (low). In cycle years where larger average abundances of small sockeye are expected ( 2014 cycle), their abundance is an index of large sockeye salmon returns the following year (McKinnell et al. 2012) but it is not clear how well this index might work in years when average abundances are expected to be low. The low abundance extrema of small sockeye salmon that was observed in the Blinkhorn test fishery in 2016 was also observed in the San Juan seine test fishery.
- There were no extrema in the San Juan gillnet test fishery in 2016, but the 2016 Blinkhorn test fishery had the most extreme abundance (low), skewness (early), compression (high), and peak date (early).


Figure 47: Large sockeye salmon catch in the Round Island gillnet test fishery (fit to a 3 pulse model rather than a 1 pulse model).

## Pink salmon (2015 only)

- The body weight of Fraser River pink salmon has exhibited a long-term decline since 1950s (Figure 48). Although different sampling methods have been used to determine annual average weight, the average weight in 2015 was the lowest in the record. No equivalent body size extremum was found in Southeast Alaska even though historical tagging records indicate a common oceanic environment.


Figure 49: Cumulative CPUE of pink salmon (\% of total) at San Juan (left) and Blinkhorn (right) test fisheries in odd years from 2003 to 2015.

- From 2002-2016 there are seven years of pink salmon returns to the Fraser River as they appear in abundance only in odd years. Migration through the San Juan seine test fishery on the West coast of Vancouver Island indicated that in some years $(2007,2009)$ a single peak describes the passage of fish, with improvements in $\mathrm{R}^{2}$ in those years of only $2.5 \%$ and $5.6 \%$, respectively, for considering that there may be two pulses of migration. In the other years, 2003, 2005, 2011-2015, there were significant improvements in fit with $\mathrm{R}^{2}$ increasing by as much as $19-42 \%$ by modelling this part of the migration as two pulses. A similar pattern appeared in the Blinkhorn seine test fishery, but some years differed in whether there was an improvement in the model fit by contemplating two peaks (Figure 49).
- The Blinkhorn seine test fishery has the added complication of greater abundances of local (nonFraser) pink salmon in the catch. The worst fit to a two pulse model occurred in 2015 in the San Juan seine test fishery because there were three obvious peaks that year. This San Juan gillnet test fishery began relatively late in 2015 and first sets yielded catches there were the largest in first sets in the 21 st century indicating that the pink salmon migration was already underway when the test fishery began, confirming the early arrivals seen in the seine test fisheries.


Figure 48: Mean body weight ( kg ) of pink salmon returning to the Fraser River.

## Cbinook salmon

- 2015 - the only extremum for large chinook salmon in Johnstone Strait was a late peak in the Blinkhorn test fishery. Small chinook salmon in the Blinkhorn test fishery had a skewness extremum (slow build to a peak) that was consistent with the late timing of the large chinook salmon. There were numerous extrema at the San Juan test fisheries; both small and large chinook salmon were the least abundant in the record in the gillnet test fisheries and most abundant in the record in the seine test fishery, suggesting a late migration timing, but the estimated peak dates were not extrema. The San Juan seine test fishery was the least compressed for small chinook salmon.
- 2016 - large chinook salmon had a compressed run in the Round Is. test fishery and the small chinook salmon had a skewed return with most arriving early. Large chinook salmon had an abundance extremum (low) and a compressed run in the Blinkhorn test fishery. There were no extrema for small chinook salmon at Blinkhorn. Small and large chinook salmon in the San Juan gillnet test fishery was the most compressed in the record. In the San Juan seine test fishery, small chinook salmon had the most skewed run (slow build to a peak) but no other extrema. Large chinook salmon on the other hand were the least abundant, a strong skewness anomaly (slow build to a peak), and a compressed peak.


## Coho salmon

Coho salmon spawning migrations occur primarily later than these test fisheries operate.

- 2015 -the seasonal pattern of catch of coho salmon in the Round Is. was the least compressed in the record but there were no extrema at the Blinkhorn test fishery. At San Juan, the seasonal pattern of catch in the seine fishery was the least compressed and the peak date of the gillnet fishery was the latest in the record.
- In 2016, there were no extrema in the Round Is. test fishery but in the Blinkhorn test fishery, the abundance was lowest and compression was the highest. At the San Juan gillnet test fishery, abundance was lowest and in the San Juan seine fishery, compression was greatest.


## Chum salmon

Chum salmon spawning migrations occur primarily later than these test fisheries operate.

- 2015 - there were no abundance/timing extrema in the Johnstone Strait test fisheries. In the Strait of Juan de Fuca test fisheries, there was an abundance extremum (low) in the gillnet fishery and a abundance extremum (high) in the seine test fishery.
- 2016 - the Blinkhorn Is. test fishery had the lowest abundance of chum salmon. Chum salmon caught in the Round Is. test fishery had the least compressed (most protracted) catch. These extrema also appeared at the San Juan gillnet and seine test fisheries.


## Steelhead trout

- 2015 - the steelhead trout passing the Johnstone Strait test fisheries had low compression in both, but they also had an abundance extremum (high) at the Blinkhorn Is. test fishery. There were no extrema at either of the San Juan test fisheries.
- 2016 - the peak date of the steelhead passage past the Round Is. test fishery was latest in the record but there were no extrema of any kind in the Blinkhorn test fishery. Like other salmonids, the compression of the passage of steelhead trout catch in the San Juan gillnet test fishery was highest. Abundance in the San Juan seine fishery was the lowest.


## U.S. Mainland

## Baker Lake

The data from Baker Lake are reconstructed prefishery abundances of sockeye salmon. In 2015, their abundance was an extremum (high). There were no other extrema in 2015 or 2016.

## Lake Washington

The data are sockeye salmon counts at Ballard Locks on the ship canal into Lake Washington. There were no extrema in either 2015 or 2016.

## Columbia River

Juvenile salmon surveys - Annual trawl surveys conducted by NOAA along the WashingtonOregon coast typically find the highest abundance of coho salmon and chinook salmon near the Columbia River in May and June. CPUE varies from year to year with lowest abundances occurring during years of strong environmental


Figure 50: Annual variation in juvenile coho and chinook. salmon CPUE during June trawl surveys, 1998-present. Source:
bttps:/ / wwww.nwfsc.noaa.gov/research/ divisions/fe/ estuarine/ oeip/kb-juvenile-salmon-sampling.cfm anomalies such as the 1998 el Niño and the 2005 downwelling year (Figure 50). There were no extreme abundance anomalies in 2014 or 2015. The highest CPUE occurred in 2013. Growth rates of juvenile coho salmon measured in 2015 off the West coast of Washington and Oregon were second highest in the past decade (Brian Beckman, NOAA, pers. comm.); 2014 was highest.

Chinook salmon - Chinook salmon return to spawn above Bonneville Dam at various ages. Larger individuals are counted as adults and smaller individuals as jacks, although both should be considered as adults according to their sexual maturity. Three run timing groups are recognized: Spring, Summer, and Fall. The Spring and Fall runs generally have prominent peaks of abundance and relatively compressed timing. The Summer group has a less compressed migration and when abundant, a peak is evident.

- 2015 - the total return of large chinook salmon was an extremum (Figure 51) as a result of Summer and Fall Run extrema added to a relatively high abundance of the Spring run. Spring and summer small chinook salmon were extremely skewed (peak during the first part of the run) and small Spring run chinook had a compression extremum (low).
- 2016 - No extrema.

Sockeye salmon - There are three populations of sockeye salmon in the run but they are so dominated by the abundance of the Osoyoos Lake population that the run was modelled as a single pulse.

- No extrema occurred in 2015 or 2016, although abundance was high in 2015.

Steelhead trout - The run of steelhead trout was modelled as a single pulse.

- 2015 - No extrema
- 2016 - Most protracted in the $21^{\text {st }}$ century. Abundance was also low but not extreme.

Coho salmon - The fraction of coho salmon run ascending to spawn above Bonneville Dam is relatively small compared to the total run to the river (L. Weitkamp, NOAA, pers. comm.). Nevertheless there are at
least two regular peaks annually for large coho salmon. The only peak date extremum (early) was found in the large coho early-run component.

- 2015 - The timing of large coho in the early run was extreme (early) and the run of late run coho was protracted.
- 2016 - There were no extrema in either run timing component in 2016. Although not an extremum of interest to this report, the 2014 ocean entry year produced remarkably few large coho salmon spawners in 2015, considering the sibling relationship that has persisted through the $21^{\text {st }}$ century (Figure 8).


Figure 51: Annual numbers of large adult chinook salmon (year indicated on each plot point) returning to Bonneville Dam (Columbia River) versus the number of small adult salmon returning the previous year.

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## Appendix 1. Oceanographic data and methods

1. Surface Air Temperature

Monthly average surface air temperatures from the NOAA NCEP/NCAR Re-analysis at http://www.esrl.noaa.gov/psd/data/gridded/data.ncep.reanalysis.html
Monthly anomalies were calculated by removing the monthly 1948-2016 long-term mean.
2. Sea Level Pressure

Monthly average surface air temperatures from the NOAA NCEP/NCAR Re-analysis at http://www.estl.noaa.gov/psd/data/gridded/data.ncep.reanalysis.html
Monthly anomalies were calculated by removing the monthly 1948-2016 long-term mean.
3. Sea Surface Temperature
3.1. Monthly average data are from
ftp://ftp.emc.ncep.noaa.gov/cmb/sst/oimonth v2/YEARLY FILES/.
3.2. Weekly average data are from
ftp://ftp.emc.ncep.noaa.gov/cmb/sst/oisst v2/YEARLY FILES/.
3.3. Daily average data are from ftp://eclipse.ncdc.noaa.gov/pub/OI-daily-v2/NetCDF/

SST anomalies were calculated by removing the appropriate (monthly, weekly, or daily) 1981-2016 longterm mean.
3.4. Kains Island lighthouse

This lighthouse and many others, has been the site of daily measurements of SST and salinity since a program of sampling was started by the Fisheries Research Board of Canada in the early $20^{\text {th }}$ century. Anomalies were computed as deviations from the long-term (1935-2016) daily averages. Data were downloaded from http://www.pac.dfo-mpo.gc.ca/science/oceans/data-donnees/lighthouses-phares/index-eng.html
4. Sea temperature and salinity depth at 5 m depth.

These data were collected and made freely available by the International Argo Program and the national programs that contribute to it (http://www.argo.ucsd.edu, http://argo.jcommops.org). The Argo Program is part of the Global Ocean Observing System. Because of their relatively sparse distribution (compared to satellite data), developing a climatology has some challenges. Two approaches were used to compute temperature climatology. The first computed average temperature and salinity in $2^{\circ}$ latitude by $5^{\circ}$ longitude blocks by month. Monthly average temperatures were computed from all observations made within a block/month. Long-term monthly averages for the block were calculated by summing across years (2003-2016) and dividing by the number of years with valid data. Anomalies were created by subtracting each monthly average from the long-term average in a block. A second approach was to use a satellite-based SST climatology made at a much finer spatial ( $1 / 4^{\circ}$ grid) and temporal (daily). When a float surfaced, its daily $1_{4}{ }^{\circ}$ location was noted and the temperature it observed at 5 m was subtracted from the average for that time/location. Using a surface climatology to compute anomalies at 5 m will underestimate the true anomaly at 5 m because the average value at the surface is slightly warmer than the average value at 5 m .
5. Mixed Layer Depth (MLD)

Mixed layer depth was determined according to the following definition: the expected standard deviation of repeated sampling of water properties ( t , s , density) is equal to zero in a mixed layer. Each profile can be examined from surface to depth where this property should hold if the layer is truly
mixed. A gradient in any property indicates that the layer is not fully mixed. In practical terms, the standard deviation can only approach zero in the mixed layer because of the precision of the instrument and other factors associated with making observations. As a consequence, an arbitrary tolerance level is needed. In the present study, it was set at $99 \%$, meaning that each measurement at depth is compared with the distribution of measurements taken at shallower depths. Assuming a normal distribution, if a deeper measurement had less than a $1 \%$ probability of coming from the distribution with the mean and s.d. of values measured above it, then the MLD was set as half the distance of the depth of that measurement from the one above. The rationale for the latter is that one doesn't know where in the last depth interval the change occurred so the midpoint was chosen.
6. Chlorophyll from satellite ocean colour

Chlorophyll concentration data products served by the NASA Goddard Space Flight Center, Ocean Ecology Laboratory, Ocean Biology Processing Group were used in this analysis. The initial download of data occurred in October 2015 with subsequent files downloaded intermittently since then. Analyses included data up to November 2016 (eg. http:// oceandata.sci.gsfc.nasa.gov/MODIS-
Aqua/Mapped/8Day/9km/chlor a/2016. SeaWiFS sensor data (1997-2002) were downloaded from https://oceandata.sci.gsfc.nasa.gov/SeaWiFS/Mapped/8Day/9km/chlor a/). Phenology was determined within each $1^{\circ} \times 1^{\circ}$ cell within the salmosphere by fitting a McKinnell growth curve configured with two pulses (spring and fall) to a cumulative curve of 8-daily average chlorophyll concentrations. The average in an 8 -day period in a cell was computed as the mean of all valid pixels within each time/space stratum. Missing data were replaced by the long-term mean of that day and grid point. Each time series was then smoothed by a 3-weekly running mean.
7. Plankton
7.1. Continuous Plankton Recorder (Pacific project)

Data for the current year are preliminary, based on processing $25 \%$ of the samples. Values are monthly means compared to the long-term monthly mean and minimum/maximum monthly values found in the time series to date since 2000. Numbers for 2016 will change as more samples are processed and quality-controlled. Four variables have been selected: total diatom abundance, mesozooplankton abundance, estimated mesozooplankton biomass (dry weight), and average copepod community size (based on Richardson et al., 2006 where the published length of the adult female represents all individuals of the species). These variables are thought to provide a useful summary of the plankton, but there are some caveats and limitations: 1) The CPR diatom numbers are biased towards the larger, chain forming varieties which may only be a small portion of the phytoplankton community, 2) the number of samples that the provisional data are based on is small, especially for smaller regions. Regions with the best sample density are: Oceanic NE Pacific, Alaskan Shelf, and S. Bering Sea. Three regions are sampled only by the east-west transect which runs only three times a year in spring, summer and fall (W. GoA, Aleutian Shelf and S Bering Sea). Monthly data for the Oceanic NE Pacific Region were provided by and courtesy to Dr. Sonia Batten, Director, CPR-Pacific). Reference:
http://www.pices.int/projects/tcprsotnp/main.aspx.

### 7.2. Coastal sampling

a) British Columbia

- figures were obtained from DFO's State of the Pacific Ocean report (Chandler et al. 2016).
b) Newport, Oregon
- There is a relationship between water type, copepod species richness, and the PDO. Two
indices were developed based on the affinities of copepods for different water types. The dominant copepod species occurring off Oregon at NH 05 were classed into two groups: those with cold-water and those with warm-water affinities. The cold-water (boreal or northern) group included the copepods Pseudocalanus mimus, Acartia longiremis, and Calanus marshallae. The warm-water group included the subtropical or southern species Mesocalanus tenuicornis, Paracalanus parvus, Ctenocalanus vanus, Clausocalanus pergens, Clausocalanus arcuicornis and Clausocalanus parapergens, Calocalanus styliremis, and Corycaeus anglicus. Source:
https://www.nwfsc.noaa.gov/research/divisions/fe/estuarine/oeip/eb-copepodanomalies.cfm.


## 8. Appendix 2. Salmon data and methods

Modelling migration
Regular observations of salmon abundance at fixed locations are standard tools in a fishery manager's tool bag. The data collected are generally of two types: counts of individual fishes as might occur at the fish ladder, or numbers caught per unit of effort as might occur at a test fishery that is intended to gauge the abundance of passing fish. These types of regular sequential observations can be described by parametric models such as the 2 parameter Gaussian (normal model which assumes that a salmon migration can be described by a mean date and its standard deviation). More complex models such as that of Schnute and Sibert (1983) allow greater flexibility by using additional parameters to capture traits such as skewness (asymmetry) of the run and compression (similar to kurtosis) which permits curves with shapes ranging from a sharp peak in abundance through to no peak. The 4 parameter Schnute-Sibert curve can be expanded to entertain runs that exhibit multiple peaks (McKinnell, unpublished) that need to be "decomposed" from the composite data. The improvement in the fit as a result of entertaining multiple components (run timing groups) can be measured and compared with simpler curves by examining the improvement of the fit of the model to the data $\left(\mathrm{R}^{2}\right)$. Where longterm observations suggest a fixed number of peaks, such as the Spring, Summer, and Fall runs of chinook salmon to the Columbia River, the expected number of components in the run was fixed, in this case at 3 components. The model then estimates the peak date, skewness, compression, and abundance of each component from the data. This differs somewhat from traditional practice which uses fixed dates (May 31, August 31) to separate Spring/Summer and Summer/Fall. The McKinnell approach allows for year to year variability in the timing of passage of each component, i.e. a late Spring run might allocate too much abundance in the Summer run. The two approaches should not differ too much in this case because the Spring and Fall peaks of are clearly identifiable. In some years, however, the end of the Spring run and the beginning of the Summer run may be more difficult to detect. Small numbers of missing data appear in most time series.
As the model fitting procedure relies on cumulative abundances, missing observations (primarily in test fisheries) were estimated by linear interpolation using the abundance on the day before and the day following the gap. To make each year comparable, regardless of abundance, each cumulative count or CPUE time series was converted to per cent. This also allowed greater stability in model fitting. Numerical instabilities arose when runs with millions of fish were run with the same tuning as runs with hundreds of fish. The solution to this problem was to convert all to cumulative per cent, then back transform this to absolute abundances after a solution was found. Prior to fitting each series was smoothed using 3-day average smoother to reduce the influence of high frequency (day to day) variability. As the analyses were done in the fall of 2016, before all returns were in for 2016, a cutoff date in 2016 was set at October 21. In reality, this affected only the Bonneville Dam analyses as other observation sites had stopped operating by this date. To make cumulative counts at Bonneville in 2016 comparable with other years, long-term average counts were used in place of observations from October 22 to November 30, 2016. By the 2016 cutoff, the peaks of all species and all timing components within each species have been seen so the effect on the 2016 results should not be too great. ${ }^{4}$

Escapement monitoring

### 8.1. Test fisheries

4 The coho salmon returns (large and small) at Bonneville were re-run with 2016 data to November 24.

## a) Nass River

The Nisga'a Fisheries Program provides weekly in-season updates on program activities including in-season Nass salmon and steelhead run size forecasts and up-to-date harvest information. These updates are available in the above-linked document. This data, public announcements and Nisga'a fishery openings and closures can be accessed from the FTP site at: ftp://ftp.lgl.com/Nass \%20Stock $\% 20$ Assessment $\% 20$ Updates $/$.
(See also: http://www.pac.dfo-mpo.gc.ca/fm-gp/northcoast-cotenord/nass-eng.html)
b) Tyee (Skeena River)

A gillnet test fishery has operated at Tyee since 1955 to determine the abundance of salmon and steelhead trout entering the lower Skeena River. The test fishery was developed to provide daily estimates of sockeye salmon escapements after removals by the commercial fishery. Tidal amplitudes exceeding 6 m are common in the region during spring tides, generating tidal currents of three to four knots. The net is allowed to drift within a channel measuring two to five kilometres long and 0.8 km wide. Until 2002, an undyed, fibrous nylon gillnet of 200 fathoms total length and 20 feet depth, made up of 10 equal length panels of mesh sizes 3.5 inches to 8 inches. Starting in 2002 a 6 strand "Alaska Twist" net has been used. Sets ( 1 hour) are made on both high and low water slack during daylight hours which usually means three sets per day. Daily escapement estimates are calculated for sockeye salmon while relative abundance and timing are calculated for the other species.
(Source: http://www.pac.dfo-mpo.gc.ca/fm-gp/northcoast-cotenord/skeenatyee-eng.html)
c) Fraser River


The Pacific Salmon Commission (PSC) manages in-season test fishing programs in Fraser River Panel waters and coordinates with Fisheries and Oceans Canada on other marine test fisheries off northern Vancouver Island. The primary pre-fishery sites for the Fraser River are Round Is. (gillnet) and Blinkhorn Is. (seine) in Johnstone St. and San Juan (gillnet and seine) at the entrance to the Strait of Juan de Fuca. At the beginning of the season, gillnet is used in the approach routes in the Strait of Juan de Fuca and Johnstone Strait before switching to seine nets when abundances tend to be at a peak. Test fishing with gillnets only occurs within the river. The starting and ending dates of each gear vary from year to year. Fishing effort is relatively constant but there are variations so the daily data were converted to CPUE.
As there are generally considered, for management purposes, to be four main run timing patterns
for sockeye salmon in a season (Killick 1955), each year of data at Whonnock was fit to a composite run timing curve that entertained up to four timing curves as this fishery registers all timing groups. Because of the mid-season gear change in the San Juan and Johnstone Strait test fisheries, each generally sees only three groups. Likewise in most years, the migration of pink salmon is described better by a model that entertains two pulses of migration. Nevertheless, a single pulse model will capture much of the variation in migration timing/abundance. For simplicity of analysis and interpretation, only single pulse models were fit for the test fisheries on the approaches to the Fraser R.
(Source: Pacific Salmon Commission; http://www.psc.org/publications/fraser-panel-in-season-information/test-fishing-results/)

### 8.2. Fish Counts

a) Alaska

Counts and descriptions of the counting locations were obtained from the Fish Counts webpage on the ADF\&G website (https://www.adfg.alaska.gov/sf/FishCounts/index.cfm? adfg=main.home). Locations were selected primarily for their duration and abundances. ADF\&G retains intellectual property rights to data collected by or for ADF\&G. Any dissemination of the data must credit ADF\&G as the source, with a disclaimer that exonerates the department for errors or deficiencies in reproduction, subsequent analysis, or interpretation.

- Yukon River (Eagle)

This sonar project is located approximately 1,200 miles up the Yukon River, 6 miles below the village of Eagle and 16 miles below the U.S./Canada border.

- Anvik River

The Anvik River is a tributary of the Yukon R. located about 300 mi . from the estuary. This is sonar project that estimates the passing abundances of pink salmon (even year) and summer-run chum salmon.

- Russian River

The weir is located at the outlet of Lower Russian Lake, about 78 miles from the mouth of the Kenai River. It takes approximately 7 to 10 days for sockeye salmon to travel from the lower Kenai River to the weir depending on water levels. Travel times are estimates and can vary significantly from this depending on conditions. The escapement goal is 22,000-42,000 Early-Run sockeye salmon and 30,000-110,000 Late-Run sockeye salmon.

- Karluk River

Karluk weir is located on the west side of Kodiak Island. The weir is near the mouth of the river just upstream from the lagoon and near the village of Karluk. It produces what usually is the largest run of sockeye salmon on Kodiak Island.

- Copper R. (Miles L.)

The Sonar on the Copper River is located at the outlet of Miles Lake, about 70 miles from the Chitina dipnet fishery. It takes approximately 2 weeks for salmon to travel this distance, but this is highly variable depending on the water level. The water levels listed here are an indication of the
general trends in the Copper River but may not be indicative of what is occurring at Chitina. The current escapement goal for Sockeye is 360,000 to 750,000 .
b) British Columbia

- Nass River

The Nisga’a Lisims Government's Fisheries and Wildlife Department has conducted extensive fisheries research on the Nass River since 1992 in partnership with Fisheries and Oceans Canada (DFO) and BC Ministry of Environment. The Nisga'a Fisheries Program celebrated 20 years of operation in 2011 and currently operates twenty annual stock assessment, catch monitoring, habitat, and management projects. The current objectives and priority activities of the Nisga'a Fisheries Program are to: monitor Nass salmon and steelhead escapement, monitor salmon and non-salmon harvests in Nisga'a fisheries, in accordance with the Nisga'a Final Agreement, determine factors limiting the production of Nass salmon and non-salmon species; and promote and support Nisga'a participation in the stewardship of Nass Area fisheries. (source: http://www.pac.dfo-mpo.gc.ca/fm-gp/northcoast-cotenord/nass-eng.html). Weekly fish wheel catches were obtained from ftp://ftp.lgl.com/Nass $\% 20$ Stock $\% 20$ Assessment $\% 20$ Updates/).

## - Docee Fence (Long Lake)

The Docee River is located in the Central Coast district of British Columbia in Management Area 10. The Docee River is less that one kilometre long and drains Long Lake into Wyclees Lagoon which drains into Smith Inlet. The Docee River Fence is located at the outlet of Long Lake. The Docee River counting fence has been in operation since 1972. A counting tower was in operation from 1962 to 1971. Daily sockeye escapement information recorded at the fence is used for the management of the commercial gillnet fishery in Smith Inlet. The counting fence generally operates from late June or early July to mid August. Sockeye are sampled from the fence for post orbital to hypural plate length and tip of nose to the fork of the tail length. Scales are taken from each fish for age determination. In 1998, the fence operation was expanded to include coho and chinook. (Source: http://www.pac.dfo-mpo.gc.ca/fm-gp/northcoast-cotenord/docee-eng.html)
c) Washington

## - Baker River Trap (Skagit)

Adjusted daily Baker Trap counts, covering years 1992-2015 and 2016 (to September 28) are the sum of the raw daily trap counts plus fish harvested in Skagit Bay/River fisheries moved forward in time to when we think they would have reached the trap if they were not harvested. For example, if we assume an estimated travel time of X days from the mouth of the river to the trap, then the "adjusted" trap count for a given day would be the raw trap count on that day + fish harvested at the mouth X days earlier. We use these adjusted counts when looking at timing for in-season run size updates, etc., rather than the raw counts, because in recent years there have been substantial commercial/sport fisheries in the bay and river below the trap that could affect the raw timing curve. There are 4 different river catch areas, plus the bay, each with its own assumed travel time from the catch area to the trap. The estimated travel times we use are based on the results of a recent sockeye tagging study. I can provide you with more details if interested. Since these adjusted counts include trap + harvest, the sum of the daily adjusted counts for each year is the total terminal run size for that year.
(Source: Peter Kairis, Biologist, Snowonish Tribe, WA, email: PKairis@skagitcoop.org)
d) Lake Washington (Ballard Locks)

- Lake Washington sockeye salmon have been counted each year since 1972 as they enter freshwater at the Hiram M. Chittenden Locks. The Washington Department of Fish and Wildlife (WDFW) counted the sockeye from 1972 through 1992, and currently Muckleshoot Indian Tribe and WDFW staffs conduct the counts cooperatively. Although small numbers of sockeye enter the system in May and early June, the period from the second week of June through the end of July is the standard counting interval used to determine if there are sufficient sockeye to open fishing seasons. Sockeye counts begin on June 12th each year to provide consistent data from year to year. The sockeye are sample counted daily during set time periods as they pass through both the locks and the fishway, and the counts are converted into a daily total number of fish passing upstream.
(Source: Aaron Dufault, WDF; http://wdfw.wa.gov/fishing/counts/sockeye/)
e) Columbia River

The Fish Passage Center provides technical assistance and information to fish and wildlife agencies and tribes, in particular, and the public in general, on matters related to juvenile and adult salmon and steelhead passage through the mainstem hydrosystem in the Columbia River Basin.
(Source: Fish Passage Center; www.fpc.org)
8.3. Body size-at-age
a) Fraser River - average weights of pink salmon were provided by Michael Lapointe (Pacific Salmon Commission).
b) Nass River - Nisga'a Fisheries Program
c) Southeast Alaska - Leon Shaul, ADF\&G
8.4. Marine survival
a) West Coast Vancouver Island and Strait of Georgia

- Survival estimates for hatchery and wild coho salmon are prepared and maintained by Steve Baillie, DFO - South Coast office


[^0]:    ${ }^{1}$ A review of forecasts obtained from the PSC model absent input from the Agency forecasts for the five stocks in this review was not performed. Conversations with John Carlile (ADF\&G) indicated that the model would need to be rerun with the Agency forecasts removed in order to determine how the PSC model would forecast absent Agency input. Given the large number of possible ways the model could be examined for the five stocks (one stock removed at a time, all stocks removed, or some combination), extremely limited staff time to do the model runs, and the scope of this review, it was determined that this evaluation would best be performed at a later date.

[^1]:    ${ }^{2}$ In this document "agency" will refer to the Alaska Department of Fish and Game (ADFG), Fisheries and Oceans Canada (CDFO), Washington Department of Fish and Wildlife (WDFW), Oregon Department of Fish and Wildlife (ODFW), Columbia River Inter-Tribal Fish Commission (CRITFC) or the U.S. Fish and Wildlife Service (USFWS).

[^2]:    ${ }^{1}$ Terminal run excludes U.S. interceptions that occur outside Districts 108 and 106.

[^3]:    * Preliminary

