Pacific Salmon Commission
Joint Chinook Technical Committee Report

Pacific Salmon Commission Chinook Model Base Period Re-Calibration Volume III: Model Parameters Report TCCHINOOK (23)-03 V3

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LIST OF ACRONYMS AND ABBREVIATIONS[1]

AABM	Aggregate Abundance Based Management	**HRI**	Harvest Rate Index
ACL	Annual catch limit	**IDF&G**	Idaho Department of Fish and Game
ADF&G	Alaska Department of Fish & Game	**IM**	Incidental Mortality
AEQ	Adult equivalent	**ISBM**	Individual Stock Based Management
AI	Abundance Index	**MAE**	Mean Absolute Error
ARIMA	Auto-Regressive Integrated Moving Average	**MAPE**	Mean Absolute Percent Error
AWG	Analytical Working Group	**MAT**	Maturation Rate
BC	British Columbia	**MDL**	Model file
BPC	Base Period Calibration	**MPE**	Mean Percent Error
BY	Brood Year	**MR**	Maturation rate
BYER	Brood Year Exploitation Rate	**MRE**	Mean Raw Error
CIG	Chinook Interface Group	**MSE**	Mean Squared Error
CBC	Central British Columbia	**MSF**	Mark-Selective Fishery
CLB	Calibration	**NBC**	Northern BC Dixon Entrance to Kitimat including Haida Gwaii
CNR	Chinook Non-retention	**NOAA**	National Oceanic and Atmospheric Administration
CRITFC	Columbia River Inter-Tribal Fish Commission	**NSD**	No Substantial Difference
CTC	Chinook Technical Committee	**NWIFC**	Northwest Indian Fisheries Commission
CWT	Coded-Wire Tag	**ODFW**	Oregon Department of Fish & Wildlife
CYER	Calendar Year Exploitation Rate	**OOB**	Out of Base
DFO	Department of Fisheries and Oceans Canada	**PC**	Proportionality Constant
DGM	Data Generation Model	**PCOH**	Partial cohort
DV	Diagnostic	**PNV**	Proportion Non-Vulnerable
ER	Exploitation Rate	**PSC**	Pacific Salmon Commission
ERA	Exploitation Rate Analysis	**PST**	Pacific Salmon Treaty
ERIS	Exploitation Rate Indicator Stock	**PT**	Pre-terminal
ETS	Exponential Smoothing	**PV**	Proportion vulnerable
EV	Environmental Variable	**QIN**	Quinault Nation
FNC	First Nations Caucus	**RMSE**	Root Mean Squared Error
FP	Fishery Policy	**ROM**	Ratio of Means
GSI	Genetic Stock Identification	**RT**	Ratio
GUI	Graphical User Interface	**RY**	Return years
HR	Harvest Rate	**SA**	Stock Aggregate

[1] Stock acronyms can be found in Appendix I.

SACE	Stock aggregate cohort evaluation
SEAK	Southeast Alaska Cape Suckling to Dixon Entrance
SPFI	Stratified Proportional Fishery Index
U.S.	United States
UAF	University of Alaska Fairbanks
USFWS	US Fish & Wildlife Service
VB	Visual Basic
VPA	Virtual Population Analysis
WCVI	West Coast Vancouver Island excluding Area 20
WDFW	Washington Department of Fish and Wildlife

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1 Introduction

Chapter 3 of the Pacific Salmon Treaty (PST) requires the Chinook Technical Committee (CTC) to "*provide annual calibrations of the Commission Chinook model with pre-season and post-season abundance indexes by April 1 of each year*" (PST, Chapter 3, subparagraph 2(b)(viii); PST 2020). To fulfill this obligation, the CTC maintains the Pacific Salmon Commission's (PSC) Chinook Model to generate key outputs of relevance to the PSC annual fishery management cycle. The model is calibrated each year, incorporating pre-season stock-specific abundance forecasts with the best available catch, exploitation rate, terminal run, and escapement estimates. The CTC relies upon the model to generate annual estimates of abundance for aggregate abundance-based management (AABM) fisheries.

The PSC Chinook Model was originally developed in the 1980s. At its inception, computational power was a bottleneck to the complexity, expansion, and maintenance of the PSC Chinook Model's code, component algorithms, and various data inputs and outputs. These constraints, as well as the CTC's limited ability to verify source data in an accepted data exchange format, allowed for modelling of only a few stocks and fisheries to represent the operation and impact of inter-jurisdictional fisheries.

As computing power increased and stock and fishery assessment programs expanded, additional stocks and fisheries were added for greater representation and relevance to Chinook fisheries management under the PST. This enhanced model stratification and improved representation of AABM and individual stock-based management (ISBM) fishery impacts.

The PSC Chinook Model produces projections of pre-fishery abundances vulnerable to AABM fisheries that are scaled relative to the agreed 1979–82 base period. These relative abundances become the abundance indices (AIs) used to determine annual catch limits (ACLs) for the upcoming season (pre-season AIs) as well as the post-season AIs for the previous year. The preceding calibration for the base period was accomplished in 1998 (referred to as 9806) and was used through to 2019. A base period calibration (BPC) is a critical component of the Chinook chapter (Chapter 3) of the PST, as AABM fishery limits in the 1999, 2009, and 2019 PST Agreements (PST 2000; PST 2010; PST 2020) are based on the model AIs that scale current conditions to the base period.

Periodic BPCs are necessary to reflect changes in available data to better represent stocks and fisheries. This is an intensive process of data collection, analyses, comparisons, and review. In general, previous attempts to reconstruct the base period were hampered by competing priorities of the CTC in fulfilling its regular duties and additional assignments, including and increasing complexity to support PST Agreement renewal negotiations. An attempt at updating the BPC began in 2013 for use in renegotiating annex chapters in the PST. This effort, which received both agency and PSC prioritization and financial support, culminated in 2019 with a successful new BPC. The new PSC Chinook Model (hereinafter referred to as the phase II Model) was formally adopted by the PSC in October 2019.

The BPC update was accomplished in two phases: phase I focused on increasing stock stratification and use of updated stock data, whereas phase II focused on increasing model fishery stratification and use of updated fishery data. The first iteration of the PSC Chinook Model improvement (phase I) resulted in finer stock resolution by adding stock groups that were not previously represented, splitting some stocks to better represent life histories and ocean distributions, or improving representation by the coded-wire tag (CWT) hatchery indicator stocks. These changes increased the number of model stocks from 30 to 41. In addition, during phase I, escapement and terminal run estimates for multiple stocks were reviewed, CWT release groups used for modelled stocks were reviewed and revised, and the Ricker $\boldsymbol{\alpha}$ productivity parameter for multiple stocks was updated. In the revised stratification of phase II, several larger fisheries were split in the model, especially terminal area fisheries. These changes increased the number of model fisheries from 25 to 48.

The intent of this three-volume report series is to document the modifications and work involved in the recent BPC. Volume One compares base period exploitation rates (ERs) with the observed catches in the previous BPC (9806) and the catches in phase II BPC fisheries (CTC 2021a). Volume Two compares base period CWT recoveries, cohort sizes, maturation rates and adult equivalents, and ERs for the model stocks from the previous BPC (9806) and the phase II BPC (CTC 2021b). This document, Volume Three, contrasts model parameters, programs, fishery indices, and model input files from the 9806 BPC with those of the phase II BPC. It also describes the process that the CTC used to determine if the new BPC was an improvement over the existing BPC. Future improvements that have been identified, although not a comprehensive list, are described in Chapter 5.

If you are interested in obtaining the complete set of files used in the BPC, please contact info@psc.org and direct your email to the Chinook Technical Committee Coordinator.

2 Description of Programs and Related Inputs

2.1 Coshak 4

The CTC uses the Coshak4 program (implemented in Visual Basic (VB)) to estimate base period ERs. The primary output of the program is the MDL (model) file, which is needed by both CalibQB6 (Section 2.4) and the Stratified Proportional Fishery Index (SPFI; Section 3.2) to Fishery Policy (FP) procedure. Many changes were made to the Coshak4 program during the phase II BPC work, but they were limited to general code maintenance, improvements to the graphical user interface (GUI), fixes to minor bugs, and changes to the files output from the program. Changes to Coshak4 are documented in Appendix A.

2.2 Out of Base Procedure

The MDL files for each stock in the model contain the "average" recoveries by stock, fishery, and age that occurred during the base period (1979–1982). For stocks that have CWT recoveries during the base period years, these "average" recoveries are produced by the Coshak4 program by averaging (weighted averaging is used for some stocks) the stock, fishery, and age-specific recoveries across the base period years. However, there are some stocks for which no base period CWT recoveries exist. For these stocks, tag codes that represent a typical pattern of CWT recoveries for the stock are chosen. However, since these recoveries happened after the base period and are likely the result of different fishing effort and stock abundances than observed during the base period, they need to be scaled (or weighted) back to the expected base period recoveries using fishery harvest rate (HR) or ER scalars. This weighting is done by implementing the Out of Base (OOB) procedure when running Coshak4.

2.2.1 Purpose of the WG4 File

The WG4 file is used during the creation of base period MDL files for stocks that do not have base period CWT information and therefore require use of the OOB procedure. The WG4 contains yearly HR or ER scalars for PSC Chinook Model fisheries. The scalars are created by dividing yearly fishery harvest rates by base period harvest rates in these same fisheries. These scalars allow for stock, age, and fishery-specific CWT recoveries in years after the base period to be translated into the expected number of base period recoveries for the same stock, age, and fishery.

2.2.2 History of the WG4 File

The WG4 file has been in use since the 1980s to allow for the creation of MDL files for stocks without base period CWT data. Prior to 2009, the WG4 file used yearly ER scalar information for the model fisheries based on fishery-specific ratio of means (ROM) indices. One drawback of using ER scalars derived from ROM indices was that when the scalars were applied to the fishery recoveries during the OOB procedure (Appendix C), it was sometimes possible to estimate more fish being harvested across all fisheries than existed in the cohort, resulting in negative escapement estimates (Appendix B). To avoid this issue, a Grand SPFI was developed in 2009 that included all model fisheries where CWT data were available (or adequate) to allow for estimation of fishery-specific HRs. The logic behind this approach was that simultaneously estimating the HR indices across all fisheries would preclude the possibility of creating HR scalars that would result in base period harvest estimates in the MDL files that exceeded the base period cohort sizes. Unfortunately, some fisheries could not be included in the Grand SPFI due to a lack of CWT recoveries resulting from either small catches, low sampling rates, or both. In fisheries that could not be included in the Grand SPFI due to insufficient CWT recoveries, scalars were constructed based on catch ratios of specific years to the average catch in the base period.

2.2.3 WG4 File Data

The specific WG4 file used for the phase II BPC was "SPFI_80FWG4_upd9-16-2016_v2.wg4". As explained in the previous paragraph, the yearly fishery indices contained in the file were generated from either the Grand SPFI or catch ratios. The WG4 data, the Grand SPFI data, and the catch ratio data are contained in the Excel Workbook entitled "SPFI_80FWG4_upd9-16-2016_v2.xlsx".

2.3 Collapse 56 to 48

The collapse 56 to 48 program was used in the phase II BPC to change the number of fisheries in the MDL files output from Coshak4, from 56 to 48. The fisheries in the 56 fishery MDL files that were aggregated are AK W/S T, AK JNO T, AK JNI T, AK JLO T, AK JLI T, AK FALL T, WCVI F/W T, WCVI SPR T, and WCVI SUM T (Table 1). Recoveries in the Alaska fisheries were summed to create model fishery ALASKA T, and the WCVI fisheries were used to create WCVI T. This program was necessary because Coshak4 can only generate MDL files using a single definition of fisheries; however, both 56 and 48 fishery MDLs are needed. The 48 fishery MDL files are input into CalibQB6, whereas the 56 fishery MDL files are needed for the SPFI to FP procedure.

The collapse 56 to 48 program was also used to create the MDL files with scaled base period recoveries in the Northern British Columbia (NBC) and West Coast of Vancouver Island (WCVI) AABM sport fisheries. MDL files with scaled output ended in "- adj".

Table 1. List of fishery acronyms and their definitions.

Acronym	Definition
AK W/S T	Alaska Winter/Spring Troll
AK JNO T	Alaska June Outside Troll
AK JNI T	Alaska June Inside Troll
AK JLO T	Alaska July Outside Troll
AK JLI T	Alaska July Inside Troll
AK FALL T	Alaska Fall Troll
WCVI F/W T	West Coast Vancouver Island Fall/Winter Troll
WCVI SPR T	West Coast Vancouver Island Spring Troll
WCVI SUM T	West Coast Vancouver Island Summer Troll

2.4 CalibQB6/Basecalib

2.4.1 General Changes

The CalibQB6 program was minimally changed during phase II of the BPC. Some minor modifications included changes to the code so that the program could read MDL files with decimal output, a reversal of the pre-base and base escapement in the calibration (CLB) file, and general maintenance to the code required for the program to run.

2.4.2 Estimation of Stock-Recruitment Parameters

The BPC program finds the Ricker 'a' parameter so that:

$$log\left(\frac{E_{BP}}{E_{PBP} \times (1 - HR_{AEQ})}\right) = a \times \left(1 - \frac{E_{PBP}}{S_{Eq}}\right)$$

where:

E_{BP} = Average Base Period escapement

E_{PBP} = Average Pre-base period escapement

HR_{AEQ} = Average total base period adult equivalent harvest rate (with shakers)

a = Ricker a parameter

$S_{Eq} = \frac{OPT}{0.5-0.07\times a}$ = Approximate equilibrium number of spawners using the Hilborn approximation, where *OPT* is the optimum number of spawners specified in the base period file (BSE).

A simple iterative search algorithm is implemented to solve this Ricker 'a' parameter. Previous versions of this program searched a parameter space for 'a' from 1 to 3 in increments of 0.1. However, the estimated Ricker 'a' parameters for several Columbia River stocks were estimated at the upper boundary of 3. The new program was changed to search the parameter space for 'a' from 1 to 6 in increments of 0.001 to more accurately estimate 'a' and because computation speed was no longer a limitation.

2.5 HRJ to Fishery Policy Program

HRJ files are output of the ERA containing age- and fishery-specific harvest rates whereas FP files are Model input files containing fishery policy scalars relative to base-period fishery patterns. The CTC uses its HRJ to FP program both to create databases of exploitation rate analysis (ERA) results and compute ROM indices. Only a few changes to the HRJ to FP Program were needed for the Analytical Work Group (AWG) to use it in the phase II BPC work. Most changes were to allow for a greater number of model stocks and fisheries.

2.5.1 Driver Files

The HRJ to FP program uses *driver files* to compute ROM indices and the resulting FP files for use with the PSC Chinook Model. All the driver files used by the old model had to be modified to reflect the new model fishery and stock definitions and new driver files had to be created for some of the new model fisheries.

3 Fishery Modeling Considerations

3.1 Christmas Tree List

The CTC AWG engaged in a review of those stocks used in the previous BPC during the multi-year base calibration endeavor and compared alternative production areas and model stocks during an AWG meeting in Vancouver, BC in the 2010s. A worksheet was drafted which showed attributes of the information available for, as well as availability and quality of data affiliated with, each stock and production area, and qualitative assessments of each attribute were assigned prior to the discussion and selection of stocks from this worksheet. Stocks selected for inclusion in future BPC fishery index steps were highlighted in green, while stocks deemed unsuitable for being carried forward were highlighted in red, hence the appellation of the "Christmas tree list". More specifically, these stocks and stock-age combinations were to be used to generate fisheries indices such as the ROM and SPFI, as well as FPA files from annual ERA output. Whereas a total of 40 stocks were selected for inclusion in base recalibration, based on qualitative criteria, only 31 were determined to be adequate for inclusion in fishery indexing (Table 2).

Table 2. Stocks chosen for inclusion in fishery index construction known as the "Christmas Tree List".

Long Cfile name	HRJ name	Start age
Atnarko Summer	ATN	2
Big Qualicum	BQR	2
Chilliwack	CHI	2
Cowlitz Fall Tule	CWF	2
Elk River	ELK	2
George Adams Fall Fingerling	GAD	2
Harrison	HAR	2
Kitsumkalum Summer	KLM	3
Columbia Lower River Hatchery	LRH	2
Lewis River Wild	LRW	2
Nicola River Spring	NIC	3
Nisqually Fall Fingerling	NIS	2
Northern SE AK	NSA	3
Puntledge Summer	PPS	2
Queets Fall Fingerling	QUE	2
Quinsam Fall	QUI	2
Robertson Creek	RBT	2
Samish Fall Fingerling	SAM	2
Lower Shuswap River Summers	SHU	2
Skagit Spring Fingerling	SKF	2
Spring Creek Tule	SPR	2
South Puget Sound Fall Fingerling	SPS	2
South Puget Sound Fall Yearling	SPY	2
Salmon River	SRH	2
Southern SE AK	SSA	3
Skagit Summer Fingerling	SSF	2
Columbia Summers	SUM	2
Transboundary Rivers	TST	3
Upriver Brights	URB	2
White River Spring Yearling	WRY	2
Willamette Spring	WSH	3

3.2 Stratified Proportional Fishery Index

3.2.1 Introduction of the Stratified Proportional Fishery Index

To account for changes in stock composition and to include stocks without base period data, the CTC created alternative derivations of fishery indices (CTC 1996). The CTC determined that a useful fishery index should reflect both changes in HR and stock distribution. Three general, desirable characteristics were identified:

1. the index should measure changes in fishery HRs if the distribution of stocks is unchanged from the base period,

2. the index should have an expected value of 1.0 for random variation around the base period fishery HR, cohort size, and stock distributions, and

3. the index should weight changes in stock distribution by abundance.

After exploring several alternatives, the CTC concluded that the best estimate for a fishery index would consist of the product of a fishery HR index and an index of stock abundance weighted by average distribution (i.e., the proportion of a cohort vulnerable to the fishery). To that effect, a report by the CTC (2009) stated that for all AABM fisheries the SPFI was the most accurate and precise in estimating the HR occurring in a fishery, and it is currently used for the Southeast Alaska (SEAK) AABM fishery.

3.2.2 Stratified Proportional Fishery Index to Fishery Policy Procedure

The SPFI to FP procedure is used to convert stratum-specific harvest rate index (HRI) values (or SPFI values) to FP scalars (as used by the Chinook Model). Only the SEAK AABM Troll fisheries uses the SPFI to FP procedure. The data required are: (1) base period ERs (from the STK file); (2) CWT recoveries by SPFI strata in the base period (from the 56 fishery MDL files), and; (3) stratum-specific HRI estimates (n_{SEAK} = 6 SPFI):

(1) $BPER_{s,a,f}$ = base period ER by stock (*s*), age (*a*), and fishery (*f*)
(2) $R_{s,a,fs}$ = base period CWT recoveries (*R*) by *s*, *a*, and SPFI strata (*fs*)
(3) $SPFI_{t,fs}$ = SPFI by time (*t*) and *fs*

The procedure begins by stratifying the $BPER_{s,a,f}$ to the SPFI strata:

$$SBPER_{s,a,fs} = \frac{R_{s,a,fs} * BPER_{s,a,f}}{\sum_{f=1}^{n} R_{s,a,fs}} \qquad \text{(A)}$$

where $SBPER_{s,a,fs}$ is the stratified base period ER by *s*, *a*, and *fs*. $SBPER_{s,a,fs}$ is then scaled to an annual scaled ER by multiplying $SBPER_{s,a,fs}$ by $SPFI_{t,fs}$:

$$SER_{s,a,fs,t} = SBPER_{s,a,fs} * SPFI_{t,fs} \qquad \text{(B)}$$

where $SER_{s,a,fs,t}$ is the scaled annual ERs by *s*, *a*, *fs*, and *t*. Lastly, the FP is computed by dividing the $SER_{s,a,fs,t}$, summed across *fs*, by $BPER_{s,a,f}$:

$$FP_{s,a,f} = \frac{\sum_{fs=1}^{fs=n} SER_{s,a,fs,t}}{BPER_{s,a,f}} \qquad \text{(C)}$$

where $FP_{s,a,f}$ is the fishery policy scalar by *s*, *a*, and *f*. Equations A, B, & C can be simplified to:

$$FP_{s,a,f,t} = \frac{\sum_{fs=1}^{fs=n}\left(\frac{R_{s,a,fs} * BPER_{s,a,f}}{\sum_{f=1}^{n} R_{s,a,fs}} * SPFI_{t,fs}\right)}{BPER_{s,a,f}} \qquad \text{(D)}$$

Note that if a fishery only has a single SPFI strata, the SPFI strata is the <u>same</u> as the Model Fishery strata, or in other words, *fs* = *f*, and equation D can be rewritten as:

$$FP_{s,a,f,t} = \frac{\frac{R_{s,a,f} * BPER_{s,a,f}}{R_{s,a,f}} * SPFI_{t,f}}{BPER_{s,a,f}} = \frac{BPER_{s,a,f} * SPFI_{t,f}}{BPER_{s,a,f}} = SPFI_{t,f} \qquad \text{(E)},$$

which is as intended. Although applying the SPFI to FP procedure to a fishery with a single SPFI strata may seem odd, the SPFI formulation may be preferred because it allows for separation of the distributional aspects of the stocks and ages to arrive at an estimate of the HR in the fishery, whereas the SA or ROM HRI estimators are based on indices of ERs instead of HRs (CTC 2009).

More information about the SPFI to FP procedure can be found in CTC 2009.

3.3 Ratio of Means

The ROM estimator is used to derive the FP estimators for both the NBC and WCVI troll fisheries. The ROM is calculated as the sum of current year ERs divided by the sum of the corresponding base period average ERs for those stocks and ages intercepted in each troll fishery.

By definition, the ROM estimator requires *some* data in the base period, a limitation that the SPFI does *not* have. In the calculation of the ROM, certain inputs are required. First, and most importantly, which stocks and ages should be included in the computation of the index must be specified. The CTC set the criteria for a stock-age's inclusion into the index as a minimum of 35 estimated CWT recoveries in that fishery over the time series. Furthermore, a given stock-age must have a minimum of 17.5 estimated CWT recoveries in a given fishery, in a given year, to be included in the calculation of the HR and HRI for that year. However, there are often circumstances where using these inclusion criteria alone is either insufficient or inappropriate, in which case, specific stock-ages may be selected manually at the discretion of the responsible management agency. There are also situations where there are very few estimated recoveries in smaller fisheries that have similar fisheries nearby. In these cases (e.g., Johnstone Strait Net), it is possible to combine recoveries from nearby fisheries to meet the inclusion criteria.

3.4 Ratio of Means Versus Stratified Proportional Fishery Index

In 2009, the CTC concluded that SPFI should be used for the NBC and WCVI AABM troll fisheries (CTC 2009). The SPFI was considered for use in both these AABM fisheries; however, during review in 2018, the CTC concluded that ROM indices should continue to be used for these two fisheries. For the NBC fishery, this was because this fishery is not stratified by time or area in the ERA; if there is only one stratum, the SPFI to FP equation reduces to just the SPFI, resulting in a constant scalar across all stocks and years. This was seen as a major limitation as trends in stock-specific impacts should be modelled. For the WCVI fishery, though it is stratified by period (fall/winter, spring, summer), over the time series, many strata have no catch or CWT recoveries in some years. Since there must be data in each stratum to compute a SPFI, use of an imputation method would be needed, but given that there were many strata without data, it was deemed that such methods would be too unstable.

3.5 Other Modeling Considerations

3.5.1 Catch and Incidental Mortality in Northern British Columbia and West Coast Vancouver Island Aggregate Abundance-Based Management Sport Fisheries

This section describes the approach to generate base period CWT estimates for the stock-specific MDL files to enable the model to generate catch and incidental mortality (IM) in the NBC and WCVI AABM sport fisheries. The procedure to generate MDL adjustments to CWT recoveries for NBC and WCVI sport fisheries from NBC and WCVI troll fisheries involved six steps:

Step 1: Calculate the 1979–1982 average catch in NBC troll from the 2017Ph2.CEI file.

Northern BC Troll	
Year	Catch
1979	147,576
1980	157,198
1981	153,065
1982	173,472
Average: 157,828	

Step 2: Calculate the 1979–1982 average catch in WCVI troll from the .CEI file.

WCVI Troll (comm troll and First Nations)	
Year	Catch
1979	477,222
1980	486,303
1981	423,266
1982	538,510
Average: 481,325	

Step 3: Calculate the 1979–1982 average catch in NBC sport from the .CEI file.

North BC AABM Sport (Areas 1, 2E & 2W)	
Year	Catch
1979	100*
1980	200
1981	184
1982	215
Average: 175 (rounded to 200)	

*The actual estimate of 0 was replaced by 100 in 1979.

Step 4: Calculate the 1979–1982 average catch in WCVI sport from the .CEI file.

WCVI Sport (AABM)

Year	Catch
1979	4,100
1980	6,100
1981	8,800
1982	10,000
Average: 7,250	

Step 5: Calculate NBC troll to AABM sport adjustment as 200/157,828=0.001267.

Step 6: Calculate WCVI troll to AABM sport adjustment as 7250/481,325=0.01506.

4 Notable Chinook Model Changes

4.1 Model Settings

4.1.1 OP7 File

OP7 files are command files. There are three of them, two for calibration stages (A and B) and one for projection (P). Two settings were changed in the OP7 file:

- The input in the “A” and “B” OP7 file specifying the number of recent environmental variables (EVs) to average for projection years was changed from 1 to 12. The rationale for this change is described in Section 4.4.
- Line 72 of the "P" OP7 was changed. This setting specifies whether to use FPs from the stage 1 or stage 2 calibration. In the stage 1 calibration, RTs (ratios) are not estimated for the projection years and are set to 1. A recent year FP x RT average for each fishery, stock and age from the stage 1 calibration is used as the FP for each projection year during the stage 2 calibration. Line 72 of the P OP7 file was changed from 1 to 2 (i.e., use stage 2 FPs, the stage 1 FP x RT recent year averages, for the projection run FP file) so that the model would project more realistic catches in the projection phase of the calibration. The choice of this setting does not affect model AIs because cohort sizes are set before fishing occurs in the model. As a result, the AIs in a projection year will not change regardless of what FP is specified.

4.1.2 FCS File

Settings for several stocks in the FCS file were changed. See Appendix I in CTC 2021c for a description of the FCS file and further details regarding specific changes to this file. Broadly the changes included:

- Environmental variables (EVs) are estimated separately for the WCVI Hatchery (WVH) and Natural (WVN) stocks rather than their data being combined to estimate a common EV.
- EVs are estimated separately for the Puget Sound Fingerling (PSF) and Yearling (PSY) stocks rather than their data being combined to estimate a common EV.

- Lyon's Ferry (LYF) return data is now calibrated to terminal run instead of escapement for consistency with other Columbia River stocks.
- North/Central British Columbia (NTH) was split into two stocks, NBC and Central British Columbia (CBC), and these two stocks are now calibrated to escapement.
- Fraser Early (FRE) was divided into four stocks, two representing spring runs (FS2, FS3), and two representing summer runs (FSO, FSS). FS2, FS3, and FSS are still calibrated to terminal run with total age whereas FSO is now calibrated to escapement with mixed age composition.
- Fraser Late (FRL) was divided into two stocks (FHF and FCF), both calibrated to age-specific data.
- Upper Georgia Strait (GSQ) was split into two stocks (UGS and PPS), both calibrated to escapement with total ages.
- Georgia Strait Lower Natural (GST) was renamed to LGS and is now calibrated to terminal run.
- Georgia Strait Lower Hatchery (GSH) had small adjustments to stock composition and was renamed to Middle Strait of Georgia (MGS) with modelled escapement now calibrated to spawning escapement rather than terminal run.
- The Alaska Springs group (AKS) was split into two stock groups (SSA and NSA) which include some hatchery production not previously represented.
- The new stocks Yakutat (YAK), Alsek (ALS), Taku and Stikine (TST), and Mid-Oregon Coast (MOC) were added to the PSC Chinook Model.

4.2 Terminal Fishery Policy Adjustments (i.e., the Larrie Method)

Fishery policy scalars are used in the PSC Chinook Model to account for changes in fishery patterns relative to those existing during the base period. When the PSC Chinook Model calibrates to a stock's observed time series of terminal runs, it is possible to determine a terminal FP that will result in model-estimated terminal catch equal to an observed catch. This requires running two separate calibrations of the PSC Chinook Model. The method relies on the premise that the model-estimated terminal run will not change between the first and second calibration. This assumption is reasonable when the PSC Chinook Model calibrates to terminal run. What happens sequentially in the model after terminal run (i.e., terminal harvest and inter-dam loss) will not affect subsequent pre-terminal and terminal cohort sizes. If terminal FPs were not the same in two separate calibrations and all else were equal, then the estimated escapement would be different. However, since the model is calibrating to terminal run, the EVs (which are scaling production from a stock recruitment function) in these two calibrations will be different, but the estimated terminal run will be the same.

The procedure to determine a terminal FP that will result in model estimated terminal catch equal to an observed catch is described below. For simplicity, stock, age, fishery and year subscripts (as defined in section 3.2.2) are omitted from the equations. The aim is to find the terminal FP to use in the second calibration, 2, FP_2, such that:

$$(1) \quad C_{Obs} = FP_2 \times BPER \times N_{Est}$$

where C_{Obs} is the observed terminal catch, $BPER$ is the base period terminal ER, and N_{Est} is the model estimated terminal run. To solve for FP_2, one calibration needs to be run first. The first calibration, 1, can use any starting terminal FP, FP_1. From this calibration the model estimated terminal catch, $C_{1,Est}$, is

$$(2) \quad C_{1,Est} = FP_1 \times BPER \times N_{Est}$$

Then, under the assumption that model estimated terminal run, N_{Est}, did not change from the first to second calibration, FP_2 can be found by substituting the $BPER \times N_{Est}$ term in equation 2, into equation 1:

$$(3) \quad \begin{aligned} C_{Obs} &= FP_2 \times \frac{C_{1,Est}}{FP_1} \\ FP_2 &= FP_1 \times \frac{C_{Obs}}{C_{1,Est}} \end{aligned}$$

With the new PSC Chinook Model, two calibrations are now run to determine terminal FPs that will result in model estimated terminal catch equal to an observed catch. This procedure is performed for all Columbia River stocks in the Columbia River net and sport fisheries. The procedure is also performed for Fraser Spring 1.2 and 1.3 and Fraser Summer 1.3 in the Fraser net and Fraser freshwater sport fisheries.

4.3 CTC Backwards Cohort Run Reconstruction Virtual Population Analysis (VPA) and Stock Aggregate Cohort Evaluation (SACE)

When the PST was first implemented, the CTC adopted a standard method of backwards cohort run reconstruction Virtual Population Analysis (VPA) to calculate spring cohort (age-specific at-sea abundance before the beginning of preterminal fisheries) for Chinook populations. The method yields relatively conservative cohort estimates. It has been the same primary architecture/methodology in the ERA and the PSC Chinook Model, and, with the 2019 phase II Chinook Model Calibration, it has also been applied in the Stock Aggregate Cohort Evaluation (SACE). The ERA for CWT Exploitation Rate Indicator Stocks (ERIS), which are assumed to represent Model Stock Aggregates (SA) in marine fisheries impacts ("the Gorilla Assumption"), is performed with a VB executable (Coshak) to calculate cohorts; cohorts are in turn used to derive maturation rates. For SAs with age-specific terminal return estimates, SACE, an R program, calculates cohorts and their maturation rates by applying ERA pre-terminal (PT) fishery total mortality rates (landed catch + IM). In calibration of the phase II Chinook Model, also currently a VB program, SACE maturation rates are used for all age--specific terminal return SAs, whereas ERA maturation rates (either for each year or just from the base period years) are used for the non-age-specific terminal return SAs.

4.3.1 Virtual Population Analysis in Exploitation Rate Analysis, Chinook Model, and Stock Aggregate Cohort Evaluation

Backwards run reconstruction progresses from the oldest to youngest age, with fish first entering the reconstruction in the cohort of their age of terminal return (terminal fishery mortality plus escapement) or PT fishery mortality, and then remaining and being expanded in abundance through the younger cohorts. The run reconstruction cohort steps are detailed here for fall Chinook, which are first aggregated at age 5 plus older ages (age 5+); spring Chinook are first aggregated at age 6+, for which the steps are the same. Fish that survived to older age cohorts are expanded in the cohorts for each younger age according to those ages' assumed natural mortality (winter survival in CTC run reconstruction) and the PT fishery total mortality rates that are observed for ERIS CWT stocks: age 5+ is expanded in age 4, ages 5+ and age 4 are expanded in age 3, ages 3, 4, and 5+ are expanded in age 2. In CTC run reconstruction of the spring cohort of the next younger age is calculated as:

$$cohort\ age\ i-1\ = \frac{cohort\ age\ i\ /\ winter\ survival\ (age\ i \rightarrow age\ i+1) +\ age\ i\ terminal\ return}{1-(age\ i\ CWT\ PT\ mortality/age\ i\ CWT\ Pop)}$$

where the assumed winter survival schedule for age i → age i+1 is: 0.7, 0.8, 0.9, and 0.9 for ages 2-6 (falls) or ages 3–7 (springs).

Spring cohort calculations for fall Chinook are:

1) Age 5+ Cohort (age 5 and older): age 5+ terminal return/(1-age 5+ PT fishery total mortality rate), alternatively expressed in the ERA as terminal return plus PT fishery total mortalities. These are fish that survived age 4 pre-terminal fishing that did not mature at age 4, and then survived through winter to age 5+ (0.9 survival).

2) Age 4 Cohort: (age 5+ cohort/0.9 + age 4 term return)/(1-age 4 PT fishery total mortality rate). Age 4 cohort includes the age 5 cohort "holdovers at sea" from age 4 that had experienced the age 4 → age 5+ winter survival (0.9); they, along with the age 4 terminal return, also experienced the age 4 PT fishery total mortality rate: the calculation brings all these fish together back to their age 4 spring abundance before PT fishing begins. Note that all these fish were "holdovers at sea" from age 3.

3) Age 3 Cohort: (age 4 cohort/0.8 + age 3 term return)/(1-age 3 PT fishery total mortality rate). Age 3 cohort includes the age 4 cohort "holdovers at sea" from age 3 that had survived to age 4, some of which had gone on to age 5+, all of which together experienced the age 3 → age 4 winter survival (0.8); they, along with the age 3 terminal return, also experienced the age 3 PT fishery total mortality rate: the calculation brings all these fish together back to their age 3 spring abundance before PT fishing begins, and all of these fish were "holdovers at sea" from age 2.

4) Age 2 Cohort: (age 3 cohort/0.7 + age 2 term return)/(1-age 2 PT fishery total mortality rate). Age 2 cohort includes the age 3 cohort "holdovers at sea" from age 2 that had gone on to age 3, many to age 4, and some to age 5+, all of which together experienced the age 2 → age 3 winter survival (0.7); they, along with the age 2 terminal return, also experienced the age 2 PT fishery total mortality rate: the calculation brings all these fish

together back to their age 2 spring abundance before PT fishing begins, all of which had survived winter at 0.6 transitioning from age 1 → age 2.

4.3.2 Stock Aggregate Cohort Evaluation

For age-specific terminal return SAs, cohorts are calculated by SACE using SA terminal return and ERIS PT fishery total mortality rates from the ERA "HRJ" file data, while age-specific cohort maturation rate estimates are derived from the cohorts; the current practical application of SACE is in the use of these maturation rates in fitting the phase II PSC Chinook Model. Maturation rates and terminal return estimates/forecasts are the two most influential inputs in calibration of the PSC Chinook Model. Maturation rates inform the model in estimating the numbers of fish, by age, returning to terminal areas each year, and thus the fish remaining at sea used in calculating AABM AIs. A cohort maturation rate is terminal run divided by the cohort remaining after PT fishing mortalities (terminal run/(cohort – PT fishery mortalities). If there are no CWT PT fishery recoveries for an age in the HRJ file (almost always this involves age 5+), average PT fishery mortality rates from other brood years (BY) are substituted in two BY groups, before and since AABM management (pre-1999 or 1999–present).

Table 3 provides an example (BY 2003; from the 2019 ERA) of the values and calculations used to estimate SA cohorts and maturation rates for Mid-Columbia Bright (MCB) fall Chinook for which Upriver Brights (URB) are the ERIS. The top section in the table shows ERA values for URB, plus the calculation of URB maturation rates using these values. The following sections in the table show SACE values and calculations, the latter being identical to that derived from the ERA, but additionally solving for the SA cohorts assuming that URB PT fishery mortality rates represent the MCB SA. Values that are used to calculate subsequent values are represented by letter symbols (*a* through *af*) in the simple equations shown in the subsequent line labelled "(…-*calcs*)"; below which they are more fully specified. Equations apply to all ages (for age 5+ there is no previous (older age in backwards run reconstruction) cohort, so 0 is inserted for the previous cohort value).

Table 3. Example of values and calculations to estimate stock aggregate cohorts and maturation rates for Mid-Columbia Bright (MCB) fall Chinook for which Upriver Brights (URB) are the exploitation rate indicator stock (ERIS).

Note: Those values that are used to calculate other values are given letter designations (a-af).

	Age 2	Age 3	Age 4	Age 5+6
CWT indicator (URB), BY2003 (ERA)				
Pre-terminal fishing total mortalities	27 (a)	27 (b)	100 (c)	17 (d)
Cohort (at-sea, spring)	860 (e)	569 (f)	316 (g)	49 (h)
Terminal run (terminal fishing + escapement)	22 (i)	145 (j)	162 (k)	33 (l)
Maturation rates-values	0.0264	0.2678	0.7497	1.0216 (1.0)
(Maturation rates-calcs)	= i/(e - a)	= j/(f - b)	= k/(g - c)	= l/(h - d)
Maturation rate = Terminal Run/(Cohort – Pre-terminal fishing total mortalities)				
MCB stock aggregate, BY = 2003 (SACE)				
Terminal run (agency)	1,906 (m)	15,833 (n)	23,565 (o)	14,524 (p)
Pre-terminal fishing total mortality rate- values	0.0314 (q)	0.0475 (r)	0.3164 (s)	0.3448 (t)
(Pre-terminal fishing total mortality rate- calcs)	= a/e	= b/f	= c/g	= d/h
Pre-terminal fishing total mortality rate = pre-terminal fishing total mortalities/cohort				
1 – pre-terminal fishing total mortality rate	0.9686 (u)	0.9525 (v)	0.6836 (w)	0.6552 (x)
Cohort (at-sea, spring)-values	162,937 (y)	109,139 (z)	70,499 (aa)	22,168 (ab)
(Cohort (at-sea, spring)-calcs)	= (z/0.7 + m)/u	= (aa/0.8 + n)/v	= (ab/0.9 + o)/w	= (0/0.9 + p)/x
Cohort = (prev. age cohort/winter survival + terminal run)/(1 – pre-terminal fishing total mortality rate)				
Pre-terminal fishing total mortalities-values	5,117 (ac)	5,183 (ad)	22,303 (ae)	7,644 (af)
(Pre-terminal fishing total mortalities-calcs)	= q * y	= r * z	= s * aa	= t * ab
Pre-terminal fishing total mortalities = pre-terminal fishing total mortality rate * cohort				
Maturation rates-values	0.0121	0.1523	0.4889	1.0000
(Maturation rates-calcs)	= m/(y - ac)	= n/(z - ad)	= o/(aa - ae)	= p/(ab - af)
Maturation rate = terminal run/(cohort – pre-terminal fishing total mortalities)				

In summary, SACE calculations use brood year SA age-specific terminal return, assume a natural winter survival schedule between age classes, and use ERA HRJ-file CWT recoveries/total mortalities in terminal return and PT fisheries to calculate SA age-specific cohorts and maturation rates. This is detailed in the following SA equations:

$$age\ i\ Pop = \frac{(age\ i+1\ Pop/survival\ age\ i \rightarrow age\ i+1) +\ age\ i\ terminal\ return}{1-(age\ i\ CWT\ PT\ morts/age\ i\ CWT\ Pop)}$$

$$age\ i\ PT\ morts\ rate = age\ i\ CWT\ PT\ morts\ rate = \frac{age\ i\ CWT\ PT\ morts}{age\ i\ CWT\ Pop}$$

$$age\ i\ PT\ morts = age\ i\ PT\ morts\ rate * age\ i\ Pop$$

$$age\ i\ maturation\ rate = \frac{age\ i\ terminal\ return}{age\ i\ Pop - age\ i\ PT\ morts}$$

where *Pop* = cohort, *survival* = winter survival between ages, and *PT morts* = total mortalities in PT fisheries.

The SA maturation rates derived using SACE typically indicated lower maturation at younger ages and higher maturation at older ages than estimated for the ERIS stocks. Results shown in the plot below for the Fraser Summer Ocean-type (FSO) SA and the Lower Shuswap (SHU) ERIS are typical of comparisons between stock group (SACE) and ERA (ERIS CWT) maturation rates (Figure 1). The points are BY average maturation rates, and the solid line is 1:1. If the maturation rates were the same the points would be evenly distributed around the 1:1 line. Instead, all but one point is below the line, indicating the ERIS has a younger maturation pattern than the SA. This suggests a significant benefit when the SACE maturation rates represent the SA in the new phase II model in place of the ERIS CWT maturation rates.

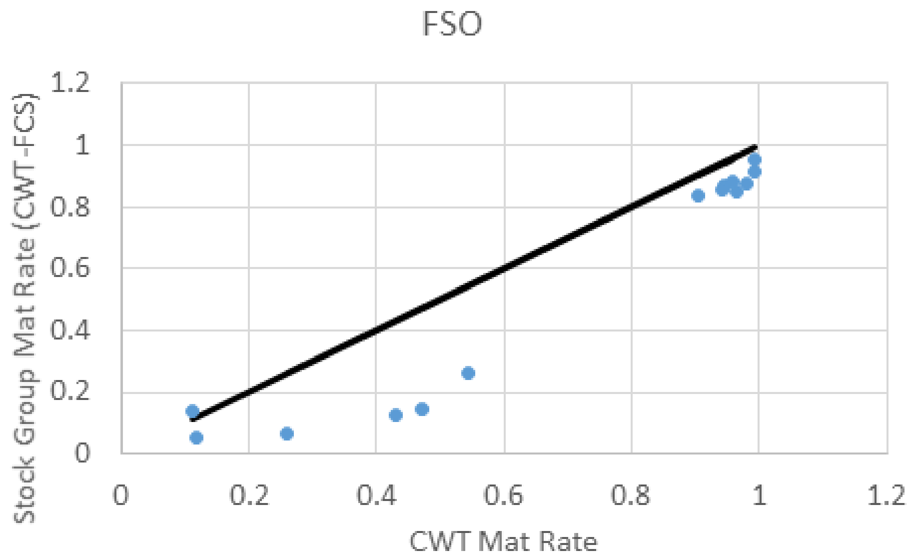


Figure 1. Scatterplot of the paired maturation rates for the Fraser Summer Ocean-type (FSO) stock group and the coded-wire tag (CWT) exploitation rate indicator stock Lower Shuswap (SHU), with a 1:1 reference line.

Multiple issues resulting from sparse CWT data were identified during the SACE and review of individual SA maturation rates, which were addressed using different approaches, depending on the issue. Sparse CWT data for ERIS stocks occurs when CWT cohort sizes are small, such as when few CWTs were released, when survival was poor, or when CWT sampling rates are too low to recover sufficient CWTs. This situation can lead to unusual cohort-age-specific ERs, which were identified for each SA using age-specific plots of maturation rates by BY (example for FSO shown in Figure 1). The escapement CWT and FCS data and age-specific maturation rates were examined for each SA cohort to identify sparse data issues and the underlying mechanisms causing them. Several approaches were then applied to address cases of sparse data depending on the mechanism. When escapement CWT data were sparse for a specific cohort-age, then a ratio-of-means estimator, based on escapement data for the same cohort for the ERIS and SA, was used to estimate the expansion factor for the specific cohort-age with the sparse data. When maturation rates were affected by sparse fisheries recoveries, CWT data, or small cohorts, the SA maturation rate for a cohort-age was estimated from the relationship between ERIS and SA maturation rates using linear regression (Figure 2). In some cases of deficient data, the SA maturation rates were averages from other BYs with sufficient data.

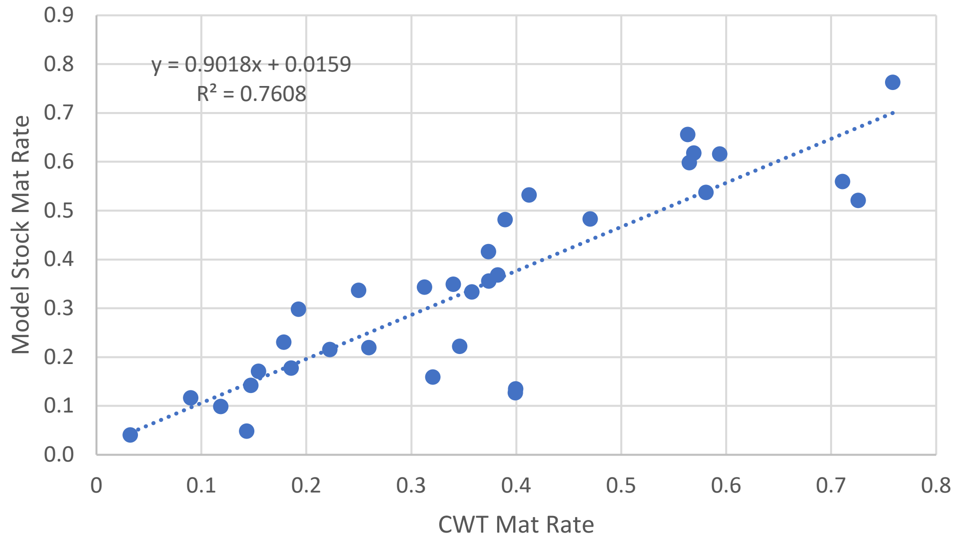


Figure 2. Scatterplot of the paired maturation rates for the Fraser Chilliwack Fall (FCF) stock group and the coded-wire tag (CWT) exploitation rate indicator stock Chilliwack (CHI), with the regression line and equation that were used to estimate the model stock maturation from the CWT maturation rate when there were sparse data issues (e.g., brood year 1987, age 3). The FCF is a hatchery stock with essentially no natural production, thus the stock aggregate and exploitation rate indicator stock maturation rates are very similar, on average.

The data quality-checking procedures were iterative for each successive BPC to validate any adjustments made to address data issues. For each SA, the age-specific maturation rates for each cohort were illustrated for the recent iteration relative to the previous one to identify any anomalies that needed further investigation (Figure 3). The review enabled rapid comparisons among cohorts for each SA, and it also facilitated comparisons among SAs and improved understanding of the maturation rate patterns among SAs with different life histories.

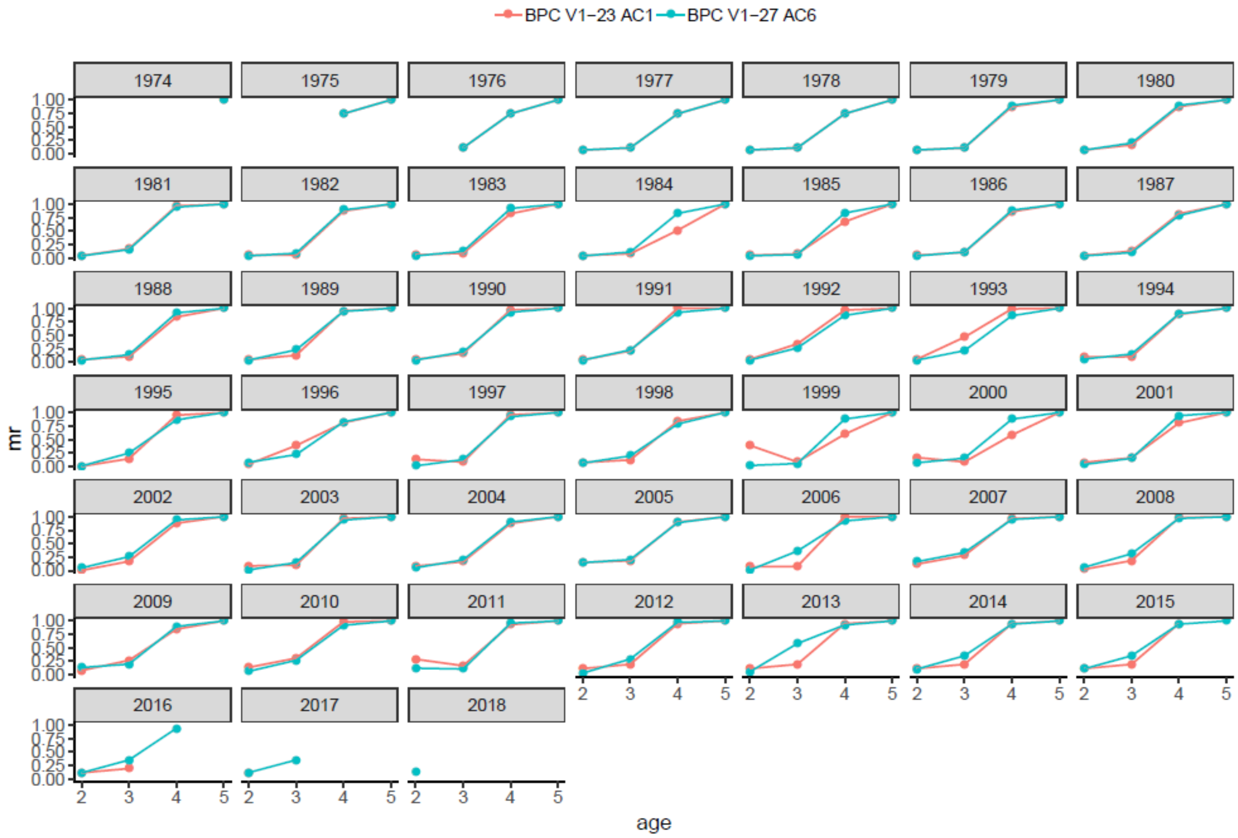


Figure 3. One of the diagnostic figures used to examine stock aggregate (SA) maturation rates for unusual patterns, such as the higher age-2 than age-3 maturation for brood year 1999 that was evident in an earlier version of the base period calibration for the Fraser Harrison Fall (FHF) SA.

Comparisons of the SACE and ERIS CWT maturation rates revealed interesting observations for some model stocks. For the North Oregon Coast (NOC) SA, the SACE and ERIS maturation rates were similar for age 2, as indicated by the even distribution around the 1:1 reference line; however, for age 3 and age 4, the maturation rates were generally higher for the ERIS than the SA, which suggests the ERIS has a relatively younger maturation schedule than the SA (Figure 4). For the URB SA, the SACE maturation rate was higher than the ERIS at age 2, but it was lower than the ERIS at ages 3 and 4. This pattern suggests the URB SA has a higher relative component of jacks than the ERIS, but a lower relative component of the cohort maturing at ages 3 and 4.

For lower Fraser River fall Chinook, comparisons of the SACE and ERIS CWT maturation rates for the hatchery SA (Fraser Chilliwack fall [FCF]) and the natural SA yielded two important insights. First, it showed that both methods yielded similar results, with no signs of any systematic biases arising from either method, when applied to an SA that was virtually all hatchery fish. Second, it showed that there can be maturation rate differences among components of SAs that appear to be related to differences in the breeding and environmental conditions in the hatchery and natural spawning areas. The FCF is virtually all hatchery origin fish that are produced at the Chilliwack hatchery, and there is very little natural production from fish spawning in the Chilliwack River. For FCF, the SACE and ERIS CWT maturation rates corresponded very well, since they were evenly distributed around the 1:1 reference lines for all ages, indicating no inherent relative biases in either method (Figure 5). The variation around the reference line represents the combination of process and measurement errors. For Fraser Harrison fall (FHF), the vast majority (>90%) of the abundance is natural production from fish spawning in the Harrison River, and the Harrison (HAR) ERIS has relied on natural-origin brood stock collected from the Harrison River and reared at the hatchery on the Chehalis River, a tributary to the Harrison River. In comparison to FCF, the SACE and CWT maturation rates for FHF are not centered around the 1:1 reference line for each age, which identifies different maturation rate patterns between the ERIS and the natural stock components for this SA.

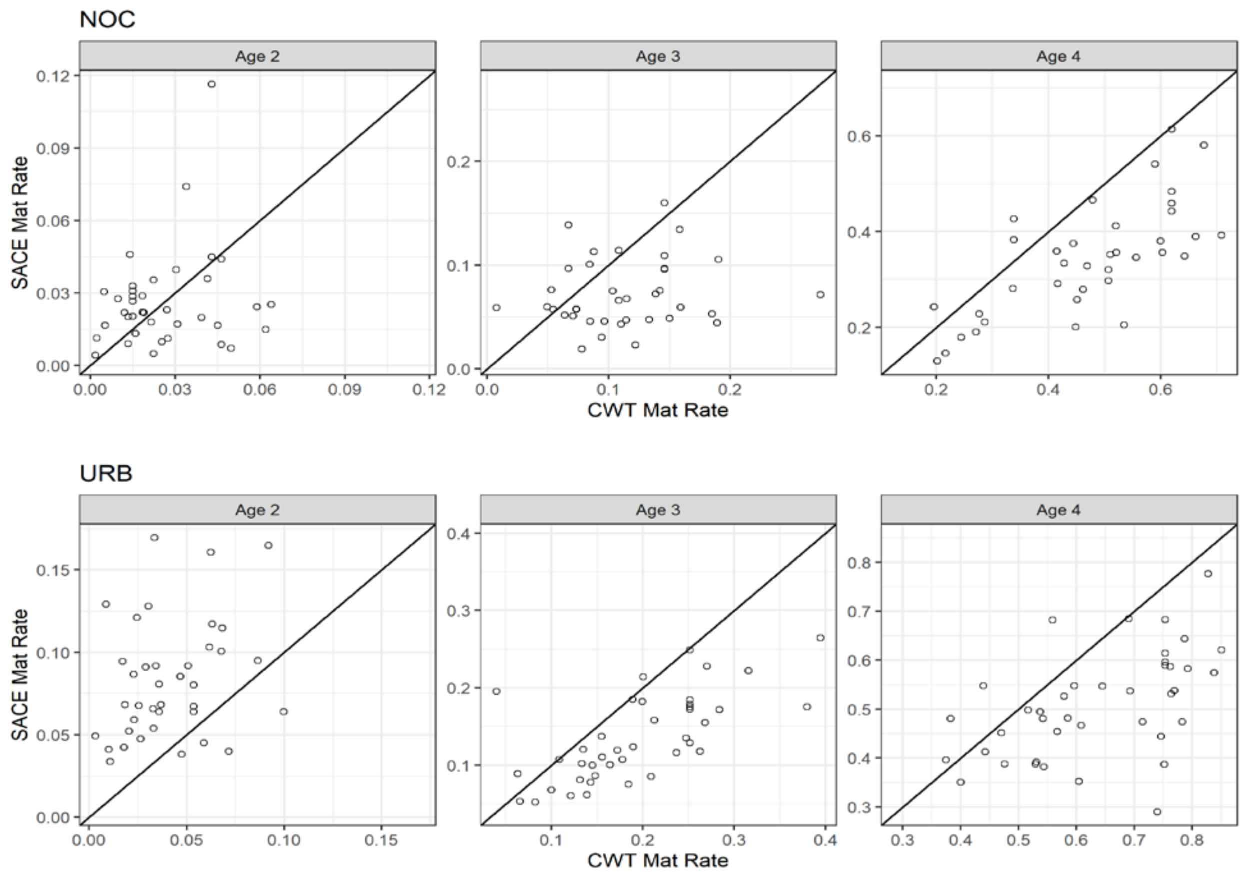


Figure 4. Scatter plots of the Stock Aggregate Cohort Evaluation (SACE) and exploitation rate indicator stock (ERIS) coded-wire tag (CWT) maturation rates by age for the North Oregon Coast (NOC; top) and Columbia Upriver Brights (URB; bottom) stock aggregates.

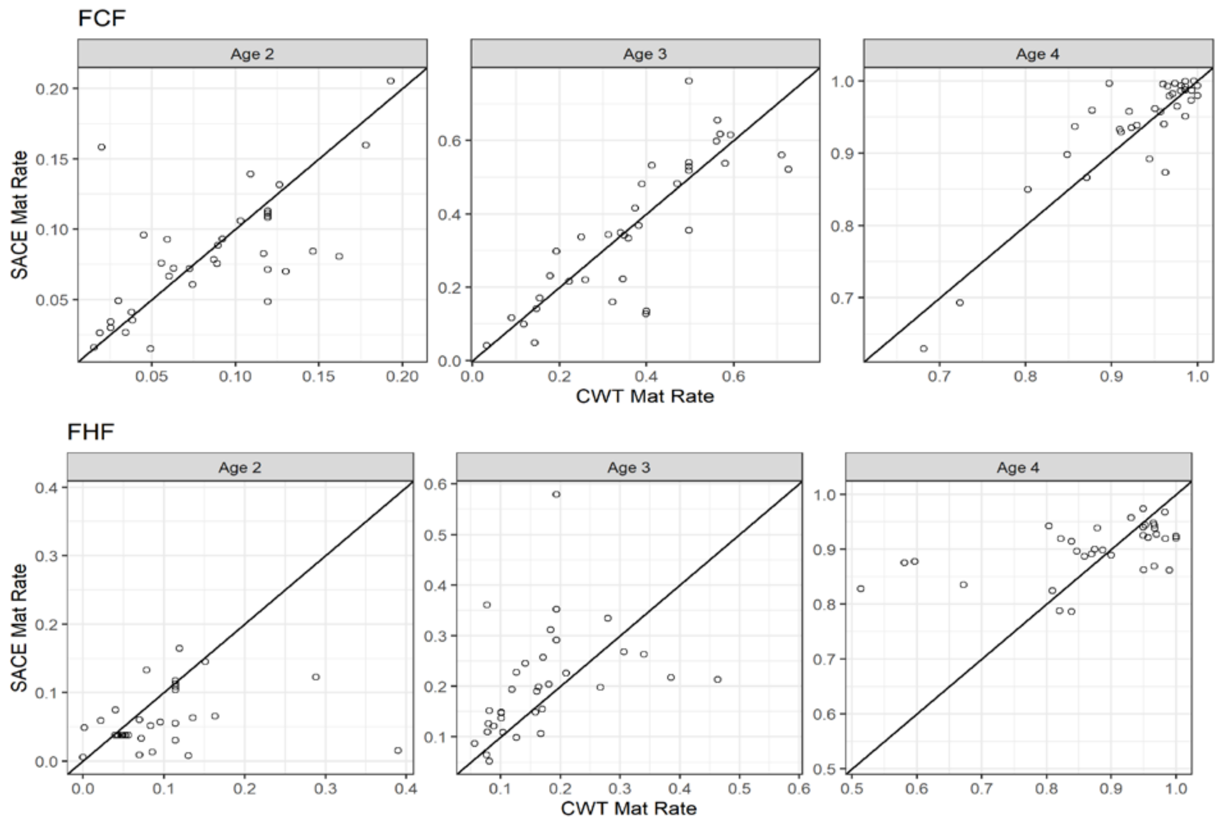


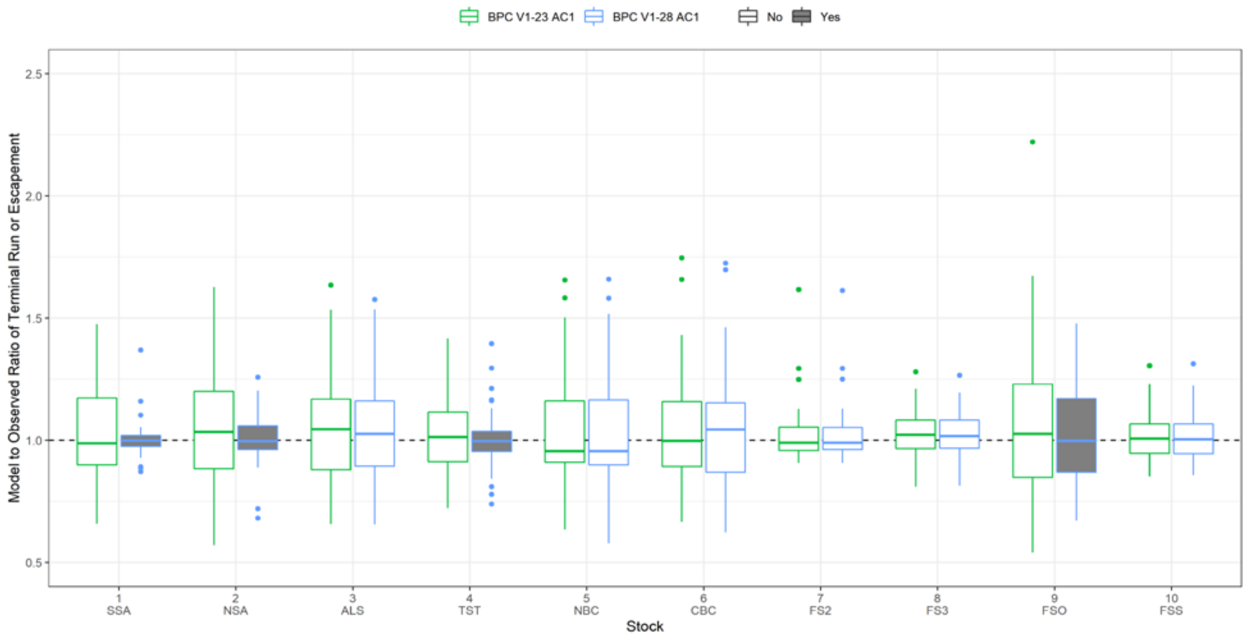
Figure 5. Scatter plots of the Stock Aggregate Cohort Evaluation (SACE) and exploitation rate indicator stock (ERIS) coded-wire tag (CWT) maturation rates for the complimentary hatchery and natural Chinook Technical Committee (CTC) model stocks for Fraser (FCF and FHF) and West Coast of Vancouver Island (WVH and WVN) fall Chinook. For FHF age 2, average values were used; observations for FHF are situations where the Chinook Model was used to estimate some of the SACE and CWT maturation rates.

During the base period calibration process, several calibration iterations marked major stages in model improvement. One of the regularly monitored model performance attributes was the ratio of the model's estimate of terminal run or escapement to the observed estimate for each model stock. In a single year, a ratio of 1 identifies 100% accuracy in the model forecast, whereas a ratio greater than 1 identifies an overestimation error by the model, and likewise an underestimation error was evident when the ratio was less than 1. These ratios were calculated for each SA and run year, and the general pattern was illustrated in boxplots, which were compared both among and within SAs for different model calibration iterations (Figure 6 and Figure 7). This approach enabled the CTC to quickly track the performance of improvements, improve knowledge about the influence of specific model improvements, and to identify any unusual circumstances for further attention.

A major stage in the base period calibration process was iteration BPCV1-23 AC1 when the refinements had been made to better represent stocks and fisheries and to include revised data. This calibration (identified by the green boxplots in Figure 6 and Figure 7) served as a baseline to compare other calibrations against and was also compared to the current version of the model (CLB 1905), identified by the red boxplots. Substantial improvements in model performance were noted for some stocks, as indicated by narrow green boxplots compared to red boxplots (e.g., BON, CWF, WCN), whereas for others, reduced overestimation errors (e.g., NKF, STL, SNO, BON), modest changes (e.g., WCN, CWS, SUM, URB, SPR), or occasionally increased errors (e.g., LRW, LYF, MCB) were noted. Descriptions of the influence of specific model improvements on the model's performance for specific stocks are outlined in CTC 2021b.

Overall, the SACE method substantially increased the model performance for the stocks that it was applied to (Figure 6 and Figure 7). The blue boxplots identify the final calibration iteration (BPC V1-28 AC1) during the phase II development process. The SACE method was applied to specific model stocks in this calibration (identified by grey shading). Some stocks had substantial reductions in the amount of error, indicated by the width of the boxes and whiskers (e.g., SSA, NSA, TST, FHF, FCF, WVN, WCH, WSH, URB, CWF, LRW, MCB, NOC, MOC), and some had reduced bias, indicated by the boxes and median being centered around a value of 1 relative to the green boxplot (e.g., NSA, TST, FSO, FHF, WVH, SKG, WCH, CWF, LRW). The stocks with the least improvement (i.e., FSO and LGS) had numerous cohorts where the SACE method could not be applied. This occurred when there was no or insufficient ERIS CWT data to represent a cohort (e.g., low sampling rates in escapement) or when there was no FCS data by age for a cohort, which happens when there is no, or inadequate scale age data collected. For the non-SACE method stocks, model performance was relatively unchanged (e.g., ALS, NBC, FS2, FS3, FSS, NKF, PSF, NKS, STL, SNO), in some cases increasing marginally (e.g., UGS, LYF), and others, decreasing marginally (e.g., CBC, PSN, PSY, WCN).

In summary, the SACE method resulted in substantial improvements in the model's performance as measured by the ratio of the modeled to observed terminal run or escapement. This innovation applied existing FCS and ERIS CWT data in a manner that enabled the model to better represent the production and abundance of terminal run or escapements. There are opportunities to further improve the model's performance for many other model stocks by adding or improving the stock assessment programs that are necessary to provide FCS data by age as well as ERIS CWT data.



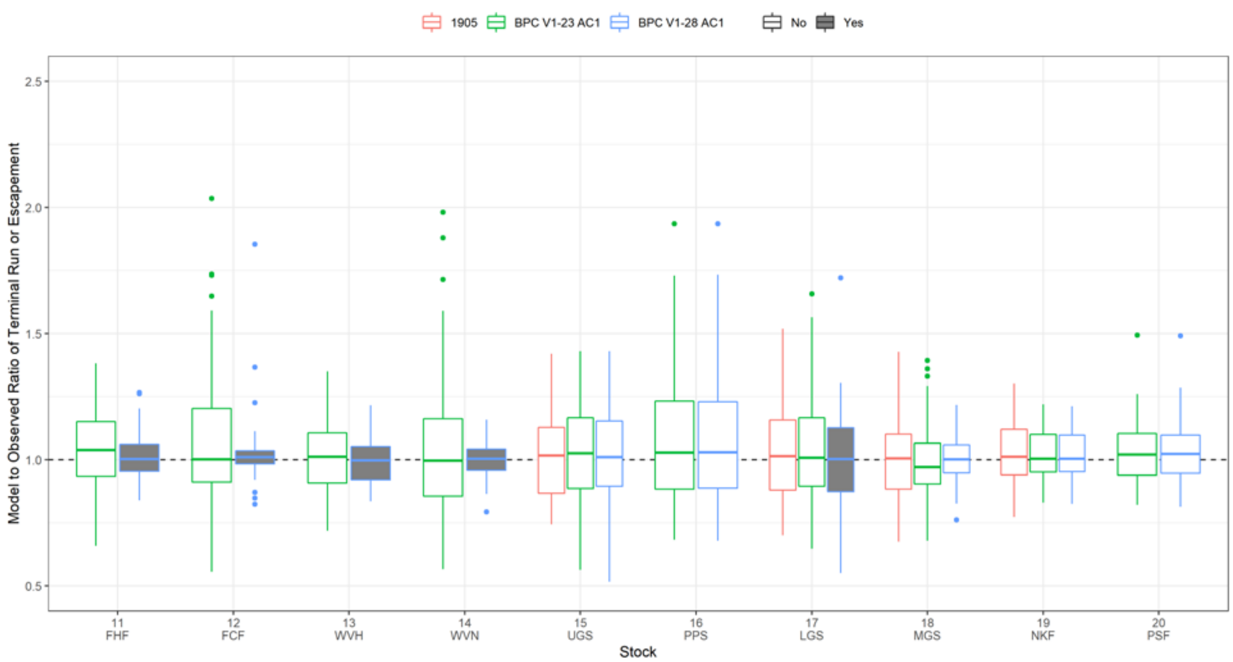
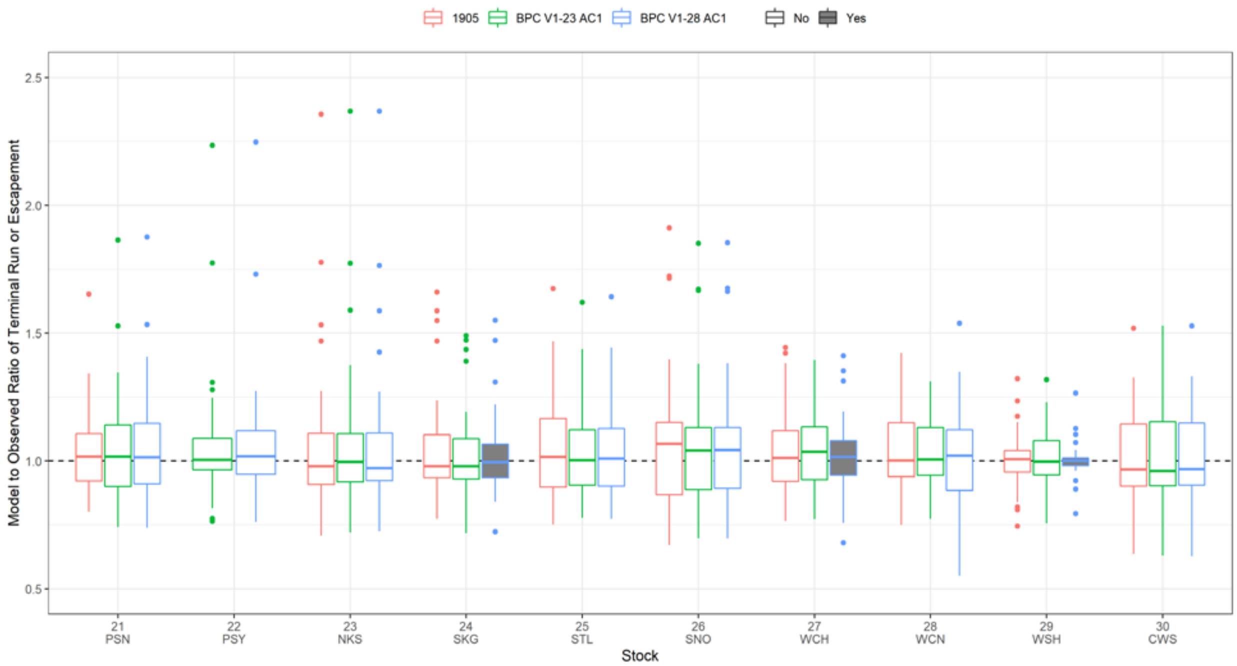


Figure 6. Boxplots of the modeled to observed ratios of terminal runs or escapement for model stocks 1 through 20. For the boxplots, the whiskers represent the 2.5th and 97.5th percentiles, the box represents the upper and lower quartiles, and the solid line represents the 50th percentile. The red boxplots correspond to the current version of the model from calibration 1905, the green boxplots correspond to the iteration of the base period calibration where new stocks, fisheries, and data revisions were incorporated, and the blue boxplots represent the final iteration of the model calibration where the Stock Aggregate Cohort Evaluation (SACE) were applied to model stocks (identified by grey shading of the blue box).



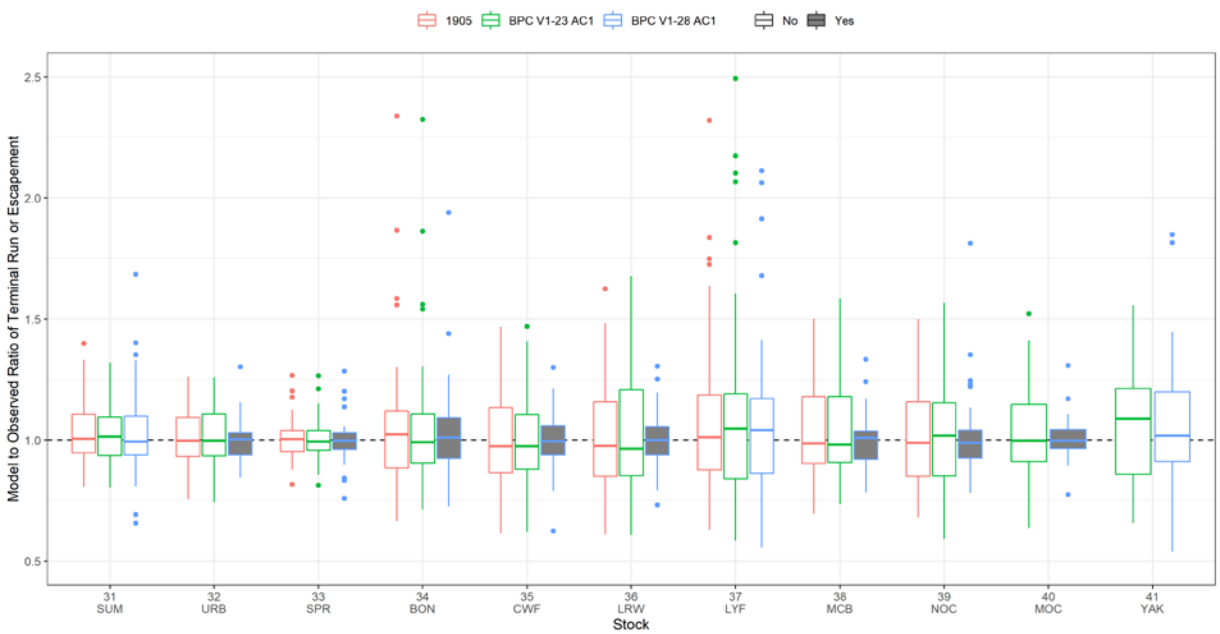


Figure 7. Boxplots of the modeled to observed ratios of terminal runs or escapement for model stocks 21 through 41. For the boxplots, the whiskers represent the 2.5th and 97.5th percentiles, the box represents the upper and lower quartiles, and the solid line represents the 50th percentile. The red boxplots correspond to the current version of the model from calibration 1905, the green boxplots correspond to the iteration of the base period calibration where new stocks, fisheries, and data revisions were incorporated, and the blue boxplots represent the iteration of the model calibration where the Stock Aggregate Cohort Evaluation (SACE) were applied to model stocks (identified by grey shading of the blue box).

4.4 Maturation Rate and Environmental Variable Factor Averages in Projection Run

The CTC memorandums to the Commission dated February 14, 2019 (Appendix D) and June 7, 2019 (Appendix E) recommended transitioning to the new phase II version of the Chinook Model following additional investigations:

- Determining an approach to choose stock-specific maturation rate (MAT) and EV assumptions that are critical to the forecasting performance of the annual calibration.
- Improving the terminal fishery exploitation rates for the north and mid-Oregon coast stocks to improve the Model's fit to observed terminal run estimates.
- Incorporation of adjustments to year- and age-specific maturation rates for stocks included in the Model's 'MATAEQ' input file using the necessary age-specific terminal run or escapement data.
- Review and update of procedures used to calculate the annual fishery policy (exploitation rate) scalars for those fisheries that use a 'ratio of means' estimator.

The results of these investigations lead to various improvements to aspects of the PSC Chinook Model's overall performance. Estimates of maturation rates change as more information becomes available and as cohorts age over time. Maturation rates are projected for incomplete broods that will be impacted in the coming season and for each incomplete age group. EVs for incomplete broods that will be impacted by the coming season must also be projected. MAT and EV values are combined to produce projected partial cohort sizes. The partial cohort sizes are the pre-fishery vulnerable abundances which provide the basis for computing the AIs when summed across all stocks and ages in a calendar year for each AABM troll fishery.

4.4.1 Methods

As the final step in development of the new phase II version of the PSC Chinook Model, the CTC AWG undertook a thorough investigation to determine the approach used in setting the MAT and EV assumptions required for the phase II model's forecasting procedure. As was done in two previous investigations, various MAT and EV combinations (henceforth MAT-EV scenarios) were identified as likely candidates to produce accurate forecasting of pre-season AIs. Retrospective model runs were then used to assess performance in minimizing pre-season AI errors (based on first post-season AIs) for this new version of the PSC Chinook Model.

In total, 29 MAT-EV scenarios were included in the analysis (Table 4), representing combinations of nine methods for forecasting maturation rates, including time series methods such as various types of Auto-Regressive Integrated Moving Average (ARIMA) and Exponential Smoothing (ETS) models (see Box 1 for additional details on ARIMA and ETS) and naïve models such as three-, six-, and nine-year averages, and 11 EV assumptions ranging from three-year to 15-year averages. One-year and two-year EV averages were not included in this exercise because previous investigations demonstrated that age-specific terminal run or escapement forecast data provided to the PSC Chinook Model (in the FCS file) is not entirely used under those EV assumptions.

Table 4. Description of maturation rate and environmental variable (MAT-EV) scenarios included in the investigation and their ordinal ranks as derived from error statistics computed from the 2014–2018 time series of AI errors. Fishery-specific ranking was based on the median ranking across six error metrics: (mean raw error, mean absolute error, mean percent error, mean absolute percent error, root mean squared error, mean squared error) whereas composite ranking is the sum of the median ranks across the three fisheries. The MAT-EV scenario with the lowest composite score (i.e., best) is highlighted.

				Fishery-specific Median Rank			
SCENARIO	**FORECAST ID**	**FORECAST METHOD**	**EV ASSUMPTION**	**SEAK**	**NBC**	**WCVI**	**Composite Rank**
1	A	ARIMA_BC_biasadj	3YA	20.5	23.5	24.0	68.0
2	B	ARIMA_BC	3YA	28.0	27.5	25.5	81.0
3	C	ARIMA	3YA	19.0	23.5	23.0	65.5
4	D	ETS_BC_biasadj	3YA	24.0	21.0	15.0	60.0
5	E	ETS_BC	3YA	24.0	21.0	15.0	60.0
6	F	ETS	3YA	10.0	13.0	10.5	33.5
7	G	3YA	3YA	20.0	14.0	17.5	51.5
8	H	6YA	3YA	13.0	14.0	17.0	44.0
9	I	9YA	3YA	21.5	23.0	26.0	70.5
10	A	ARIMA_BC_biasadj	6YA	16.0	18.0	20.0	54.0
11	B	ARIMA_BC	6YA	26.5	23.5	22.5	72.5
12	C	ARIMA	6YA	16.5	17.5	19.0	53.0
13	D	ETS_BC_biasadj	6YA	12.0	12.0	9.5	33.5
14	E	ETS_BC	6YA	21.0	17.0	12.5	50.5
15	F	ETS	6YA	7.0	7.5	7.5	22.0
16	G	3YA	6YA	15.5	8.5	14.0	38.0
17	H	6YA	6YA	11.0	9.0	11.0	31.0
18	I	9YA	6YA	17.5	17.5	22.0	57.0
19	G	3YA	1Y	28.0	28.0	27.0	83.0
20	H	6YA	1Y	15.0	24.5	27.0	66.5
21	I	9YA	1Y	27.0	29.0	29.0	85.0
22	F	ETS	4YA	9.0	12.0	14.0	35.0
23	F	ETS	5YA	8.0	10.0	8.5	26.5
24	F	ETS	7YA	6.0	6.5	5.5	18.0
25	F	ETS	8YA	5.5	5.0	5.5	16.0
26	F	ETS	9YA	4.0	4.0	3.0	11.0
27	F	ETS	10YA	3.0	3.0	2.0	8.0
28	F	ETS	12YA	1.0	1.0	1.0	3.0
29	F	ETS	15YA	2.0	2.0	4.0	8.0

Time series models included variants with implementation of Box-Cox transformations (ARIMA_BC and ETS_BC) and bias adjustments after Box-Cox back-transformation (ARIMA_BC_biasadj and ETS_BC_biasadj). The scenarios were based on calibration years 2009–2019 and required running the V1.27 (AC5) version of the phase II PSC Chinook Model a total of 891 times. Six statistical metrics of error (mean raw error, mean absolute error, mean percent error, mean absolute percent error, mean squared error, and root mean squared error) were used to assess pre-season-to-post-season errors in the AIs as well as in the stock-specific partial cohort (PCOH).

Two ranking approaches were used to evaluate the MAT-EV scenario performance: a customary ordinal ranking and a relative ranking in which the actual statistical error from each scenario was divided by the statistical error of the scenario with the lowest error (i.e., the highest-ranked scenario). For each AABM fishery, the median of the individual ranks for each of the six error statistics was used to evaluate each scenario by the two ranking approaches. Lastly, for both ordinal and relative ranking approaches, a composite ranking was computed as the sum of the median ranks.

The performance of all scenarios was explored separately for two time series of pre-season-to-post-season errors: (1) 2014–2018, a recent time period with high variability in ocean conditions and abundance; and (2) 2009–2018, a longer time period that encompasses the previous PST agreement. Since the analyses based on both time series produced similar statistical results, the following sections focus primarily on the 2014–2018 time series, which is also most relevant in terms of large and alternating errors in pre-season AIs.

4.4.2 Results and Conclusions

The first round of analyses from Scenarios 1–21 showed that the basic time series ETS method outperformed all other MAT forecasting methods and subsequent analyses focused on combinations of ETS with additional EV assumptions attempting to minimize errors. The latter analyses systematically increased the number of recent years (3 to 15) in the EV average looking for minimization of errors. Minimization of AI and PCOH mean raw errors was achieved with the inclusion of 12 recent years in the EV average (Figure 8 and Figure 9).

The results of this investigation, based on the composite ranks across the three AABM fisheries for the 2014–2018 time series of AI errors, are shown in Table 4. Scenario 28 (ETS maturation rate forecast and 12-year average EV assumption) was clearly identified as the scenario producing the smallest AI errors. The results based on the longer 2009–2018 time series and those derived from the analysis of PCOH also supported this conclusion. Detailed statistical summaries and MAT-EV scenario rankings are shown in Appendix F for AI data and Appendix G for PCOH data.

A comparison of pre-season-to-post-season AI raw errors (based on annual calibrations 2009–2010 to 2018–2019) between the ‘best’ MAT-EV scenario identified in this investigation (ETS & 12YA EV) and the MAT-EV scenario used for calibration purposes in the current version of the Chinook Model (9YA & 1Y EV) showed large improvements for both AIs (Figure 10) and PCOHs (Figure 11) in all three AABM fisheries, particularly in years with large errors and for NBC and WCVI. A comparison of composite rankings (based on the relative ranking approach) is also shown in Figure 12 for both AI and PCOH data, highlighting the large improvements in model performance attained by using the ETS & 12YA EV scenario. Figure 12 also depicts a declining trend in composite ranking (i.e., increasing trend in performance) from ETS scenario 22 (four-year EV average) to scenario 28 (12-year EV average), and then an increase in composite ranking (i.e., a deterioration in performance) for scenario 29, characterized by a 15-year EV average. Hence, this type of comparison also showed evidence that minimization of errors had been achieved across AABM fisheries under MAT-EV scenario 28.

The CTC therefore recommends using the ETS method to forecast maturation rates and the 12-year average of recent years to forecast EVs for abundance projections with the phase II version of the Chinook Model.

4.4.3 Final Remarks

The experience gained during this investigation and increasing evidence of a trend toward earlier maturation in stocks throughout the geographic region encompassed by the PST, has led the CTC to consider carrying out a similar investigation at regular intervals (e.g., every 5 years). The main goal of this interval review would be to attest the validity of the 'best' MAT-EV scenario in the face of additional data.

The forecasting of EVs in PSC Chinook Model runs has been historically based on naïve models exclusively. Future MAT-EV investigations could incorporate the use of time series models (as already done for maturation rates) to take advantage of their ability to incorporate automatic model selection and detect trends and patterns in EVs.

Box 1— Brief description of Exponential Smoothing (ETS) and Auto-Regressive Integrated Moving Average (ARIMA) models.

Exponential Smoothing (ETS) models are a general class of novel state-space models for forecasting a univariate time series (Gelper et al. 2010). The acronym ETS denotes the error (E), trend (T), and seasonal (S) components that can be used to describe the time series to be forecasted. The trend component represents the growth or the decline of the time series over an extended period of time. For time series defined at time intervals which are fractions of a year (e.g., months), the seasonal component is a pattern of change that repeats itself from year to year. The error component captures irregular, short-term fluctuations present in the series, which cannot be attributed to the trend and seasonal components.

ARIMA models are a general class of models for forecasting a univariate time series which can be stationarized by transformations such as differencing and logging (Chatfield 2004). The acronym ARIMA stands for "Auto-Regressive Integrated Moving Average." ARIMA models are represented using the ARIMA notation (p, d, q), where p is the number of autoregressive terms, d is the number of (non-seasonal) differences, and q is the number of lagged forecast errors in the forecasting equation.

The Box-Cox transformation can be applied to each time series prior to carrying out time series modeling. The transformation can stabilize the variance of the original time series (e.g., by removing large fluctuations in the series or by making the patterns noticed in the series more consistent across the entire span of the series). As a result, the transformation can lead to simpler forecasting models which may produce more accurate forecasts. The Box-Cox transformation encompasses a family of transformations that includes logarithmic and power transformations. Its application involves identifying an appropriate exponent (*lambda*) which indicates the power to which all of the original time series values should be raised prior to modeling. The method identifies the lambda value which minimizes the coefficient of variation for subseries of the original time series. Once the optimal value for the exponent lambda governing the Box-Cox transformation is determined, the ARIMA (or ETS) models are applied to the Box-Cox transformed data in order to produce point forecasts of abundance. These point forecasts are back-transformed via a reverse Box-Cox transformation to obtain point forecasts on the original scale. Further details about the Box-Cox transformation can be found in Hyndman and Athanasopoulos 2018.

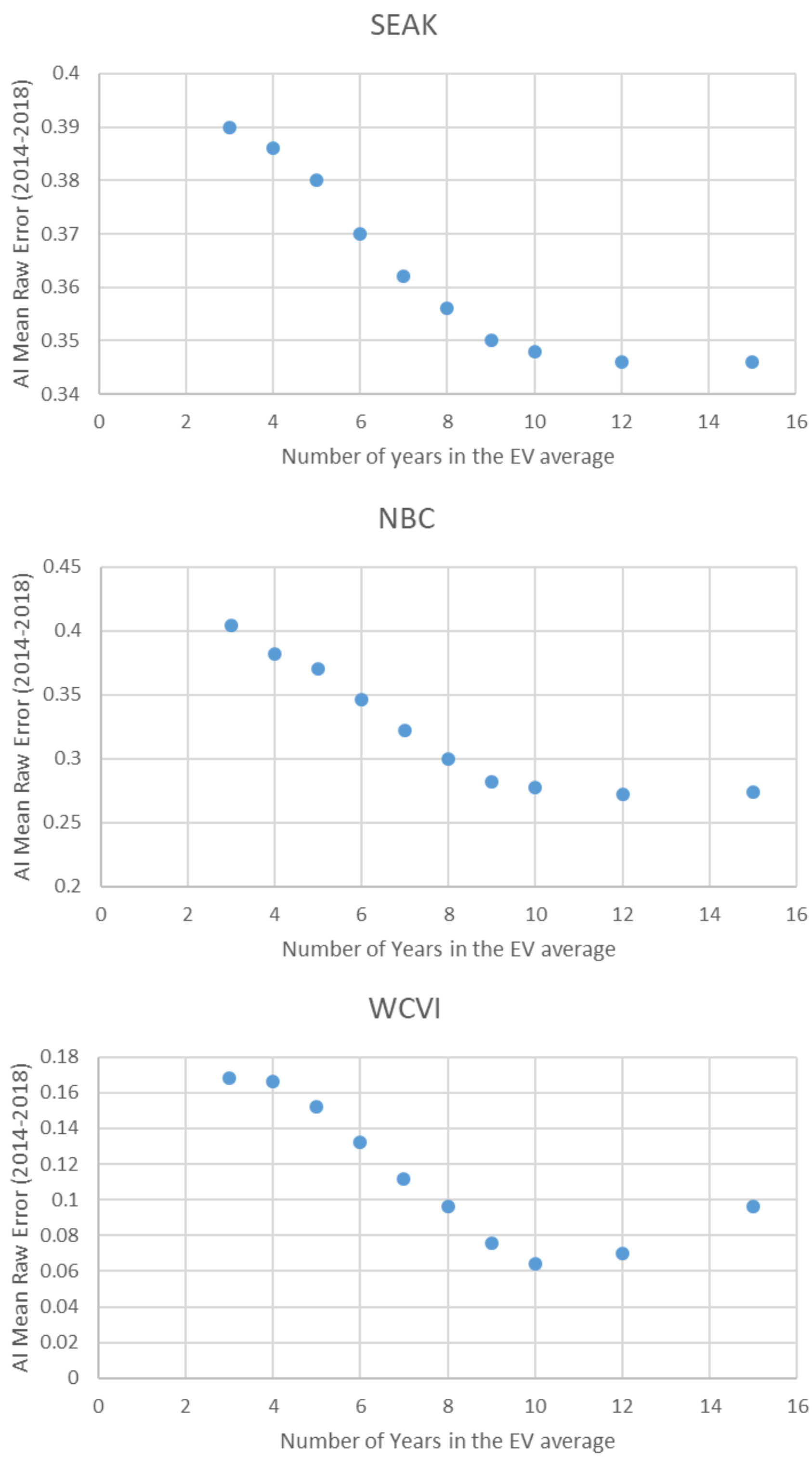


Figure 8. Relationship between the abundance index (AI) mean raw error produced by the exponential smoothing (ETS) maturation rate (MAT) forecasting method and the number of years used to calculate the environmental variable (EV) average for each aggregate abundance-based management (AABM) fishery.

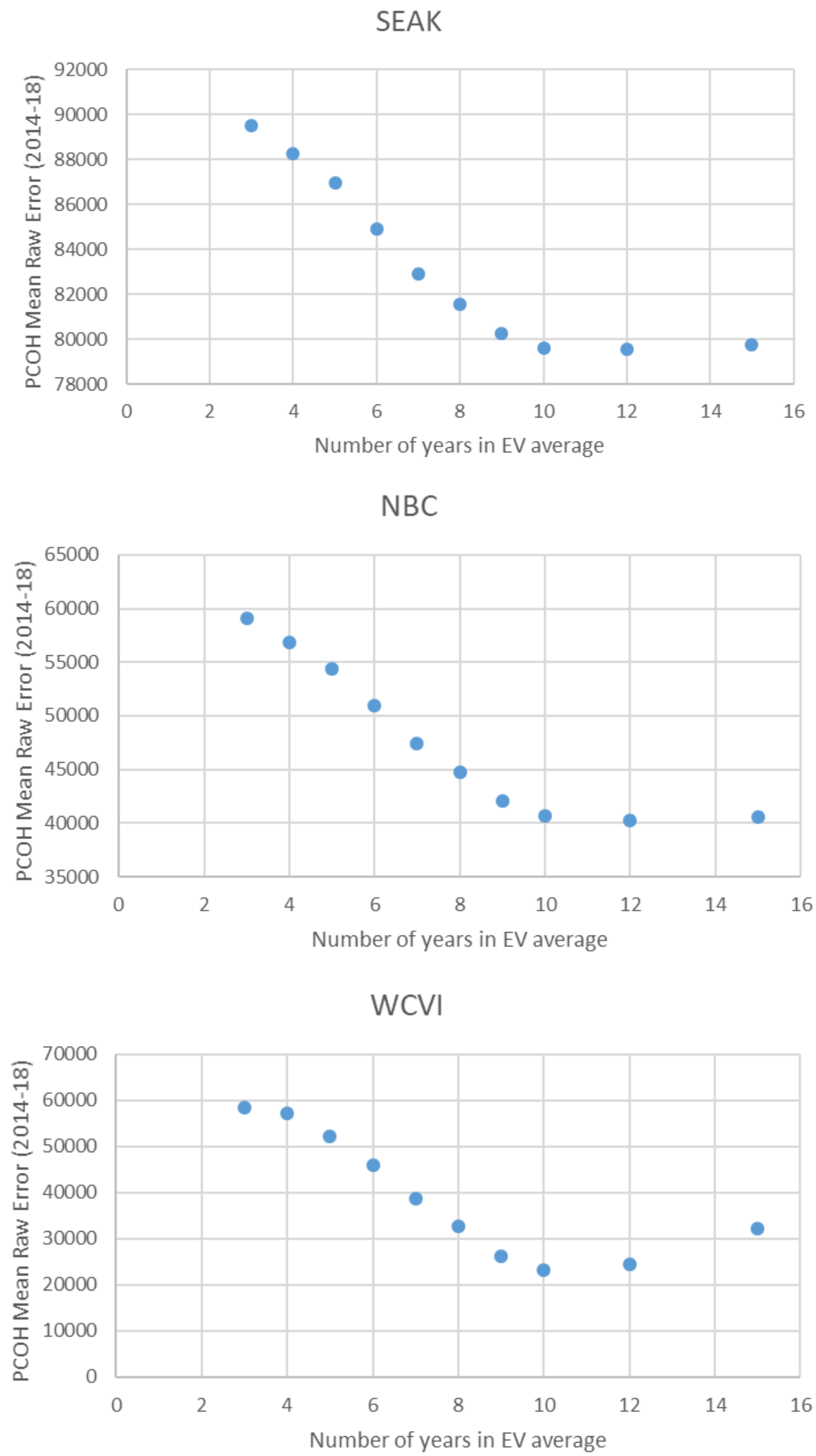


Figure 9. Relationship between the partial cohort (PCOH) mean raw error produced by the exponential smoothing (ETS) maturation rate (MAT) forecasting method and the number of years used to calculate the environmental variable (EV) average for each aggregate abundance-based management (AABM) fishery.

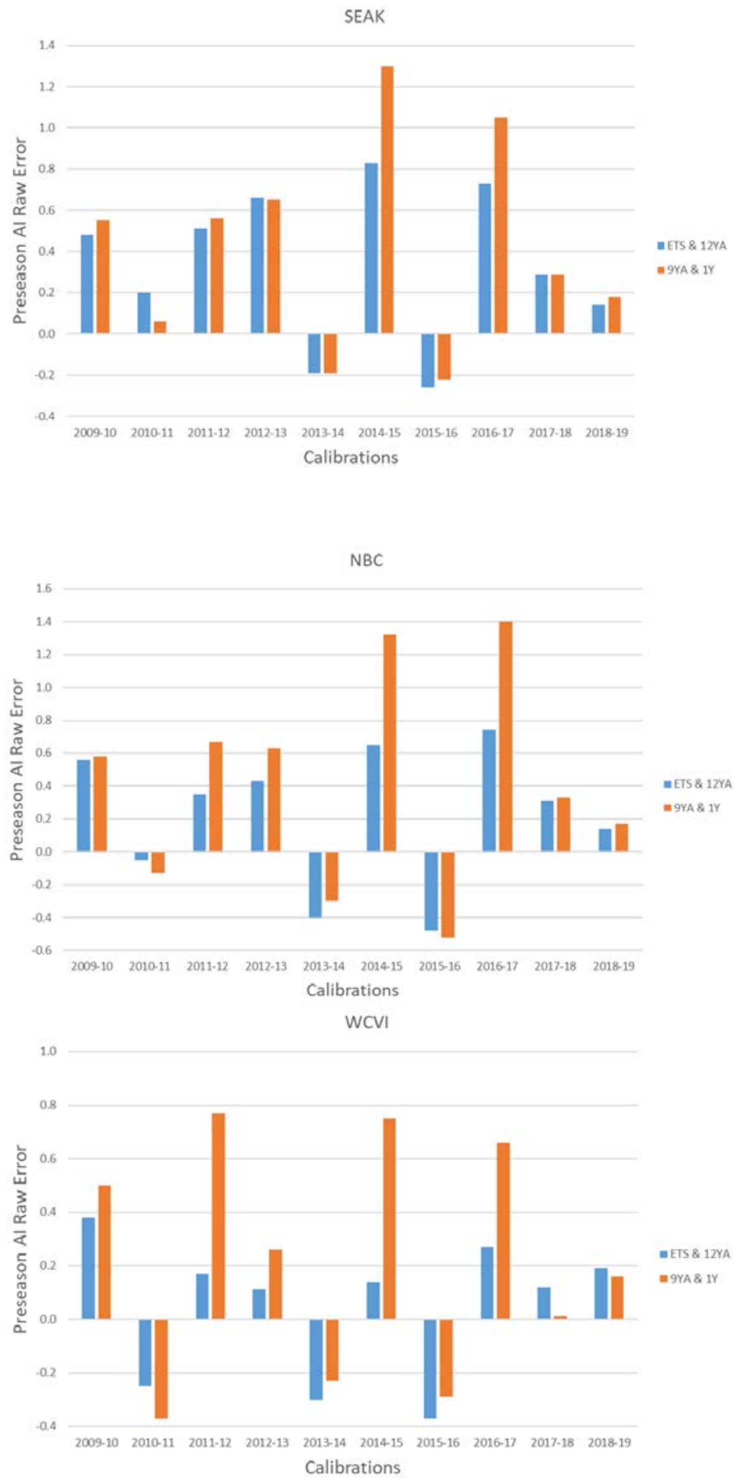


Figure 10. Comparison of pre-season-to-post-season abundance index (AI) raw errors (calibrations 2009–10 to 2018–19) between the 'best' maturation rate and environmental variable (MAT-EV) scenario identified in this investigation and the one used for the current version of the model for each aggregate abundance-based management (AABM) fishery.

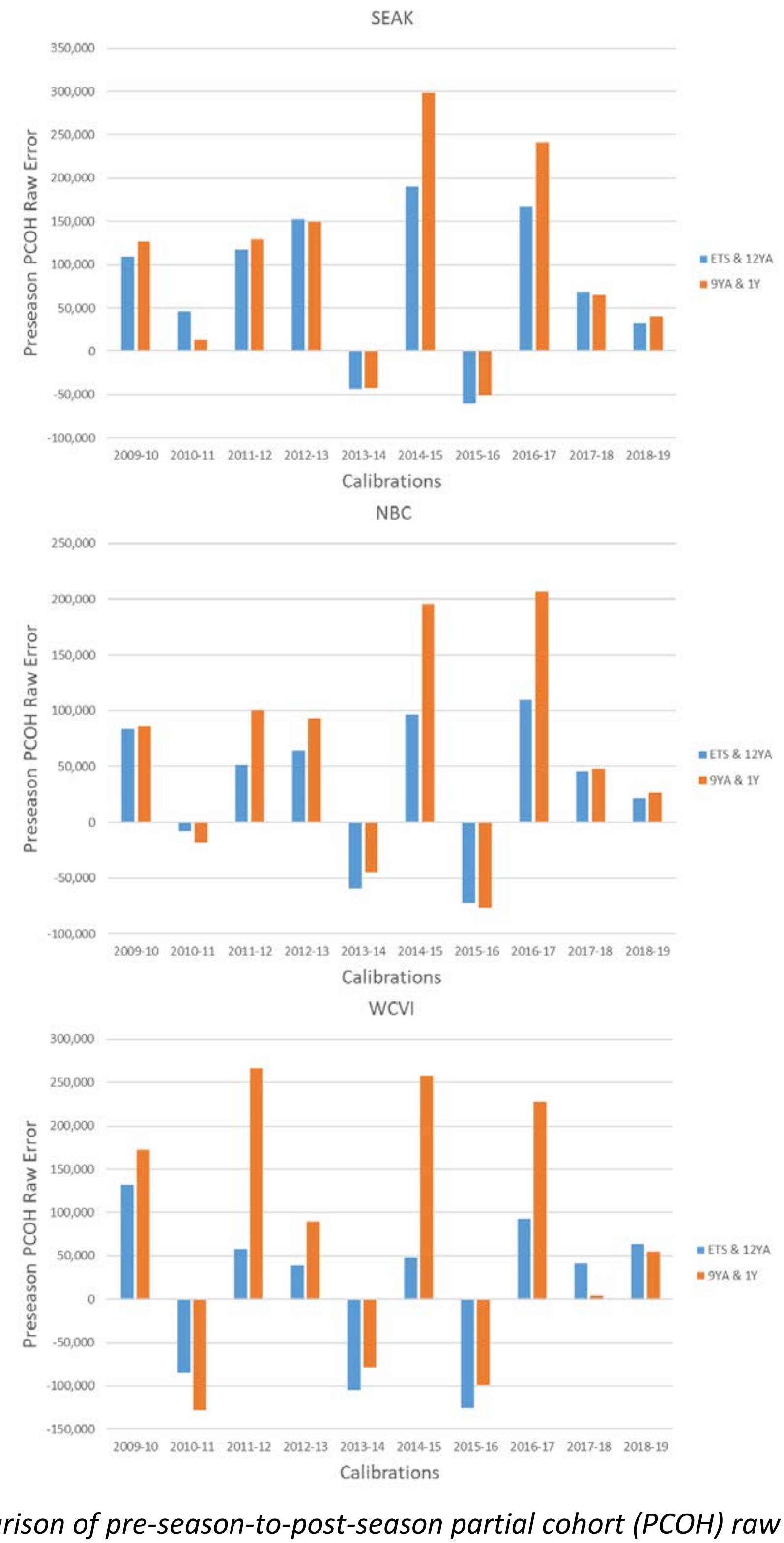
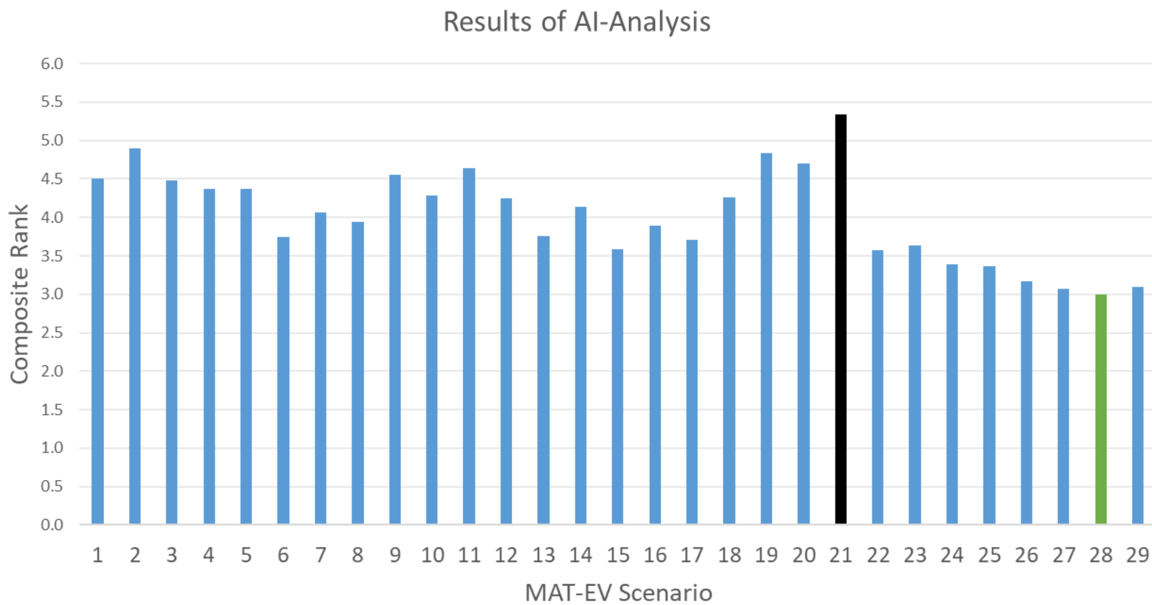


Figure 11. Comparison of pre-season-to-post-season partial cohort (PCOH) raw errors (calibrations 2009–10 to 2018–19) between the 'best' maturation rate and environmental variable (MAT-EV) scenario identified in this investigation and the one used for the current version of the model for each aggregate abundance-based management (AABM) fishery.



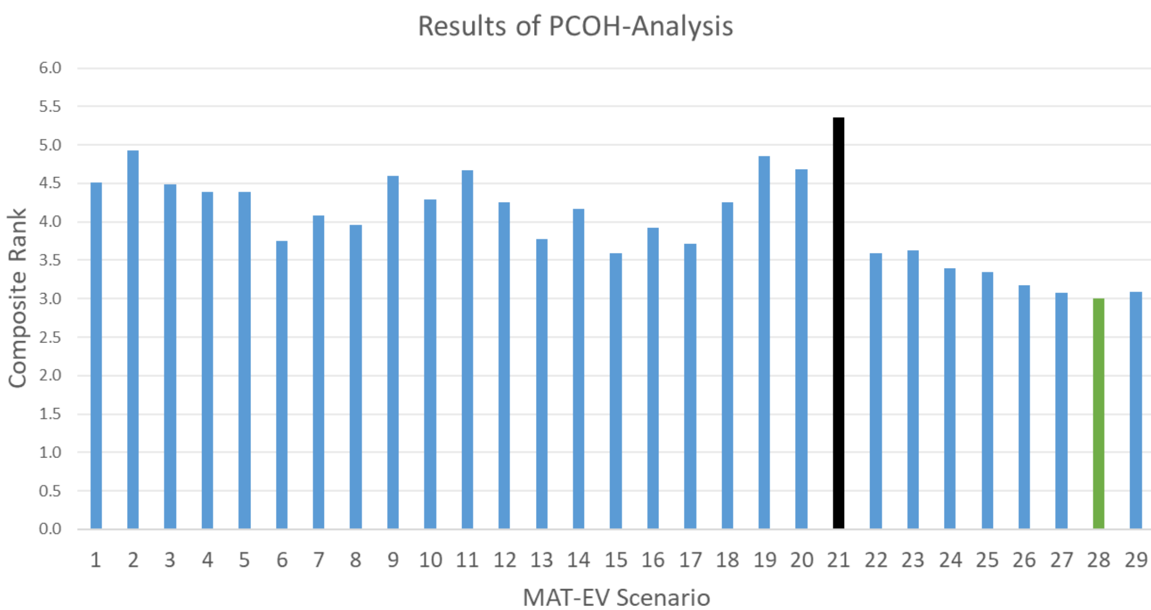


Figure 12. Composite relative ranks of maturation rate and environmental variable (MAT-EV) scenarios based on the analysis of AI (top; abundance index) and PCOH (bottom; partial cohort) data. 'Best' scenario is highlighted in green whereas worst scenario is highlighted in black. See Table 3 for MAT-EV scenario description.

5 Future Work Identified During the Base Period Calibration Process

The BPC process required an in-depth examination of the PSC Chinook Model that resulted in a better understanding and critical evaluation of the model's strengths and weaknesses. Making substantial improvements to a model's weaknesses is typically much more difficult than building upon its strengths, and it involves an evaluation of the efficacy of particular improvements. Because of this, and the extent of the work and evaluations, not all improvements to the PSC Chinook Model that were identified during the BPC process could be made during this iteration of model improvements. Some required more time than was available to the CTC and others required more investigation, development, and/or validation before they could be implemented. The goal of this section is to document the many potential model improvements identified but not implemented during the BPC process in order to serve as starting points for future model improvement work.

5.1 Phase III Work

Several model improvement activities identified during the BPC process were mentioned in Chapter 3 of the 2019 PST. Paragraph 14 states:

> *"The CTC shall complete its Phase 3 work (e.g., improved capabilities for pre-season abundance forecasts, representation of MSF [mark-selective fisheries] and other types of fisheries regulations, inclusion of release data to estimate incidental mortalities in Chinook fisheries, incorporation of stock-specific growth functions, etc.) in time to support the five-year review. The Commission shall receive the model improvements from Phase 3 and make a decision about their implementation".*

5.1.1 Representation of Mark-Selective Fisheries and Other Types of Fisheries Regulations

The phase II version of the PSC Chinook Model does not explicitly account for mark-selective fisheries (MSF) regulations, and differences in proportions of model stock cohorts that are marked with adipose fin clips. There are several challenges in the current model structure that make accounting for MSFs difficult.

Most stocks in the PSC Chinook Model are considered "aggregates" meaning they consist of different populations, which could be of hatchery-marked and unmarked origin (i.e., many hatcheries have and continue to produce unmarked Chinook salmon). Even before modeling the dynamics of a MSF, all the model stock aggregates in the PSC Chinook Model would need to be split into unmarked and marked components to adequately represent the differential mortalities for kept hatchery-marked fish and released unmarked fish that occur in MSFs.

Modeling the dynamics of MSFs is difficult in and of itself, and all the analytical methods considered have had limitations to their application. However, there are algorithms and methods for single-index and double-index tag exploitation rate indicator stock programs that could be used to estimate MSF-related mortalities. Currently, the PSC ad-hoc Calendar Year Exploitation Rate (CYER) Work Group is evaluating different algorithms to estimate MSF-related mortalities via simulation techniques, using the CTC's Data Generation Model (DGM). Based on the outcomes of this work group's evaluations, phase III work could involve incorporating one or more of these algorithms into the PSC Chinook Model.

Finally, to model the impact of MSFs, the number of Chinook kept and released by mark status needs to be identified by ERA fishery strata. If this information is unavailable, then the times and areas in which MSFs occurred need to be identified. At present, no comprehensive or up-to-date database that identifies the occurrence of MSFs exists. Such a database would need to be collated and processes for applying such data to potential MSF algorithms or other analytical methods would need to be incorporated into the phase III PSC Chinook Model. Improvements to Incidental Mortality Estimation

5.1.2 Improvements to Incidental Mortality Estimation

The PSC Chinook Model accounts for incidental mortalities due to catch and release of Chinook below the legal size-limit, in addition to non-landed mortalities due to drop-off/out. This is handled by providing fishery-specific proportion non-vulnerable (PNV) estimates and assumed IM rates that are applied to the model's estimate of kept catch. Paragraphs 4(c) and 4(d) of Chapter 3 of the 2019 PST instruct the CTC to "*provide estimates of encounters of Chinook released in fisheries that, when multiplied by assumed gear-specific mortality rates, provide estimates of incidental mortality*" and this work was completed in February 2022. Therefore, instead of modeling incidental mortalities through fishery-specific assumptions of the PNV, it should be possible to replace these model-generated estimates with empirical data, after the empirical release data can be aligned with fishing regulations, size categories, and the mark status of the releases.

In addition to including agency estimates of releases, the programming routine used to calculate IMs can be modified to be capable of using releases for different size categories, such as sublegal, legal, large, etc. The representation of size categories has become more important as different size-based regulations are used in recreational fisheries, including mixed bag MSFs. These size-based regulations are used to limit impacts on specific stocks when the stock composition varies in a fishery by age and size.

To improve the stock-specific estimates of IM, it may be helpful to include stock-specific growth functions and yearly ocean environmental conditions to represent the stock-, brood year- and age-specific PNVs. Chinook salmon stocks can have different growth functions (Morishima and Chen 2006), due to basic differences between stream- and ocean-type life histories, but also due to stock-specific variation in growth rates among stocks with similar life histories (Xu et al. 2020). There are also interannual variations in growth rates between ages for a stock that are associated with ocean environmental conditions (Xu et al. 2020).

Any such improvements made during phase III work must involve clear documentation of currently used methods, potential issues or shortcomings, identification and description of various improvements to address them, and then the modification to the ERA and/or PSC Chinook Model computer programs and validation of such changes. Lastly, these improvements will need to be outlined and described in the ERA and Model documentation.

5.2 Phase III and Beyond

In addition to those improvements described above and referenced in the 2019 PST Agreement, several others could be made during phase III development of the PSC Chinook Model. These improvements generally fall into three categories: stock stratification, model inputs, and model structure.

5.2.1 Improved Model Stock Stratification

As mentioned above, many stocks in the PSC Chinook Model are considered "aggregates" and are comprised of different populations. Model stock SUM (Upper Columbia summer Chinook) represents all summer Chinook production upstream of Priest Rapids Dam on the Columbia River. Natural origin Upper Columbia summer Chinook have an ocean-type life history, but summer Chinook hatcheries produce both subyearling and yearling fish. Due to the differential ocean entry timing of subyearling and yearling Chinook from the same brood year, this model stock should be stratified into two components to improve the representation of maturation patterns. This has never been done because run reconstructions and forecasts of this stock are structured by ocean residence time, not life-history type (i.e., returns and forecasts for 2-salt, 3-salt and 4-salt of combined subyearling and yearling types). Stratifying the model stock into subyearling and yearling components could be done if the run reconstruction and forecast process was changed or was post-hoc adjusted.

Model stock TST (Taku and Stikine) represents production from both rivers; however, management actions are often independent of one another. The stocks were combined because some of the mixed stock harvest used in the run reconstruction is estimated using genetic mixed stock analysis, which is not able to differentiate between the two stocks. Using the stock-specific run reconstructions available from the Transboundary Technical Committee would enable the CTC to stratify the TST model stock.

In this recent round of model improvements, genetic stock composition data were used to compare to the model stock composition to identify where stock representation was improved or not. This type of examination can be used to guide further areas where some stocks are under/overrepresented in the model.

5.2.2 Improved Fishery Stratification

Nearly all net fishing gears in a fishing area are grouped into single net fisheries, however the stock and age compositions can vary among the catches by these gears and the IM rate can differ substantially among gear types. For example, net fisheries can include seine, dip, drift gill, and set gill nets for which release mortality and drop-out rates can differ substantially. The CTC considered this during the recent phase II model improvement, but there were difficulties separating the catches to their appropriate net gears. Though challenging, the CTC may be able to develop some approaches to better stratify the historic data and to better represent contemporary fisheries. This may not improve the quality of historic net fishery IM, but it could improve the IM for recent and future net fisheries. For example, some historic fishery data (and associated CWT data) should be split from simply "net" into gillnet and seine catch retrospectively based on assumed harvest ratios or other types of information.

5.2.3 Improved Model Inputs

In addition to a number of improvements to model inputs mentioned in paragraph 14 of Chapter 3 of the 2019 PST Agreement (e.g., external estimates sub-legal encounters), several others should be considered.

Inter-dam loss (IDL) values are used in the PSC Chinook Model to account for loss of adult Chinook in the Columbia River between river mouth entry and escapement. These IDL estimates represent the proportion of the unharvested adult fish that died prior to spawning due to difficulties in passing dams, thermal stress, etc. Currently IDL estimates are derived by dam counts and all sources of removals (e.g., harvest estimates, brood stock collection, etc.). However, all the adult fish ladders at dams on the Columbia River are equipped with PIT tag detection systems. Therefore, it is possible to utilize the extensive PIT-tagging that is already occurring in the Columbia River Basin to derive IDL estimates. For instance, a modified Cormack-Jolly-Seber (CJS) model that accounts for removals of harvested adults could be developed. This would provide an equivalent estimate of IDL and would have the additional benefit of providing estimates of uncertainty.

The PSC Chinook Model estimates an EV which can be thought of as a brood-year specific deviation from a stock-recruitment curve. EVs are not estimated for incomplete broods and must be projected. The model projects EVs for incomplete broods by averaging previous EVs in a specified time period (e.g., 12 years). A simple average does not leverage any trend in the EV time series. More sophisticated time series modeling approaches, such as ARIMA, exponential smoothing or others in ForecastR (Velez-Espino et al. 2019), might do a better job at projecting EVs. Smaller deviations between projected and actual EVs would presumably result in smaller pre- and post-season AI deviations.

5.2.4 Structural Model Improvements

Many different phase II PSC Chinook Model inputs and outputs are expressed as relative to the 1979–1982 time period (i.e., the base period). For instance, a harvest rate index is a ratio of the current year's harvest rate to the average harvest rate during the base period. The reliance on a base period has several desirable properties, but it can also be limiting, particularly when a stock lacks data (e.g., CWT recoveries) during the base period. An alternative to developing modeling procedures to account for lack of data during the base period, such as the out-of-base procedure described in this report, a more contemporary base period containing complete datasets for all model stocks could be used. This would additionally frame model inputs and outputs in relation to a more relevant time period, such as one beginning in 1999 (i.e., the start of AABM fishery management), or one spanning 2009–2015 which is the new reference period for ISBM fisheries, and also when the PSC and agencies made considerable improvements to CWT data (PSC 2015)). Alternatively, a new CTC model could be developed that does not employ a base period, rather stocks and fisheries could be evaluated based on estimations of actual abundances/catches, both pre-terminal and terminal, in each year across the time series using standardized methods each year.

The phase II PSC Chinook Model operates on a single annual time step. Furthermore, fisheries are assumed to operate on a single pool of fish in the ocean. In reality, stock and fishery dynamics vary both temporally within a year and spatially across the ocean. Therefore, stratifying the PSC Chinook Model into smaller time-steps within a year (e.g., weeks, months or seasons) and finer geographic regions could seem a natural progression in improving the model. Though such finer-scale stratification may improve model predictions and thus be desirable, there are many issues to consider carefully. For instance, increasing model complexity is limited by data availability, and so a finer spatiotemporally stratified model may not be applicable to as many model stocks. Nonetheless, future work to improve the model should investigate whether such finer stratification is possible, perhaps for fisheries with sufficient data.

The current model has a calibration step for age 3, 4, and 5 terminal run or escapement data provided by agencies. However, there are other types of forecasts that could improve the model's estimates of cohort abundances, but for which the model currently does not have the capability to calibrate to. For example, pre-fishery age-specific ocean cohort abundances, as well as post-terminal fishery maturation rates, are now estimated/forecasted for all ages (falls: 2–5+; springs 3–6+) for many model stocks using the SACE procedure, something the CTC could explore doing for all the model stocks. Additionally, it may be possible to modify the ERA and the Chinook Model to separately represent the production of age 6 (fall) or age 7 (spring) fish for stocks with substantial numbers of these age classes.

As part of the model improvement program identified in the 2009 PST Agreement, the CTC developed the DGM to simulate Chinook production and fisheries that the CTC could use to evaluate new metrics (e.g., for ISBM), abundance estimation algorithms (e.g., independent, discrete, linear catch equations) and management strategies. For example, statistical catch-at-age models have been suggested as a potential way to improve the abundance estimates used for coastwide management, but they would need to be evaluated relative to a 'true' abundance compared to the performance of the current model; a simulation framework was identified as a suitable approach, but the SACE procedure may also provide for such estimation of 'true" abundance. Another consideration is that the current model has key underlying assumptions, a primary one being that of stable fishing and stock distributions across the time series. Such assumptions could be tested among different models to identify their relative performance under varying fishing and stock distributions.

Another recommendation identified during the base period calibration activities was to explore the utility of including other relevant information in modeling (beyond catch, escapement, and CWT data). In particular, fishing effort, genetic stock composition by age, and other contemporary information about the variation in the spatial-temporal distribution of Chinook stocks, which may be influenced by varying ocean environmental conditions, should be considered.

Finally, an often-discussed shortcoming of the current ERA and Chinook Model is that both produce outputs that lack any measures of uncertainty. Exploration of model improvements that account for uncertainty in data inputs and provide measures of uncertainty for model outputs should also be considered during future model development.

6 References Cited

Amended Annex IV of the Treaty between the Government of Canada and the Government of the United States of America concerning Pacific Salmon. Entry into force 1 January 2020.

Amended Annex IV of the Treaty between the Government of Canada and the Government of the United States of America concerning Pacific Salmon. Entry into force 1 January 2010.

Amended Annex IV of the Treaty between the Government of Canada and the Government of the United States of America concerning Pacific Salmon. Entry into force 1 January 2000.

Chatfield, C. 2004. The Analysis of Time Series: An Introduction. Chapman and Hall/CRC Press, Boca Raton.

CTC (Chinook Technical Committee). 1996. 1994 Annual Report. Pacific Salmon Commission Joint Chinook Technical Committee Report TCCHINOOK (96)-1. Vancouver, BC.

Chinook Technical Committee (CTC). 2009. Special Report of Chinook Technical Committee HRI Workgroup on the Evaluation of Harvest rate indices for use in Monitoring Harvest Rate Changes in Chinook AABM Fisheries. Pacific Salmon Commission Joint Chinook Technical Committee Report TCCHINOOK (09)-2. Vancouver, BC.

CTC. 2021a. Pacific Salmon Commission Chinook Model Base Period Re-Calibration, Volume I: Fisheries. Pacific Salmon Commission Joint Chinook Technical Committee Report TCCHINOOK (21)-02 V1. Vancouver, BC.

CTC. 2021b. Pacific Salmon Commission Chinook Model Base Period Re-Calibration, Volume II: Stocks. Pacific Salmon Commission Joint Chinook Technical Committee Report TCCHINOOK (21)-02 V2. Vancouver, BC.

CTC. 2021c. 2020 PSC Chinook Model Calibration. Pacific Salmon Commission Joint Chinook Technical Committee Report TCCHINOOK (21)-04. Vancouver, BC.

Gelper, S., Fried, R., and Croux, C. Robust forecasting with exponential and Holt-Winters smoothing. Journal of Forecasting 29(3): 285-300.

Hyndman, R.J. and Athanasopoulos, G. 2018. Forecasting: principles and practice, 2nd edition, OTexts: Melbourne, Australia. OTexts.com/fpp2. Accessed on December 21, 2022.

Morishima, G.S. and Chen, D.-G. Estimation of Mean Length at Age and Fishery Harvest Rates for the CTC Model. Final Report to the PSC Chinook Technical Committee. Project NFFP5000-5-00008.

Pacific Salmon Commission (PSC) Joint CWT Implementation Team. 2015. Five-year synthesis report of the PSC Coded Wire Tag (CWT) Improvement Program. Pacific Salmon Comm. Tech. Rep. No. 33: 48 p.

Vélez-Espino, L.A., Parken, C.K., Clemons, E.R., Peterson, R., Ryding, K., Folkes, M., and Pestal, G. (2019). ForecastR: tools to automate procedures for forecasting of salmonid terminal run and escapement. Final Report submitted to the Southern Boundary Restoration and Enhancement Fund, Pacific Salmon Commission, Vancouver BC. Available online.

Xu, Y., Decker, A.S., Parken, C.K., Ritchie, L.M., Patterson, D.A., and Fu, C. 2020. Climate effects on size-at-age and growth rate of Chinook Salmon (Oncorhynchus tshawytscha) in the Fraser River, Canada. Fisheries Oceanography 29(5): 381-395.

APPENDICES

Appendix A. Coshak 4 Program Modifications

Date	Version	Programmer(s)	Details
Jul 16, 2014	Coshak4_V2.4 16Jul2014.zip		
Jul 16, 2014	Coshak4_ V2.4 16Jul2014.zip	John Carlile	From an email sent from John Carlile to the AWG on 7/16/2014: "I have posted a new version of Cohshak4 entitled "Coshak4_V2.4 16Jul2014.zip" to the PSC FTP site. This new version prints out the name of the CMB, PSL, CCF and WG4 files that you used at the top of the OUT file right below the date and time."
Jul 17, 2014	Coshak4_ V2.4 17Jul2014.zip	John Carlile and Randy Peterson	From an email sent from John Carlile to the AWG on 7/17/2014: "Randy and I fixed the Y2K problem and reposted "Coshak4_V2.4 17Jul2014.zip" to the FTP site. The program should now do the OOB correctly even if you have codes from brood years after 1999." ALSO see the document Ethan sent around.
Aug 4, 2014	Coshak4_ V2.5 8Aug2014.zip	John Carlile and Randy Peterson	From an email sent from Henry Yuen to John Carlile and Larrie LaVoy on 8/4/2014: "Hi John I had to comment out lines 985, 986, and 988 'If FIRSTPASS = True Then '<-- this is causing problem with mixed BP and OOB codes 'FishName(IZ) = "" FishName(IZ) = CMBFishName(IZ) 'End If to work around an error message that appeared for a cds file with mixed BP and OOB tag codes as for the SUM stock. I didn't get the error message if the cds file was all BP or all OOB. Fish name after combining fisheries should be the name of the 68 fisheries in the cmb files instead of the names of the 188 fisheries in the CFiles. If FIRSTPASS = FALSE, then FishName(IZ) would remain the names found in the Cfiles. Therefore, I commented out the if statement. A copy of the revised code is attached but you have to rename .txt to .vb Thanks, Henry"

Date	Version	Programmer(s)	Details
Sept 10, 2014	Coshak4_ V2.5 10Sep2014.exe	Henry Yuen	From an email sent from Henry Yuen to the AWG on 9/10/2014: "I just uploaded revised version of Coshak4_V2.5 10Sep2014.exe which now has a help file based on John's email procedures (see below) and a new disclaimer in the out file as Gayle requested: "cohort sizes are the pre-fishery cohorts with age-specific natural mortality removed". The help file is just a strawman to get us started and I'll add more details and screen shots later plus what ever else the AWG want to include in the help file. Anything that will help jog people's memories a few years down the road. Thanks, Henry"
Oct 9, 2014	Coshak4 V2.6 9Oct2014.exe	Henry Yuen	From an email sent from Henry Yuen to the AWG on 10/9/2014: "There is a new version of Coshak4 on the ftp site. This version will search for CWT recoveries with values between 0 and 0.5 and replace them with 1 in both the MDL and .out files. It will also write a file name "lessThanHalfRoundUp.csv" which is a log of the catches before they were changed. None of my stocks has recoveries between 0 and 0.5. Please test on your stocks and let me know if there are any problems. The only problem that I could see was if both age 5 and age 6 were changed to 1 and then added together in the MDL and .out files. They would show a value of 2."
Nov 10, 2014	Coshak4 V2.9 10Nov2014.exe	Henry Yuen	Email from Henry Yuen to the AWG on 10/9/2014: "Gayle found a minor error in the most recent version of Coshak4 where the audit trail in the .out file did not print the correct name of the terminal fishery where catch was being moved to escapement even though the catch was being moved correctly. The latest version will now print the correct terminal fishery name in the .out file. If you did not move catches from a terminal net or terminal sport fishery to escapement, then there is no need to rerun your MDL files. If you did move catches from a terminal net or terminal sport fishery to escapement, then there is still no need to rerun your MDL files. If you want the want the correct terminal

Date	Version	Programmer(s)	Details
			fishery name in the .OUT file, then rerun only the affected MDL files with the revised program. There is also a revised help file "Base Period Calibration Procedures.chm" listing the sequence of events in COSHAK4 and when the options occur e.g., moving escapement strays to escapement occurs before the cohort analysis whereas moving terminal catch to escapement occurs after the cohort analysis. Hopefully this will clue us in as to what happened and when."
Nov 12, 2014	?	Henry Yuen	Email from Henry Yuen to the AWG on 11/12/2014: "Hi Randy, Gayle, Ethan, and John I uploaded a newer version of the help file and coshak4. The both have today's date "12Nov2014" Both the help file and the prompts in Coshak4 have been updated to explain the following: Use the 168 to 68 cmb file to move "CWT recoveries" for escapement strays to escapement. No shakers or CNR mortalities are calculated for the CWT recoveries that were moved to escapement. Hint, this occurs before the cohort analysis so we are dealing with CWT recoveries, not catch or associated shakers and CNR incidental mortalities. After the cohort analysis, follow the Coshak4 prompts to move terminal catches and their associated shakers and CNR mortality to escapement. The list of eligible terminal fisheries have been expanded to include TAK term T, N, and S as well as TOR term T. If you chose to move catches to escapement via the 68 to 32 CMB file, their associated shakers and CNR mortalities will be moved as well. Growing up in Hawaii where pidgin English was the first language, I have never been good at proper English. If you can think of a better way to explain the above than what I presented in the help files, let me know and I will rewrite the help files. " And a follow up email sent from Henry to the AWG on 11/12/2014: "Hi Larrie,

Date	Version	Programmer(s)	Details
			No changes were made to the calculations in Coshak4. The changes in Coshak4 were (1) The main screen was reworded to match the help file (2) The move terminal catch to escapement was reworded to remind users that shakers and CNR incidental mortalities would be move along with the terminal catch (3) The list in the move terminal catch to escapement screen was expanded to include TAK TERM T TAK TERM N TAK TERM S TOR TERM T On Wed, Nov 12, 2014 at 3:27 PM, Larrie LaVoy - NOAA Federal <larrie.lavoy@noaa.gov> wrote: Henry, Does this coshak calculate anything different than the one you gave us on thursday that dealt with escapement mapping. Or is it just have additional help wording in the program windows?”
Nov 18, 2014	Coshak4_V2.9 18Nov2014.exe	Randy Peterson	Email from Randy Peterson to the AWG on 11/18/2014: “Hi Everyone, I have uploaded a new version of CoShak4 to the ftp server and attached a new 189 to 69 CMB file to this email. These changes won’t impact everyone, but please read further to make sure. Changes to 189 to 69 CMB: Fisheries 182, 183, and 184 (Cost Recovery, Personal Use, and Subsistence) are now mapped to escapement in the 189 to 69 step. Where were they previously? Nowhere; poof, they’d simply disappear. Now they’re back via CMB. Changes to CoShak4: CoShak4 was <u>not</u> moving shaker, legal CNR, sublegal CNR, and legal drop-off mortalities to escapement. It was moving landed catch only. I’ve altered CoShak4 so it now moves all mortality to escapement, if so desired (see the attached picture for a how). 1) In the “move terminal catch including shakers and CNR IM to escapement” form, a new column has been added called “addMortToEsc.” If it’s your desire to move mortalities to escapement, leave the box

<table>
<tr><th>Date</th><th>Version</th><th>Programmer(s)</th><th>Details</th></tr>
<tr><td></td><td></td><td></td><td>“checked”. IMPORTANT NOTE: as written, CoShak4 will move the same fraction of IM mortality to escapement as your landed catch. That is if you are checking an isSelected box, and say you move 70% of the landed catch to escapement, AND you leave the addMortToEsc box checked, CoShak4 will move 70% of the IMs to escapement. If you uncheck the addMortToEsc box, it’ll only move 70% of the landed catch.
2) I’ve added TCA & TUS TERM STRAY N to the list of fisheries that users can select in the aforementioned form that users can select.
3) The OUT file has been altered so that the mortality being moved to escapement is documented
4) The OUT file has been altered so that all recoveries and mortality being moved to escapement is documented at the bottom of the OUT file.

The new CoShak4 executable can be downloaded.
And its source code is available.

Have fun AWGers,

Randy,”</td></tr>
<tr><td>Nov 25, 2014</td><td>Coshak4_ V2.9 25Nov2014.exe</td><td>Henry Yuen</td><td>Email from Henry Yuen to the AWG on 11/25/2014:

“

The latest version has an expanded audit or breadcrumb trail which is a log of all the options that you selected except for the edit escapement details. This should allow the recreation of the MDL files years from now by a total stranger (if you did not edit escapement). However, this version does not provide any details on (1) which version of Coshak4 was used and (2) how the escapement was edited. There are a lot of escapement editing options and keystrokes to capture. That would have to wait for another day because I would rewrite the Coshak4 so it can log options selected and input values on the fly instead of trying to save all of this in an array and writing them at the end when the .out file is written. Anyway, this is what the breadcrumb trail looks like. It is presented in the same order as the program prompts so the audit trail could double as a cookbook recipe.

yearling stock: True
apply IDL to escapement: False
Weight within Brood Year by production releases: False</td></tr>
</table>

Date	Version	Programmer(s)	Details
			Exclude Escapements from Between Brood Year Weighting: True use fishery specific PNV use shaker method 1 CDS File: CKO_BY77_78_noOOB.CDS search for Cfiles with the the following extension: .CKO start age in Cfile or MDL file: 2 last age in CFile or MDL file: 6 search for FRE in PNV file name for .out and .MDL file: FSS 1st CMB File: STD69Fnov18new.cmb PSL File: STD68FCNR14_2013_Fixed.PSL CCF File: DOMBY.CCF escapement was not edited prior to between BY weighting 2nd CMB File: 69_to_33Fnov10.cmb terminal fishery: TCOL R N terminal fishery: TFRASER N terminal fishery: TCOL R S if you elected to move terminal catch to escapement, the details will appear here WG4 File: NULL”
Nov 26, 2014	Coshak4_ V2.9 26Nov2014.exe	Henry Yuen	Email from Henry Yuen to the AWG on 11/25/2014: “yet another upgrade of Coshak4, this time with 26Nov2014 in the name instead of 25Nov2014. The 26Nov2014 upgrade will now log how escapements were edited. The log will look like this depending on the option selected for brood year 77 calculated 26.9999995529652 for age 3 from 0.100000001490116 exploitation rate for brood year 77 calculated 152.999997466803 for age 4 from 0.100000001490116 exploitation rate for brood year 77 calculated 494.999991804361 for age 5 from 0.100000001490116 exploitation rate for brood year 77 calculated 44.999999254942 for age 6 from 0.100000001490116 exploitation rate for brood year 78 user supplied 6 escapement for age 3 for brood year 78 user supplied 6 escapement for age 4 for brood year 78 user supplied 220 escapement for age 5 for brood year 78 user supplied 12 escapement for age 6 for brood year 79 calculated 38.2106324011086 escapement for age 3 from 0.1 maturity rate

Date	Version	Programmer(s)	Details
			for brood year 79 calculated 69.9880952380952 escapement for age 4 from 0.3 maturity rate for brood year 79 calculated 27.5555555555556 escapement for age 5 from 0.5 maturity rate for brood year 79 calculated 45 escapement for age 6 from 0.1 maturity rate The prompt for starting age in the Cfiles has also been changed. If you can think of better language, let me know and I'll make the changes."
Nov 27, 2014	Coshak4_ V2.9 27Nov2014.exe	Henry Yuen	Email from Henry Yuen to the AWG on 11/26/2014: "Ladies and Gentlemen, back by popular demand, Coshak4_V2.9 27Nov2014 -breadcrumb trail.zip with new code to log the name (version) of Coshak4 used to create the .out and .mdl files. Looks like this Current Date: 11-26-2014 Current Time: 08:56:08 Coshak4 version: C:\Users\lactc6\Documents\VBnet projects\Coshak4_V2.9 26Nov2014 -breadcrumb trail\bin\Release\Coshak4_V2_9.EXE No more excuses why a complete stranger cannot reproduce your mdl files decades from now. As before, the latest version has been uploaded to the ftp site. "
Apr 28, 2015	Coshak4_ V2.10 28Apr2015 -CMB spreadsheet	Henry Yuen	But given the program name I can guess it had to do with migrating from the previous CMB layout to its current layout.
May 5, 2015	Coshak4_ V2_10 5May2015	Henry Yuen	Email from Henry Yuen to John Carlile, Gayle Brown, and Randy Peterson on 5/5/2015: "Hi Randy, I finally got Coshak4_V2_10 5May2015 to read a CMB spreadsheet instead of the legacy .CMB file. However, the PSC FTP site is still down so here is the VB module renamed as a txt file so it can get pass my email filters. I ran into 2 issues creating the std to 69 fishery spreadsheet. (1) If you compare the CMB spreadsheet with the spreadsheet named "URB_traceCMBmap-look for missing fisheries.xlsx" you will see that in the original CMB file, TSGS S from the 188

Date	Version	Programmer(s)	Details
			CFile fisheries was not assigned any of the 69 fisheries in the CMB file. The same for cost rec, per use, and subs. I took the liberty of assigning those 4 fisheries to the 69 CMB fisheries according to this year's ERA in order to make Coshak4 work. (2) In the 69 CMB fisheries, 2 of them, 26 TGEO ST TERM N and 54 TFRASER TERM S had no fisheries assigned to them. Presumable, in the next go around, we are going use the same CMB spreadsheets for both the base period calibration and the ERA, then both of the above will become non-issue. I ran a test using URB (because it has no recoveries from the above mentioned fisheries) and was able to reproduce my MDL and OUT files from last year."
May 20, 2015	Coshak4_ V2.12	Henry Yuen	Email from Henry Yuen to the AWG on 6/10/2015: "Hello to all, (1) At our last meeting in Portland, John asked about the "IDL" problem. The "IDL" problem is actually a misnomer. I found a bug that started with "Coshak4_V2.9 18Nov2014 - CMB stray to esc move IM" and was carried over to "Coshak4_V2.9 27Nov2014 -breadcrumb trail" and "Coshak4_V2.10 28Apr2015 -CMB spreadsheet". It involves the following screen: Notice that all of the default values for fraction of terminal catch to move to escapement = 1 and the default values for AddMortToEsc is checked (i.e. TRUE) For the Columbia River Stocks, even though the is Selected box is unchecked, Coshak4 will still move all of the COL R N and COL R S shakers to escapement because of the default values. The results has the appearance of IDL being applied twice. Furthermore, both COL R N and COL R S = 0. So not only is the escapement wrong, the terminal catch is also wrong which in turn messes up the base period exploitation rates and cohort sizes. The bug is my fault. I should have done more testing before releasing the code changes. The latest version, "Coshak4_V2.11 20May2015.exe" had addition code to change the default values for fraction of terminal catch to move to escapement = 0 and the default values for AddMortToEsc = FALSE if isSelected is False. I sent revised LYF, SPR, SUM, and URB MDL files to Randy so he can see if that makes the "IDL" program go away in the STK files. It did

Date	Version	Programmer(s)	Details
			when I did a test run but maybe there are still other problems that addMortToEsc fix does not address. By the way, I don't know who has the Cfiles and other data to create the NKF MDL file. If you can send it to me, I will rerun the NKF MDL file using "Coshak4_V2.11 20May2015.exe"and see the addMortToEsc fix addresses the problem with the cohort ratios. (2) At our last meeting in Portland, Gayle also announced that we would have to redo our Cfiles for the next go around of the base period calibration. When that time comes, please use the latest version "Coshak4_V2.11 20May2015.exe". The .exe file can be downloaded. and the source code can downloaded."
Sept 4, 2015	Coshak4_ V2.13	Randy Peterson	Email from Randy Peterson to the AWG on 9/4/2015: "I've uploaded Coshak4 V2_13 4Sept2015 to the Sharepoint website under AWG -> Computer Programs. I've included both the source code and executable. Here's what changed from V_2.12 to V_2.13: • Hardcoded terminal fishery mappings are no longer hardcoded, but are "discovered" via starting your fishery name with a T or X: e.g. **T**AK TERM N or **X**CA ESCAPE STRAY • All over the program the wrong version was being printed on the GUI forms. I think I found most and updated all appropriately. • Requirement of to have the CMB file ending with "_CMB.xlsx" removed."
Oct 8, 2015	Coshak4_ V2.14	Randy Peterson	v2.14 corrected the issue in v2.13 that terminal net flag was not assigning correctly (new debug file added)
Oct 8, 2015	Coshak4_ V2.15	Randy Peterson	the "z" prefix doesn't work to combine two MDLs
Sept 22, 2016	Coshak4_ V2.16	Randy Peterson	Email excerpt from Gayle Brown sent to Randy Peterson on 4/26/2017: "The description on this version states that the only change to the Sep 2016 version was to migrate it from VB 2010 to VB 2013."
May 31, 2017	Coshak4_ V2.17	Randy Peterson	Email from Randy Peterson to the AWG on 5/31/2017: "A new version of CoShak4 is on SharePoint under AWG/Computer Programs. The files are Coshak4_V2.17 31May2017 exe.zip and Coshak4_V2.17 31May2017 source.zip. Version 2.17 changes the MDL file format from 5

Date	Version	Programmer(s)	Details
			character integers that have no special character to denote a different fishery to a double precision rounded to 6 decimal places separated by commas. See below. Note that you don't <u>necessarily</u> <u>have to</u> re-run MDLs using the new version of CoShak4. The reason for this modification is the WCVI and NBC scaling routines, which can result in fractions of recoveries, but this doesn't *have* to occur in CoShak4. I will modify the *collapse SPFI to Model fishery strata* program such that it can read MDL files using either the old or new MDL file format, but it will only write MDL files using the new file format. "
Jun 7, 2017	Coshak4_ V2.18	Randy Peterson	From an email sent from me to the AWG on 6/7/2017: "Gayle pointed out that the "model stock" list in CoShak4 was outdated and she was having to manually rename some of the files. I've updated the program with the latest list of model stock name/acronyms. See SharePoint for the latest and greatest under AWG/Computer Programs/2017"

APPENDIX B. MEMO FROM GARY MORISHIMA REGARDING NEGATIVE NUMBERS IN ESCAPEMENT BASE PERIOD RECALIBRATION

M E M O R A N D U M

TO: CTC ISBM & Model Improvement Groups

FR: Gary S. Morishima

Re: Out of Base Adjustment Procedure

Date: June 10, 2011

INTRODUCTION: Several aspects of models and regimes employed by the CTC AWG depend upon CWT-recovery patterns during a specified base period, e.g., 1979–1981. However, several stocks of interest do not have CWT releases that were harvested by fisheries during the base period. In addition, discontinuities in tagging programs have resulted in "holes" in data series that would be useful for certain types of analyses.

Several years ago, the CTC AWG developed methods to make Out of Base (OOB) adjustments to recoveries of CWT release groups to estimate the numbers of CWTs that would have been expected to be recovered had the fish been available during the specified base period. By and large, methods are implemented via computer code in various programs and are not well documented. Recently, a number of concerns have arisen which prompted my revisiting OOB methods to provide a basis for reviewing computer code to make OOB adjustments.

PURPOSE: This memo describes methods for performing Out of Base (OOB) adjustments for estimating the number of CWT recoveries that would have been expected in pre-terminal fisheries, terminal fisheries, and escapements.

METHODS: OOB adjustment methods involve a two step process.: (1); and (2) a forward projection to generate expected recoveries had the CWT group been harvested during the specified base period.

Step1: Perform cohort analysis on estimated (observed expanded for sampling rate) on recoveries for the CWT group to be adjusted to base period conditions to estimate shakers, CNR Mortality, maturation rates, encounter rates for legal sized fish in landed catch. The cohort analysis will generate age-fishery specific estimates of the number of fish in catch, shaker, CNR Legal, and CNR Sublegal mortalities, plus estimates of age-specific cohort sizes and maturation rates.

Assuming that all legal-sized landed fish are retained, the encounter rate for legal-sized fish in the landed catch is:

$$LCER_{f,a} = \frac{R_{f,a}}{N_a * PV_{f,a}} \quad (1)$$

The encounter rate for mortalities of sub-legal sized fish (shakers) is:

$$SER_{f,a} = \frac{S_{f,a}}{N_a * PNV_{f,a}} \quad (2)$$

The encounter rate for mortalities of CNR Legals is:

$$CNRLER_{f,a} = \frac{CNRL_{f,a}}{N_a * PV_{f,a}} \quad (3)$$

The encounter rate for mortalities of CNR Sublegals is:

$$CNRSLER_{f,a} = \frac{CNRSL_{f,a}}{N_a * PNV_{f,a}} \quad (4)$$

Step 2: Beginning with the Age 2 cohort size estimated from Step 1, project the cohort forward to generate the expected number of recoveries had the CWT group been harvested during the specified base period.

The forward projection must contend with a variety of differences between the the regulations in place during the time that CWT group was actually recovered and those in effect during the base period. The following types of OOB adjustments are described in this memo:

- fishery harvest rates
- size limit changes
- CWT sampling rates
- CNR restrictions

The key assumptions in the OOB procedure are that: (1) the age-specific encounter rates are the same during both the period that the CWT group was recovered and the selected base period, i.e., methods of fishing, such as gear restrictions (e.g., depth of fishing, lure types, mesh size) do not significantly affect fish vulnerability; and (2) the maturation rates experienced by the CWT group to be adjusted would not have been affected by base period conditions.

Starting with the estimated age 2 cohort size from step 1:

PreTerm **Landed Catch:** Compute the number of legal-sized fish from the CWT release group in landed catch in preterminal fisheries.

Fishery Harvest Rates: Multiply cohort size by the encounter rates (eq 1) divided by the appropriate fishery index value for landed catch derived from CWT exploitation rate analysis.

Rearranging eq1,

$$R^o_{f,a} = \frac{LCER_{f,a} * N^o_a * PV_{f,a}}{FI_{f,a}} \quad \text{(PT-1)}$$

Size Limits: When the size limit is the same during the recovery and base periods, no adjustment is needed. When size limits differ, multiply the recoveries computed by eq PT-1 by the ratio between the proportion vulnerable (PV) during the base period and the PV in effect when the CWTs were collected**:**

$$R^o_{f,a} = \frac{LCER_{f,a} * N^o_a * PV_{f,a}}{FI_{f,a}} * \frac{BPPV_{f,a}}{PV_{f,a}} = \frac{LCER_{f,a} * N^o_a * BPPV_{f,a}}{FI_{f,a}} \quad \text{(PT-2)}$$

When the PVs are unchanged from the base period, the ratio of course becomes 1.0, so eq PT-2 can be used whether or not size limits have been changed.

Sampling Rate: When the fishery sampling rate is the same during the recovery and base periods, no adjustment is needed. When sampling rates differ, multiply the estimated recoveries by the ratio between the sampling rate during the base period and the rate experienced by the CWT group to be adjusted.

$$R_{f,a}^{o} = \frac{LCER_{f,a} * N_a^o * PV_{f,a}}{FI_{f,a}} * \frac{BPSR_{f,a}}{SR_{f,a}} \quad \text{(PT-3)}$$

When the sampling rates are unchanged from the base period, the ratio of course becomes 1.0, so eq PT-3 can be used whether or not sampling rates have changed.

Note that these three adjustments are linear, so they can be combined into a single equation. For software coding, a single equation can be used without the need for conditional if or case statements.

Incidental Mortalities. Once the expected CWT recoveries during the base period are estimated, the associated incidental mortalities can be determined using the same computer code used for the standard cohort analysis and base period PVs, CNR specifications, and sampling rates, Methods for estimating incidental mortalities are described below.

DropOff mortality of legal-sized fish: When the fishery drop off rate is the same during the recovery and base periods, no adjustment is needed. When dropoff rates differ, multiply the estimated recoveries by the ratio between the dropoff rate during the base period and the rate experienced by the CWT group to be adjusted.

$$DO_{f,a}^{o} = R_{f,a}^{o} * \frac{BPDOR_{f,a}}{DOR_{f,a}} \quad \text{(PT-4)}$$

When the drop off rates are unchanged from the base period, the ratio of course becomes 1.0, so eq PT-4 can be used whether or not drop off rates have changed.

Shakers (sub-legal mortalities incurred during taking landed catch):

Fishery Harvest Rates: The simplest way to estimate shaker mortalities would be to assume that they would be directly proportional to landed catch.

$$S_{f,a}^{o} = \frac{R_{f,a}^{o} * S_{f,a}}{R_{f,a}} \quad \text{(P-5)}$$

Size Limits: When the size limit is the same during the recovery and base periods, no adjustment is needed. Again, assuming that shaker loss is proportional to landed catch, multiply the expected landed catch recoveries by the shaker to landed catch ratio and the ratio between the PNV during the base period and the PNV in effect when the CWTs were collected**.**

$$S_{f,a}^{o} = \frac{R_{f,a}^{o} * S_{f,a}}{R_{f,a}} * \frac{BPPNV_{f,a}}{PVN_{f,a}} \quad \text{(PT-6)}$$

When the PNVs are unchanged from the base period, the ratio of course becomes 1.0, so eq PT-6 can be used whether or not size limits have been changed.

<u>Sampling Rate:</u> When the fishery sampling rate is the same during the recovery and base periods, no adjustment is needed. When sampling rates differ, multiply the estimated recoveries in the landed catch by the ratio between shakers and landed catch and the sampling rate during the base period and the rate experienced by the CWT group to be adjusted.

$$.S^{o}_{f,a} = R^{o}_{f,a} * \frac{S_{f,a}*BPSR_{f,a}}{R_{f,a}*SR_{f,a}} \qquad \text{(PT-7)}$$

<u>DropOff mortality of sub-legal-sized fish:</u> When the fishery drop off rate is the same during the recovery and base periods, no adjustment is needed. When dropoff rates differ, multiply the estimated shaker mortalities by the ratio between the dropoff rate during the base period and the rate experienced by the CWT group to be adjusted.

$$SDO^{o}_{f,a} = S^{o}_{f,a} * \frac{BPDOR_{f,a}}{DOR_{f,a}} \qquad \text{(PT-8)}$$

<u>Chinook Non-Retention (CNR) Mortalities</u>: When there was no CNR fishery during the base period, CNR mortalities for the OOB adjustment procedure = 0. CNR that would have occurred during the base period can be estimated using the normal cohort analysis procedures and estimated OOB-adjusted CWT recoveries.

Term **Terminal Run:** Compute the number of fish returning to terminal areas by multiplying the remaining cohort after preterminal fishery impacts by the maturation rate estimated by the cohort analysis on the CWT group to be adjusted.

$$\boldsymbol{TR^{o}_{a} = \left[\!\left[N^{o}_{a} - \sum\left[R^{0}_{f,a} + S^{0}_{f,a} + DO^{0}_{f,a} + SDO^{0}_{f,a} + CNR^{0}_{f,a} \right] \right]\!\right] * MR_{a}} \qquad \textit{\textbf{(T-1)}}$$

Landed catch and incidental mortalities would be estimated using analogs to the {PT equations}, with terminal run sizes substituted for cohort sizes.

Escapements are estimated by simply subtracting terminal fishery moralities from the terminal run.

Aging Compute the cohort size for the next age.

$$\boldsymbol{N^{o}_{a+1} = TR^{o}_{a} * \frac{(1-MR_{a})*S_{a+1}}{MR_{a}}} \qquad \textit{\textbf{(A-1)}}$$

Repeat for all ages in cohort.

Step 3: Using the OOB projected CWT recoveries, a cohort analysis can be performed with base period regulations, such as size limits & CNR, to generate estimates of age-fishery specific exploitation/harvest rates.

APPENDIX C. BRISCOE MEMO REGARDING OUT-OF-BASE METHODS

Memorandum

To: AWG

From: Ryan Briscoe

RE: Why negative escapement is calculated when running the out of base procedure in Coshak4.

While investigating the Coshak4 code to determine why Antonio was getting negative escapement numbers in his final .MDL files, I discovered that there is a problem with the way we do the out of base procedure. The algorithm we use to adjust the harvest rates by the .WG4 file scalar can result in a terminal harvest rate > 1, which in turn results in a terminal catch that is larger than the terminal run and thus we get negative escapement numbers. The process and relevant equations are described below. Note: I did not include all the intermediate equations, just the ones related to the problem.

First, the terminal harvest rate by fishery *I* and age *J* is calculated from the cfile data using the following equation:

`HRCat(I, J) = MyCATCH(I, J) / termrun` (1)

`HRCat(I, J)` = terminal harvest rate in fishery I for age J

`MyCATCH(I, J)` = catch in fishery I and age J from the cfile

`termrun` = terminal run for a particular age, equivalent to the terminal catch + Escapement from cfiles

Then, the terminal harvest rate calculated above is adjusted using the following equation:

`HRCat(Fish, J) = HRCat(Fish, J) / AdjustWeight(Fish, yr)` (2)

`HRCat(Fish, J)` = terminal harvest rate in fishery Fish for age J

`AdjustWeight(Fish, yr)` = fishery index scalar from the .WG4 file

The terminal catch is calculated using the adjusted harvest rate as:

`TempCatch(Fish, age) = TermRun * HRCat(Fish, age)` (3)

`TempCatch(Fish, age)`= terminal catch for fishery Fish and age J

Finally, the escapement is calculated as:

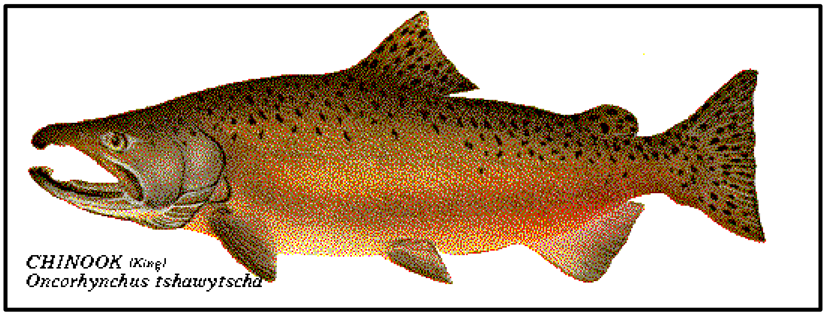
```
Escape(age) = TermRun – MATCATCH                                   (4)
```

`MATCATCH =` sum of `TempCatch(Fish, age)` for a particular age

The problem exists when the .WG4 file scalar, or `AdjustWeight(Fish, yr)` in equation 2, is greater than the harvest rate `HRCat(I, J)` calculated from cfiles in equation 1. This will result in an adjusted terminal harvest rate greater than 1, which leads to terminal catch greater than the terminal run in equation 3. Subsequently, the escapement will be a negative number because the terminal catch, MATCATCH, in equation 4 will be greater than the terminal run.

For example: If the harvest rate calculated from the 1989 Atnarko brood year cfiles for Central Net is 0.6 and the .WG4 value for 1992 in Central Net is 0.3, then the adjusted harvest rate for 1989 brood year age 3 fish caught in Central Net would be calculated as 2. If the 1992 age 3 terminal run is 1000 fish, equation 3 would estimate a terminal catch of 2000 age 3 fish in Central Net, leaving an escapement of negative 1000 fish.

APPENDIX D. MEMO DATED FEBRUARY 14, 2019



PSC Chinook Technical Committee

TO: Pacific Salmon Commission

FROM: Gayle Brown, Jon Carey, John Carlile

DATE: February 14, 2019

SUBJECT: Phase 2 base period recalibration of the PSC Chinook Model: Use of new model

The CTC has produced a new base period calibration of the PSC Chinook model (BPCV1-25 AC6). This version offers considerable improvements compared to the current model, including more accurate fishery stratification, better stock representation, improved fishery indices, and corrected data. The BPC Assessment package, based on eight evaluation diagnostics requested by the CIG, demonstrates improved performance for the new model compared to the current model. A synthesis of this evaluation is presented in the attached assessment framework document.

Based on these results, the CTC has determined that the new model represents a substantial improvement. The CTC recommends transitioning to use of the new model after further investigation of the following items:

- The approach to use in determining the environmental variable survival factors (EVs) and maturation rates (ETA: June 2019). This is critical to improving the forecasting performance of the annual calibration.
- Fine-tuning of terminal exploitation rates for the Oregon coast (ETA: March 2019).

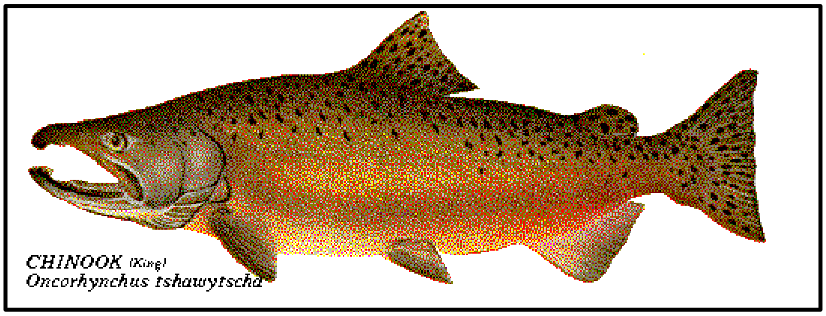
Due to the time-frame needed to address these items and to accomplish annual tasks (ERA, annual model calibration), the CTC recommends that the current model be used for determining the 2019 pre-season AIs and the 2018 post-season AIs. Resolution of policy issues regarding the translation of Table 1 are not dependent on completion of the items listed above.

cc John Field

Alison Chang

Patti Vandetta

APPENDIX E. MEMO DATED JUNE 7, 2019



PSC Chinook Technical Committee

TO: Pacific Salmon Commission

FROM: Gayle Brown, Jon Carey and John Carlile

DATE: June 7, 2019

SUBJECT: Update on Phase 2 base period recalibration of the PSC Chinook Model

In a Feb 14, 2019 memo to the Commission, the CTC recommended transitioning to the new Phase II version of the Chinook Model following two additional investigations:

- Determining an approach to choose stock specific environmental variable survival factors (EVs) and maturation rate assumptions that are critical to the forecasting performance of the annual calibration.
- Improving the terminal fishery exploitation rates for the north and mid-Oregon coast stocks to improve the Model's fit to observed terminal run estimates.

During the above investigations, the CTC also made improvements to two other key aspects of the Model's calibration procedure:

- Incorporation of adjustments to year- and age-specific maturation rates for stocks included in the Model's 'MATAEQ' input file using the necessary age-specific terminal run or escapement data.
- Review and update of procedures used to calculate the annual fishery policy (exploitation rate) scalars for those fisheries that use a 'ratio of means' (ROM) estimator.

The CTC has completed the above investigations and the results are briefly summarized below. The investigations have resulted in improvements to aspects of the Model's overall performance. The CTC recommends transitioning to use of the new Phase II Model based on the configuration and inputs to Phase II annual calibration V1-27 (AC6).

cc John Field

Alison Chang

Courtney Hann

Selection of maturation rate and EV assumptions for use in the Phase II Model projections

As the final step in development of the new Phase II version of the Chinook Model, the CTC Analytical Work Group undertook a thorough investigation to determine the approach to use in setting the maturation rate (MR) and EV assumptions required for the Phase II Model's forecasting procedure. As was done in two previous investigations, various maturation rate and EV combinations (henceforth MAT-EV scenarios) were identified as likely candidates to aid accurate forecasting of pre-season AIs. Retrospective Model runs were then used to assess performance in minimizing pre-season AI errors for this new version of the Chinook Model.

In total, 29 MAT-EV scenarios were included in the analysis, representing combinations of nine methods for forecasting maturation rates (including time series methods such as various types of ARIMA and Exponential Smoothing [ETS] models and naïve models such as three-year averages, six-year averages, and nine-year averages) and 11 EV assumptions (different year averages). The scenarios were based on calibration years 2009–2019 and required running the V1.27 (AC5) version of the Phase II Model a total of 891 times. Six statistical metrics of error (Mean Raw Error, Mean Absolute Error, Mean Percent Error, Mean Absolute Percent Error, Mean Squared Error and Root Mean Squared Error) were used to assess pre-season-to-post-season errors in the AIs as well as in the stock-specific partial cohort abundances (PCOH). The PCOH are the pre-fishery vulnerable abundances which provide the basis for computing the AIs when summed across all stocks and ages in a calendar year for each AABM troll fishery.

The first round of analyses from Scenarios 1-21 showed that the basic ETS method outperformed all other MR forecasting methods and subsequent analyses focused on combinations of ETS with various EV assumptions. The performance of all scenarios was explored separately for two time series of pre-season-to-post-season errors: (1) 2014–2018, a recent time period with high variability in ocean conditions and abundance; and, (2) 2009–2018, a longer time period that encompasses the last PST agreement.

The results of this investigation, based on a composite score across the three AABM fisheries for the 2014–2018 time series of AI errors, are shown in Appendix E1. Scenario 28 (ETS maturation rate forecast and 12-year average EV assumption) was clearly identified as the scenario producing the smallest AI errors. The results based on the longer 2009–2018 time series and those derived from the analysis of PCOH also supported this conclusion. The CTC plans to further detail this investigation in a technical note.

The experience gained during this investigation, and increasing evidence of a trend toward earlier maturation in stocks throughout the geographic region encompassed by the PST, has led the CTC to consider carrying out a similar investigation at regular intervals (e.g., every 5 years).

Refinement of terminal fishery exploitation rates for MOC and NOC

Terminal freshwater sport catches generated by the Phase II Model for the MOC and NOC Model stocks were unrealistically high compared to observed catches. Model outputs (e.g., the AIs, fishery stock compositions, etc.) were being adversely impacted because these two stocks contribute to coast wide fishery catches. To address this situation, revised terminal freshwater sport harvest rates (base period average and annual time series) were incorporated into the Phase II Model after being re-estimated using ODFW "punch-card" catch estimates and new escapement estimates from Mark-Recapture studies. In addition to this change, the decision was made to obtain base period CWT estimates for the MOC using the 'out-of-base' procedure rather than using observed CWT data from the base period that were incomplete. These changes greatly improved the correspondence between observed and Model-generated terminal catch for the two stocks (see Appendix E2) and other aspects of Model performance (see Appendix E3-Appendix E5).

Adjusting CWT indicator stock maturation rates to improve the Model's fit to observed calendar year terminal runs and escapements of Model stocks

Stock, brood, and age-specific maturation rates are inputs into the annual Model calibration procedure but for various reasons, maturation rates calculated from CWT indicator stocks do not always enable the Model to generate calendar-year age compositions that correspond well with observed escapements or terminal returns. The CTC developed and made an initial test in February 2019 of a method for adjusting maturation rates for Model stocks included in the Model's MATAEQ input file and for which there was available data of sufficient quality. This method was broadly applied to all possible candidate stocks in the latest round of Model improvements and has been found, as expected, to noticeably improve the Model's fit to observed calendar year escapements or terminal returns (see Appendix E3).

Updating of fishery indices used to scale base period exploitation rates

Procedures to calculate fishery indices, which are applied in each calendar year to scale base period exploitation rates for Model stocks caught in each Model fishery, were reviewed and updated using current CWT data. The ROM metric was maintained as the fishery index used for the two Canadian AABM troll fisheries although adoption of a SPFI had been proposed and explored. The stock-specific version of the SPFI appears less capable compared to the ROM of reflecting changes across years in stock-specific impacts due to management actions taken to avoid Canadian stocks of concern. Finally, fishery scalars for a number of net fisheries were reviewed and modified using observed catch data to reflect a shift since the 1979–1982 base period to more terminal locations (e.g., Canadian net fisheries) where local abundant stocks could be targeted. Changes to the fishery scalars affect all data generated by the Phase II Model and have contributed to increased correspondence between Model and genetically-based catch estimates for Model stock groupings in the AABM troll fisheries (see Appendix E3-Appendix E5).

AIs generated by version 1-27 (AC6) of the Phase II Model

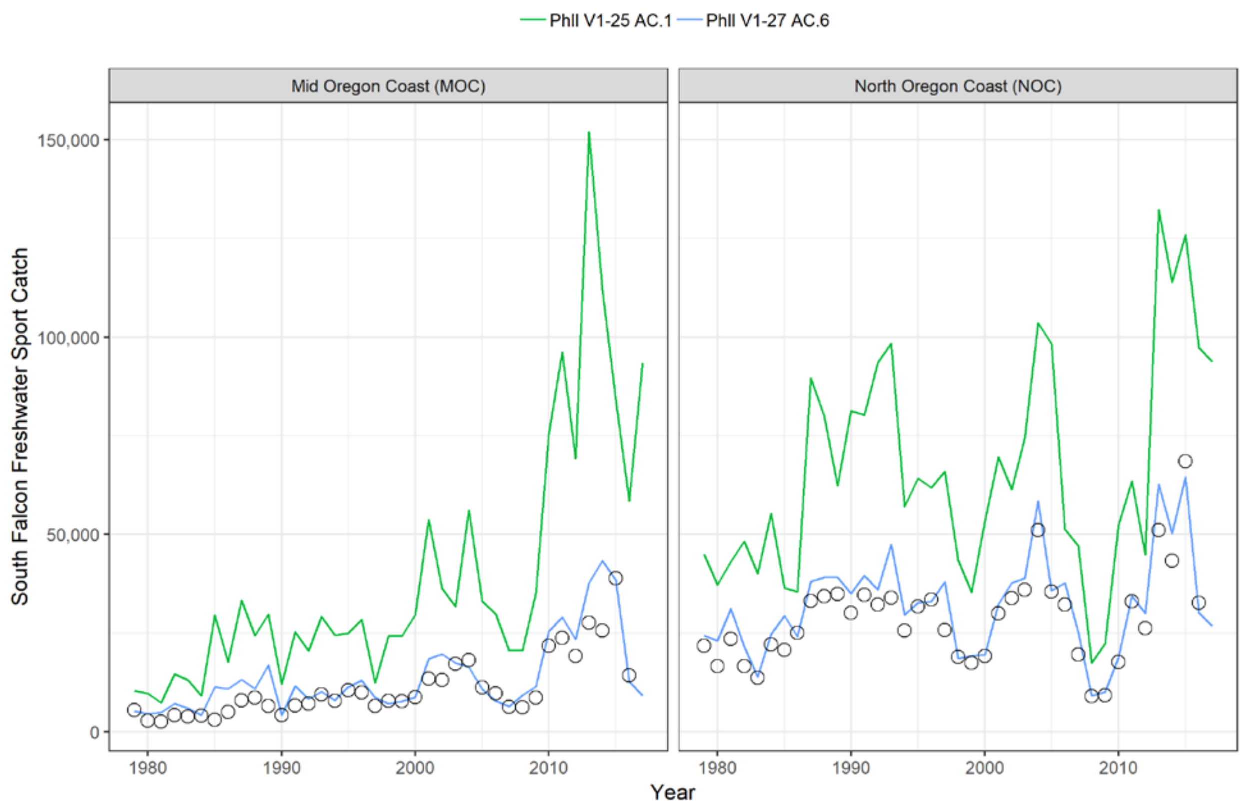
Following the conclusion of the above investigations, an annual calibration of the Phase II Model was completed that incorporated all of the identified improvements. The CTC recommends transitioning to use of the Phase II Model based on the configuration and inputs of this annual calibration, V1-27 (AC6).

AIs generated by calibrations of the Phase II Model and the old Model in 2019 for each AABM fishery show quite similar patterns across years although there are noticeable differences among the calibrations unique to each fishery (Appendix E7). Comparison of AIs from the two Phase II calibrations, V1-23 (AC1) from February and V1-27 (AC6) from June, show noticeable change for the SEAK and NBC fisheries (compare blue and green lines in Appendix E7) whereas there was little change for the WCVI fishery. Comparison of AIs from the most recent Phase II calibration V1-27 (AC6) of the new Model and the March 2019 calibration of the old Model (CLB1905) show relatively close correspondence for the SEAK fishery (compare blue and red lines in Appendix E7). Correspondence was lower in some years for the NBC fishery and lower still for the WCVI fishery. Differences between the new and old Models tended to be most noticeable in peak and trough AI years.

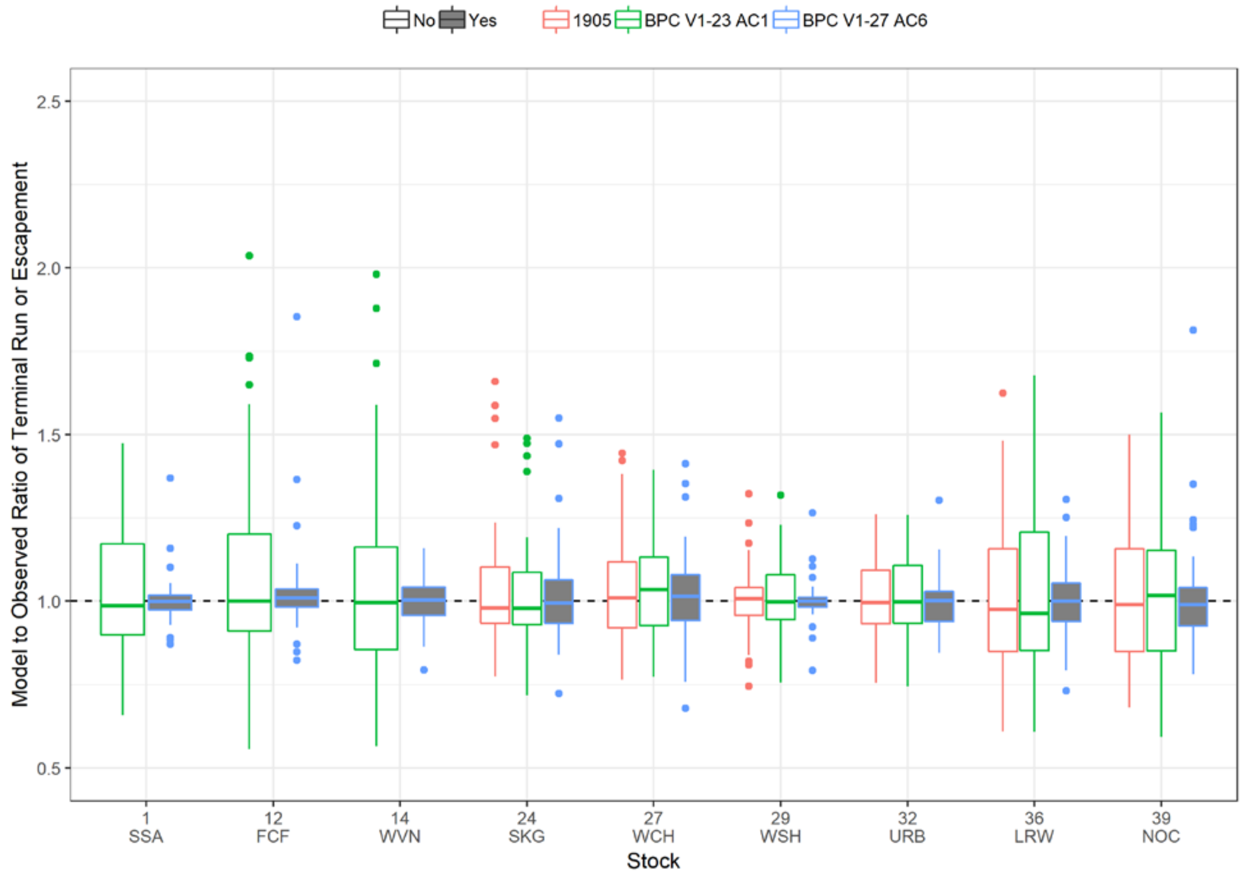
Different AI time series are produced by the new and old Models. Implications for the relationship between the allowable catches specified at each AI in Appendix E1, however, will not be known until the allowable catches in Table 1 are recalculated using the new AIs, updated harvest rate indices (HRIs), and fishery catches. The updated values will result in new values for the proportionality constants (PC) for each AABM fishery, and the new PCs will affect the allowable catches in Appendix E1. This information is in preparation by the CTC and can be available for review with the Chinook Interface Group, as needed, during the bilateral CTC meeting, June 10-14, 2019.

Appendix E1— Description of MAT-EV scenarios included in the investigation and their ordinal ranks as derived from error statistics computed from the 2014–2018 time series of AI errors. Fishery-specific ranking was based on the median ranking across six error metrics (MRE, MAE, MPE, MAPE, RMSE, and MSE) whereas composite ranking is the sum of the median ranks across the three fisheries. The MAT-EV scenario with the lowest (i.e., best) composite score is highlighted.

				Fishery-specific Median Rank			
SCENARIO	**FORECAST ID**	**FORECAST METHOD**	**EV ASSUMPTION**	**SEAK**	**NBC**	**WCVI**	**Composite Rank**
1	A	ARIMA_BC_biasadj	3YA	20.5	23.5	24.0	68.0
2	B	ARIMA_BC	3YA	28.0	27.5	25.5	81.0
3	C	ARIMA	3YA	19.0	23.5	23.0	65.5
4	D	ETS_BC_biasadj	3YA	24.0	21.0	15.0	60.0
5	E	ETS_BC	3YA	24.0	21.0	15.0	60.0
6	F	ETS	3YA	10.0	13.0	10.5	33.5
7	G	3YA	3YA	20.0	14.0	17.5	51.5
8	H	6YA	3YA	13.0	14.0	17.0	44.0
9	I	9YA	3YA	21.5	23.0	26.0	70.5
10	A	ARIMA_BC_biasadj	6YA	16.0	18.0	20.0	54.0
11	B	ARIMA_BC	6YA	26.5	23.5	22.5	72.5
12	C	ARIMA	6YA	16.5	17.5	19.0	53.0
13	D	ETS_BC_biasadj	6YA	12.0	12.0	9.5	33.5
14	E	ETS_BC	6YA	21.0	17.0	12.5	50.5
15	F	ETS	6YA	7.0	7.5	7.5	22.0
16	G	3YA	6YA	15.5	8.5	14.0	38.0
17	H	6YA	6YA	11.0	9.0	11.0	31.0
18	I	9YA	6YA	17.5	17.5	22.0	57.0
19	G	3YA	1Y	28.0	28.0	27.0	83.0
20	H	6YA	1Y	15.0	24.5	27.0	66.5
21	I	9YA	1Y	27.0	29.0	29.0	85.0
22	F	ETS	4YA	9.0	12.0	14.0	35.0
23	F	ETS	5YA	8.0	10.0	8.5	26.5
24	F	ETS	7YA	6.0	6.5	5.5	18.0
25	F	ETS	8YA	5.5	5.0	5.5	16.0
26	F	ETS	9YA	4.0	4.0	3.0	11.0
27	F	ETS	10YA	3.0	3.0	2.0	8.0
28	F	ETS	12YA	1.0	1.0	1.0	3.0
29	F	ETS	15YA	2.0	2.0	4.0	8.0

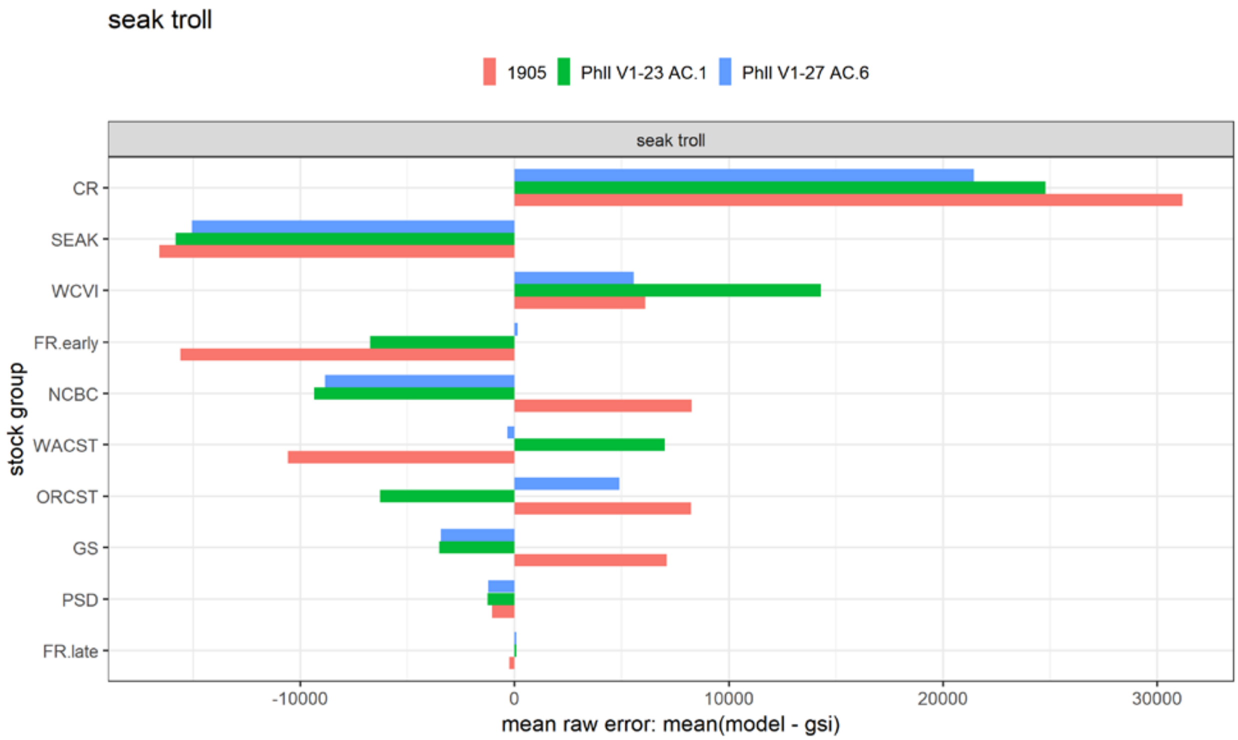


Appendix E2— Annual observed and Model-generated terminal freshwater sport catches of the MOC and NOC Model stocks. Open circles indicate observed catches. The solid green line shows the catches generated by Phase II annual calibration V1-25 (AC1) in February 2019 prior to refinements to the base period and annual fishery exploitation rates for the two stocks. The solid blue line shows the catches generated by Phase II annual calibration V1-27 (AC6) in June 2019 following the refinements. Note that correspondence with the observed catches and the considerably improved by the refinements incorporated into V1-27 (AC6).



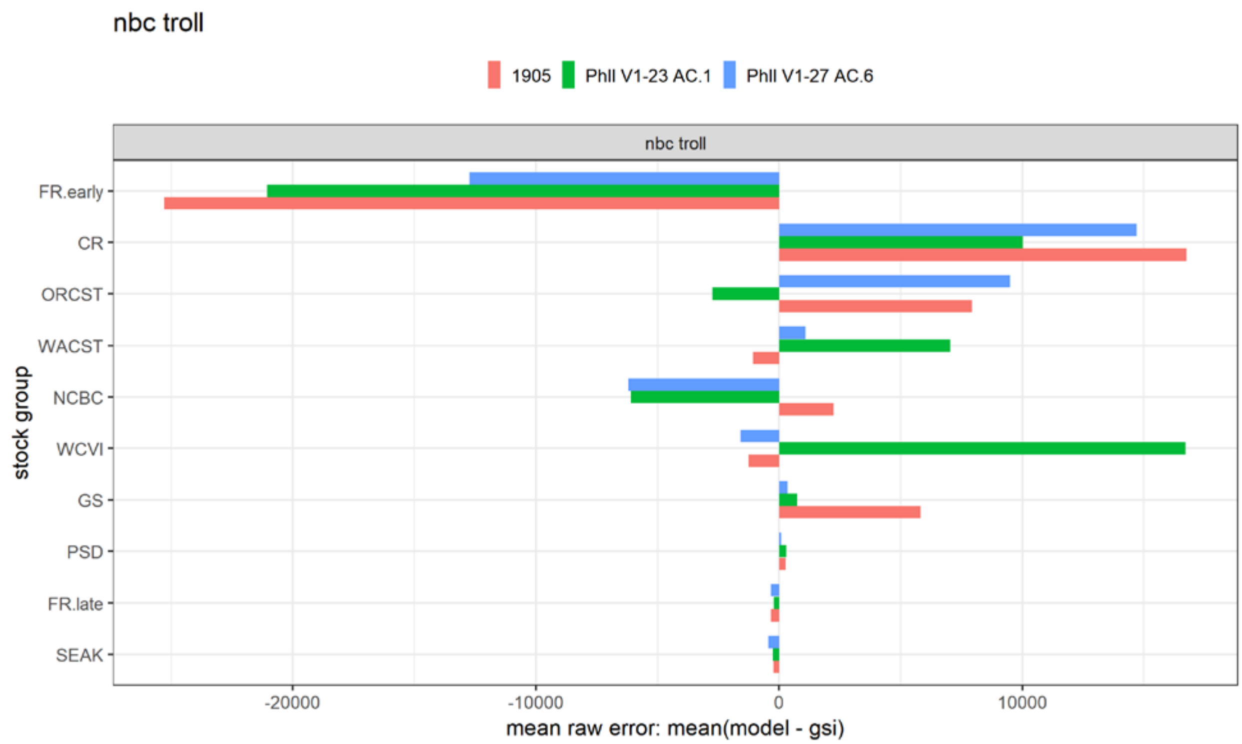
Appendix E3— Box plot summaries of the ratio of the Model-to-observed estimates of calendar year escapements or terminal returns for a selected subset of the 19 Model stocks for which adjusted maturation rates have been used in the V1-27 (AC6) annual calibration.

Note: Box plots outlined in green are from Phase II annual calibration V1-23 (AC1) in which the adjustments were not applied for any Model stock. Filled box plots outlined in blue are from results produced by the V1-27 (AC6) annual calibration with the maturation rate adjustments applied. For those Phase II Model stocks with a corresponding stock in the old Model, the box plots outlined in red summarize results generated by annual calibration CLB1905. Note that a smaller vertical box dimension equates to closer correspondence between Model and observed escapements or terminal runs. Also note that the more closely aligned the colored horizontal line bisecting a box is to the dotted horizontal line passing through the graph at a Y-axis value of 1.0, the less tendency there is for the Model to over- or underestimate the observed values for a stock. Results for the other 9 stocks not included in this figure display a similar pattern to those shown.



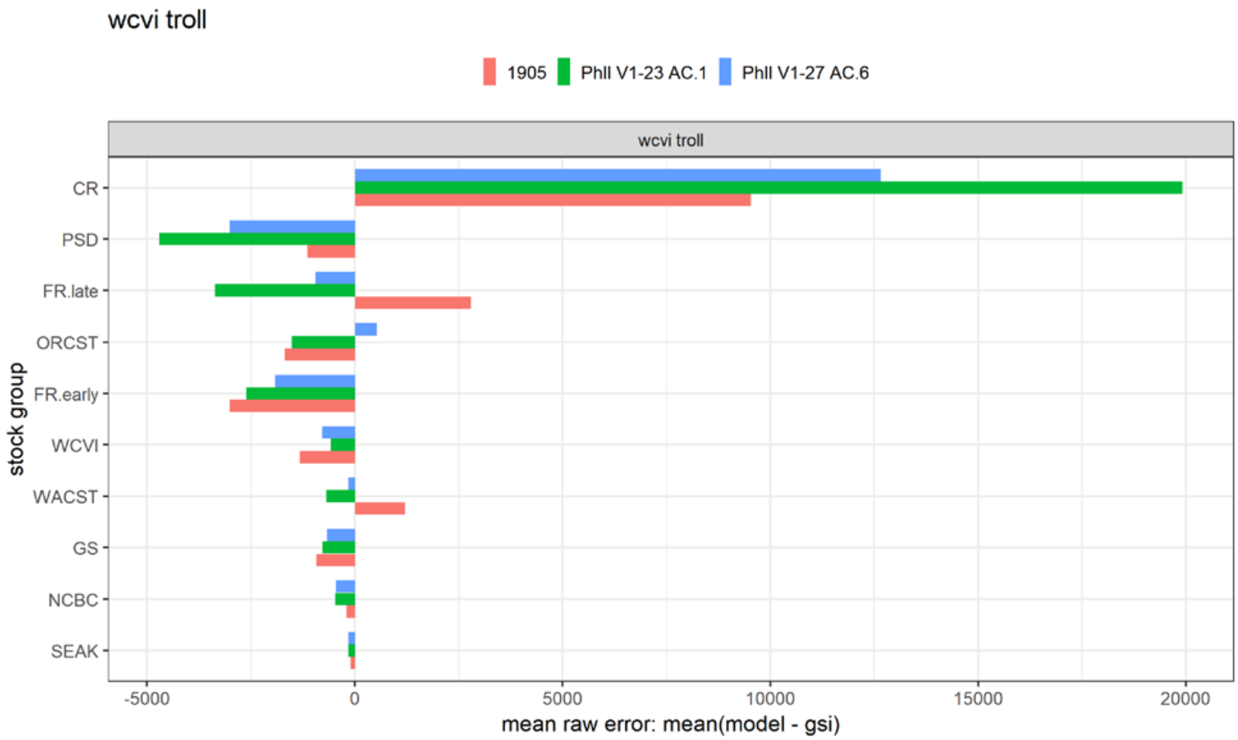
Appendix E4— Average differences in catch estimates generated by the Model for groupings of Model stocks caught in the SEAK AABM troll fishery compared to a genetically-based (GSI) estimate for recent years when both estimates were available (2005–2016).

Note: Blue horizontal bars represent the comparison with the June 2019 Phase II annual calibration V1-27 (AC6). Green bars show the average difference between the GSI estimate and the February 2019 Phase II annual calibration V1-23 (AC1) estimate and red bars the comparison with the March 2019 annual calibration of the old Model (CLB1905). The shorter a bar is (or the closer the vertical edge of a bar to the vertical zero line), the smaller the difference between the Model's and the genetically-based catch estimate. In addition, blue bars shorter than green bars indicate an improvement in Phase II Model performance in calibration V1-27 (AC6) compared to V1-23 (AC1). Blue bars shorter than red bars indicate better performance in Phase II V1-27 (AC6) version of the new Model compared to the old Model as measured by correspondence with genetically-based catch estimates. Stocks are ordered from top to bottom of the graph according to the magnitude of the average genetically-based estimate of catch in the fishery.



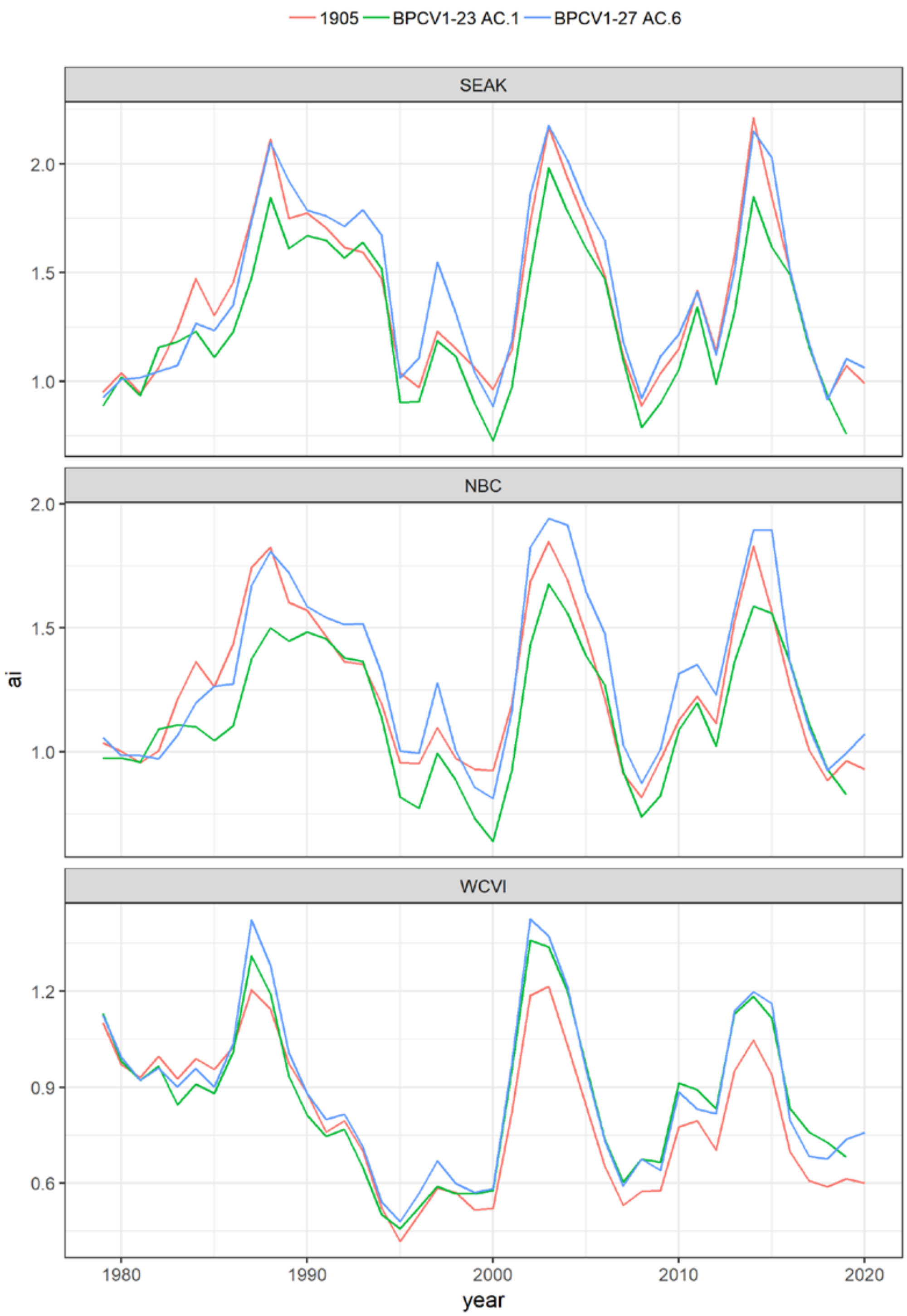
Appendix E5— Average differences in catch estimates generated by the Model for groupings of Model stocks caught in the NBC AABM troll fishery compared to a genetically-based estimate for recent years when both estimates were available (2002–2016).

Note: See the caption for Appendix E4 for further explanation but note that stocks are ordered from top to bottom of the graph according to the magnitude of the average genetically-based estimate of catch in the fishery.



Appendix E6— Average differences in catch estimates generated by the Model for groupings of Model stocks caught in the WCVI AABM troll fishery compared to a genetically-based estimate for recent years when both estimates were available (2007–2015).

Note: See the caption for Appendix E4 for further explanation but note that stocks are ordered from top to bottom of the graph according to the magnitude of the average genetically-based estimate of catch in the fishery.



Appendix E7— Time series of AIs for each AABM fishery produced by two calibrations of the new Phase II version of the Chinook Model and the old version of the Chinook Model.

Note: The blue line in each panel displays the AIs produced by the June 2019 Phase II V1-27 (AC6) calibration for 1979 – 2020. The green line displays the AIs from the February 2019 Phase II calibration V1-23 (AC1) for 1979–2019. The red line displays the AIs from the March 2019 annual calibration of the old Model (CLB1905) for 1979–2020.

Appendix F. Abundance index error summary statistics and scenario rankings for aggregate abundance-based management fisheries (based on the 2014–2018 time series of errors)

Appendix F1— Definitions of acronyms used in Appendix F tables.

Acronym	Definition
MRE	Mean raw error
MAE	Mean absolute error
MPE	Mean percent error
MAPE	Mean absolute percent error
RMSE	Root mean squared error
MSE	Mean squared error

Appendix F2— Abundance index (AI) error summary statistics for Southeast Alaska (SEAK) (2014–2018). See Appendix E1 for maturation rate and environmental variable (MAT-EV) scenario description.

SCENARIO	MRE	MAE	MPE	MAPE	RMSE	MSE
1	0.474	0.55	28.7%	32.2%	0.648	0.420
2	0.564	0.612	33.3%	35.5%	0.735	0.540
3	0.472	0.548	28.0%	31.5%	0.657	0.432
4	0.510	0.566	29.6%	32.2%	0.696	0.484
5	0.510	0.566	29.6%	32.2%	0.696	0.484
6	0.390	0.474	23.1%	27.0%	0.568	0.323
7	0.428	0.572	26.7%	33.5%	0.657	0.432
8	0.430	0.486	24.5%	27.0%	0.595	0.354
9	0.494	0.554	26.5%	29.0%	0.686	0.470
10	0.454	0.542	28.0%	32.1%	0.623	0.388
11	0.538	0.598	32.1%	34.9%	0.704	0.496
12	0.454	0.542	27.5%	31.5%	0.634	0.402
13	0.394	0.49	23.7%	28.3%	0.575	0.331
14	0.488	0.556	28.7%	31.9%	0.669	0.447
15	0.370	0.466	22.3%	26.8%	0.545	0.297
16	0.404	0.56	25.9%	33.2%	0.629	0.395
17	0.406	0.478	23.6%	26.8%	0.568	0.323
18	0.470	0.546	25.8%	29.0%	0.657	0.432
19	0.464	0.636	28.0%	36.1%	0.746	0.556
20	0.450	0.538	24.6%	28.5%	0.671	0.451
21	0.520	0.608	26.9%	30.6%	0.769	0.591
22	0.386	0.478	23.0%	27.3%	0.566	0.249
23	0.380	0.472	22.9%	27.3%	0.552	0.305
24	0.362	0.462	21.8%	26.5%	0.539	0.291
25	0.356	0.464	21.6%	26.6%	0.538	0.289
26	0.350	0.458	21.1%	26.2%	0.531	0.282
27	0.348	0.456	21.0%	26.0%	0.531	0.281
28	0.346	0.450	20.7%	25.5%	0.526	0.277
29	0.346	0.450	20.7%	25.6%	0.528	0.279

Appendix F3— Scenario's ordinal ranking for Southeast Alaska (SEAK) (2014–2018). See Appendix E1 for maturation rate and environmental variable (MAT-EV) scenario description. 'Best' scenario is highlighted.

SCENARIO	MRE	MAE	MPE	MAPE	RMSE	MSE	Median Rank
1	22	19	24	24	17	17	20.5
2	29	28	29	28	27	27	28.0
3	21	18	21	18	19	19	19.0
4	25	23	26	22	24	24	24.0
5	25	23	26	22	24	24	24.0
6	10	9	10	10	10	10	10.0
7	14	25	18	26	20	20	20.0
8	15	12	13	9	13	13	13.0
9	24	20	17	16	23	23	21.5
10	17	15	22	21	14	14	16.0
11	28	26	28	27	26	26	26.5
12	17	15	20	19	16	16	16.5
13	11	13	12	13	12	12	12.0
14	23	21	25	20	21	21	21.0
15	7	7	7	8	7	8	7.0
16	12	22	16	25	15	15	15.5
17	13	10	11	7	11	11	11.0
18	20	17	15	15	18	18	17.5
19	19	29	23	29	28	28	28.0
20	16	14	14	14	22	22	15.0
21	27	27	19	17	29	29	27.0
22	9	11	9	12	9	1	9.0
23	8	8	8	11	8	9	8.0
24	6	5	6	5	6	7	6.0
25	5	6	5	6	5	6	5.5
26	4	4	4	4	4	5	4.0
27	3	3	3	3	3	4	3.0
28	1	1	1	1	2	3	1.0
29	2	2	2	2	1	2	2.0

Appendix F4— Scenario's relative ranking for Southeast Alaska (SEAK). See Appendix E1 for maturation rate and environmental variable (MAT-EV) scenario description. 'Best' scenario is highlighted.

SCENARIO	MRE	MAE	MPE	MAPE	RMSE	MSE	Median Rank
1	1.37	1.22	1.39	1.26	1.23	1.69	1.32
2	1.63	1.36	1.61	1.39	1.40	2.17	1.50
3	1.36	1.22	1.35	1.23	1.25	1.73	1.30
4	1.47	1.26	1.43	1.26	1.32	1.94	1.38
5	1.47	1.26	1.43	1.26	1.32	1.94	1.38
6	1.13	1.05	1.12	1.06	1.08	1.30	1.10
7	1.24	1.27	1.29	1.31	1.25	1.73	1.28
8	1.24	1.08	1.19	1.06	1.13	1.42	1.16
9	1.43	1.23	1.28	1.14	1.30	1.89	1.29
10	1.31	1.20	1.36	1.26	1.18	1.56	1.28
11	1.55	1.33	1.56	1.37	1.34	1.99	1.46
12	1.31	1.20	1.33	1.23	1.21	1.62	1.27
13	1.14	1.09	1.15	1.11	1.09	1.33	1.12
14	1.41	1.24	1.39	1.25	1.27	1.80	1.33
15	1.07	1.04	1.08	1.05	1.04	1.19	1.06
16	1.17	1.24	1.25	1.30	1.20	1.59	1.25
17	1.17	1.06	1.14	1.05	1.08	1.30	1.11
18	1.36	1.21	1.25	1.14	1.25	1.73	1.25
19	1.34	1.41	1.36	1.41	1.42	2.23	1.41
20	1.30	1.20	1.19	1.12	1.28	1.81	1.24
21	1.50	1.35	1.30	1.20	1.46	2.38	1.41
22	1.12	1.06	1.11	1.07	1.08	1.00	1.07
23	1.10	1.05	1.11	1.07	1.05	1.22	1.08
24	1.05	1.03	1.05	1.04	1.03	1.17	1.04
25	1.03	1.03	1.04	1.04	1.02	1.16	1.04
26	1.01	1.02	1.02	1.03	1.01	1.13	1.02
27	1.01	1.01	1.01	1.02	1.01	1.13	1.01
28	1.00	1.00	1.00	1.00	1.00	1.12	1.00
29	1.00	1.00	1.00	1.00	1.00	1.11	1.00

Appendix F5— Abundance index (AI) error summary statistics for Northern British Columbia (NBC) (2014–2018). See Appendix E1 for maturation rate and environmental variable (MAT-EV) scenario description.

SCENARIO	MRE	MAE	MPE	MAPE	RMSE	MSE
1	0.474	0.622	31.7%	38.1%	0.702	0.493
2	0.534	0.666	34.6%	40.2%	0.758	0.574
3	0.470	0.618	31.2%	37.5%	0.708	0.501
4	0.492	0.6	32.0%	36.8%	0.698	0.487
5	0.492	0.6	32.0%	36.8%	0.698	0.487
6	0.404	0.536	27.2%	33.0%	0.620	0.384
7	0.354	0.558	25.2%	34.2%	0.622	0.387
8	0.402	0.546	26.4%	32.5%	0.629	0.395
9	0.470	0.622	29.4%	35.4%	0.712	0.507
10	0.416	0.596	29.1%	36.8%	0.645	0.416
11	0.470	0.638	31.7%	38.8%	0.694	0.482
12	0.412	0.592	28.7%	36.4%	0.646	0.417
13	0.372	0.536	26.3%	33.7%	0.584	0.341
14	0.436	0.58	29.7%	36.0%	0.639	0.409
15	0.346	0.514	24.6%	32.0%	0.564	0.318
16	0.300	0.536	23.0%	33.3%	0.574	0.330
17	0.348	0.532	24.5%	32.3%	0.580	0.336
18	0.412	0.604	27.5%	35.1%	0.657	0.432
19	0.428	0.688	28.8%	40.2%	0.812	0.659
20	0.464	0.664	28.7%	37.1%	0.807	0.651
21	0.540	0.748	31.8%	40.0%	0.907	0.822
22	0.382	0.538	26.2%	33.1%	0.605	0.233
23	0.370	0.522	26.0%	32.7%	0.575	0.331
24	0.322	0.502	23.2%	31.2%	0.547	0.299
25	0.300	0.492	21.9%	30.4%	0.533	0.284
26	0.282	0.478	20.5%	29.2%	0.519	0.270
27	0.278	0.474	20.2%	28.8%	0.517	0.267
28	0.272	0.464	19.4%	27.9%	0.513	0.263
29	0.274	0.466	19.7%	28.2%	0.511	0.261

Appendix F6— Scenario's ordinal ranking for Northern British Columbia (NBC) (2014–2018). See Appendix E1 for maturation rate and environmental variable (MAT-EV) scenario description. 'Best' scenario is highlighted.

SCENARIO	MRE	MAE	MPE	MAPE	RMSE	MSE	Median Rank
1	25	23	24	25	23	23	23.5
2	28	27	29	29	26	26	27.5
3	23	22	23	24	24	24	23.5
4	26	19	27	20	21	21	21.0
5	26	19	27	20	21	21	21.0
6	15	10	15	11	13	13	13.0
7	10	15	10	15	14	14	14.0
8	14	14	14	9	15	15	14.0
9	23	23	21	17	25	25	23.0
10	18	18	20	22	17	17	18.0
11	22	25	25	26	20	20	23.5
12	16	17	17	19	18	18	17.5
13	12	12	13	14	11	12	12.0
14	20	16	22	18	16	16	17.0
15	8	7	9	7	7	8	7.5
16	5	11	6	13	8	9	8.5
17	9	9	8	8	10	11	9.0
18	16	21	16	16	19	19	17.5
19	19	28	19	28	28	28	28.0
20	21	26	18	23	27	27	24.5
21	29	29	26	27	29	29	29.0
22	13	13	12	12	12	1	12.0
23	11	8	11	10	9	10	10.0
24	7	6	7	6	6	7	6.5
25	5	5	5	5	5	6	5.0
26	4	4	4	4	4	5	4.0
27	3	3	3	3	3	4	3.0
28	1	1	1	1	2	3	1.0
29	2	2	2	2	1	2	2.0

Appendix F7— Scenario's relative ranking for Northern British Columbia (NBC). See Appendix E1 for maturation rate and environmental variable (MAT-EV) scenario description. 'Best' scenario is highlighted.

SCENARIO	MRE	MAE	MPE	MAPE	RMSE	MSE	Median Rank
1	1.74	1.34	1.64	1.37	1.37	2.12	1.50
2	1.96	1.44	1.79	1.44	1.48	2.47	1.63
3	1.73	1.33	1.61	1.34	1.38	2.15	1.50
4	1.81	1.29	1.65	1.32	1.37	2.09	1.51
5	1.81	1.29	1.65	1.32	1.37	2.09	1.51
6	1.49	1.16	1.40	1.18	1.21	1.65	1.31
7	1.30	1.20	1.30	1.23	1.22	1.67	1.26
8	1.48	1.18	1.36	1.17	1.23	1.70	1.30
9	1.73	1.34	1.52	1.27	1.39	2.18	1.45
10	1.53	1.28	1.50	1.32	1.26	1.79	1.41
11	1.73	1.38	1.64	1.39	1.36	2.07	1.52
12	1.51	1.28	1.48	1.31	1.26	1.79	1.39
13	1.37	1.16	1.36	1.21	1.14	1.47	1.28
14	1.60	1.25	1.53	1.29	1.25	1.76	1.41
15	1.27	1.11	1.27	1.15	1.10	1.37	1.21
16	1.10	1.16	1.19	1.20	1.12	1.42	1.17
17	1.28	1.15	1.27	1.16	1.13	1.45	1.21
18	1.51	1.30	1.42	1.26	1.29	1.86	1.36
19	1.57	1.48	1.49	1.44	1.59	2.83	1.53
20	1.71	1.43	1.48	1.33	1.58	2.80	1.53
21	1.99	1.61	1.64	1.44	1.77	3.54	1.71
22	1.40	1.16	1.35	1.19	1.18	1.00	1.19
23	1.36	1.13	1.34	1.17	1.13	1.42	1.26
24	1.18	1.08	1.20	1.12	1.07	1.28	1.15
25	1.10	1.06	1.13	1.09	1.04	1.22	1.10
26	1.04	1.03	1.06	1.05	1.02	1.16	1.04
27	1.02	1.02	1.04	1.03	1.01	1.15	1.03
28	1.00	1.00	1.00	1.00	1.00	1.13	1.00
29	1.01	1.00	1.02	1.01	1.00	1.12	1.01

Appendix F8— AI error summary statistics for West Coast Vancouver Island (WCVI) (2014–2018). See Appendix E1 for maturation rate and environmental variable (MAT-EV) scenario description.

SCENARIO	MRE	MAE	MPE	MAPE	RMSE	MSE
1	0.202	0.306	24.4%	32.0%	0.328	0.108
2	0.224	0.312	26.0%	32.3%	0.339	0.115
3	0.208	0.304	24.8%	31.8%	0.328	0.108
4	0.194	0.282	22.9%	29.6%	0.303	0.092
5	0.194	0.282	22.9%	29.6%	0.303	0.092
6	0.168	0.264	20.5%	27.7%	0.283	0.080
7	0.172	0.288	21.3%	30.5%	0.305	0.093
8	0.190	0.274	22.7%	29.2%	0.305	0.093
9	0.230	0.31	25.8%	31.7%	0.348	0.121
10	0.164	0.3	21.8%	31.7%	0.313	0.098
11	0.186	0.31	23.4%	32.3%	0.323	0.104
12	0.166	0.298	21.9%	31.5%	0.312	0.097
13	0.134	0.27	18.5%	28.9%	0.280	0.078
14	0.154	0.278	20.0%	29.4%	0.287	0.082
15	0.132	0.264	17.9%	27.9%	0.277	0.077
16	0.138	0.286	18.8%	30.6%	0.297	0.088
17	0.152	0.272	19.8%	29.1%	0.286	0.082
18	0.192	0.308	23.4%	32.0%	0.322	0.104
19	0.192	0.348	22.7%	35.0%	0.404	0.163
20	0.208	0.336	23.1%	33.2%	0.415	0.172
21	0.258	0.374	27.0%	35.5%	0.471	0.222
22	0.166	0.282	20.8%	29.6%	0.293	0.073
23	0.152	0.264	19.8%	28.2%	0.272	0.074
24	0.112	0.248	16.0%	26.3%	0.261	0.068
25	0.096	0.248	14.7%	26.2%	0.267	0.071
26	0.076	0.232	12.4%	24.2%	0.253	0.064
27	0.064	0.224	10.9%	23.1%	0.247	0.061
28	0.070	0.218	10.9%	22.2%	0.237	0.056
29	0.096	0.232	13.9%	24.2%	0.246	0.060

Appendix F9— Scenario's ordinal ranking for West Coast Vancouver Island (WCVI) (2014–2018). See Appendix E1 for maturation rate and environmental variable (MAT-EV) scenario description. 'Best' scenario is highlighted.

SCENARIO	MRE	MAE	MPE	MAPE	RMSE	MSE	Median Rank
1	24	22	25	23	24	24	24.0
2	27	26	28	25	25	25	25.5
3	25	21	26	22	23	23	23.0
4	22	14	20	14	15	15	15.0
5	22	14	20	14	15	15	15.0
6	16	9	13	7	10	11	10.5
7	17	18	15	17	18	18	17.5
8	19	12	18	12	17	17	17.0
9	28	25	27	21	26	26	26.0
10	13	20	16	20	20	20	20.0
11	18	24	23	26	22	22	22.5
12	14	19	17	19	19	19	19.0
13	8	10	8	10	9	10	9.5
14	12	13	12	13	12	13	12.5
15	7	7	7	8	8	9	7.5
16	9	17	9	18	14	14	14.0
17	10	11	11	11	11	12	11.0
18	21	23	24	24	21	21	22.0
19	20	28	19	28	27	27	27.0
20	25	27	22	27	28	28	27.0
21	29	29	29	29	29	29	29.0
22	14	16	14	16	13	7	14.0
23	10	7	10	9	7	8	8.5
24	6	5	6	6	5	5	5.5
25	4	6	5	5	6	6	5.5
26	3	3	3	3	4	4	3.0
27	1	2	1	2	3	3	2.0
28	2	1	2	1	1	1	1.0
29	5	4	4	4	2	2	4.0

Appendix F10— Scenario's relative ranking for West Coast Vancouver Island (WCVI). See Appendix E1 for maturation rate and environmental variable (MAT-EV) scenario description. 'Best' scenario is highlighted.

SCENARIO	MRE	MAE	MPE	MAPE	RMSE	MSE	Median Rank
1	3.16	1.40	2.24	1.44	1.39	1.93	1.69
2	3.50	1.43	2.38	1.46	1.43	2.05	1.76
3	3.25	1.39	2.27	1.43	1.39	1.93	1.68
4	3.03	1.29	2.10	1.34	1.28	1.64	1.49
5	3.03	1.29	2.10	1.34	1.28	1.64	1.49
6	2.63	1.21	1.87	1.25	1.19	1.43	1.34
7	2.69	1.32	1.95	1.38	1.29	1.66	1.52
8	2.97	1.26	2.07	1.32	1.29	1.66	1.49
9	3.59	1.42	2.36	1.43	1.47	2.16	1.81
10	2.56	1.38	1.99	1.43	1.32	1.75	1.59
11	2.91	1.42	2.14	1.46	1.36	1.86	1.66
12	2.59	1.37	2.00	1.42	1.32	1.73	1.58
13	2.09	1.24	1.69	1.31	1.18	1.40	1.35
14	2.41	1.28	1.83	1.33	1.21	1.47	1.40
15	2.06	1.21	1.64	1.26	1.17	1.37	1.31
16	2.16	1.31	1.72	1.38	1.25	1.57	1.48
17	2.38	1.25	1.81	1.31	1.21	1.46	1.39
18	3.00	1.41	2.14	1.44	1.36	1.85	1.65
19	3.00	1.60	2.08	1.58	1.71	2.92	1.89
20	3.25	1.54	2.11	1.50	1.75	3.07	1.93
21	4.03	1.72	2.47	1.60	1.99	3.96	2.23
22	2.59	1.29	1.91	1.34	1.24	1.30	1.32
23	2.38	1.21	1.81	1.28	1.15	1.33	1.30
24	1.75	1.14	1.47	1.19	1.10	1.22	1.20
25	1.50	1.14	1.34	1.18	1.13	1.27	1.23
26	1.19	1.06	1.13	1.09	1.07	1.14	1.11
27	1.00	1.03	1.00	1.04	1.04	1.09	1.03
28	1.09	1.00	1.00	1.00	1.00	1.00	1.00
29	1.50	1.06	1.27	1.09	1.04	1.08	1.09

Appendix F11— Scenario's composite ordinal ranking. See Appendix E1 for maturation rate and environmental variable (MAT-EV) scenario description. 'Best' scenario is highlighted.

	Median Ranks (AI Analysis)			
SCENARIO	**SEAK**	**NBC**	**WCVI**	**Composite**
1	20.5	23.5	24.0	68.0
2	28.0	27.5	25.5	81.0
3	19.0	23.5	23.0	65.5
4	24.0	21.0	15.0	60.0
5	24.0	21.0	15.0	60.0
6	10.0	13.0	10.5	33.5
7	20.0	14.0	17.5	51.5
8	13.0	14.0	17.0	44.0
9	21.5	23.0	26.0	70.5
10	16.0	18.0	20.0	54.0
11	26.5	23.5	22.5	72.5
12	16.5	17.5	19.0	53.0
13	12.0	12.0	9.5	33.5
14	21.0	17.0	12.5	50.5
15	7.0	7.5	7.5	22.0
16	15.5	8.5	14.0	38.0
17	11.0	9.0	11.0	31.0
18	17.5	17.5	22.0	57.0
19	28.0	28.0	27.0	83.0
20	15.0	24.5	27.0	66.5
21	27.0	29.0	29.0	85.0
22	9.0	12.0	14.0	35.0
23	8.0	10.0	8.5	26.5
24	6.0	6.5	5.5	18.0
25	5.5	5.0	5.5	16.0
26	4.0	4.0	3.0	11.0
27	3.0	3.0	2.0	8.0
28	1.0	1.0	1.0	3.0
29	2.0	2.0	4.0	8.0

Appendix F12— Scenario's composite relative ranking. See Appendix E1 for maturation rate and environmental variable (MAT-EV) scenario description. 'Best' scenario is highlighted.

	Median Ranks (AI Analysis)			
SCENARIO	**SEAK**	**NBC**	**WCVI**	**Composite**
1	1.32	1.50	1.69	4.51
2	1.50	1.63	1.76	4.89
3	1.30	1.50	1.68	4.48
4	1.38	1.51	1.49	4.37
5	1.38	1.51	1.49	4.37
6	1.10	1.31	1.34	3.74
7	1.28	1.26	1.52	4.07
8	1.16	1.30	1.49	3.94
9	1.29	1.45	1.81	4.56
10	1.28	1.41	1.59	4.29
11	1.46	1.52	1.66	4.64
12	1.27	1.39	1.58	4.24
13	1.12	1.28	1.35	3.76
14	1.33	1.41	1.40	4.14
15	1.06	1.21	1.31	3.58
16	1.25	1.17	1.48	3.89
17	1.11	1.21	1.39	3.71
18	1.25	1.36	1.65	4.26
19	1.41	1.53	1.89	4.84
20	1.24	1.53	1.93	4.70
21	1.41	1.71	2.23	5.34
22	1.07	1.19	1.32	3.58
23	1.08	1.26	1.30	3.64
24	1.04	1.15	1.20	3.40
25	1.04	1.10	1.23	3.36
26	1.02	1.04	1.11	3.17
27	1.01	1.03	1.03	3.08
28	1.00	1.00	1.00	3.00
29	1.00	1.01	1.09	3.10

APPENDIX G. PARTIAL COHORT (PCOH) ERROR SUMMARY STATISTICS AND SCENARIO RANKINGS FOR AGGREGATE ABUNDANCE-BASED MANAGEMENT FISHERIES BASED ON THE 2014–2018 TIME SERIES OF ERRORS

Appendix G1— Partial cohort (PCOH) error summary statistics for Southeast Alaska (SEAK) (2014–2018). See Appendix E1 for maturation rate and environmental variable (MAT-EV) scenario description.

SCENARIO	MRE	MAE	MPE	MAPE	RMSE	MSE
1	108815	125935	28.7%	32.2%	148222	21969749719
2	129007	140068	33.2%	35.5%	168137	28269910069
3	108944	126250	28.2%	31.7%	151379	22915521078
4	117143	129824	29.6%	32.2%	159779	25529197630
5	117143	129824	29.6%	32.2%	159779	25529197630
6	89518	109148	23.1%	27.2%	130537	17039794920
7	97870	130689	26.7%	33.4%	150297	22589243123
8	98079	111198	24.4%	26.9%	135944	18480641134
9	112923	126820	26.4%	29.0%	156963	24637334964
10	103937	123934	27.9%	31.9%	142598	20334134237
11	123712	137848	32.3%	35.2%	161974	26235706108
12	104155	124328	27.5%	31.5%	145672	21220269417
13	90631	112730	23.9%	28.4%	132221	17482330780
14	111938	127720	28.7%	31.9%	153667	23613597727
15	84914	107435	22.4%	27.0%	125157	15664286054
16	92525	128112	25.8%	33.1%	144104	20766017402
17	92935	109236	23.6%	26.8%	129846	16859981049
18	107473	124679	25.6%	28.8%	150448	22634629887
19	107161	145818	28.2%	36.1%	171498	29411733642
20	103629	123187	24.8%	28.6%	153714	23627946831
21	118986	139095	26.8%	30.5%	176492	31149470374
22	88268	110037	23.0%	27.5%	129558	13075898396
23	86931	108290	22.9%	27.3%	126305	15953027954
24	82893	106001	21.9%	26.6%	123138	15163009226
25	81579	105734	21.6%	26.5%	122396	14980853377
26	80238	104466	21.2%	26.1%	121151	14677558646
27	79612	103948	20.9%	25.9%	120958	14630795822
28	79544	103439	20.8%	25.6%	121034	14649236948
29	79773	103422	20.9%	25.8%	120569	14536967122

Appendix G2— Scenario's ordinal ranking for Southeast Alaska (SEAK) (2014–2018). See Appendix E1 for maturation rate and environmental variable (MAT-EV) scenario description. 'Best' scenario is highlighted.

SCENARIO	MRE	MAE	MPE	MAPE	RMSE	MSE	Median Rank
1	21	18	24	22	17	17	19.5
2	29	28	29	28	27	27	28.0
3	22	19	23	19	20	20	20.0
4	25	23	26	23	24	24	24.0
5	25	23	26	23	24	24	24.0
6	10	9	10	10	11	11	10.0
7	14	25	18	26	18	18	18.0
8	15	12	13	8	13	13	13.0
9	24	20	17	16	23	23	21.5
10	17	15	21	21	14	14	16.0
11	28	26	28	27	26	26	26.5
12	18	16	20	18	16	16	17.0
13	11	13	12	13	12	12	12.0
14	23	21	25	20	21	21	21.0
15	7	7	7	9	7	8	7.0
16	12	22	16	25	15	15	15.5
17	13	10	11	7	10	10	10.0
18	20	17	15	15	19	19	18.0
19	19	29	22	29	28	28	28.0
20	16	14	14	14	22	22	15.0
21	27	27	19	17	29	29	27.0
22	9	11	9	12	9	1	9.0
23	8	8	8	11	8	9	8.0
24	6	6	6	6	6	7	6.0
25	5	5	5	5	5	6	5.0
26	4	4	4	4	4	5	4.0
27	2	3	2	3	2	3	2.5
28	1	2	1	1	3	4	1.5
29	3	1	3	2	1	2	2.0

Appendix G3— Scenario's relative ranking for Southeast Alaska (SEAK). See Appendix E1 for maturation rate and environmental variable (MAT-EV) scenario description. 'Best' scenario is highlighted.

SCENARIO	MRE	MAE	MPE	MAPE	RMSE	MSE	Median Rank
1	1.37	1.22	1.38	1.25	1.23	1.68	1.31
2	1.62	1.35	1.60	1.38	1.39	2.16	1.50
3	1.37	1.22	1.36	1.24	1.26	1.75	1.31
4	1.47	1.26	1.43	1.25	1.33	1.95	1.38
5	1.47	1.26	1.43	1.25	1.33	1.95	1.38
6	1.13	1.06	1.11	1.06	1.08	1.30	1.10
7	1.23	1.26	1.28	1.30	1.25	1.73	1.27
8	1.23	1.08	1.17	1.05	1.13	1.41	1.15
9	1.42	1.23	1.27	1.13	1.30	1.88	1.29
10	1.31	1.20	1.34	1.25	1.18	1.56	1.28
11	1.56	1.33	1.56	1.37	1.34	2.01	1.46
12	1.31	1.20	1.32	1.23	1.21	1.62	1.27
13	1.14	1.09	1.15	1.11	1.10	1.34	1.12
14	1.41	1.23	1.38	1.24	1.27	1.81	1.33
15	1.07	1.04	1.08	1.05	1.04	1.20	1.06
16	1.16	1.24	1.24	1.29	1.20	1.59	1.24
17	1.17	1.06	1.14	1.04	1.08	1.29	1.11
18	1.35	1.21	1.23	1.12	1.25	1.73	1.24
19	1.35	1.41	1.36	1.41	1.42	2.25	1.41
20	1.30	1.19	1.19	1.11	1.27	1.81	1.23
21	1.50	1.34	1.29	1.19	1.46	2.38	1.40
22	1.11	1.06	1.11	1.07	1.07	1.00	1.07
23	1.09	1.05	1.10	1.06	1.05	1.22	1.08
24	1.04	1.02	1.05	1.04	1.02	1.16	1.04
25	1.03	1.02	1.04	1.03	1.02	1.15	1.03
26	1.01	1.01	1.02	1.02	1.00	1.12	1.01
27	1.00	1.01	1.01	1.01	1.00	1.12	1.01
28	1.00	1.00	1.00	1.00	1.00	1.12	1.00
29	1.00	1.00	1.01	1.00	1.00	1.11	1.00

Appendix G4— Partial cohort (PCOH) error summary statistics for Northern British Columbia (NBC) (2014–2018). See Appendix E1 for maturation rate and environmental variable (MAT-EV) scenario description.

SCENARIO	MRE	MAE	MPE	MAPE	RMSE	MSE
1	70038	92042	31.6%	38.0%	103736	10761131696
2	78932	98693	34.6%	40.2%	112079	12561619465
3	69445	91259	31.0%	37.3%	104600	10941115899
4	72737	88837	31.9%	36.7%	103307	10672308575
5	72737	88837	31.9%	36.7%	103307	10672308575
6	59124	79070	26.8%	32.8%	91322	8339784150
7	52543	82961	25.3%	34.3%	92483	8553034873
8	59903	81194	26.6%	32.7%	93393	8722266551
9	70400	92959	29.8%	35.8%	106380	11316693587
10	61203	88377	29.0%	36.8%	95359	9093284775
11	69556	94728	31.8%	38.9%	102892	10586686247
12	60623	87666	28.4%	36.2%	95927	9202015803
13	55337	79141	26.4%	33.5%	86446	7472919224
14	64083	85666	29.4%	35.8%	94495	8929241061
15	50998	76187	24.5%	32.0%	83510	6973940788
16	44485	79794	23.1%	33.5%	85410	7294854287
17	51350	78195	24.3%	32.0%	85352	7284957294
18	60967	89413	27.3%	35.0%	97354	9477878420
19	63536	101951	28.7%	40.1%	120455	14509306329
20	68403	97898	28.5%	36.9%	119252	14220929855
21	80224	110804	31.9%	40.1%	134251	18023388598
22	56860	79847	26.3%	33.2%	89804	5110241839
23	54358	77296	25.7%	32.6%	85168	7253663016
24	47478	74243	23.1%	31.1%	80787	6526505946
25	44710	73274	22.0%	30.5%	79275	6284506061
26	42122	71278	20.7%	29.4%	77340	5981439160
27	40723	70058	19.9%	28.7%	76518	5854943962
28	40265	69003	19.4%	27.9%	76234	5811553995
29	40541	68967	19.7%	28.1%	75697	5729971702

Appendix G5— Scenario's ordinal ranking for Northern British Columbia (NBC) (2014–2018). See Appendix E1 for maturation rate and environmental variable (MAT-EV) scenario description. 'Best' scenario is highlighted.

SCENARIO	MRE	MAE	MPE	MAPE	RMSE	MSE	Median Rank
1	24	23	24	25	23	23	23.5
2	28	27	29	29	26	26	27.5
3	22	22	23	24	24	24	23.5
4	26	19	26	20	21	21	21.0
5	26	19	26	20	21	21	21.0
6	14	10	15	11	13	13	13.0
7	10	15	10	15	14	14	14.0
8	15	14	14	10	15	15	14.5
9	25	24	22	18	25	25	24.5
10	18	18	20	22	17	17	18.0
11	23	25	25	26	20	20	24.0
12	16	17	17	19	18	18	17.5
13	12	11	13	14	11	12	12.0
14	20	16	21	17	16	16	16.5
15	8	7	9	8	7	8	8.0
16	5	12	7	13	10	11	10.5
17	9	9	8	7	9	10	9.0
18	17	21	16	16	19	19	18.0
19	19	28	19	27	28	28	27.5
20	21	26	18	23	27	27	24.5
21	29	29	28	28	29	29	29.0
22	13	13	12	12	12	1	12.0
23	11	8	11	9	8	9	9.0
24	7	6	6	6	6	7	6.0
25	6	5	5	5	5	6	5.0
26	4	4	4	4	4	5	4.0
27	3	3	3	3	3	4	3.0
28	1	2	1	1	2	3	1.5
29	2	1	2	2	1	2	2.0

Appendix G6— Scenario's relative ranking for Northern British Columbia (NBC). See Appendix E1 for maturation rate and environmental variable (MAT-EV) scenario description. 'Best' scenario is highlighted.

SCENARIO	MRE	MAE	MPE	MAPE	RMSE	MSE	Median Rank
1	1.74	1.33	1.63	1.36	1.37	2.11	1.50
2	1.96	1.43	1.78	1.44	1.48	2.46	1.63
3	1.72	1.32	1.60	1.33	1.38	2.14	1.49
4	1.81	1.29	1.65	1.31	1.36	2.09	1.51
5	1.81	1.29	1.65	1.31	1.36	2.09	1.51
6	1.47	1.15	1.38	1.17	1.21	1.63	1.29
7	1.30	1.20	1.31	1.23	1.22	1.67	1.27
8	1.49	1.18	1.37	1.17	1.23	1.71	1.30
9	1.75	1.35	1.54	1.28	1.41	2.21	1.47
10	1.52	1.28	1.50	1.32	1.26	1.78	1.41
11	1.73	1.37	1.64	1.39	1.36	2.07	1.52
12	1.51	1.27	1.46	1.29	1.27	1.80	1.38
13	1.37	1.15	1.36	1.20	1.14	1.46	1.28
14	1.59	1.24	1.52	1.28	1.25	1.75	1.40
15	1.27	1.10	1.26	1.14	1.10	1.36	1.20
16	1.10	1.16	1.19	1.20	1.13	1.43	1.17
17	1.28	1.13	1.25	1.14	1.13	1.43	1.20
18	1.51	1.30	1.41	1.25	1.29	1.85	1.35
19	1.58	1.48	1.48	1.43	1.59	2.84	1.53
20	1.70	1.42	1.47	1.32	1.58	2.78	1.52
21	1.99	1.61	1.65	1.44	1.77	3.53	1.71
22	1.41	1.16	1.36	1.19	1.19	1.00	1.19
23	1.35	1.12	1.33	1.17	1.13	1.42	1.25
24	1.18	1.08	1.19	1.11	1.07	1.28	1.15
25	1.11	1.06	1.14	1.09	1.05	1.23	1.10
26	1.05	1.03	1.07	1.05	1.02	1.17	1.05
27	1.01	1.02	1.03	1.03	1.01	1.15	1.02
28	1.00	1.00	1.00	1.00	1.01	1.14	1.00
29	1.01	1.00	1.01	1.01	1.00	1.12	1.01

Appendix G7— Partial cohort (PCOH) error summary statistics for West Coast Vancouver Island (WCVI) (2014–2018). See Appendix E1 for maturation rate and environmental variable (MAT-EV) scenario description.

SCENARIO	MRE	MAE	MPE	MAPE	RMSE	MSE
1	69177	104697	24.2%	31.7%	112538	12664755654
2	77990	108352	26.2%	32.5%	117374	13776713880
3	71204	104480	24.6%	31.6%	112622	12683760106
4	66507	97109	22.8%	29.5%	104457	10911249250
5	66507	97109	22.8%	29.5%	104457	10911249250
6	58462	90918	20.6%	27.8%	97616	9528966109
7	59233	99184	21.3%	30.5%	105121	11050368279
8	65070	94083	22.4%	28.9%	105099	11045725786
9	79027	106642	25.7%	31.6%	119654	14317025196
10	55662	103278	21.5%	31.5%	107849	11631367111
11	63946	107052	23.4%	32.4%	111402	12410296906
12	57362	103335	21.9%	31.5%	107877	11637483753
13	46403	93260	18.5%	29.0%	96580	9327634756
14	54036	96709	20.3%	29.7%	99932	9986400116
15	45941	90616	18.1%	27.9%	94964	9018174061
16	47974	98856	18.9%	30.6%	102507	10507691388
17	52523	93994	19.8%	29.2%	98942	9789451464
18	64816	105735	22.9%	31.7%	110901	12299130847
19	66662	119959	22.8%	35.0%	139630	19496673144
20	70942	115089	22.8%	32.9%	142206	20222507766
21	89268	128627	27.0%	35.4%	161781	26173041366
22	57184	96932	20.8%	29.6%	100529	8538814316
23	52205	89970	19.7%	28.0%	92912	8632630472
24	38597	85089	16.0%	26.2%	89844	8072014284
25	32585	83844	14.4%	25.7%	90449	8181059866
26	26095	79546	12.3%	24.0%	86954	7560915183
27	23154	77542	11.2%	23.2%	85281	7272767445
28	24339	74533	10.9%	22.0%	80729	6517234145
29	32125	78786	13.5%	23.8%	83882	7036176209

Appendix G8— Scenario's ordinal ranking for West Coast Vancouver Island (WCVI) (2014–2018). See Appendix E1 for maturation rate and environmental variable (MAT-EV) scenario description. 'Best' scenario is highlighted.

SCENARIO	MRE	MAE	MPE	MAPE	RMSE	MSE	Median Rank
1	24	22	25	23	23	23	23.0
2	27	26	28	26	25	25	26.0
3	26	21	26	21	24	24	24.0
4	21	15	19	13	15	15	15.0
5	21	15	19	13	15	15	15.0
6	16	9	13	7	10	11	10.5
7	17	18	15	17	18	18	17.5
8	20	12	18	10	17	17	17.0
9	28	24	27	22	26	26	26.0
10	13	19	16	20	19	19	19.0
11	18	25	24	25	22	22	23.0
12	15	20	17	19	20	20	19.5
13	8	10	8	11	9	10	9.5
14	12	13	12	16	12	13	12.5
15	7	8	7	8	8	9	8.0
16	9	17	9	18	14	14	14.0
17	11	11	11	12	11	12	11.0
18	19	23	23	24	21	21	22.0
19	23	28	22	28	27	27	27.0
20	25	27	21	27	28	28	27.0
21	29	29	29	29	29	29	29.0
22	14	14	14	15	13	7	14.0
23	10	7	10	9	7	8	8.5
24	6	6	6	6	5	5	6.0
25	5	5	5	5	6	6	5.0
26	3	4	3	4	4	4	4.0
27	1	2	2	2	3	3	2.0
28	2	1	1	1	1	1	1.0
29	4	3	4	3	2	2	3.0

Appendix G9— Scenario's relative ranking for West Coast Vancouver Island (WCVI). See Appendix E1 for maturation rate and environmental variable (MAT-EV) scenario description. 'Best' scenario is highlighted.

SCENARIO	MRE	MAE	MPE	MAPE	RMSE	MSE	Median Rank
1	2.99	1.40	2.22	1.44	1.39	1.94	1.69
2	3.37	1.45	2.40	1.48	1.45	2.11	1.80
3	3.08	1.40	2.25	1.44	1.40	1.95	1.69
4	2.87	1.30	2.09	1.34	1.29	1.67	1.51
5	2.87	1.30	2.09	1.34	1.29	1.67	1.51
6	2.52	1.22	1.89	1.26	1.21	1.46	1.36
7	2.56	1.33	1.95	1.39	1.30	1.70	1.54
8	2.81	1.26	2.05	1.32	1.30	1.69	1.51
9	3.41	1.43	2.36	1.44	1.48	2.20	1.84
10	2.40	1.39	1.97	1.43	1.34	1.78	1.61
11	2.76	1.44	2.15	1.48	1.38	1.90	1.69
12	2.48	1.39	2.00	1.43	1.34	1.79	1.61
13	2.00	1.25	1.70	1.32	1.20	1.43	1.37
14	2.33	1.30	1.86	1.35	1.24	1.53	1.44
15	1.98	1.22	1.65	1.27	1.18	1.38	1.33
16	2.07	1.33	1.73	1.39	1.27	1.61	1.50
17	2.27	1.26	1.81	1.33	1.23	1.50	1.41
18	2.80	1.42	2.10	1.44	1.37	1.89	1.67
19	2.88	1.61	2.09	1.60	1.73	2.99	1.91
20	3.06	1.54	2.09	1.50	1.76	3.10	1.93
21	3.86	1.73	2.48	1.61	2.00	4.02	2.24
22	2.47	1.30	1.91	1.35	1.25	1.31	1.33
23	2.25	1.21	1.80	1.27	1.15	1.32	1.30
24	1.67	1.14	1.46	1.19	1.11	1.24	1.22
25	1.41	1.12	1.32	1.17	1.12	1.26	1.21
26	1.13	1.07	1.12	1.09	1.08	1.16	1.11
27	1.00	1.04	1.02	1.05	1.06	1.12	1.05
28	1.05	1.00	1.00	1.00	1.00	1.00	1.00
29	1.39	1.06	1.24	1.08	1.04	1.08	1.08

Appendix G10— Scenario's composite ordinal ranking. See Appendix E1 for maturation rate and environmental variable (MAT-EV) scenario description. 'Best' scenario is highlighted.

	Median Ranks (PCOH Analysis)			
SCENARIO	**SEAK**	**NBC**	**WCVI**	**Composite**
1	19.5	23.5	23	66.0
2	28	27.5	26	81.5
3	20	23.5	24	67.5
4	24	21	15	60.0
5	24	21	15	60.0
6	10	13	10.5	33.5
7	18	14	17.5	49.5
8	13	14.5	17	44.5
9	21.5	24.5	26	72.0
10	16	18	19	53.0
11	26.5	24	23	73.5
12	17	17.5	19.5	54.0
13	12	12	9.5	33.5
14	21	16.5	12.5	50.0
15	7	8	8	23.0
16	15.5	10.5	14	40.0
17	10	9	11	30.0
18	18	18	22	58.0
19	28	27.5	27	82.5
20	15	24.5	27	66.5
21	27	29	29	85.0
22	9	12	14	35.0
23	8	9	8.5	25.5
24	6	6	6	18.0
25	5	5	5	15.0
26	4	4	4	12.0
27	2.5	3	2	7.5
28	1.5	1.5	1	4.0
29	2	2	3	7.0

Appendix G11— Scenario's composite relative ranking. See Appendix E1 for maturation rate and environmental variable (MAT-EV) scenario description. 'Best' scenario is highlighted.

	Median Ranks (PCOH Analysis)			
SCENARIO	**SEAK**	**NBC**	**WCVI**	**Composite**
1	1.31	1.50	1.69	4.51
2	1.50	1.63	1.80	4.93
3	1.31	1.49	1.69	4.49
4	1.38	1.51	1.51	4.39
5	1.38	1.51	1.51	4.39
6	1.10	1.29	1.36	3.76
7	1.27	1.27	1.54	4.08
8	1.15	1.30	1.51	3.96
9	1.29	1.47	1.84	4.60
10	1.28	1.41	1.61	4.29
11	1.46	1.52	1.69	4.67
12	1.27	1.38	1.61	4.26
13	1.12	1.28	1.37	3.78
14	1.33	1.40	1.44	4.17
15	1.06	1.20	1.33	3.59
16	1.24	1.17	1.50	3.92
17	1.11	1.20	1.41	3.72
18	1.24	1.35	1.67	4.26
19	1.41	1.53	1.91	4.85
20	1.23	1.52	1.93	4.68
21	1.40	1.71	2.24	5.36
22	1.07	1.19	1.33	3.59
23	1.08	1.25	1.30	3.63
24	1.04	1.15	1.22	3.40
25	1.03	1.10	1.21	3.34
26	1.01	1.05	1.11	3.17
27	1.01	1.02	1.05	3.07
28	1.00	1.00	1.00	3.00
29	1.00	1.01	1.08	3.09

APPENDIX H. ASSESSMENT OF PHASE II PACIFIC SALMON COMMISSION CHINOOK MODEL

The Chinook Interface Group (CIG) directed the CTC to evaluate the merits of the phase II PSC Chinook Model utilizing the updated base period calibration in a memo dated February 19, 2016. This memo identified eight items that the CTC should use to assess the merits of the model. These eight items are shown in Appendix H1.

Appendix A. Task 1 Response – CTC Model Phase 2 Comparison/Evaluation Diagnostics

1. **Abundance Indices**
2. **Retrospective Exercise**
3. **Brook-year exploitation rate by stock, age and fishery between models and CWTs.**
    a. **Evaluate by terminal and pre-terminal**
4. **Comparison of stock composition between models.**
    a. **Compare to GSI data where available.**
5. **Comparison of terminal runs and escapement.**
6. **Cohort sizes.**
7. **Catches.**
8. **EVs**
    a. **Time series.**
    b. **Correlation with CWT survival indices.**

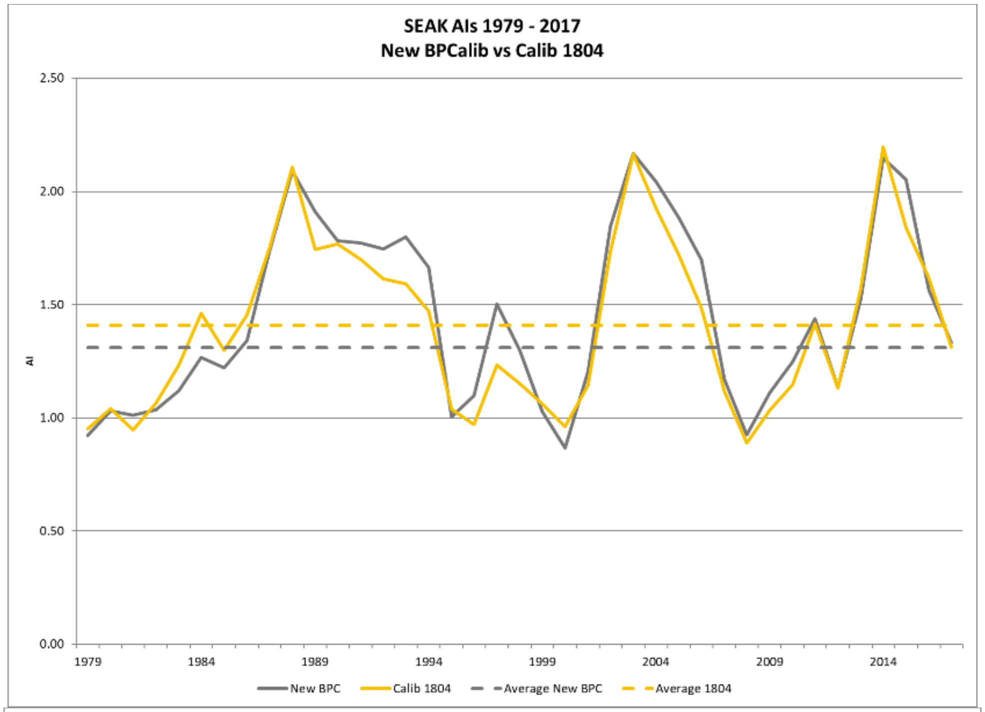
Appendix H1— Eight assessment items used to assess the merits of the phase II Model Calibration.

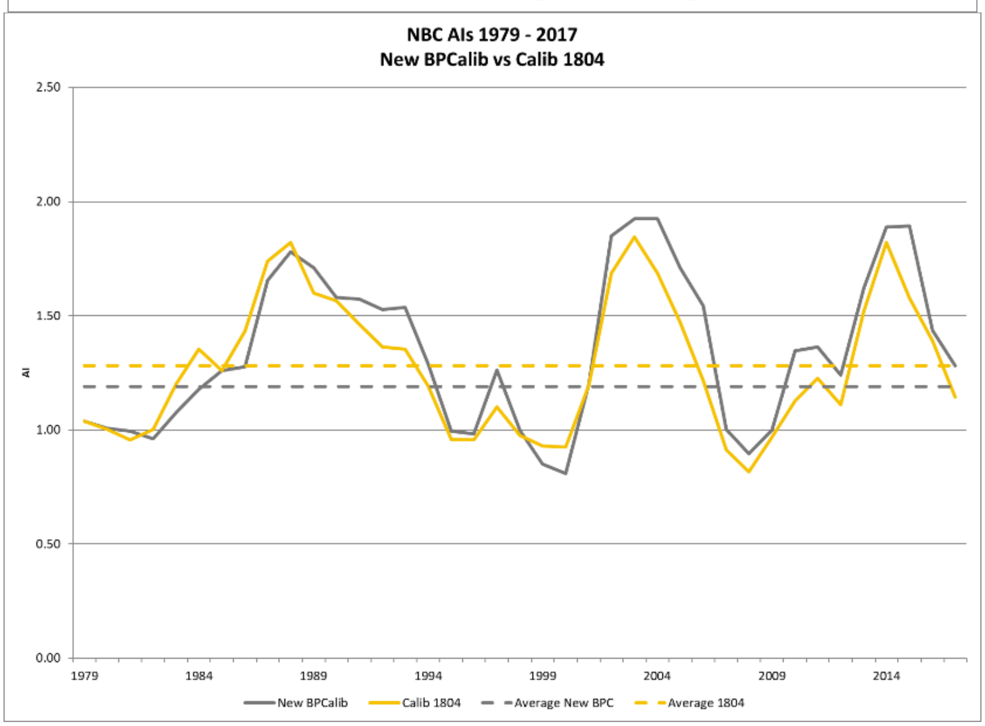
Evaluation of these eight items took place several times and informed the CTC's decision to recommend the model to the CIG. This appendix documents the final assessment that took place on calibration "BPC V125 AC6". The full assessment document for item 4, "Comparison of stock composition between models" is provided in CTC 2021a. Additionally, a statistical evaluation combining information from all eight assessment items is provided. For the sake of brevity, full assessment documentation for items 1–3 and 5–8 are not provided, but brief examples for each are given. Because updates to this model were made after this last assessment occurred, this Appendix finishes with a brief description of model changes from the phase II PSC Chinook Model version control file. These changes cover all model iterations prior to using the phase II Model for setting annual catch limits in 2020.

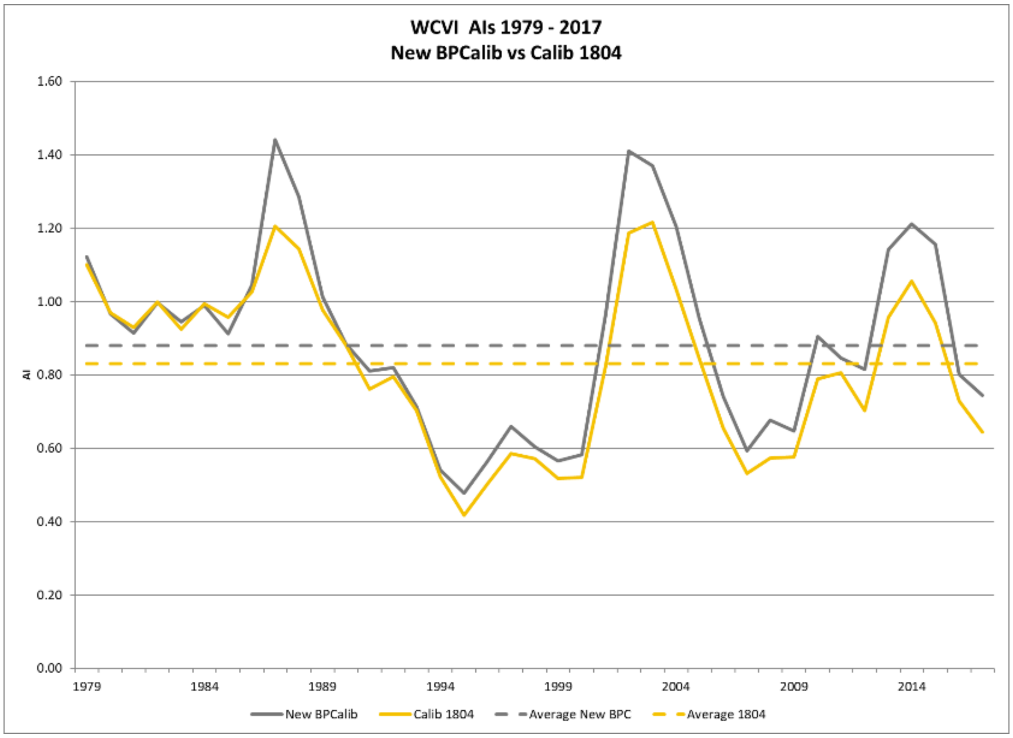
<u>ASSESSMENT ITEM 1. ABUNDANCE INDICES</u>

The phase II Model, utilizing the updated base period calibration, resulted in a new set of AIs for all AABM fisheries. This assessment item compared AIs in SEAK, NBC and WCVI troll AABM fisheries and also outlined the various approaches to translate Table 1 (Chapter 3 of the 2019 PST Agreement) catches once a new time series of AIs and SPFIs were generated.

Visual comparisons of AIs were generated for each AABM fishery. Generally, the AIs produced by both the 9806 version and phase II Model are similar and the phase II Model appears to reflect increases and decreases in abundance as estimated by the previous model calibration. For SEAK and NBC, on average, the new model estimates of AI are ~7% less than values from CLB1804 whereas for WCVI, the new model AIs are on average greater by ~6%.







Appendix H2— Abundance Index (AI) comparison between Model Calibration 1804 and the phase II calibration for Southeast Alaska (SEAK, top), Northern British Columbia (NBC, center), and West Coast Vancouver Island (WCVI, bottom).

Underlying Table 1 in Chapter 3 of the 2019 PST Agreement is a series of equations that relate catch, abundance, and harvest rate. New time series of AIs and new SPFIs from phase II raises the question about how best to translate Table 1. Four methods were developed. Each method is similar in that in the equation, two of the three variables are held constant – troll catch (TrC), abundance (AI), and harvest rate (HRI) – and then the equation is rearranged to solve for the third *unknown* variable. These four methods are:

1. Maintain the HRI-AI relationship and allow catch to change
2. Maintain the catch-AI relationship and allow HRI to change
    a. The new model AI time series is used verbatim
    b. The new model AI time series is adjusted
3. Maintain the catch-HRI relationship and allow AI to change

The equations that underlie Table 1 are:

$$HRI = \frac{TrC}{e^{PC} * AI}$$

and

$$TrC = HRI * e^{PC} * AI$$

and

$$AI = \frac{TrC}{e^{PC} * HRI}$$

and

$$\overline{PC} = \frac{1}{n} * \left[\sum_{i=1985}^{1997} \ln\left(\frac{TrC_i}{AI_i * SPFI_i} \right) \right]$$

and for SEAK

$$AC_{SEAK} = 17{,}000 + \frac{TrC}{0.8}$$

and for NBC

$$AC_{NBC} = \frac{TrC}{0.8}$$

and for WCVI

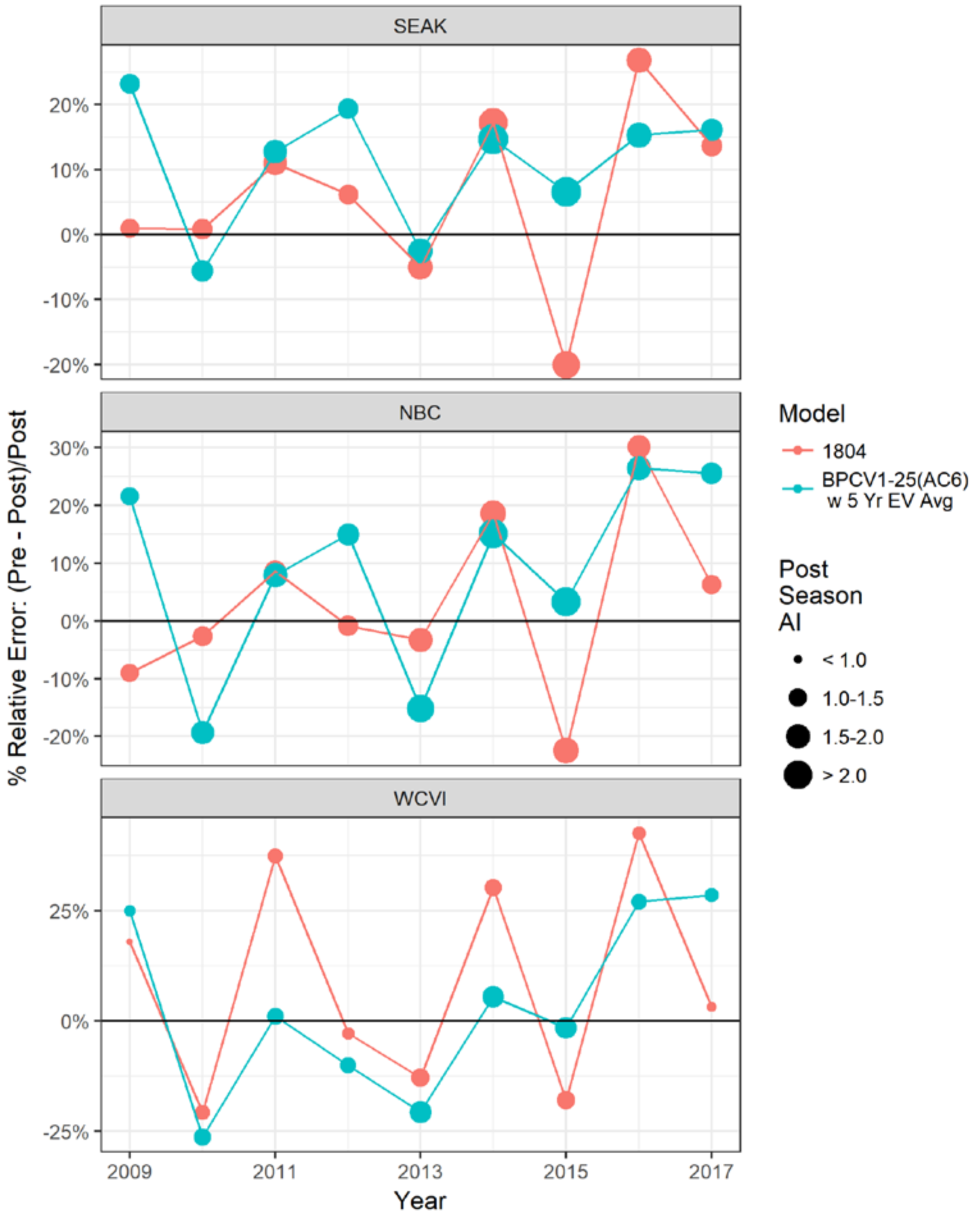
$$AC_{WCVI} = \frac{TrC}{0.8}$$

where $\overline{PC}$ is the 2009–2015 average proportionality constant. As the variable name would imply, the average proportionality constant acts as a scalar in the functional relationship between catch, abundance, and harvest rate. Hence, for each method, if the $\overline{PC}$ in the new model (phase II) increases relative to the PC in the current model (9806), the expected result of this change would be:

- Method 1: increase allowable catch
- Methods 2a and 2b: decrease the HRI
- Method 3: decrease the AI

ASSESSMENT ITEM 2. RETROSPECTIVE EXERCISE

This assessment item determined whether the 9806 Model or phase II Model resulted in smaller deviations between the pre- and post-season AIs. Because agency supplied pre-season forecasts are extremely influential to the pre-season AI, these forecasts were removed from this evaluation and each model forecasted the return of each stock. The results were mixed. Additionally, the interpretation of the results depends on the perspective of the direction of error with relation to the magnitude of the AI.



Appendix H3— Deviations between pre- and post-season abundance indices (AIs) estimated by the 9806 Model and phase II Model for Southeast Alaska (SEAK, top), Northern British Columbia (NBC, center), and West Coast Vancouver Island (WCVI, bottom).

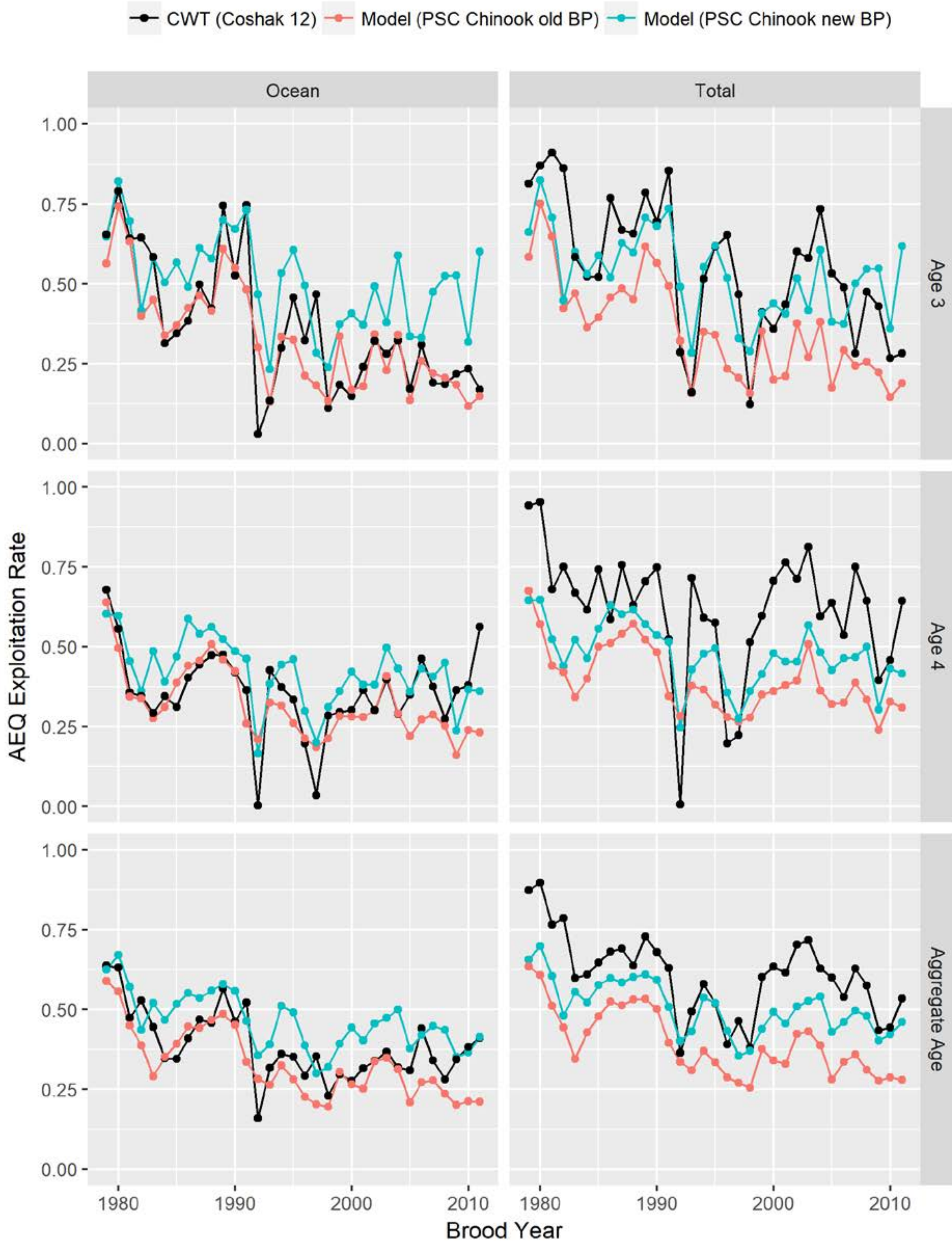
ASSESSMENT ITEM 3. BROOD YEAR EXPLOITATION RATES

This assessment compared CWT derived ERs from Coshak to 9806 and phase II Model derived ERs. This assessment was used as a diagnostic tool for each model and was also used as a performance tool. Drastically different CWT and model-based estimates of ER prompted further investigation to aspects controlling model-based ERs (e.g., FPs). One model's ERs providing better alignment with CWT derived ERs indicated preference for that model. These evaluations were conducted on a stock-specific basis.

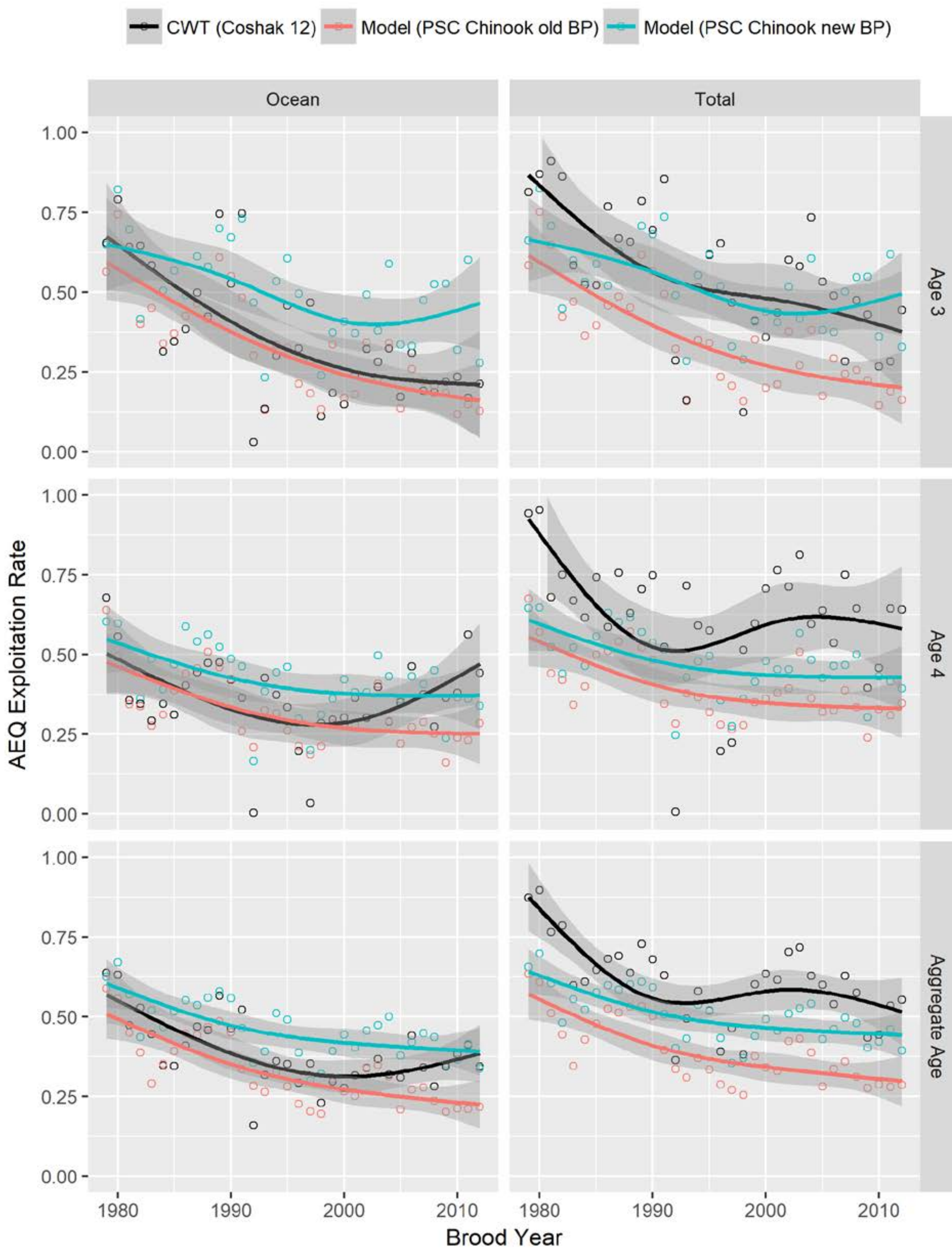
Each stock-specific evaluation consisted of three pages with six graphs each arranged in two columns and three rows displaying a time series of brood year simple exploitation rates. An example set of plots is provided for the WCVI Hatchery stock. The left column displayed adult equivalent (AEQ)-adjusted ocean (i.e., preterminal) ERs summed across preterminal fisheries. The right column displayed the total (preterminal and terminal) ERs summed across all fisheries. The first page of graphs displayed the actual calculated values connected by straight line segments (Appendix H4). The second page of graphs displayed the actual calculated values and a smoothed trend line generated by a spline function passing through the points (Appendix H5). The third page of graphs showed a scatterplot of ERs with the corresponding one-to-one line (Appendix H6).

Preterminal fishery rates were adjusted for brood and age-specific adult equivalency. The top row displayed ERs for the next-to-youngest age class, the middle row displayed ERs for the next-to-oldest age class and the bottom row displayed the total for all ages by brood.

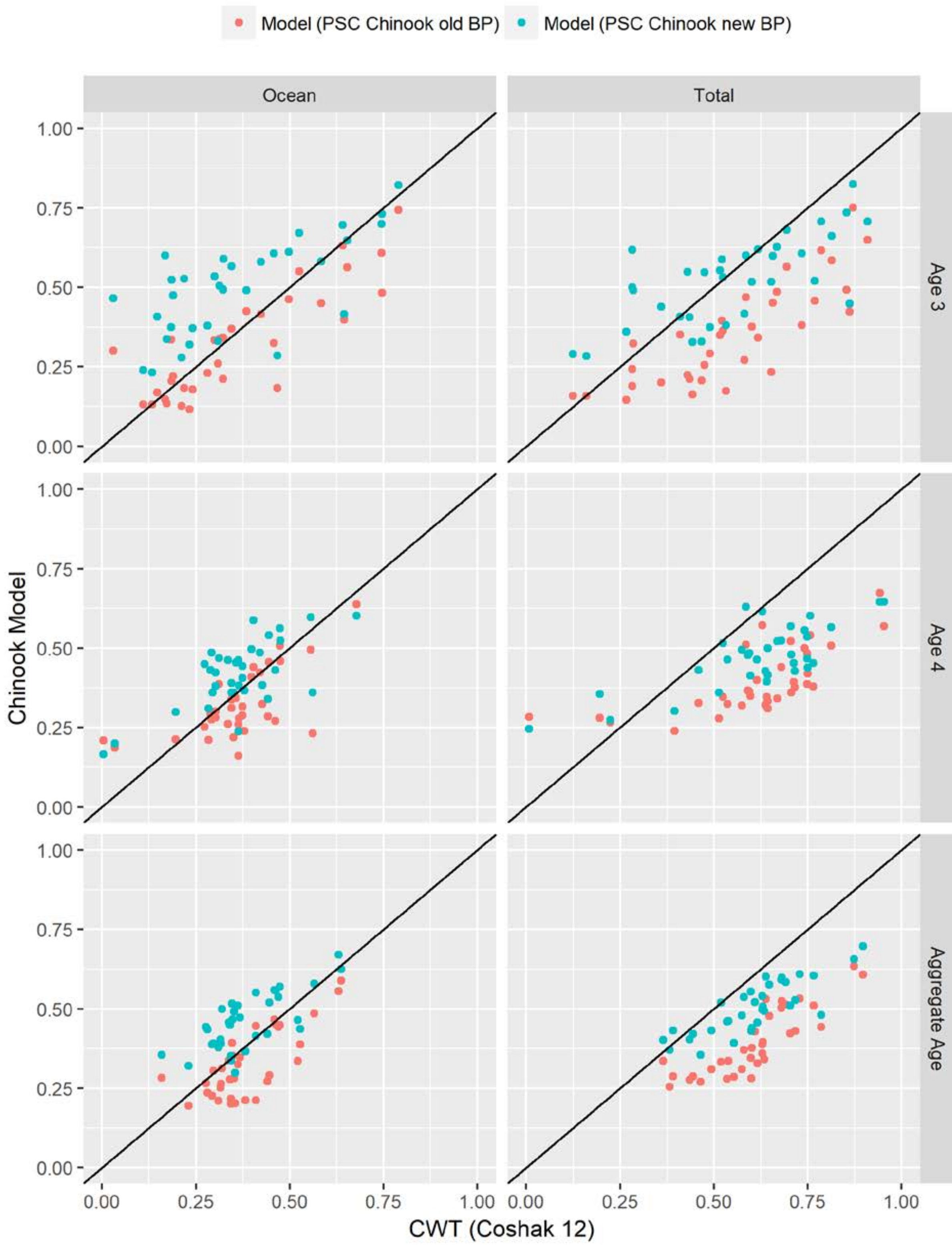
The model ERs were calculated using data from the CCC file. The CWT-based estimates were taken directly from cohort analysis output in the 'THRC.CSV' output files generated using Coshak. In each case, the preterminal estimates did not include the mortalities occurring in the ocean net fisheries at the 'mature net ages' for each stock but these mortalities are included in the total ERs. The preterminal and terminal fishery impacts can differ depending on the stock due to a difference in the treatment of certain impacts in marine sport fisheries. In the annual ERA, certain marine sport mortalities considered terminal for a specific stock are grouped under the terminal fishery category whereas in the model calibration procedure, these fishery mortalities are grouped under the preterminal fishery category. The difference in sorting of sport impacts into preterminal versus terminal categories can cause deviations between ERs based on the model and CWTs.



Appendix H4— Actual calculated values of adult equivalent (AEQ)-adjusted ocean exploitation rates summed across preterminal fisheries (left column), and total (preterminal and terminal) exploitation rates summed across all fisheries.



Appendix H5— Actual calculated values presented with a smoothed trend line of adult equivalent (AEQ)-adjusted ocean exploitation rates summed across preterminal fisheries (left column) and total (preterminal and terminal) exploitation rates summed across all fisheries.

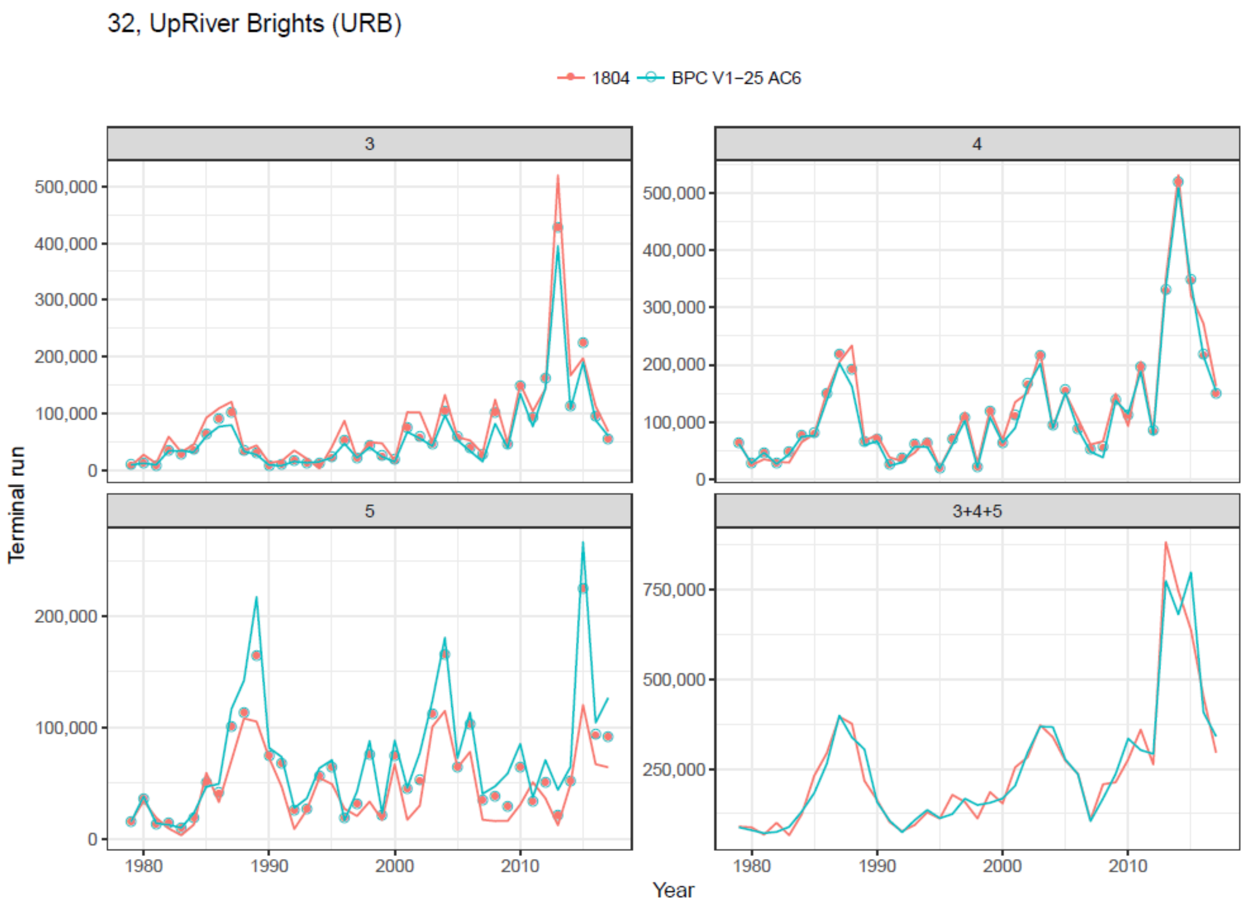


Appendix H6— Scatterplot of adult equivalent (AEQ)-adjusted ocean exploitation rates summed across preterminal fisheries (left column) and total (preterminal and terminal) exploitation rates summed across all fisheries. The solid line is the one-to-one line.

ASSESSMENT ITEM 5. TERMINAL RUN AND ESCAPEMENT

Through estimation of EVs, the PSC Chinook Model fits to the observed terminal run or escapement for a single stock and brood. These fits will be nearly perfect on a brood-year basis, but not on a calendar year basis. This qualitative examination produced plots to examine the model's fit to the observed calendar year terminal run or escapement (summed across ages). In general, phase II Model stocks that were able to go through the SACE procedure and provide maturity rates adjusted for the observed terminal run provided much better fits to terminal run or escapement.

An example plot for the Upriver Bright (URB) stock is provided in Appendix H7.



Appendix H7— Example plot of observed calendar year escapement for Columbia Upriver Brights (URB) between the 9806 Model (1804) and the phase II Model.

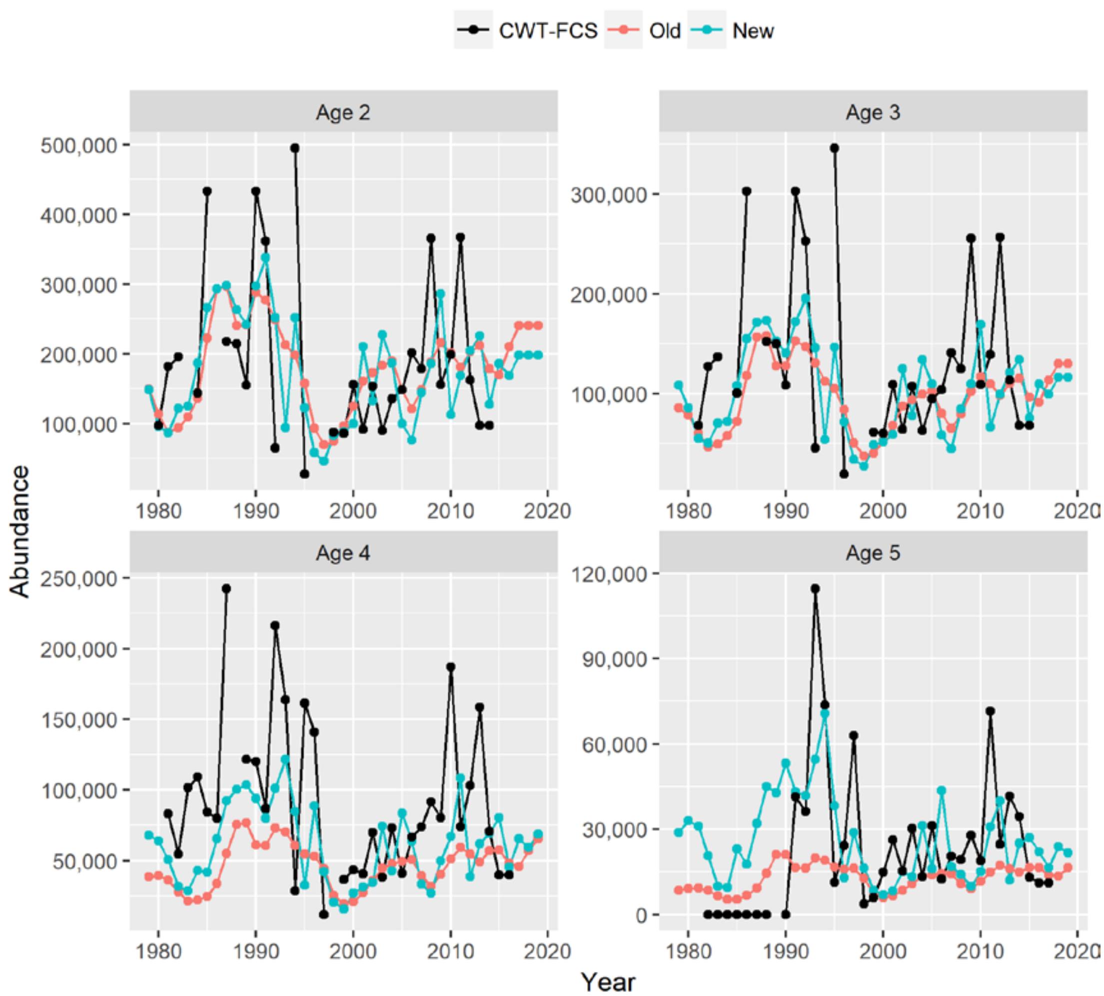
ASSESSMENT ITEM 6. COHORT SIZES

This evaluation assessed 9806 and phase II model generated pre-terminal cohort sizes. This was facilitated by comparing model estimated cohort sizes to those generated by the SACE procedure. Section 4.3 provides more detail on the SACE procedure. In summary, the SACE procedure uses CWT-derived ERs from Coshak and backwards cohort analysis techniques to build by-age run reconstructions that are scaled to the units of abundance in the FCS file. This produces cohort values that represent "real fish" (referred to as CWT-FCS cohorts) to compare to 9806 and phase II modeled cohorts.

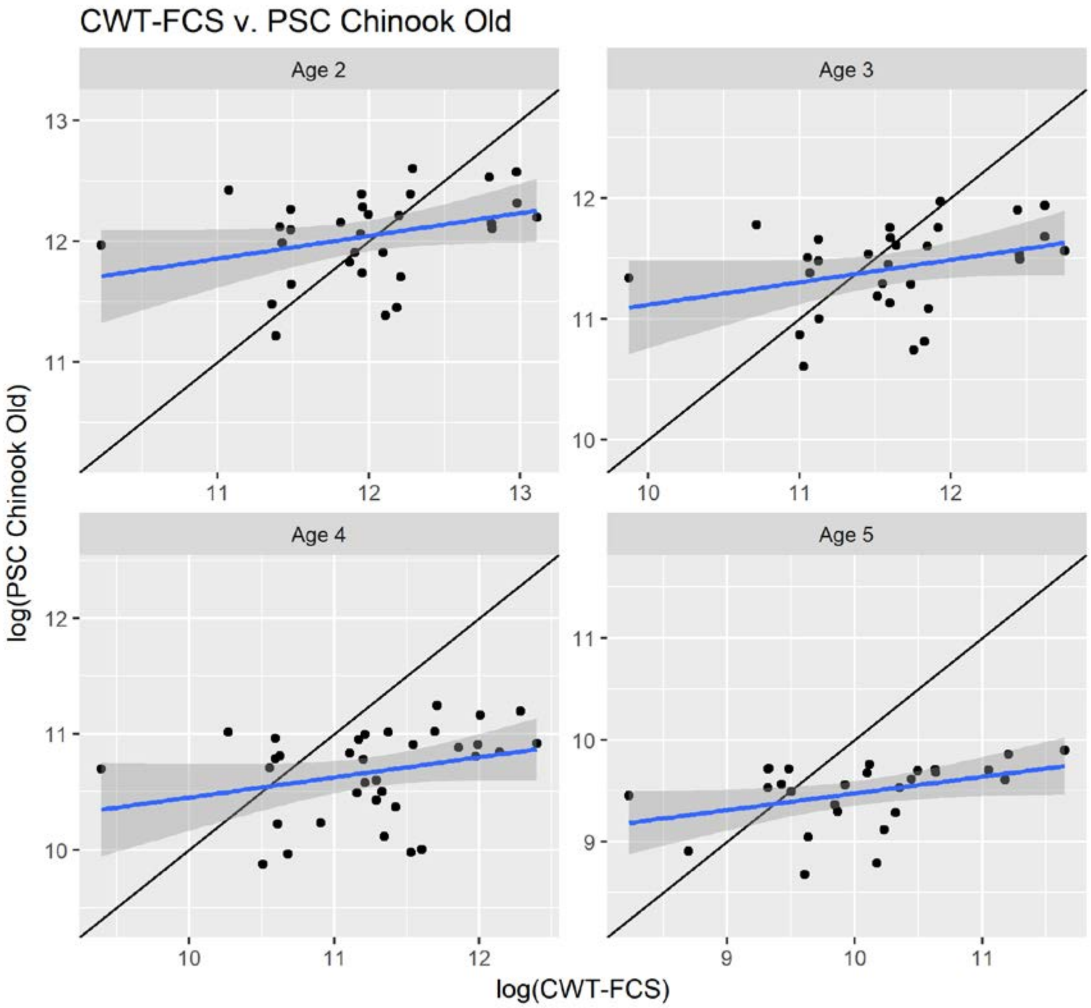
Time series plots of the CWT-FCS cohorts against 9806 and phase II cohorts were produced in addition to plots of log-log linear regressions of the 9806 and phase II cohorts against the CWT-FCS cohorts. These plots were accompanied by statistical tests that the intercept and slope of this relationship equals 0 and 1 respectively. These null hypothesis tests assessed whether there was evidence of a difference and bias in the modeled estimated cohort sizes relative to the CWT-FCS cohorts. An example set of output is provided for the Washington Coastal Hatchery (WCH) stock below.

```
## CWT-FCS v. PSC Chinook Old
##
##             H0: Intercept = 0         H0: Slope = 1
##       R2   b0     b0.SE b0.t  b0.p b1   b1.SE b1.t  b1.p
## Age 2 0.11   4.88  3.79  1.29 0.21 0.59 0.31  -1.30 0.20
## Age 3 0.11   4.98  3.61  1.38 0.18 0.58 0.32  -1.32 0.20
## Age 4 0.09   6.03  3.03  1.99 0.06 0.49 0.28  -1.80 0.08
## Age 5 0.24 -41.32 15.36 -2.69 0.01 5.23 1.64   2.58 0.01
##
##       H0: log(CWT-FCS) = log(PSC Chinook Old)
##       pair.diff pair.t pair.p
## Age 2 -0.06     -0.50  0.62
## Age 3  0.21      1.85  0.07
## Age 4  0.58      5.27  0.00
## Age 5 -1.65     -2.35  0.02
##
##
##  CWT-FCS v. PSC Chinook New
##
##             H0: Intercept = 0         H0: Slope = 1
##       R2   b0   b0.SE b0.t b0.p b1   b1.SE b1.t  b1.p
## Age 2 0.13 5.92  2.97 1.99 0.06 0.51 0.25  -2.00 0.05
## Age 3 0.13 5.86  2.85 2.06 0.05 0.50 0.25  -2.01 0.05
## Age 4 0.10 6.77  2.34 2.90 0.01 0.41 0.21  -2.75 0.01
## Age 5 0.00 6.84 12.19 0.56 0.58 0.09 1.22  -0.74 0.46
##
##       H0: log(CWT-FCS) = log(PSC Chinook New)
##       pair.diff pair.t pair.p
## Age 2 -0.03     -0.30  0.77
## Age 3  0.14      1.24  0.22
## Age 4  0.35      3.07  0.00
## Age 5 -2.23     -3.02  0.00
```

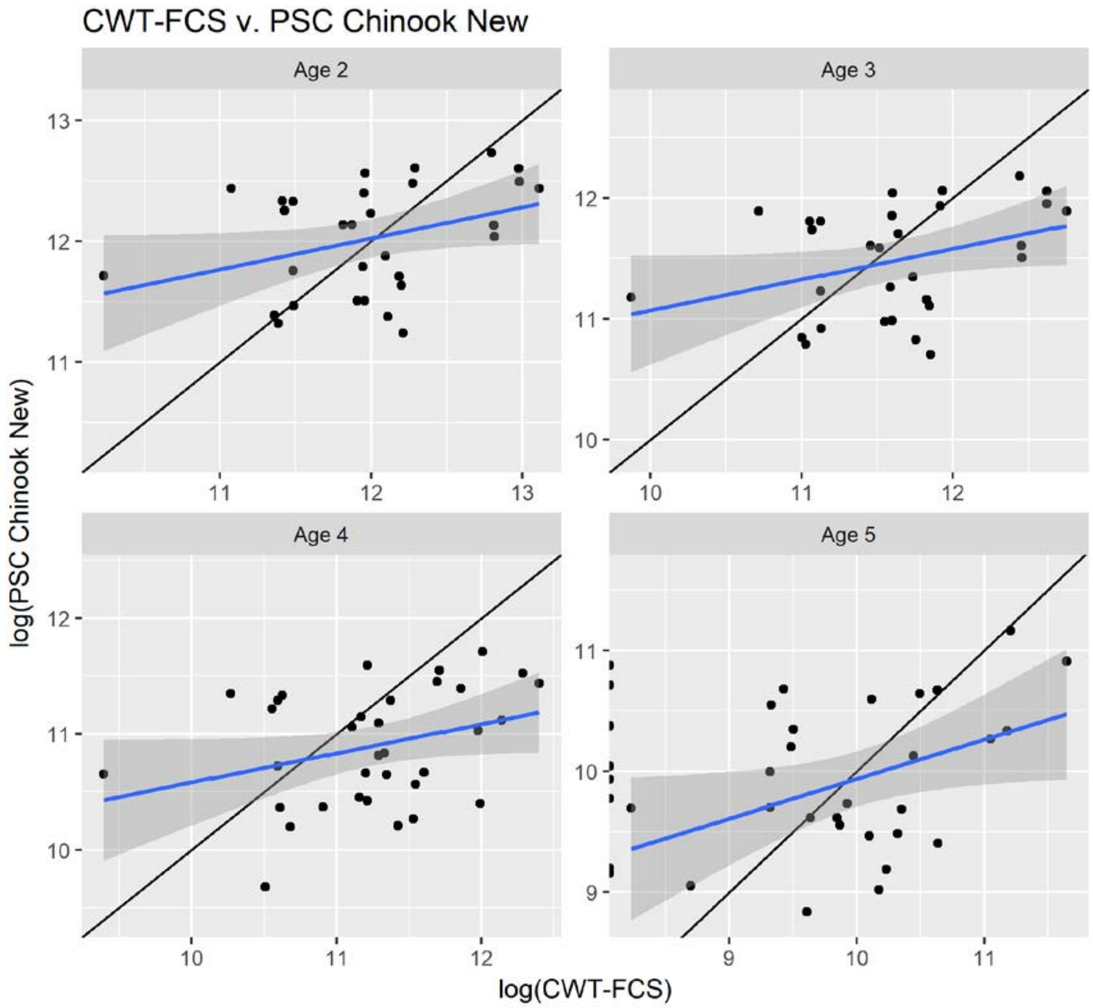
```
##
##
##  PSC Chinook Old v. PSC Chinook New
##
##             H0: Intercept = 0          H0: Slope = 1
##        R2   b0    b0.SE b0.t  b0.p b1   b1.SE b1.t  b1.p
## Age 2 0.73 -1.07 1.28  -0.84 0.41 1.08 0.11   0.78 0.44
## Age 3 0.72 -0.99 1.23  -0.80 0.43 1.09 0.11   0.82 0.42
## Age 4 0.66 -0.51 1.31  -0.39 0.70 1.07 0.12   0.57 0.58
## Age 5 0.42  0.91 1.70   0.53 0.60 0.97 0.18  -0.17 0.87
##
##        H0: log(PSC Chinook Old) = log(PSC Chinook New)
##        pair.diff pair.t pair.p
## Age 2 -0.07     -1.80  0.08
## Age 3  0.02      0.58  0.57
## Age 4  0.23      5.02  0.00
## Age 5  0.62      8.93  0.00
```



Appendix H8— Example for Washington Coast Hatchery (WCH) of cohort abundance using different estimation methods.



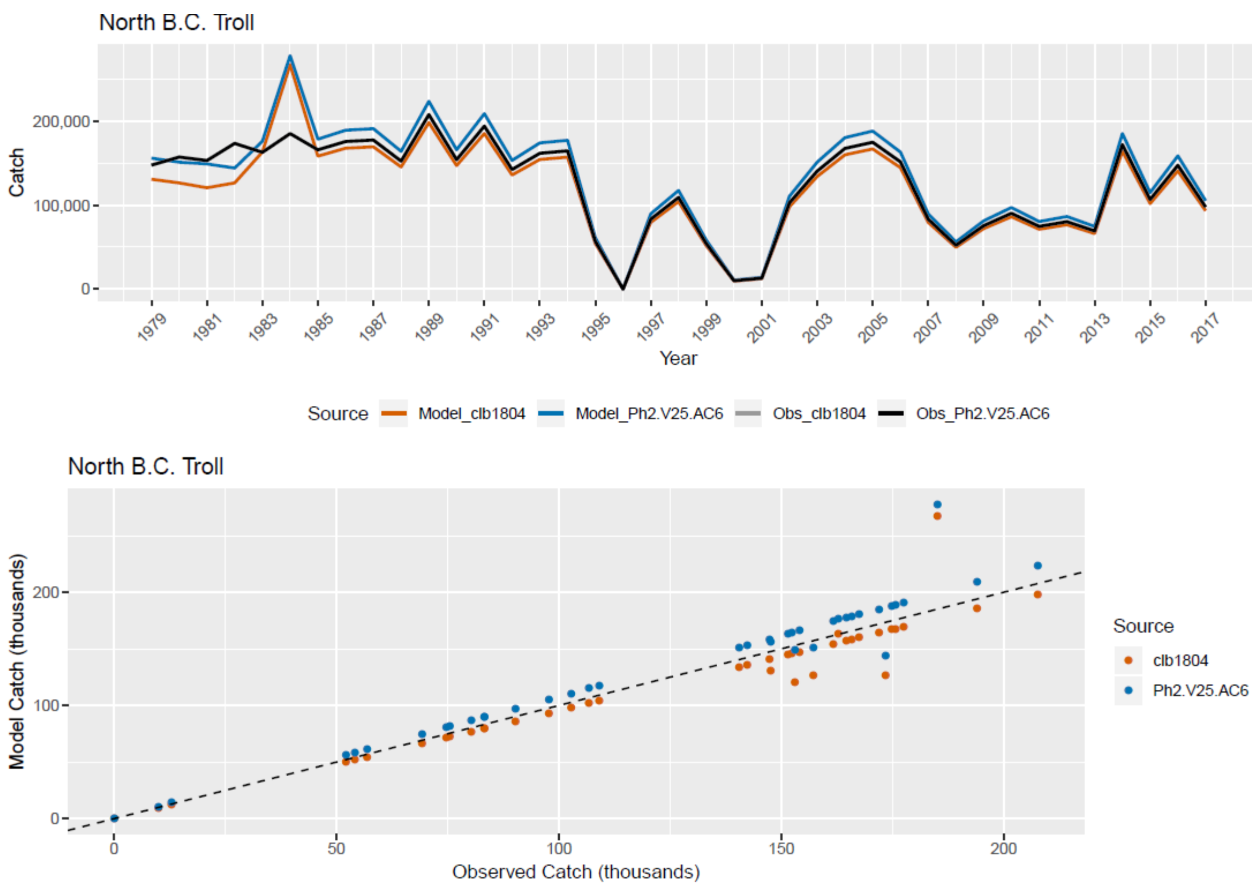
Appendix H9— Example for Washington Coast Hatchery (WCH) of log-linear regressions of 9806 Model cohort abundance compared with Stock Aggregate Cohort Evaluation (SACE) cohort abundance.



Appendix H10— Example for Washington Coast Hatchery (WCH) of log-linear regressions of phase II Model cohort abundance compared with Stock Aggregate Cohort Evaluation (SACE) cohort abundance.

ASSESSMENT ITEM 7. CATCHES

The assessment item compared catches generated from the 9806 and phase II Model to corresponding observed old phase II catches. The assessment identified instances where 9806 and phase II catches differed. For some fisheries, higher phase II catches were expected due to additional stocks being modeled in the phase II Model. In other fisheries, lower phase II catches were expected due to moving catch from pre-terminal to terminal fisheries. Fishery- and stock-specific graphs were generated in order to facilitate this assessment. An example set of plots for the NBC AABM troll fishery is provided below.

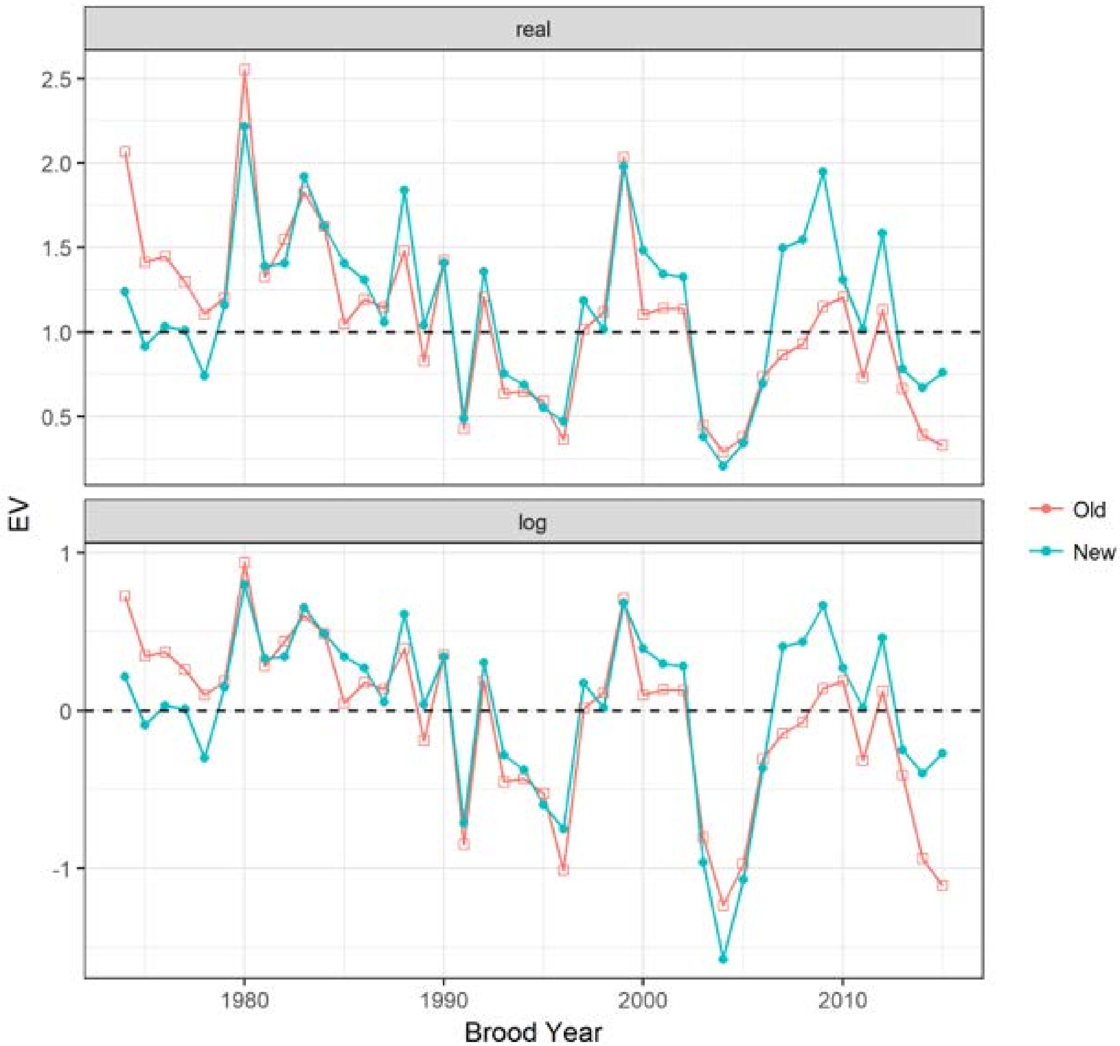


Appendix H11— Example of time series of catches (top) and comparison (bottom) between the 9806 Model and phase II Model for Northern British Columbia Aggregate Abundance-Based Management (AABM) fishery.

ASSESSMENT ITEM 8. ENVIRONMENTAL VARIABLES

Natural mortality of Chinook salmon varies from year to year especially in the period prior to initial recruitment to a fishery. This variability is incorporated in the PSC Chinook Model through the use of EVs. EVs are stock- and brood year-specific multiplicative scalars applied to recruitment resulting from the brood year escapement and the assumed productivity function. EVs also adjust for biases resulting from errors in data or assumptions by the model (e.g., maturity) since the scalars are found by minimizing the difference between the model predicted and observed terminal run or escapement. Therefore, EVs correct for two confounding factors: (1) year to year variability in pre-recruitment survival, and (2) adjustments for all other errors in the model. Examining the time series of EVs is a useful diagnostic to examine year-to-year variability in pre-recruitment survival and can flag potential misspecifications in the model. This assessment attempted to identify anomalously low or high EVs as a means to flag potential issues in the 9806 and phase II Models. The trends in EVs were also insightful for examining long-term changes in productivity.

The figures in this assessment showed the time series of 9806 and phase II Model EVs on a stock-by-stock basis. The EVs were plotted in two panels on the real and log scale. The log scale was useful for deciphering the patterns in EVs when extremely large EVs masked the pattern. The log scale was also more appropriate since EVs are multiplicative. A real EV near 1 or log EV near 0 is a useful benchmark to compare the EVs against. An example plot for the North Oregon Coast (NOC) model stock is provided below.



Appendix H12— Example of time series of environmental variables (EVs) for the North Oregon Coast (NOC) stock. The top panel presents the EV time series on the real scale; the bottom panel presents the EV time series on a log scale.

STATISICAL ASSESSMENT OF BASE PERIOD CALIBRATION (BPC V25-AC6)

The objectives for phase I and phase II of the base period calibration work undertaken by the CTC are listed in Box 2.

Box 2— List of objectives and improvements identified for phases I and II of the base period calibration.

Objectives of BPC (Phase I)

- The new model stratification allows the CTC to gain accuracy in the depiction of stocks contributing to PST fisheries.
    - Expansion of stock representation in the base period to gain appropriate stock differentiation.

Objectives of BPC (Phase I & Phase II)

- The new model stratification allows the CTC to more accurately represent AABM and ISBM fishery impacts.
- It allows for the incorporation of SPFIs or ROM indices for NBC and WCVI troll fisheries (V25-AC6 used the ROM for these fisheries).
- It allows the CTC to represent impacts north and south of Cape Falcon in Southern U.S. fisheries, sport fisheries in north and central British Columbia and Strait of Georgia
- It allows for finer stock resolution of fishery impacts and finer resolution of terminal harvests.
    - Some stock groups were simply not represented previously (e.g., Transboundary Rivers, Yakutat, and Mid-Oregon Coastal).
    - Some stocks were split to better represent life histories and ocean distributions (e.g., Fraser Early was split into Fraser Early Springs 1.2, Fraser Early Springs 1.3, Fraser Early Summers 0.3, and Fraser Early Summers 1.3).
    - The CWT codes or proxy group used for some stocks have changed to provide better distribution and maturation representation (e.g., Lower Georgia Strait is now represented by Cowichan CWTs instead of Big Qualicum CWTs).

Other changes and improvements

- Escapement/terminal run estimates were updated for a number of stocks.

All of these objectives and improvements were incorporated into the 'new' version of the PSC Chinook Model BPC V1-21 assessed in January 2017. Additional BPC work and investigations were undertaken by the AWG in response to both CTC and Commission observations and queries concerning BPC V1-21. The changes listed in Box 3 were incorporated into BPC V25-AC6.

Box 3— List of changes incorporated into base period calibration V25-AC6.

Other changes and improvements

- Maturation rates now represent stock aggregates rather than just CWT indicator stocks. In addition, the number of stocks represented in the MATAEQ model input file has nearly doubled.
- Age-specific input data have been added to select stocks represented in the FCS model input file.
- Stock-specific fishery harvest scalars have been updated, added and reviewed for all AABM fisheries and most ISBM fisheries.
- An additional model-fitting methodology has been developed and deployed to better model harvest in selected terminal fisheries.
- Where determined appropriate and fitting, escapement time series have been updated to terminal run currencies.
- Stock naming conventions were normalized.
- Programs used to convert ERA output to stock-specific fishery index model input were modified and de-bugged.
- Stock and age inclusion criteria for the SPFI were reviewed extensively and modified.
- Another year's annual calibration was added into the overall BPC assessment.

The CTC has been asked to assess the BPC on the basis of eight diagnostics (Box 4). The goal of the assessment was to evaluate and compare the performance of 'old' and 'new' versions of the PSC Chinook Model relative to observed values (e.g., escapement, terminal run and catch) or independently-calculated (e.g., CWT-based ERs and genetic-based stock composition) values. Preliminary BPC assessments have shown that reporting the multiple materials (tables, figures, summaries, etc.) produced to address all of the diagnostics in Box 4 requires substantial effort. In addition, it has become apparent that the evaluation of the results will benefit from an assessment framework that can integrate the results of the eight diagnostics. The following section introduces a framework for such synthesis.

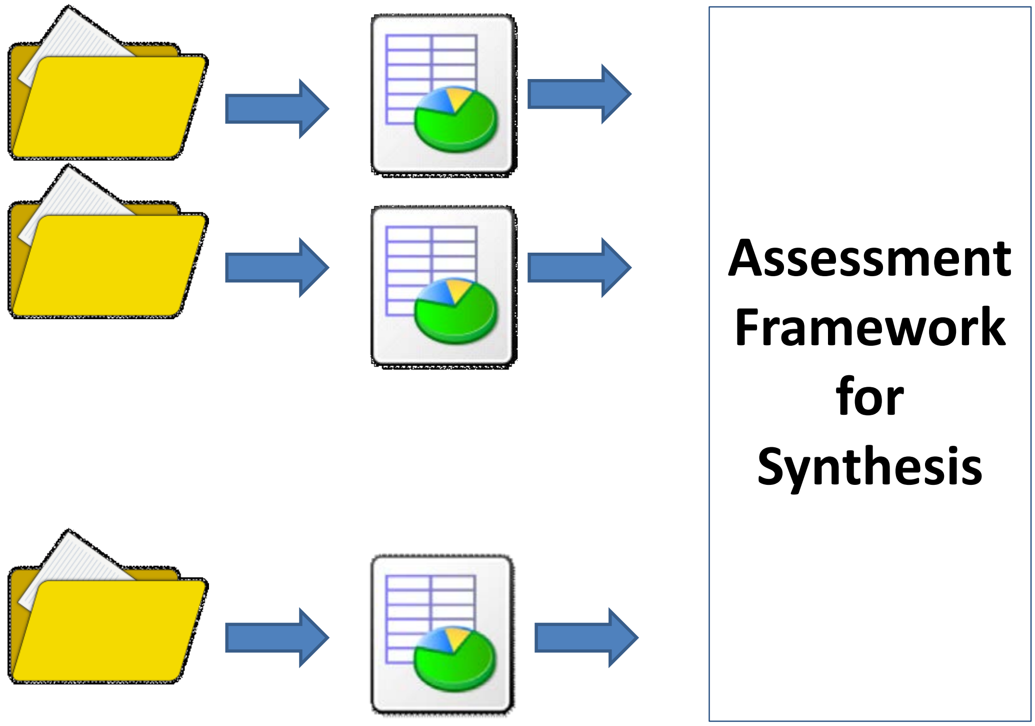
Box 4— Diagnostics identified for the base period calibration assessment.

Comparison and Evaluation diagnostics

1. Abundance indices
2. Retrospective evaluation of pre-season to first post-season AIs
3. Brood-year exploitation rate by stock, age and fishery between models and CWTs
   - Evaluate by terminal and pre-terminal
4. Comparison of stock composition between models
   - Compare to genetic stock ID (GSI) data
5. Comparison of terminal runs and escapement
   - Model fit to terminal run and escapement
6. Cohort sizes
   - Compare to observed cohort (i.e., CWT-FCS data)
7. Catches
   - Model fit to catch
8. EVs
   - Time series
   - Correlation with CWT survival indices

Assessment framework to evaluate PSC Chinook Model using new BPC

Previous BPC assessments have been based on evaluating detailed model outputs (Level 1 in Appendix H13) with only a few diagnostics being developed to the point of reaching conclusions or summarizing the information (Level 2 in Appendix H13). Level 1 information usually consists of numerous figures and/or tables representing model output and different comparisons that can be particularly useful to identify data anomalies for specific stocks or fisheries. Level 2 assessments summarize the information and should allow determination of whether model performance was improved, maintained or eroded for each diagnostic. Examples of Level 2 information produced in previous BPC assessments include statistical evaluations of model fit (‘old’ [9806] and ‘new’ [phase II] versions) to terminal run, escapement, and catch. The assessment framework introduced here (Level 3 in Appendix H13), and detailed in Appendix H14, is a method to integrate all Level 2 information in a way that facilitates making conclusions on the relative merit of the new BPC.



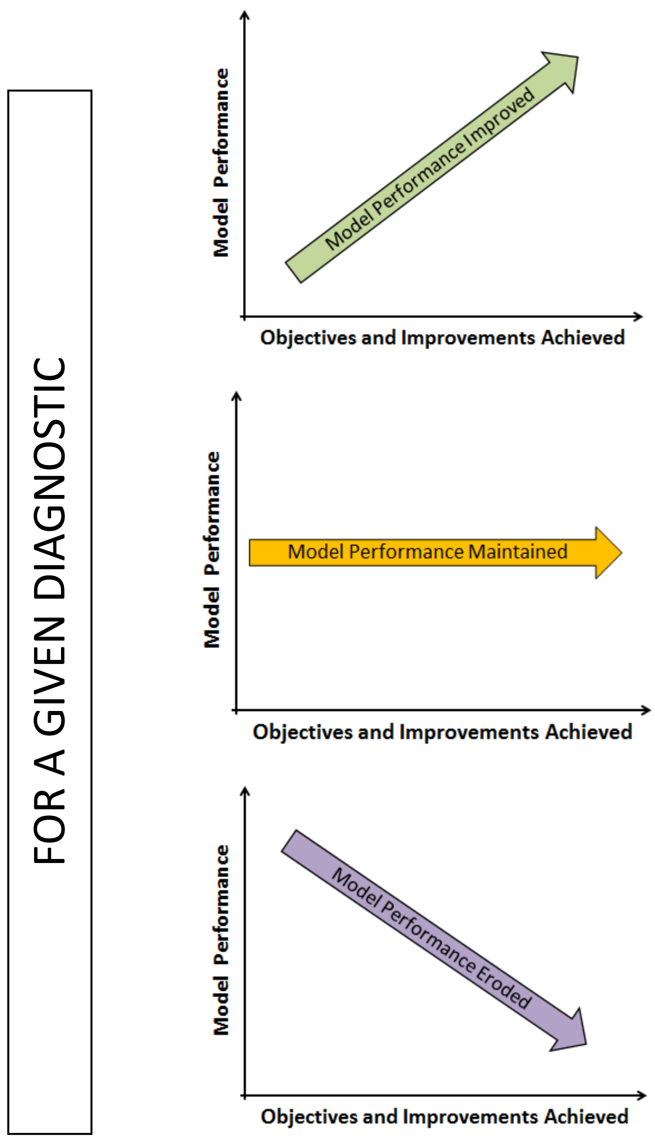
Appendix H13— Schematic of base period calibration assessment levels, from the production of detailed model output (Level 1) to the generation of summaries for individual diagnostics (Level 2) to the integration of Level-2 information into a common assessment framework (Level 3).

The assessment framework has two dimensions: (i) achieving general objectives and improvements; and (ii) evaluating model performance for each of the diagnostics. The BPC objectives and improvements were achieved for the phase II BPC, and by definition represent an improvement in dimension one. The second dimension represents the quantitative evaluation of model performance ('old' vs. 'new') for each of the diagnostics in Box 4. The assessment therefore has three possible outcomes: (a) BPC objectives were achieved and model performance was improved; (b) BPC objectives were achieved and model performance was maintained; and, (c) BPC objectives were achieved but model performance was eroded (see Appendix H14). Although it might seem redundant to include 'achieving general objectives and improvements' in each outcome, it maintains the perspective needed for reaching a conclusion relative to both dimensions.

Model performance improvements cannot be evaluated for diagnostic 1 (AIs) because there is no reference data to compare. Therefore, diagnostics 1 and 2 (retrospective exercise) in Box 4 were combined into a single diagnostic.

The framework depicted in Appendix H14 was applied to diagnostics based on model output from CLB1804 and BPC V25-AC6. The statistical approaches used below to summarize Level 2 information are not the only methods to summarize results (other approaches have also been proposed to present Level 2 assessments) but these are consistent with the guidelines provided by the CIG in February, 2016: "*Statistical measures [for the calibration assessment] may include mean percent error, mean absolute percent error, and/or mean squared error."*

Half of the sub-levels in all diagnostics, except diagnostic 4 (stock composition), were based on truncated time series (return years [RYs] 1999–2015, 2016, 2017, or the brood years (BYs) contributing to these RYs) in response to the guidance provided to the CTC by the CIG in February 2016. This factor was not applicable to diagnostic 4 (stock composition) because years currently included in the evaluation start in 2005 given the available GSI data.



Appendix H14— Conceptual framework for the evaluation of base period calibration's individual diagnostics. Numbers on the right represent evaluation scores (S). Top: Objectives were achieved and model performance was improved (S = 2). Middle: Objectives were achieved and model performance was maintained (S = 1). Bottom: Objectives were achieved but model performance was eroded (S = 0).

Level 2 and Level 3 BPC assessments (BPC V25-AC6 & CLB1804)

1. **Abundance Indices**
2. **Retrospective Exercise**

} Combined

Level 2 assessment

Appendix H15— Comparison of model abundance index (AI) pre-season-to-first post-season AI errors (2009–2017) between 'old' (CLB1804) and 'new' (BPC2018[1]) versions of the Pacific Salmon Commission Chinook Model for Southeast Alaska (SEAK), Northern British Columbia (NBC) and West Coast of Vancouver Island (WCVI) aggregate abundance-based management (AABM) fisheries. The comparison is based on mean percent error (MPE)[2] as a measure of accuracy, mean absolute percent error (MAPE) as a measure of precision, and mean squared error (MSE) as a measure of both accuracy and precision. NSD = no substantial difference.

Model	Accuracy (MPE)			Precision (MAPE)			Acc. & Prec. (MSE)		
	SEAK	NBC	WCVI	SEAK	NBC	WCVI	SEAK	NBC	WCVI
CLB1804	5.7%	2.8%	8.6%	11.3%	11.3%	20.6%	0.059	0.050	0.042
BPC2018	11.1%	9.0%	3.2%	12.9%	16.6%	16.2%	0.044	0.069	0.031
Best	*Old**	*Old**	*New**	*NSD*	*Old**	*NSD*	*NSD*	*NSD*	*NSD*

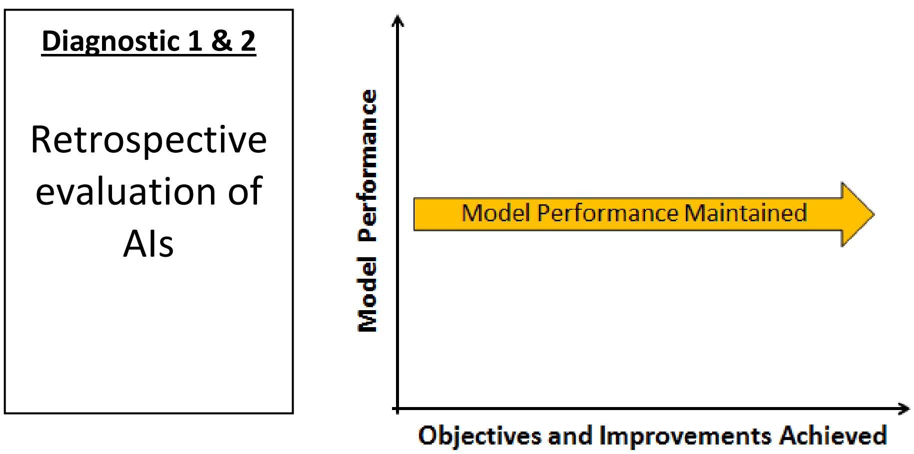
[1] Five-year average environmental variables (EVs) were used for BPC2018 projection years (CLB1804 used 1-year EVs).
[2] Negative values indicate pre-season AIs underestimate post-season AIs on average whereas positive values indicate pre-season AIs overestimate post-season AIs on average.
Difference levels:
NSD diff. < abs(0.05)
** abs(0.05) ≤ diff. < abs(0.1)*
*** abs(0.1) ≤ diff. < abs(0.15)*
**** diff. ≥ abs(0.15)*

Appendix H16— Comparison of model abundance index (AI) pre-season-to-first post-season pre-fishery abundances[1] (driver stocks) errors (2009–2017) between 'old' (CLB1804) and 'new' (BPC2018[2]) versions of the Pacific Salmon Commission Chinook Model for Southeast Alaska (SEAK), Northern British Columbia (NBC) and West Coast of Vancouver Island (WCVI) aggregate abundance-based management (AABM) fisheries. The comparison is based on mean percent error (MPE)[2] as a measure of accuracy, mean absolute percent error (MAPE) as a measure of precision, and mean squared error (MSE) as a measure of both accuracy and precision. NSD = no substantial difference.

Model	Accuracy (MPE)				Precision (MAPE)			
	SEAK	NBC	WCVI	ALL	SEAK	NBC	WCVI	ALL
CLB1804	10.9%	8.1%	11.5%	12.2%	28.4%	29.8%	36.3%	33.1%
BPC2018	12.6%	10.6%	11.5%	11.2%	28.9%	26.4%	30.7%	30.3%
Best	*NSD*	*NSD*	*NSD*	*NSD*	*NSD*	*NSD*	*New**	*NSD*

[1] Pre-fishery abundance are the stock-specific vulnerable abundances making up the numerator of AIs.
[2] 5-year average environmental variables (EVs) were used for BPC2018 projection years (CLB1804 used 1-year EVs).
[3] Negative values indicate pre-season AIs underestimate post-season AIs on average whereas positive values indicate pre-season AIs overestimate post-season AIs on average.
Difference levels:
NSD diff. < abs(0.05)
** abs(0.05) ≤ diff. < abs(0.1)*
*** abs(0.1) ≤ diff. < abs(0.15)*
**** diff. ≥ abs(0.15)*

<u>*Level 3 assessment*</u>



Appendix H17—Level 3 assessment outcome for comparison of abundance indices and the retrospective exercise.

3. Brood Year Exploitation Rates

Level 2 assessment

Appendix H18— Comparison of Chinook Model adult equivalent (AEQ) exploitation rates (ERs) to coded-wire tag (CWT)-based ERs between 'old' (CLB1804) and 'new' (BPC2018) versions of the model (brood years 1979–2013 and 1994–2013[1]). ERs include incidental mortality. The comparison is based on mean percent error (MPE)[2] as a measure of accuracy and mean absolute percent error (MAPE) as a measure of precision as applied to three ER categories: Pre-terminal, Terminal, and Total. The version of the model performing better is highlighted. NSD = no substantial difference.

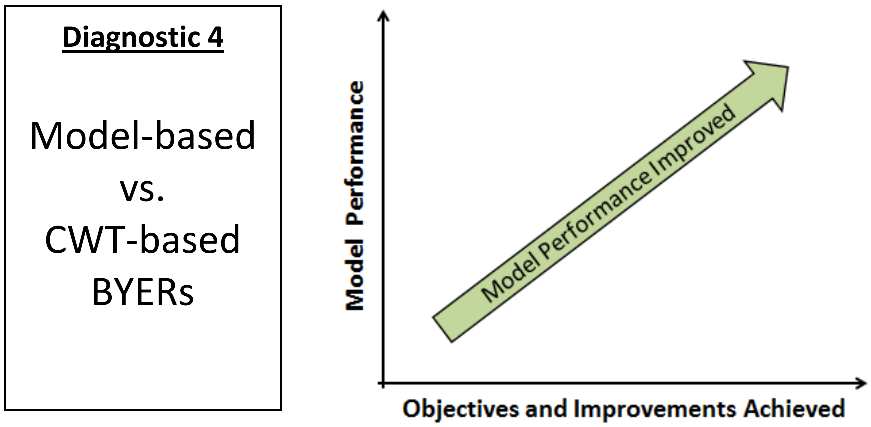
Brood Years	TEST	Model	Accuracy (MPE)		Precision (MAPE)	
1979-2013	All stocks Pre-terminal	CLB1804	12.9%	Old *	30.4%	NSD
		BPC2018	19.1%		31.5%	
	Common stocks Pre-terminal	CLB1804	12.9%	NSD	30.4%	NSD
		BPC2018	15.3%		30.7%	
	All stocks Terminal	CLB1804	39.0%	New***	74.2%	New*
		BPC2018	19.7%		68.7%	
	Common stocks Terminal	CLB1804	39.0%	NSD	74.2%	New*
		BPC2018	36.3%		65.3%	
	All stocks Total	CLB1804	-6.7%	NSD	27.3%	NSD
		BPC2018	-6.0%		25.3%	
	Common stocks Total	CLB1804	-6.7%	New*	27.3%	NSD
		BPC2018	1.2%		22.5%	
1994-2013	All stocks Pre-terminal	CLB1804	8.6%	Old *	32.2%	NSD
		BPC2018	17.6%		32.3%	
	Common stocks Pre-terminal	CLB1804	8.6%	Old *	32.2%	NSD
		BPC2018	14.7%		31.1%	
	All stocks Terminal	CLB1804	35.7%	New***	77.1%	New*
		BPC2018	6.6%		70.0%	
	Common stocks Terminal	CLB1804	35.7%	New*	77.1%	New**
		BPC2018	30.1%		64.7%	
	All stocks Total	CLB1804	-8.8%	NSD	28.5%	NSD
		BPC2018	-8.4%		27.2%	
	Common stocks Total	CLB1804	-8.8%	NSD	28.5%	NSD
		BPC2018	-5.4%		24.3%	

[1] Brood years contributing to calendar years 1999–2015.
[2] Negative values indicate the model underestimates ERs on average whereas positive values indicate the model overestimates ERs on average.
Difference levels:

NSD	*diff. < abs(0.05)*
*	*abs(0.05) ≤ diff. < abs(0.1)*
**	*abs(0.1) ≤ diff. < abs(0.15)*

*** diff. ≥ abs(0.15)

Level 3 assessment



Appendix H19— Level 3 assessment outcome for brood year exploitation rates (BYERs).

4. Stock Composition: Model vs. Genetic Stock Identification

Level 2 assessment

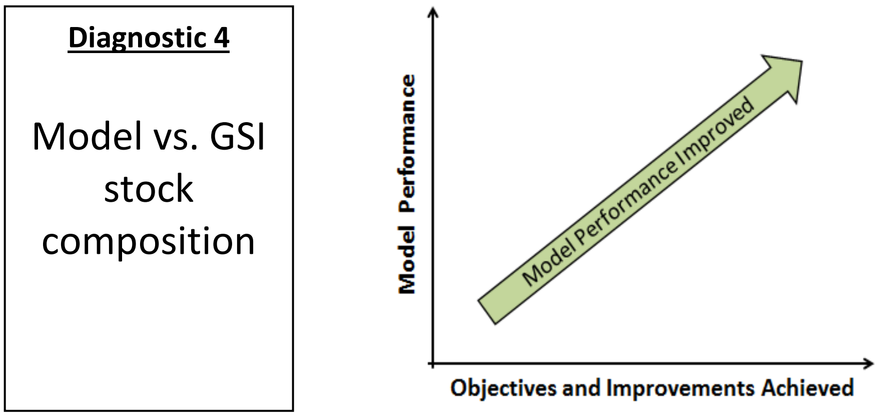
Appendix H20— Comparison of model-to-genetic stock identification root mean square error (RMSE) values for combined stock-fishery (2007–2015) compositions between CLB2018 and an annual calibration using the new BPC2018. NSD = no substantial difference.

Model	RMSE (1000s of fish)					
	SEAK Troll	NBC Troll	WCVI Troll	ALL Troll	SEAK Sport	ALL Fisheries
CLB1804	163.0	152.6	67.4	175.3	63.9	207.7
BPC2018	101.8	102.9	38.8	150.5	41.3	191.6
Best Model	*New****	*New****	*New****	*New****	*New****	*New**
	MPE (%)					
CLB1804	-3.5	-42.1	-19.0	-32.4	-128.3	-42.4
BPC2018	6.8	9.8	31.9	10.0	-10.1	9.4
Best Model	*NSD*	*New****	*Old***	*New****	*New****	*New****
	MAPE (%)					
CLB1804	54.8	80.5	94.8	66.3	168.8	76.2
BPC2018	34.2	38.0	43.9	26.6	54.6	25.6
Best Model	*New****	*New****	*New****	*New****	*New****	*New****

Difference levels:

NSD	*diff. < abs(0.05)*
***	*abs(0.05) ≤ diff. < abs(0.1)*
****	*abs(0.1) ≤ diff. < abs(0.15)*
*****	*diff. ≥ abs(0.15)*

Level 3 assessment



Appendix H21— Level 3 assessment outcome for model versus genetic stock identification (GSI) stock composition.

5. Model fit to terminal run and escapement

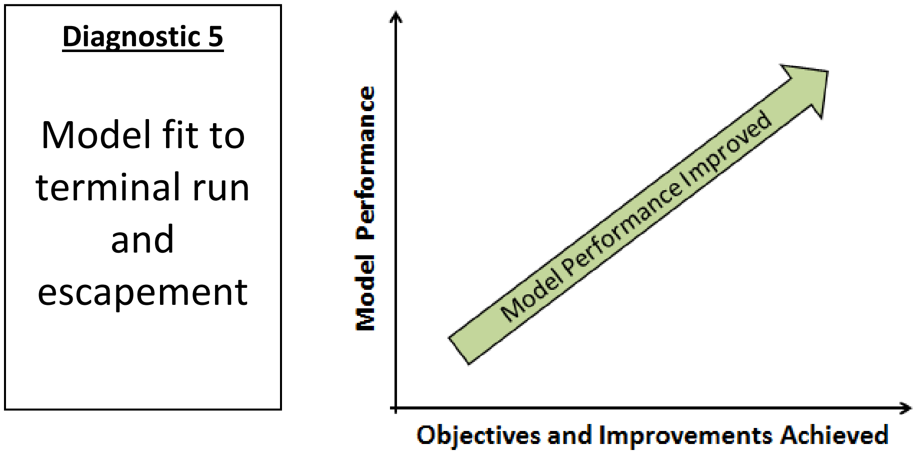
<u>*Level 2 assessment*</u>

Appendix H22— Comparison of Pacific Salmon Commission Chinook Model fit to observed terminal and/or escapement data (i.e., FCS file) between CLB1804 (old) and BPC2018 (new). The comparison is at the Return-Year level and based on mean percent error (MPE) as a measure of accuracy and mean absolute percent error (MAPE) as a measure of precision as applied to different subsets of model stocks[1]. The version of the model performing better is highlighted. NSD = no substantial difference.

Calendar Years	TEST	Accuracy (MPE)				Precision (MAPE)			
		Age-structured Stocks			Non-structured Stocks	Age-structured Stocks			Non-structured Stocks
		3	4	5	Total abundance	3	4	5	Total abundance
1979-2017	(A) All Stocks	*New***	*NSD*	*Old****	*NSD*	*New***	*New**	*NSD*	*NSD*
	(B) All Stocks Escapement Only	*New***	*New**	*Old**	*NSD*	*New****	*New**	*NSD*	*NSD*
	(C) All Stocks Terminal Run Only	*New***	*New**	*Old****	*NSD*	*New***	*New**	*New**	*NSD*
	(D) Common Stocks	*New****	*NSD*	*Old****	*NSD*	*New****	*New**	*New**	*NSD*
	(E) Common Stocks Escapement Only	*New****	*NSD*	*New****	*NSD*	*New****	*NSD*	*New****	*NSD*
	(F) Common Stocks Terminal Run Only	*New***	*NSD*	*Old****	*NSD*	*New***	*New**	*NSD*	*NSD*
1999-2015	(A) All Stocks	*New**	*NSD*	*Old****	*NSD*	*New**	*New**	*New****	*NSD*
	(B) All Stocks Escapement Only	*New**	*New***	*Old**	*NSD*	*New**	*New**	*New****	*NSD*
	(C) All Stocks Terminal Run Only	*New***	*NSD*	*Old****	*NSD*	*New***	*New**	*New**	*NSD*
	(D) Common Stocks	*New**	*NSD*	*Old****	*NSD*	*New****	*New**	*New****	*NSD*
	(E) Common Stocks Escapement Only	*NSD*	*NSD*	*New****	*NSD*	*New****	*Old**	*New****	*NSD*
	(F) Common Stocks Terminal Run Only	*New**	*NSD*	*Old****	*NSD*	*New***	*New**	*New**	*NSD*

[1] Values of statistics are not included in the table given the large number of diagnostic sub-levels.
- Old number of stocks = 30 (28 time series sets)
- New number of stocks = 41 (41 time series sets)
- Number of common stocks = 25
Difference levels:
NSD diff. < abs(0.05)
** abs(0.05) ≤ diff. < abs(0.1)*
*** abs(0.1) ≤ diff. < abs(0.15)*
**** diff. ≥ abs(0.15)*

Level 3 assessment



Appendix H23— Level 3 assessment outcome for model fit to terminal run and escapement.

6. Cohort sizes

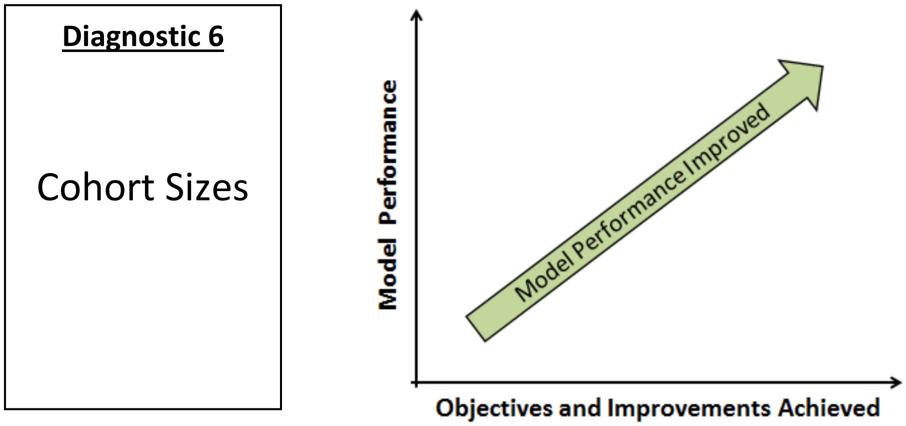
<u>Level 2 assessment</u>

Appendix H24— Comparison of Pacific Salmon Commission Chinook Model cohort-size error between CLB1804 (old) and BPC2018 (new). The error statistics are relative to reconstructed cohorts (i.e., SACE cohorts). The comparison is based on mean percent error (MPE)[1] as a measure of accuracy and mean absolute percent error (MAPE) as a measure of precision as applied to different subsets of model stocks. The version of the model performing better is highlighted. NSD = no substantial difference.

Calendar Years	TEST	Model	Accuracy (MPE)				Precision (MAPE)			
			Age-2	Age-3	Age-4	Age-5	Age-2	Age-3	Age-4	Age-5
1979-2015	All Stocks	CLB1804	13.6%	-7.3%	-27.2%	-34.5%	31.5%	31.5%	36.8%	64.2%
		BPC2018	35.9%	15.3%	1.2%	3.0%	39.7%	33.4%	31.3%	41.1%
			*Old****	*Old**	*New****	*New****	*Old**	*NSD*	*New**	*New****
	Common Stocks	CLB1804	13.6%	-7.3%	-27.2%	-34.5%	31.5%	31.5%	36.8%	64.2%
		BPC2018	25.8%	13.1%	-7.1%	-8.1%	33.4%	31.2%	30.2%	34.8%
			*Old****	*Old**	*New****	*New****	*NSD*	*NSD*	*New**	*New****
1999-2015	All Stocks	CLB1804	8.6%	-8.1%	-30.8%	-25.6%	22.5%	25.5%	35.2%	59.7%
		BPC2018	43.8%	17.2%	3.6%	0.9%	43.8%	29.2%	31.9%	39.1%
			*Old****	*Old**	*New****	*New****	*Old**	*NSD*	*NSD*	*New**
	Common Stocks	CLB1804	8.6%	-8.1%	-30.8%	-25.6%	22.5%	25.5%	35.2%	59.7%
		BPC2018	22.7%	-4.2%	-12.3%	-13.6%	23.6%	27.1%	26.8%	36.7%
			*Old***	*NSD*	*New****	*New***	*NSD*	*NSD*	*New**	*New****

[1] Negative values indicate the model underestimates cohort sizes on average whereas positive values indicate the model overestimates cohort sizes on average.
- Old number of stocks with FCS age-specific data matching CWT-FCS cohort size data = 11
- New number of stocks with FCS age-specific data matching CWT-FCS cohort size data = 17
Difference levels:
NSD diff. < abs(0.05)
** abs(0.05) ≤ diff. < abs(0.1)*
*** abs(0.1) ≤ diff. < abs(0.15)*
**** diff. ≥ abs(0.15)*

Level 3 assessment



Appendix H25— Level 3 assessment outcome for cohort size estimates.

7. Model fit to catch

<u>*Level 2 assessment*</u>

Appendix H26— Comparison of Pacific Salmon Commission (PSC) Chinook Model fit to observed catch data (i.e., CEI file[1]) between 'old' and 'new' versions of the model, all/common fisheries for 1979–1984 & 1985–forward. The comparison is based on mean percent error (MPE)[2] as a measure of accuracy and mean absolute percent error (MAPE) as a measure of precision as applied to two sets of fisheries. The version of the model performing better is highlighted. NSD = no substantial difference.

Calendar Years	TEST	Model	Accuracy (MPE)		Precision (MAPE)	
1979-1984	All Fisheries	CLB1804	-8.5%	*Old**	28.8%	*Old**
		BPC2018	-16.8%		35.6%	
	Common Fisheries	CLB1804	-8.5%	*Old**	28.8%	*Old**
		BPC2018	-18.0%		34.6%	
	Pooled Pre-terminal Catch (All)	CLB1804	-6.8%	*Old**	11.0%	*Old**
		BPC2018	-14.2%		16.4%	
	Pooled Pre-terminal Catch (Common)	CLB1804	-6.8%	*Old**	11.0%	*Old**
		BPC2018	-16.1%		17.5%	
1985 - Forward	All Fisheries	CLB1804	-14.6%	*NSD*	16.8%	*NSD*
		BPC2018	-15.8%		21.5%	
	Common Fisheries	CLB1804	-14.6%	*NSD*	16.8%	*NSD*
		BPC2018	-18.6%		18.6%	
	Pooled Pre-terminal Catch (All)	CLB1804	0.3%	*Old**	4.9%	*NSD*
		BPC2018	-5.8%		6.3%	
	Pooled Pre-terminal Catch (Common)	CLB1804	0.1%	*Old***	4.9%	*Old***
		BPC2018	-15.1%		15.1%	

[1] South of Falcon troll and South of Falcon sport were excluded from the evaluation because a significant portion of the observed catch in these fisheries is from stocks not included in the PSC Chinook Model.
[2] Negative values indicate the model underestimates catch on average whereas positive values indicate the model overestimates catch on average.
- Total number of pre-terminal (PT) fisheries = 22
- Number of common PT fisheries = 20
- Fishery-Years with catch < 10 were excluded from the analysis
Difference levels:
NSD diff. < abs(0.05)
** abs(0.05) ≤ diff. < abs(0.1)*
*** abs(0.1) ≤ diff. < abs(0.15)*
**** diff. ≥ abs(0.15)*

Appendix H27— Comparison of Chinook Model fit to observed catch data (i.e., CEI file) between 'old' and 'new' versions of the model, aggregate abundance-based management (AABM) troll fisheries for 1979–1984 and 1985–forward. The comparison is based on mean percent error (MPE) as a measure of accuracy and mean absolute percent error (MAPE) as a measure of precision as applied to two sets of fisheries. The version of the model performing better is highlighted. NSD = no substantial difference.

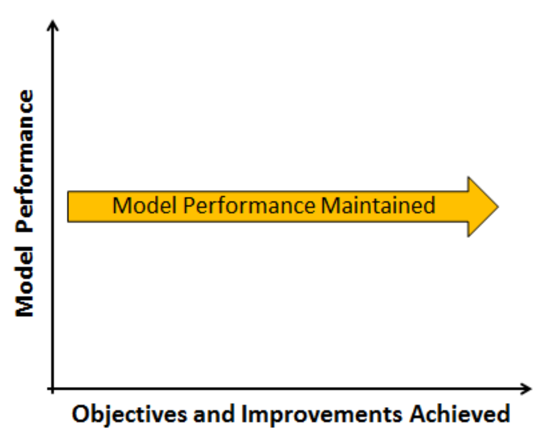
Calendar Years	TEST	Model	Accuracy (MPE)		Precision (MAPE)	
1979-1984	SEAK Troll	CLB1804	-14.7%	NSD	14.7%	NSD
		BPC2018	-14.5%		14.5%	
	NBC Troll	CLB1804	-5.8%	NSD	20.7%	New*
		BPC2018	6.7%		14.6%	
	WCVI Troll	CLB1804	-15.7%	New**	31.8%	NSD
		BPC2018	-3.8%		33.7%	
1985 - Forward	SEAK Troll	CLB1804	-15.9%	NSD	15.9%	NSD
		BPC2018	-15.8%		15.8%	
	NBC Troll	CLB1804	-4.5%	NSD	4.5%	NSD
		BPC2018	7.6%		7.6%	
	WCVI Troll	CLB1804	-17.1%	New**	17.1%	New**
		BPC2018	-5.6%		5.6%	

Difference levels:
NSD diff. < abs(0.05)
** abs(0.05) ≤ diff. < abs(0.1)*
*** abs(0.1) ≤ diff. < abs(0.15)*
**** diff. ≥ abs(0.15)*

Level 3 assessment

Diagnostic 7

Model fit to Catch



Appendix H28— Level 3 assessment outcome for model fit to observed catch.

8. Time series of EVs

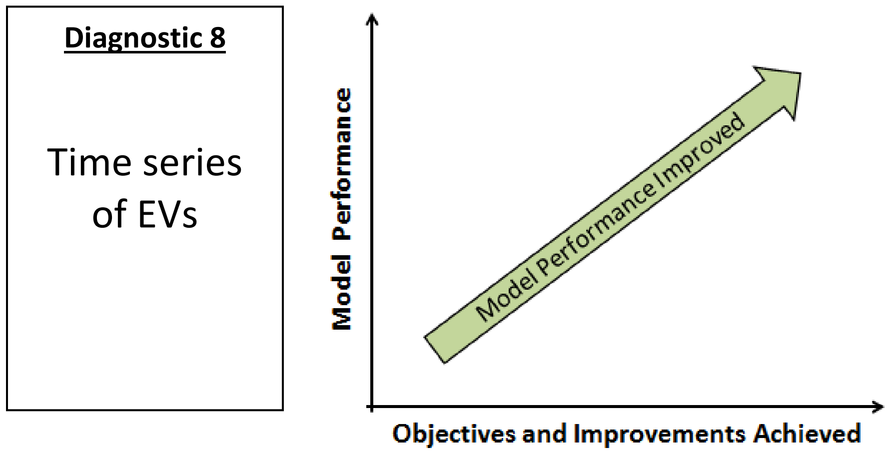
Level 2 assessment

Appendix H29— Comparison of environmental variable (EV) statistics between 'old' and 'new' versions of the model. Statistics are based on brood years 1979–2013 and 1993–2013[1] and two sets of stocks: (i) all stocks; and (ii) a subset of stocks with EV averages ≥ 0.5 and ≤ 2.0. EV averages outside of this range were considered 'extreme'. The last column identifies the 'best' model. The criteria for model selection are: (a) EV statistic closer to 1[2] (for mean); (b) smaller percent of stocks with 'extreme' average EVs; and (c) smaller percent of stocks with weak correlations. The version of the model performing better is highlighted. NSD = no substantial difference.

Brood Years	TEST	Statistic	CLB1804	BPC2018	Best
1979-2013	All Stocks	Mean	1.43	1.45	*NSD*
		% of Extreme EVs	43.3%	22.0%	*New****
		% of Stocks with EV-CWT Survival correlations < 0.4	57.1%	54.5%	*NSD*
	Subset of stocks with average EV ≥ 0.5 AND ≤ 2.0	Mean	0.90	1.01	*Old***
1993-2013	All Stocks	Mean	1.27	1.33	*Old **
		% of Extreme EVs	56.7%	29.3%	*New****
		% of Stocks with EV-CWT Survival correlations < 0.4	45.0%	39.5%	*New****
	Subset of stocks with average EV ≥ 0.5 AND ≤ 2.0	Mean	0.97	0.90	*New**

[1]Brood years contributing to calendar years 1999–2015.
[2]EV values closer to 1.0 indicate the assumptions of the model produce brood-year escapement data matching better input abundance data.
Difference levels:
NSD diff. < abs(0.05)
** abs(0.05) ≤ diff. < abs(0.1)*
*** abs(0.1) ≤ diff. < abs(0.15)*
**** diff. ≥ abs(0.15)*

<u>*Level 3 assessment*</u>



Appendix H30— Level 3 assessment outcome for time series of environmental variables (EVs).

Level 3 assessment summary

Appendix H31— Summary of Level-3 BPC2018 performance relative to CLB1804 for each the individual diagnostics (DVs).

DV Number	Diagnostic	Level-3 Performance
1 & 2	AI Retrospective Evaluation	Maintained
3	BY Exploitation Rates	Improved
4	Stock Composition	Improved
5	Terminal Run and Escapement	Improved
6	Cohort Sizes	Improved
7	Catch	Maintained
8	EVs	Improved

DOCUMENATION OF MODEL CHANGES

Calibration	Description of Changes
BPC V125 AC6	- The last model that the formal 8 item assessment was conducted on
BPCV125 AC7	- Examined effect of removing SACE derived maturity rates from MATAEQ file
BPCV125 AC8	- Built off of BPC V125 AC6 - Updated with an additional year of data - Changes to FPA files to follow convention used in annual calibration. If stock-specific rows exists in FPA file with non-1 FPs, then 0 row should also have calculated non-1 FPs in order to produce better stock composition in fishery - Changes to years utilized by HRJ to FPA program (from 1979–1984 to 1979–1994) for determining stocks that meet criteria to contribute to fishery index - Time series of terminal returns or escapement in FCS file changed for several stocks. For Columbia Rivers stocks, this was done for consistency between brood tables for SACE process and return tables for FCS file. - Additional stocks added to SACE procedure and added to MATAEQ file - Reverted back to unadjusted STK file per Friday conference call on 5/10/19.
BPC V125 AC9	- ALS and YAK returns updated in FCS file - LGS calibrated to terminal run instead of escapement - BQR now used for MGR maturity rates - Fixed bug in SACE program (stock indexing issue)
BPC V126 AC1	- New BSE/STK file based on MOC and NOC MDL changes - New Alaska troll FPA file based on MOC and NOC MDL changes - Updated maturity rates for FCF
BPC V127 AC1	- New BSE / STK file based on MOC and NOC MDL changes
BPC V127 AC2	- Change in LGS maturity rate - Georgia Straight Sport FPA file updated (1983 / 1984 FPs weren't being updated)
BPC V127 AC3	- 1981–2013 maturity rates for FCF updated - Juan de Fuca net FPA file updated (previous FPs weren't being updated)
BPC V127 AC4	- Updated MOC and NOC forecast (previous entry was 2018 return) - Update WCVI troll FPA file (previous DRV file for HRJ to FPA program was incorrect)
BPC V127 AC5	- FSO FPs in NBC Troll FPA were not updating. The ERA was redone for this stock to include base period years. FPs are now updated. - New FSO ERA resulted in updates to 0 line in all AABM troll fisheries. - ELK recoveries in NBC troll were too sparse to generate FPs after 1999 for MOC. ELK and SRH recoveries are now combined for MOC and NOC to generate FPs. - Instead of forcing FP's to zero for WVH and WVN between 2000 and 2010, FPs are now calculated (and are close to zero). However, 2002 and 2011 and 2012 FPs were extremely high due high age 5 harvest rate and failed criteria of age 3 and 4. In this instance, FPs are manually set to 0.005.
BPC V127 AC6	- Based on investigation, exponential smoothing now use for projected maturity rates and 12-year average used for projected EVs
BPC V128 AC1	- BSE file changed for new naming conventions for Fraser stocks. "Harrison Fall" now "Fraser Harrison Fall" and "Chilliwack Fall Hatchery" now "Fraser Chilliwack Fall Hatchery"

APPENDIX I. STOCK ACRONYMS

Stock groups used in the phase II PSC Chinook Model, associated CWT indicator(s), location, run type, and smolt age.

Area	Model Stock	CWT Indicator	Run Type	Smolt Age
Southeast Alaska	Southern Southeast Alaska (SSA)	Whitman Lake (AHC), Little Port Walter (ALP), Deer Mountain (ADM), Neets Bay (ANB)	Spring	Age 1
	Northern Southeast Alaska (NSA)	Crystal Lake (ACI)	Spring	Age 1
Transboundary	Alsek (ALS)	Wild – No indicator	Spring	Age 1
	Taku and Stikine (TST)	Wild Taku and Stikine Rivers	Spring	Age 1
	Yakutat Forelands (YAK)	Wild – No indicator	Spring	Age 1
North/Central British Columbia	Northern B.C. (NBC)	Kitsumkalum (KLM)	Summer	Age 0
	Central B.C. (CBC)	Atnarko (ATN)	Summer	Age 1
West Coast Vancouver Island	WCVI Hatchery (WVH)	Robertson Creek (RBT)	Fall	Age 0
	WCVI Natural (WVN)	Robertson Creek (RBT)	Fall	Age 0
Strait of Georgia	Upper Strait of Georgia (UGS)	Quinsam (QUI)	Fall	Age 0
	Middle Strait of Georgia (MGS)	Big Qualicum (BQR)	Fall	Age 0
	Puntledge Summers (PPS)	Puntledge (PPS)	Summer	Age 0
	Lower Strait of Georgia (LGS)	Cowichan (COW); Nanaimo (NAN)[1]	Fall	Age 0
Fraser River	Fraser Spring 1.2 (FS2)	Nicola (NIC)	Spring	Age 1
	Fraser Spring 1.3 (FS3)	Dome (DOM)[2]	Spring	Age 1
	Fraser Ocean-type 0.3 (FSO)	Lower Shuswap (SHU)	Summer	Age 0
	Fraser Summer Stream-type 1.3 (FSS)	Chilko (CKO)	Summer	Age 1
	Fraser Harrison Fall (FHF)	Harrison (HAR)	Fall	Age 0
	Fraser Chilliwack Fall Hatchery (FCF)	Chilliwack (CHI)	Fall	Age 0
North Puget Sound	Nooksack Spring (NKS)	Nooksack Spring Fingerling (NSF)	Spring	Age 0
	Nooksack Fall (NKF)	Samish Fall Fingerling[3] (SAM)	Summer/Fall	Age 0
	Skagit Wild (SKG)	Skagit Summer Fingerling (SSF)	Summer	Age 0
	Stillaguamish Wild (STL)	Stillaguamish Fall Fingerling (STL)	Summer/Fall	Age 0
	Snohomish Wild (SNO)	Snohomish Wild (SNO)	Summer/Fall	Age 0
South Puget Sound	Puget Sound Fingerling (PSF)	S. Puget Sound Fall Fingerling[3] (SPS)	Summer/Fall	Age 0
	Puget Sound Natural Fall (PSN)	S. Puget Sound Fall Fingerling[3] (SPS)	Summer/Fall	Age 0
	Puget Sound Yearling (PSY)	South Puget Sound Fall Yearling (SPY); University of Washington Accelerated (UWA)[4]	Summer/Fall	Age 1
Washington Coast	Washington Coast Natural (WCN)	Hoko Fall Fingerling (HOK)	Fall	Age 0
	Washington Coast Hatchery (WCH)	Queets Fall Fingerling (QUE); Tsoo-Yess Fall Fingerling (SOO)	Fall	Age 0
Columbia River	Lower Bonneville Hatchery (BON)	Columbia Lower River Hatchery[3] (LRH)	Fall Tule	Age 0
	Fall Cowlitz Hatchery (CWF)	Cowlitz Tule (CWF)	Fall Tule	Age 0
	Cowlitz Spring Hatchery (CWS)	Cowlitz Spring Hatchery (CWS)	Spring	Age 1
	Lewis River Wild (LRW)	Lewis River Wild (LRW)	Fall Bright	Age 0
	Spring Creek Hatchery (SPR)	Spring Creek Tule[3] (SPR)	Fall Tule	Age 0
	Willamette River Spring (WSH)	Willamette Spring[3] (WSH)	Spring	Age 1
	Mid-Columbia River Brights	Mid-Columbia River Brights (MCB)	Fall	Age 0
	Columbia River Summer (SUM)	Columbia Summers[5] (WA) (SUM)	Summer	Age 0/1
	Upriver Brights (URB)	Columbia Upriver Bright (URB)[1]	Fall Bright	Age 0
Snake River	Lyons Ferry (LYF)	Lyons Ferry[3,5] (LYF)	Fall Bright	Age 0
North Oregon Coast	North Oregon Coast (NOC)	Salmon (SRH)	Fall	Age 0
Mid Oregon Coast	Mid-Oregon Coast (MOC)	Elk River (ELK)	Fall	Age 0

[1] Tagged releases for the Nanaimo Fall stock were discontinued after the 2004 brood.
[2] Hatchery production of the Dome Creek stock was discontinued after the 2002 brood.
[3] Double index tags associated with this stock.
[4] The last year included in the exploitation rate analysis for University of Washington Accelerated was 1984.
[5] Subyearlings have been CWT-tagged since brood year (BY) 1986, except for BYs 1993–1997.