PACIFIC SALMON COMMISSION
JOINT CHINOOK TECHNICAL COMMITTEE REPORT

2023 REVIEW OF THE CATCH PER UNIT EFFORT-BASED APPROACH AND RESPONSE TO CHAPTER 3, SUBPARAGRAPH 7(b) TASKS FOR THE SOUTHEAST ALASKA AGGREGATE ABUNDANCE-BASED MANAGEMENT FISHERY

REPORT TCCHINOOK (23)-05

October 20, 2023

Membership of the Chinook Technical Committee

Canadian Members	United States Members
Dr. Antonio Velez-Espino, Co-Chair, DFO	Dr. Milo Adkison, Co-Chair, ADF&G
Ms. Laura Tessier, Co-Chair, DFO	Mr. Jonathan Carey, Co-Chair, NOAA Fisheries
Dr. Norah Brown, DFO	Mr. Ethan Clemons, ODFW
Ms. Sabrina Crowley, FNC	Mr. Timothy Dalton, ODFW
Ms. Katie Davidson, DFO	Dr. Derek Dapp, WDFW
Mr. Michael Folkes, DFO	Mr. Brian Elliott, ADF&G
Mr. Nicholas Komick, DFO	Ms. Danielle Evenson, ADF&G
Ms. Chelsea May, DFO	Mr. Gary Freitag, UAF
Ms. Elinor McGrath, FNC	Mr. Tommy Garrison, CRITFC
Dr. Teresa Ryan, FNC	Ms. Sara Gilk-Baumer, ADF&G
Mr. Noel Swain, DFO	Dr. Steven Haeseker, USFWS
Ms. Nicole Trouton, DFO	Mr. Grant Hagerman, ADF&G
Ms. Heidi van Vliet, DFO	Dr. Galen Johnson, NWIFC
Ms. Lauren Weir, DFO	Mr. Edgar Jones, ADF&G
Dr. Catarina Wor, DFO	Dr. Jake Kvistad, WDFW
	Mr. David Leonard, ADF&G
	Dr. Martin Liermann, NOAA Fisheries
	Mr. Scott Marshall, IDF&G
	Ms. Marianne McClure, CRITFC
	Dr. Oliver Miler, NWIFC
PSC Support	Dr. Gary Morishima, QIN
Ms. Caroline Graham, CTC Coordinator	Mr. Jeff Nichols, ADF&G
Ms. Merran Hague, Stock Assessment Biologist	Mr. Randy Peterson, ADF&G
Mr. Mark McMillan, Database Manager	Ms. Anne Reynolds-Manney, ADF&G
Ms. Serena Wong, Data & Assessment Biologist	Dr. Mark Sorel, WDFW
	Dr. Charlie Waters, NOAA Fisheries

List of Acronyms and Abbreviations

AABM	Aggregate Abundance-Based Management
ACL	Annual Catch Limit
ADF&G	Alaska Department of Fish & Game
AI	Abundance Index
AIC	Akaike Information Criterion
BPC	Base Period Calibration
CIG	Chinook Interface Group
CLB	Calibration
CPUE	Catch Per Unit Effort
CRITFC	Columbia River Intertribal Fish Commission
CTC	Chinook Technical Committee
DFO	Canadian Department of Fisheries and Oceans
FNC	First Nations Caucus
FPD	Fisheries Performance Data
IDF&G	Idaho Department of Fish and Game
LM	Linear Model
NBC	Northern British Columbia
NOAA	National Oceanic and Atmospheric Administration
NWIFC	Northwest Indian Fisheries Commission
ODFW	Oregon Department of Fish and Wildlife
PE	Prediction Error
PSC	Pacific Salmon Commission
PST	Pacific Salmon Treaty
PTI	Power Troll Index
QIN	Quinault Indian Nation
SEAK	Southeast Alaska
UAF	University of Alaska Fairbanks
USFWS	United States Fish and Wildlife Service
WCVI	West Coast of Vancouver Island
WDFW	Washington Department of Fish and Wildlife

TABLE OF CONTENTS

LIST OF TABLES

List of Appendices

1. INTRODUCTION

On February 16, 2023, the Commission agreed to suspend the use of the CPUE-based approach to determine the catch limit for the Southeast Alaska (SEAK) aggregate abundance-based management (AABM) fishery. At the same time, the Commission agreed that a new multivariate model in conjunction with 17 tiers would be used to set the catch limit for the SEAK AABM fishery in 2023. To make an informed decision as to whether to continue to use this new method to set the SEAK AABM catch limit for 2024 and subsequent years, the Commission requested a review of the catch per unit effort (CPUE)-based approach, as per Appendix A to Annex IV, Chapter 3, paragraph 12 of the 2019 Pacific Salmon Treaty (PST) Agreement:

> *The Commission may request CTC* (Chinook Technical Committee) *support in conducting up to two reviews of the CPUE-based approach to decide whether to continue to use this method to determine the catch limit for the SEAK AABM fishery, to return back to use of the Commission Chinook model, or to adopt an alternative method as determined by the Parties, to determine pre-season estimates of the aggregate AI* (abundance index) *of Chinook stocks available to the SEAK troll fishery and the relationship between the catch and AIs specified in Table 1.*

The Commission requested that the CPUE-based approach review include the information outlined in Chapter 3, subparagraph 7(d) (*Section 2*) and any additional information that could better inform the Commission's decision as to whether to continue using the new multivariate model and the 17 tiers to set the SEAK AABM fishery catch limit for 2024 and subsequent years (*Section 3*). Furthermore, during the February 2023 Pacific Salmon Commission (PSC) Annual Meeting, the Commission requested that the CTC conduct further analyses to inform how a trigger point for Chapter 3, subparagraph 7(b) for the SEAK AABM fishery could be set in the future if the multivariate model in conjunction with the 17 tiers continues to be utilized to set the SEAK AABM catch limit moving forward (*Section 4*). Below is the CTC response to the tasks identified by the Commission at the February 2023 PSC Annual Meeting regarding the SEAK AABM fishery.

2. CPUE-BASED APPROACH REVIEW

As stated in Chapter 3, subparagraph 7(d) of the 2019 PST Agreement, the CPUE-based approach review was to be based on the following information:

- (i) a comparison of cumulative actual catch and the cumulative post-season catch limit from the Commission Chinook model (**Table A**)
- (ii) a comparison of the cumulative performance of the CPUE-based catch limit and the pre-season catch limit from the Commission Chinook model to predict the catch limit estimated from the first post-season calibration of the Commission Chinook model (model error; **Table B**), and
- (iii) a comparison of the abundance tier selected by use of the CPUE method and the abundance tier that is selected by use of the pre-season calibration of the Commission Chinook model with the abundance tier selected from the first post-season calibration derived from the Commission Chinook model (**Table C**).

Below is the requested information for Chapter 3, subparagraphs 7(d)(i)–7(d)(iii).

Table A. *7(d)(i): A comparison of cumulative actual catch for the SEAK AABM fishery and the cumulative post-season catch limit from the Commission Chinook model.*

Year	Actual Catch	Table 2 Post-season ACL[1]	Post-season ACL – Actual Catch[2]
2019	140,307	140,323	-16 (-0.01%)
2020	204,624	140,323	64,301 (45.8%)
2021	202,082	140,323	61,759 (44.0%)
2022	238,621	140,323	98,298 (70.1%)
Cumulative	***785,634***	***561,292***	***224,342 (40.0%)***

[1] ACL = allowable catch limit determined based on Chinook model abundance indices (AIs) and Table 2.

[2] Nominal error with percent error in brackets.

Table B. *7(d)(ii): A comparison of the cumulative performance of the CPUE-based catch limit for the SEAK AABM fishery and the pre-season catch limit from the Commission Chinook model to predict the catch limit estimated from the first post-season calibration of the Commission Chinook model.*

Year	Pre-season ACL[1]		Post-season ACL[1]		Pre-season CPUE ACL – Table 2 Post-season ACL[2]	Pre-season Model ACL – Table 1 Post-season ACL[2]
	CPUE	Chinook Model	Table 2	Table 1		
2019	140,323	133,600	140,323	127,130	0 (0.0%)	6,470 (5.1%)
2020	205,165	140,000	140,323	135,640	64,842 (46.2%)	4,360 (3.2%)
2021	205,165	190,000	140,323	161,349	64,842 (46.2%)	28,651 (17.8%)
2022	266,585	146,400	140,323	120,714	126,262 (90.0%)	25,686 (21.3%)
Cumulative	***817,238***	***610,000***	***561,292***	***544,833***	***255,946 (45.6%)***	***65,167 (12.0%)***

[1] ACL = annual catch limit; annual pre-season values are determined for the CPUE method via CPUE abundance indices (AIs) and Table 2, while those for the Chinook Model are determined via model AIs and Table 1; post-season ACLs are determined for the CPUE method and Chinook model via post-season Chinook model AIs with Table 2 and Table 1, respectively.

[2] Model error defined as the pre-season minus post-season ACL (CPUE – Table 2 or Chinook Model – Table 1), shown as nominal error with percent error in brackets.

Table C. *7(d)(iii): A comparison of the abundance tier selected by use of the CPUE method and the abundance tier that is selected by use of the pre-season calibration of the Commission Chinook model with the abundance tier selected from the first post-season calibration derived from the Commission Chinook model.*

Year	Pre-season[1]				Post-season Chinook Model[1]	
	CPUE-based Method		Chinook Model			
	CPUE	Tier	AI	Tier	AI	Tier
2019	3.38	3	1.07	3	1.04	3
2020	4.83	4	1.13	3	1.11	3
2021	3.85	4	1.28	4	1.23	3
2022	7.05	5	1.16	3	1.04	3

[1] Table 2 Abundance tiers determined pre-season from either CPUE or pre-season Chinook model calibration abundance indices (AI) and post-season from post-season Chinook model calibration AIs.

During the February 2023 PSC Annual Meeting, the Commission agreed to suspend the use of the CPUE-based approach to determine pre-season catch limits for the SEAK AABM fishery due to its poor performance and as demonstrated in **Table A**, **Table B**, and **Table C**.

3. MULTIVARIATE MODEL ADDITIONAL ANALYSES

Following the 2022 PSC Chinook Model Calibration (CLB 2203), the SEAK AABM fishery triggered Chapter 3, subparagraph 7(b):

> *If, in two consecutive years, the NBC* (Northern British Columbia) *or WCVI* (West Coast Vancouver Island) *AABM fishery catches exceed post-season limits by more than 10%, or the SEAK AABM fishery the pre-season tier and catches exceed the post-season tier, then:*
>
> *(i)* *the Commission shall request that the management entity responsible for the management of that AABM fishery take necessary actions to minimize variance between the pre-season and post-season catch limits commencing the following year. By the end of the annual meeting of the Commission, the Commission shall discuss proposals from the management entity regarding the actions to be taken and the expected outcomes of those actions before those actions are implemented, and*
>
> *(ii)* *the CTC shall recommend to the Commission a plan to improve the performance of pre-season, in-season, and other management tools so that the deviations between catches and post-season fishery limits to AABM fisheries are narrowed to a maximum level of 10%.*

The CTC's initial response to the task outlined in subparagraph 7(b)(ii) can be found in **Appendix A** and Alaska Department of Fish and Game's (ADF&G) analytical response to the task outlined in subparagraph 7(b)(i) can be found in **Appendix B**. At the January 2023 PSC Post-Season Meeting, the PSC requested that the CTC resolve any differences and summarize the technical merits of selecting Method 4.2 or Method 4.3 (as defined in **Appendix A,** noting that Method 4.3 is the same model as the best model put forward by ADF&G in **Appendix B**). Additionally, the PSC requested that the CTC (1) provide additional assessments that evaluate the performance of the two proposed models with and without tiers and (2) summarize the technical merits of the use of tiers versus no tiers and identify any potential technical improvements to the tiers proposed by ADF&G (17 tiers proposed in **Appendix B**). The CTC response to these requests can be found in **Appendix C.**

On February 16, 2023, the Commission agreed that a new multivariate model (Method 4.3; **Appendix A; Equation 1**) in conjunction with 17 catch tiers (**Appendix C**) would be used to set the catch limit for the SEAK AABM fishery in 2023. In this method, the catch limit is determined from a 17-tier table based on a predicted post-season AI (*Post AI*) determined from a linear model including the pre-season AI (*Pre AI*) and projected AI (*Projection*) from the current year's calibration and previous year's calibration, respectively, and the SEAK Winter Troll CPUE as covariates. At the Commission's request, the CTC undertook further analyses to evaluate this new method to better inform the Commission's decision as to whether to continue using Method 4.3 and the 17 tiers to set the SEAK AABM fishery catch limit for 2024 and subsequent years under the current Agreement.

$$Post\ AI = \beta_0 + \beta_1 Pre\ AI + \beta_2 \ln{(CPUE)} + \beta_3 Projection$$

Equation 1

In response to concerns about autocorrelated errors in Method 4.3, the CTC expanded ADF&G's cross-validation approach described in **Appendix B** to include an AR(1) autocorrelation term as an additional predictor in a candidate model (**Table D**; **Table E**; **Table F**). The originally-proposed model (i.e., **Equation 1**) still came out as the best of the expanded set of models; with the AR1 term, the standard deviation from cross-validation was 32,659 vs 32,389 for the model without this term. The CTC further examined the model residuals for evidence of autocorrelation and found very little.

The CTC also revisited another proposed multivariate model (Method 4.2; **Appendix A**) and evaluated its performance with the addition of an AR(1) autocorrelation term (**Table D**). Adding the term improved the method's retrospective performance as shown in **Appendix D**. The standard deviation derived from cross-validation errors did not significantly change going from 47,197 to 47,125 with the addition of the AR(1) term.

Table D. *Cross-validation assessment of Methods 4.3 and 4.2, with and without AR1 autocorrelation terms. "Typical error" is the leave-one-out cross-validation prediction standard deviation (i.e., the square root of the average squared cross-validation forecast error) for each method.*

	Method 4.3	Method 4.3 + AR1	Method 4.2	Method 4.2 + AR1
Typical error	32,659	32,659	47,197	47,125

Table E. *Pre- and post-season abundance indices (AIs), associated 17-tier annual catch limits (ACLs), and corresponding ACL deviations determined from Method 4.3 based on CPUE, pre-season AI, and projected AI as predictors. Summary values represent cumulative deviations for the total deviation and mean deviations for the percent deviation.*

Year	Pre-season AI	Post-season AI	Pre-season ACL	Post-season ACL	Deviation	
					Total	%
2019	0.98	1.07	111,888	127,130	-15,242	-12%
2020	1.13	1.11	142,101	142,101	0	0%
2021	1.17	1.23	142,101	157,072	-14,971	-10%
2022	1.35	1.04	206,027	127,130	78,897	62%

Table F. *Pre- and post-season abundance indices (AIs), associated 17-tier annual catch limits (ACLs), and corresponding ACL deviations determined from Method 4.3 based on CPUE, pre-season AI, and projected AI as predictors and including an AR(1) autocorrelation term. Summary values represent cumulative deviations for the total deviation and mean deviations for the percent deviation. For 2019, the prediction fell into Tier 1, which requires a Commissioner's discussion to determine the pre-season ACL.*

Year	Pre-season AI	Post-season AI	Pre-season ACL	Post-season ACL	Deviation	
					Total	%
2019	0.79	1.07	NA	127,130	NA	NA
2020	0.97	1.11	111,888	142,101	-30,213	-21%
2021	1.15	1.23	142,101	157,072	-14,971	-10%
2022	1.45	1.04	206,027	127,130	78,897	62%

The CTC noted a situation where the precision of the input data used to fit the model shifted the estimated ACL from one tier to another. In order to avoid ambiguity in these rare cases, the CTC recommends use of AI values rounded to two digits in data sets for annually updating the model for predicting the post-season AI and in calculating ACLs from these predictions in the interest of consistency and facilitating reproducibility. This adheres to the long-standing practice of rounding the AI to two digits both before calculating the ACL from the ACL-AI tier tables, and in publishing AI values.

4. 7(B) TRIGGER ANALYSES FOR SEAK AABM FISHERY

At the February 2023 PSC Annual meeting, the PSC requested the CTC conduct further analyses to inform how a trigger point for Chapter 3, subparagraph 7(b) for the SEAK AABM fishery could be set in the future if Method 4.3 and the 17-tier approach continue to be utilized to set the SEAK AABM catch limit. The CTC addressed this request from three different perspectives: (1) an evaluation of the potential for SEAK AABM ACL buffers from the point of view of parity among the three AABM fisheries; (2) the use of simulations to calculate probabilities of triggering 7(b); and, (3) an appraisal of the history of SEAK AABM overages (and NBC and WCVI underages) during this Agreement.

To avoid ambiguity, trigger point is defined here as an acceptable, agreed to deviation or buffer between actual catch and post-season ACL beyond which subparagraph 7(b) would be triggered.

1. The CTC assessed the potential for SEAK AABM ACL buffers from a parity perspective, by examining the feasibility of implementing buffers similar to the 10% ACL buffer permitted for the NBC and WCVI AABM fisheries. This evaluation was based on two measurements: ACL deviations between midpoints of contiguous tiers and ACL ranges within a single tier. This evaluation showed that midpoint ACL deviations between contiguous tiers and within-tier ACL ranges are smaller than 10% in most cases but greater than 10% for tiers 5, 6, 7, 10, and 13. Therefore, a tier-specific buffer (trigger point) system could be considered for parity among AABM fisheries (**Appendix E**). The tier-specific buffers would need to be discrete and would vary since the percent differences in catch limits between tiers are not consistent.
2. A simulation based on cross-validation using the forecasting Method 4.3 was used to calculate the range of historical values of the post-season AI using the new 17-tier table and the standard deviation of the forecast residuals for AIs over the period 2001–2022 (**Appendix F**). This simulation estimated a 15.3% probability of triggering 7(b) based on 1-tier midpoint ACL deviations. This analysis also estimated a 6% probability of the pre-season ACL exceeding the post-season ACL by 10% in two consecutive years.
3. An evaluation of the performance of each of the three AABM fisheries during this Agreement relative to the post-season ACLs during this Agreement (**Appendix G**) raised the following observations:
    a. In response to the poor performance and history of overages resulting from the implementation of the CPUE-Table 2 system, a new model (Method 4.3) and a new 17-tier table have been introduced to determine the SEAK AABM catch limit in 2023; the real-world performance of this new system has not been evaluated yet.
    b. Tiers already represent a buffer system; some of the tiers in the new 17-tier table are above and some below the 10% ACL buffer applied to the other AABM fisheries.

c. Modifications to subparagraph 7(b) could be considered in the future, depending on performance of the new system (Method 4.3 & 17-tier table) in 2023. These modifications could be characterized either by adding discrete tier-specific ACL buffers for SEAK AABM catch or other means such as reducing the 10% buffer for NBC and WCVI to an agreed lower level, making all tiers the same size with 10% ACL ranges or returning to the use of the Chinook Model and Table 1.

Based on the above evaluations and analyses, and due to uncertainty about the future approach to setting SEAK AABM catch limits, the CTC recommends postponing further evaluation of ACL buffers for the SEAK AABM catch until we know more about the real-world performance of the new system (Method 4.3 & 17-tier table).

Appendices

APPENDIX A: MEMO FROM CTC TO PSC: RESPONSE TO CH. 3, 7(B)(II) TASK

TO: Pacific Salmon Commission
FROM: Chinook Technical Committee
DATE: January 6, 2023
SUBJECT: CTC Response to Ch. 3, 7(b)(ii) task: Exploration of alternative approaches to minimize deviations between Chinook salmon pre-season and post-season annual catch limits in the Southeast Alaska aggregate abundance-based management fishery
CC: National Correspondents

Executive Summary

For the Southeast Alaska (SEAK) aggregate abundance-based management (AABM) fishery, both the pre-season annual catch limit (ACL) and the observed catch have exceeded the post-season ACL for two consecutive years (2020 and 2021). Per the provisions identified in paragraph 7(b) of the 2019 Pacific Salmon Treaty (PST) Agreement, this circumstance requires further action. In response to the provisions identified in 7(b)(ii), this document summarizes the Chinook Technical Committee's (CTC) exploration of alternative approaches to the catch per unit effort (CPUE) and PST Table 2 approach currently used to determine pre-season ACLs for the SEAK AABM fishery (see Appendix B in Chapter 3 of the 2019 PST Agreement) in order to minimize deviations between pre-season and post-season ACLs for the fishery. This memo focuses on four types of alternative pre-season forecast modeling approaches, and several methods that fall within those approaches, that were evaluated by the CTC:

1. Reverting to use of the Pacific Salmon Commission (PSC) Chinook Model abundance indices (AIs) and PST Table 1 to determine pre-season ACLs (Chapter 3 of the 2019 PST Agreement) (Method 1)
2. Non-tier approaches that preserve the original AI-CPUE relationship (Method 2)
3. Approaches that rely on updated AI-CPUE time series (Methods 3.1–3.3, as detailed herein)

4. Multivariate regressions (Methods 4.1–4.3, as detailed herein)

The PSC Phase II Chinook Model AIs and Table 1 are currently used to determine pre- and post-season ACLs for the Northern BC (NBC) and West Coast Vancouver Island (WCVI) AABM fisheries, while for the SEAK AABM fishery, pre-season ACLs are determined by the CPUE method and Table 2 and post-season ACLs are determined by the Chinook Model AIs and Table 2 (PST 2019). The alternative approaches considered here differ in a number of ways, such as their relative reliance on recent or alternative sources of data, and the benefits and drawbacks to each are discussed below. The CTC evaluated the performance of the four approaches across a 3-year evaluation time period (2019–2021). Performance of the alternative approaches in relation to the current approach was evaluated in terms of both the overall and relative magnitude of deviations between pre- and post-season ACLs and the likelihood of incurring deviations greater than 10%. All four alternative approaches presented herein reduce pre-season-to-post-season deviations and decrease the likelihood of having two consecutive years with deviations greater than 10% across the 2019–2021 time period relative to the current CPUE-Table 2 approach, which overestimated post-season ACLs by over 40% in two recent consecutive years.

Reverting to using Chinook Model AIs and Table 1 to determine both pre-season and post-season ACLs would likely be the simplest alternative approach and resulted in deviations of less than 10% for 2019 and 2020, but greater than 10% for 2021. However, of the alternatives evaluated by the CTC, two of the multivariate regressions (Methods 4.2 and 4.3) resulted in the lowest annual and cumulative deviations between pre- and post-season ACLs compared to all approaches examined (see Summary Table). One of the multivariate regressions, which predicts pre-season ACLs based on Chinook Model pre-season AI, Catch, Effort, and an interaction term between Catch and Effort in place of a CPUE term, produced the smallest retrospective cumulative deviation amongst all approaches explored herein, and was the only one to produce deviations smaller than 10% in all three years (2019–2021). The second multivariate regression, developed by Alaska Department of Fish and Game (ADF&G) as per 7(b)(i) provisions (see ADF&G 7(b)(i) analyses 2022), predicts pre-season ACLs using the Chinook Model pre-season AI, one-year-ahead projection, and CPUE. This regression produced the second smallest retrospective cumulative deviation, with deviations smaller than 10% in 2019 and 2020, and one of -14.6% in 2021. This latter method was the only assessed model that produced negative deviations in two of the three evaluation years (2019, 2021) and had the highest performance among models assessed via cross-validation (see methods and caveats described in sections below).

Given these results, the CTC recommends using one of these two multivariate regressions (Method 4.2 or 4.3) to determine SEAK AABM fishery pre-season ACLs until the CPUE method review (outlined in paragraph 7(d) of Chapter 3 of the 2019 PST Agreement) can be conducted.

Summary Table. *Annual and cumulative percent deviations in pre-season-to-post-season annual catch limits (ACL) for the Southeast Alaska (SEAK) aggregate abundance-based management (AABM) fishery determined from the current application of catch per unit effort (CPUE) and the Pacific Salmon Treaty (PST) Table 2, the application of the Pacific Salmon Commission (PSC) Phase II Chinook Model abundance indices (AIs) and PST Table 1, and the two multivariate forecast models resulting in the smallest 2019–2021 cumulative deviation in ACLs amongst all alternative approaches examined by the Chinook Technical Committee (CTC) to date. The table (Table 1 or Table 2) used to determine the pre- and post-season ACLs is specified in the 'ACL Derivation' column. Percent deviation values are color-coded in green for single years with deviations < 10%, in yellow for single years with deviations > 10%, and in red for two consecutive years with deviations > 10%.*

Approach	Method	ACL Derivation	Year	Pre-to-Post Deviation	Cumulative Deviation
Current SEAK Approach	CPUE	Pre: Table 2 Post: Table 2	2019	0.0%	129,684
			2020	46.2%	
			2021	46.2%	
Same as NBC and WCVI	Method 1: Chinook Model	Pre: Table 1 Post: Table 1	2019	5.1%	39,481
			2020	3.2%	
			2021	17.8%	
Multivariate	Method 4.2: LM (Chinook Model Pre + Catch + Effort + Catch x Effort)	Pre: Table 1 Post: Table 1	2019	-7.0%	3,931
			2020	9.5%	
			2021	0.0%	
	Method 4.3: Chinook Model Pre + CPUE + 1 Year Ahead Projection	Pre: Table 1 Post: Table 1	2019	-8.1%	-29,554
			2020	3.1%	
			2021	-14.6%	

Introduction

The 2019 Pacific Salmon Treaty (PST) Agreement requires an assessment of aggregate abundance-based management (AABM) fishery performance relative to post-season annual catch limits (ACLs). The Pacific Salmon Commission (PSC) Chinook Model estimates an annual abundance index (AI) for all AABM fisheries to track the abundance of fish available to them in a given year. For the Southeast Alaska (SEAK) AABM fishery, catch rates of Chinook are also used as indices of fish abundance. Under the current management system, the SEAK winter troll catch per unit effort (CPUE) is translated into a pre-season ACL for the SEAK AABM fishery using a look-up table (Table 2 in Chapter 3 of the 2019 PST Agreement). This table was developed by analyses that used this CPUE-based approach as a predictor of the post-season AI (Annex IV, Chapter 3, Appendix B, Paragraphs 4–6). In evaluating performance of the SEAK AABM fishery post-season, the Treaty requires that the first post-season AI from the PSC Chinook Model be translated to a post-season ACL using this same table, which is then compared to both the pre-season ACL and the observed catch.

In certain situations, the Commission may be required to notify relevant management entities of necessary additional actions. Specifically, per paragraph 7(b), the Parties agree that *"if, in two consecutive years, the NBC* [Northern BC] *or WCVI* [West Coast Vancouver Island] *AABM fishery catches exceed post-season limits by more than 10%, or the SEAK AABM fishery the pre-season tier and catches exceed the post-season tier, then:*

(i) the Commission shall request that the management entity responsible for the management of that AABM fishery take necessary actions to minimize variance between the pre-season and post-season catch limits commencing the following year. By the end of the annual meeting of the Commission, the Commission shall discuss proposals from the management entity regarding the actions to be taken and the expected outcomes of those actions before those actions are implemented, and

(ii) the CTC shall recommend to the Commission a plan to improve the performance of pre-season, in-season, and other management tools so that the deviations between catches and post-season fishery limits to AABM fisheries are narrowed to a maximum level of 10%."

For the SEAK AABM fishery, both the pre-season ACL and the observed catch have exceeded the post-season ACL for two consecutive years (2020 and 2021; Table A). Per paragraph 7(b) of the 2019 PST Agreement this requires further action.

Table A. *Pre-season catch per unit effort (CPUE), tier, and annual catch limit (ACL), observed Treaty catch, and post-season abundance indices (AI), tier, and ACLs by year for the Southeast Alaska (SEAK) aggregate abundance-based management (AABM) fishery. The 'Pre > Post' and 'Obs > Post' columns indicate years where the pre-season tier or observed catches exceeded the post-season tier or ACL, respectively.*

	Pre-season				Post-season				
Year	CPUE	Tier	ACL	Observed	AI	Tier	ACL	Pre > Post	Obs > Post
2019	3.38	3	140,323	140,307	1.04	3	140,323	No	No
2020	4.83	4	205,165	204,624	1.11	3	140,323	Yes	Yes
2021	3.85	4	205,165	202,082	1.23	3	140,323	Yes	Yes

This document summarizes the CTC's exploration of alternative approaches to minimize deviations between pre-season and post-season ACL in the SEAK AABM fishery in response to the provisions of the

2019 PST Agreement as identified in subparagraph 7(b)(ii). The CTC opted to evaluate these approaches across a 3-year time period from 2019 to 2021 corresponding to the implementation of the 2019 PST Agreement and the use of the CPUE model. Four types of alternative pre-season modeling approaches are evaluated herein:

1. Reverting to use of the Pacific Salmon Commission (PSC) Chinook Model abundance indices (AIs) and PST Table 1 to determine pre-season ACLs (Chapter 3 of the 2019 PST Agreement) (Method 1)
2. Non-tier approaches that preserve the original AI-CPUE relationship (Method 2)
3. Approaches that rely on updated AI-CPUE time series (Methods 3.1–3.3, detailed below)
4. Multivariate regressions (Methods 4.1–4.3, detailed below)

Additional approaches that could be explored in the future are also identified.

In-season methods were not explored because the use of tiers for setting ACLs and for post-season comparison make adjusting catch into a lower tier difficult. The effective in-season models and methods are not available until near the end of July, at which point adjusting a catch limit to a lower tier is not feasible and highly allocative in nature. For the SEAK AABM fishery, allocative decisions need to be considered by the Alaska Board of Fisheries and adjustments between late July and the end of the fishing season are undesirable.

The CTC's observations and recommendations derived from this exercise are provided in the last section of this document. Note that any references to 'Table 1' or 'Table 2' in the following sections denote Table 1 or Table 2 in Chapter 3 of the 2019 PST Agreement, which are non-tiered or tiered harvest control rules, respectively. Similarly, any reference to CPUE in the following sections denotes the SEAK CPUE from the early winter power troll fishery in district 113.

Alternative Approaches

1. Using the Chinook Model and Table 1 for pre-season and post-season ACLs

The first alternate approach uses the PSC Chinook Model to produce SEAK's pre-season and post-season AIs and Table 1 to determine the corresponding ACLs for a given year. Essentially, this is the approach used for the NBC and WCVI AABM fisheries in the current PST Agreement and corresponds to the SEAK AABM provisions in the previous PST Agreement. Cumulative pre-to-post deviations from 2019–2021 for the PSC Chinook Model (Phase II) & Table 1 approach are about one third of the pre-to-post deviations from the current CPUE & Table 2 approach (Table B). The Chinook Model & Table 1 approach produced deviations of less than 10% for years 2019 and 2020 and 18% for 2021, whereas the CPUE & Table 2 approach produced a 0% deviation for 2019 and deviations of 46% for 2020 and 2021.

Table B. *Annual (2019–2021) and cumulative comparisons of Southeast Alaska (SEAK) annual catch limits (ACL) and pre-post deviations between those determined by the current catch per unit effort (CPUE) & Table 2 approach and those determined by the Phase II Chinook Model pre-season and post-season abundance indices (AIs) combined with Table 1. The percent deviation for the latter are shown in the last column. Summary values represent cumulative deviations for the total deviation and mean deviations for the percent deviation.*

Year	CPUE & Table 2				Chinook Model AI & Table 1			
	Pre Tier ACL	Post Tier ACL	Deviation Total	Deviation %	Pre Table 1 ACL	Post Table 1 ACL	Deviation Total	Deviation %
2019	140,323	140,323	0	0.0%	133,500	127,100	6,400	5.1%
2020	205,165	140,323	64,842	46.2%	140,000	135,700	4,300	3.2%
2021	205,165	140,323	64,842	46.2%	190,000	161,300	28,700	17.8%
Summary	***550,653***	***420,969***	***129,684***	***30.8%***	***463,500***	***424,100***	***39,400***	***9.3%***

2. Non-tier CPUE approach: Preserving the original AI-CPUE relationship

A non-tiered version of Table 2 was generated by translating the original AI-CPUE power relationship (derived using AIs from the 9806 configuration of the Chinook Model) to one based on AIs from the new, Phase II configuration of the Model. This approach aimed to preserve the original AI-CPUE relationship, rather than refitting the relationship with a new AI time series. The major axis regression that informed the catch neutral translations of Table 1 (2019 PST Agreement) was utilized in this approach and is described in further detail in Appendix A.

The ACLs derived from Table 1, the current tiered CPUE & Table 2, and this non-tiered CPUE & Table 2 approach are presented in Table C below. The percent deviation is computed by comparing the ACL based on the current and non-tiered Table 2 to the ACL from Table 1 based on the first post-season AI. The non-tiered version of Table 2 helped to reduce the average percent deviation in catches from 29.58% to 22.44%. This is primarily due to the 2021 non-tiered catch value which fell within a different tier than the tier indicated by the CPUE that year. This can be explained by rounding errors in breakpoints and is described in more detail in Appendix A.

In general, this non-tiered approach (Figure 1) did not drastically reduce the percent deviation of pre- to post-season ACLs relative to the current tiered approach, resulting in a higher percent deviation in 2019 (4.76%) and only a marginal reduction in 2020 (0.36%). This non-tiered approach will result in increases and decreases in ACLs relative to the current tiered approach depending on how far the observed CPUE falls from the mid-point CPUE of the tier. For instance, the 2019 ACL increases because observed CPUE is above the mid-point of the tier.

Table C. *Comparison of Annual Catch Limits (ACLs) and deviation in ACLs (compared to Table 1 ACLs) using the current tiered catch per unit effort (CPUE) & Table 2 approach and a non-tiered version.*

Year	First Post AI	Table 1 Post ACL	CPUE	Table 2 Pre ACL		Table 2 Pre ACL - Table 1 Post ACL			
						Tiered		Non-tiered	
				Tiered	Non-tiered	Total	%	Total	%
2019	1.07*	127,100	3.38	140,323	146,400	13,223	10.40%	19,300	15.18%
2020	1.11	135,700	4.83	205,165	204,700	69,465	51.19%	69,000	50.85%
2021	1.23	161,300	3.85	205,165	163,500	43,865	27.19%	2,200	1.36%
Summary		***424,100***		***550,653***	***514,600***	***126,553***	***29.60%***	***90,500***	***22.47%***

* The 9806 Post-season AI of 1.04 was converted to a Phase II AI of 1.07.

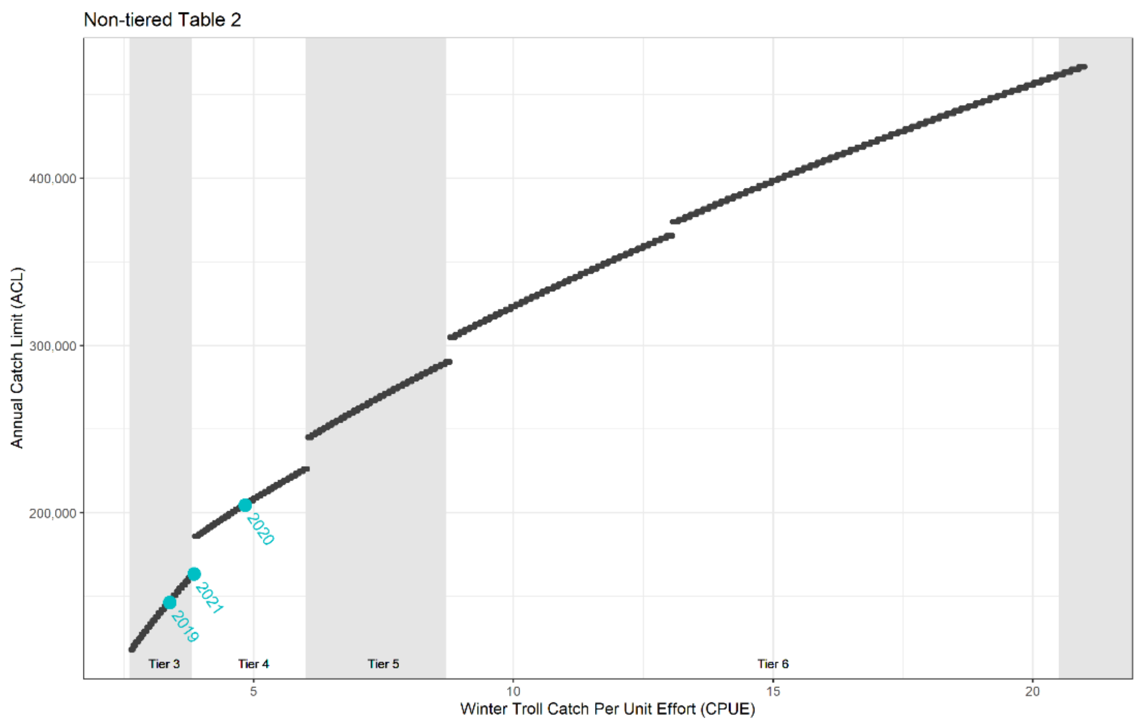


Figure 1. *Graphical representation of a non-tiered version of Table 2. The green points show the Annual Catch Limit (ACL) from 2019–2021 using this non-tiered approach.*

3. Approaches relying on updated AI-CPUE time series

The current CPUE method used to produce pre-season ACLs for the SEAK AABM fishery relies on a power regression between SEAK CPUE values and first post-season AIs from the PSC Chinook Model for years 2001–2015. The methods described in this section rely on incremental modifications to three elements of the current approach: updated CPUE-AI relationships, updated post-season AI time series produced directly by the Phase II PSC Chinook Model, and reliance on Table 1 ACLs or Table 2 tiered ACLs. The rationale for these modifications are:

- Method 3.1: Post-season AI metrics are currently based on projections from the Phase II Model. *Why not use the post-season AI time series directly produced by the Phase II Model to revamp and update the CPUE-AI relationship?*
- Method 3.2: The PSC Chinook Model calibration involves annual updating of input data prior to AI projections. *Why not annually update the CPUE-AI relationship?*
- Method 3.3: The current tiered Table 2 approach produces either zero or very large model errors and deviations. *Why not consider a non-tiered approach (e.g., relying on Table 1 or a non-tiered version of Table 2)?*

3.1 Updating AI-CPUE time series: Method 3.1 with Table 1 and Table 2 variations

The simplest modification to the current CPUE method would be to update the current CPUE-AI regression by expanding the time period to 2001–2021 in order to include all post-season data available to date. By using the time series of AIs from Calibration 2203 (Figure 2), this regression includes the first post-season AI for 2021, the second post-season AI for 2020, the third post-season AI for 2019, and so on. This is a deviation from the current approach that relies entirely on first post-season values. The estimated post-season AI values for a given catch year are expected to change slightly between the first and third post-season calibrations, after which they stabilize. However, relying on a single calibration to produce the entire time series of AIs is a practical step since it does not require retrospective generation of first post-season AIs. In addition, the predictive utility of the updated regression is moderate (Figure 2; R^2=0.66).

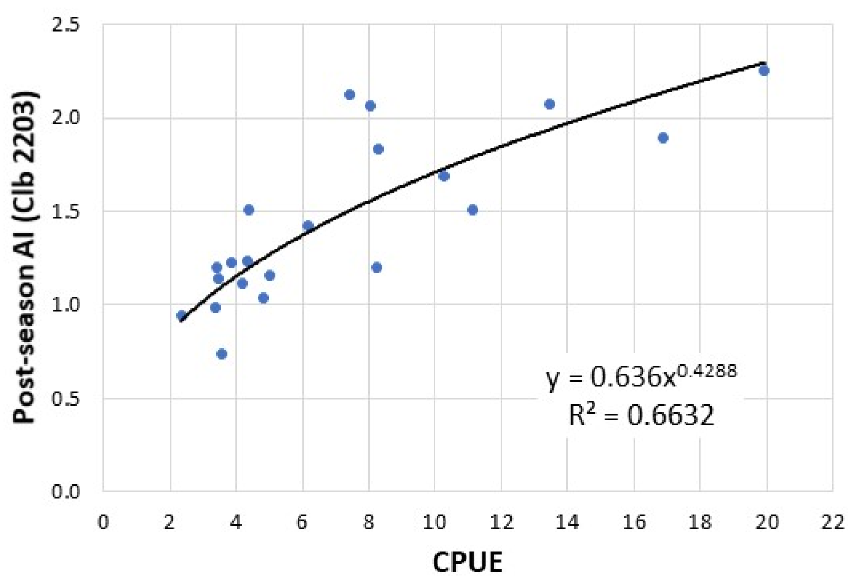


Figure 2. *Power regression based on Southeast Alaska (SEAK) catch per unit effort (CPUE) values and SEAK abundance indices (AIs) produced by Calibration 2203 and including years 2001–2021.*

Using this regression to produce pre-season AIs for the SEAK fishery, one could determine the corresponding ACL based on Table 1 (non-tiered) or Table 2 (tiered). Table D shows that these two methods did not have the positive deviation in 2021 produced by the current CPUE & Table 2 method. In addition, the method relying on Table 1 to determine ACLs reduced the magnitude of the deviation in 2020 by 30% (from 64,842 to 45,612). The cumulative deviations were reduced by 75% (from 129,684 to 32,058) and 50% (from 129,684 to 64,842) relative to the current method using the updated regression and Table 1, and the updated regression and Table 2, respectively.

Table D. *Annual (2019–2021) and cumulative deviations of Southeast Alaska (SEAK) annual catch limit (ACL) using two alternative pre-season approaches: (1) updated regression & Table 1 and (2) updated regression & Table 2. Recalculated pre-season ACLs are shown in Appendix B. Summary values represent cumulative deviations for the total deviation and mean deviations for the percent deviation.*

Year	Pre-season regression ACL		Post Tier ACL Table 2	Pre-season Regression ACL - Post Tier ACL			
				Table 1		Table 2	
	& Table 1	& Table 2		Total	%	Total	%
2019	127,130	140,323	140,323	-13,193	-9.4%	0	0.0%
2020	185,935	205,165	140,323	45,612	32.5%	64,842	46.2%
2021	139,962	140,323	140,323	-361	-0.3%	0	0.0%
Summary	***453,027***	***485,811***	***420,969***	***32,058***	***7.6%***	***64,842***	***15.4%***

3.2 Updating AI-CPUE time series: Method 3.2 with Table 1 vs. Table 2 variations

A variation of the methods described in the previous section is to generate a new regression each year based on new CPUE data and AIs from annual PSC Chinook Model calibrations (Table E) instead of relying on CLB 2203 to produce AIs for all years up to 2022 (Table D). In this approach, four annual PSC Chinook Model calibrations were used as the source for pre-season AIs for 2019–2022 and post-season AIs for 2018–2021 with a new CPUE-AI power regression generated each year to produce the SEAK AI forecast used to determine the pre-season ACL. Note that regressions do not include pre-season values (dark blue boxes in Table E) to avoid circularity of forecasted values.

Table E. *Time series of catch per unit effort (CPUE) values and abundance indices (AIs) produced by final calibrations of the Pacific Salmon Commission (PSC) Chinook Model and informing Southeast Alaska (SEAK) AI forecasting for catch years 2019–2022.Values shaded in dark blue are pre-season AIs.*

Year	CPUE	Chinook Model Calibrations			
		(CLB 1905)	(CLB 2002)	(CLB 2104)	(CLB 2203)
2001	8.25	1.15	1.18	1.20	1.20
2002	16.88	1.74	1.86	1.89	1.89
2003	19.93	2.17	2.21	2.25	2.25
2004	8.03	1.93	2.03	2.07	2.07
2005	8.30	1.73	1.81	1.83	1.83
2006	10.26	1.48	1.68	1.69	1.69
2007	3.43	1.12	1.19	1.20	1.20
2008	2.34	0.89	0.93	0.94	0.94
2009	3.46	1.04	1.11	1.14	1.14
2010	4.34	1.15	1.20	1.23	1.23
2011	6.17	1.42	1.40	1.42	1.43
2012	5.00	1.14	1.14	1.15	1.16
2013	4.40	1.58	1.49	1.52	1.51
2014	7.44	2.21	2.09	2.13	2.13
2015	13.43	1.85	2.02	2.06	2.07
2016	11.12	1.51	1.47	1.51	1.51
2017	4.21	1.16	1.12	1.12	1.11
2018	3.58	0.92	0.84	0.73	0.74
2019	3.38	1.04	1.10	0.96	0.99
2020	4.83		1.13	1.11	1.04
2021	3.85			1.28	1.23
2022	7.02				1.16

The forecasted pre-season AIs and recalculated ACLs based on Table 1 or Table 2 are shown in Table F. Similar to results for Method 3.1, these two variations removed the positive deviation in 2021 produced by the current CPUE & Table 2 approach (Table F). In addition, the method relying on Table 1 to determine ACLs reduced the magnitude of the deviation in 2020 by 28%. Relative to the current method, the cumulative deviations were reduced by 66% using the updated regression and Table 1 and by 50% using the updated regression and Table 2 (Table G).

Table F. *Regression parameters, forecasted pre-season abundance indices (AIs), and annual catch limits (ACLs) based on Table 1 or Table 2 for years 2019–2021.*

Calibration	Time series	Regression Parameters			Forecasted Pre-season AI		ACL	
		a	b	R^2	Year	AI	Table 1	Table 2
CLB 1905	2001-2018	0.689	0.377	0.57	2019	*1.09**	137,824	140,323
CLB 2002	2001-2019	0.673	0.400	0.66	2020	1.26	187,274	205,165
CLB 2104	2001-2020	0.626	0.436	0.66	2021	1.13	139,962	140,323

* AI and ACL in CLB 9806 scale

Table G. *Annual (2019–2021) and cumulative comparisons of pre-post season deviations in Southeast Alaska (SEAK) annual catch limits (ACLs) determined by the current catch per unit effort (CPUE) & Table 2 approach, and two alternative pre-season AI forecast approaches: (1) annually updated regression & Table 1 and (2) annually updated regression & Table 2. Summary values represent cumulative deviations for the total deviation and mean deviations for the percent deviation.*

Year	CPUE & Table 2				Pre-season Regression ACL - Post Tier ACL			
	Pre Tier	Post	Deviation		Table 1		Table 2	
	ACL	Tier ACL	Total	%	Total	%	Total	%
2019	140,323	140,323	0	0.0%	-2,499	-1.8%	0	0.0%
2020	205,165	140,323	64,842	46.2%	46,951	33.5%	64,842	46.2%
2021	205,165	140,323	64,842	46.2%	-361	-0.3%	0	0.0%
Summary	***550,653***	***420,969***	***129,684***	***30.8%***	***44,091***	***10.5%***	***64,842***	***15.4%***

3.3 Updating AI-CPUE time series: Method 3.3

Another variation to the approaches relying on updated AI-CPUE time series consists of using annually updated regressions as shown in Table F but without using any Table 2 ACL values for calculation of deviations. In other words, all statistics (i.e., regression-calculated ACLs and ACL deviations) are based on pre-season and post-season ACLs from Table 1. This method similarly removed the positive deviation in 2021 produced by the current CPUE & Table 2 method, reduced the magnitude of the deviation in 2020 by 20%, and reduced the cumulative deviation by 68%, relative to the current approach (Table H). This approach produced a small 2019–2021 cumulative deviation and the second most negative annual deviation for any given year (2021) among all alternative approaches examined herein.

Table H. *Annual (2019–2021) and cumulative comparison of Southeast Alaska (SEAK) annual catch limit (ACL) pre-post deviations resulting from annually updated regressions in Table D and post-season ACLs from Table 1.*

Year	Post-season Table 1 ACL	Pre-season Regression & Table 1 ACL	Deviation	
			Total	%
2019	127,130	137,824	10,693	8.4%
2020	135,685	187,274	51,589	38.0%
2021	161,349	139,962	-21,387	-13.3%
Cumulative			***40,895***	***11.1%***

4. Methods relying on multivariate regressions

4.1 LM based on Chinook Model pre-season AI and CPUE values

A linear model (LM), using pre-season AIs from the PSC Chinook Model in combination with SEAK CPUE data as predictors was used to forecast post-season AIs for the SEAK AABM fishery. The LM was updated each year with new pre-season AI and CPUE data as shown in Table I. Both pre-season and post-season AI and ACL values used for this method were based on Table 1 (i.e., Table 2 tiers were not used). This decision was made based on results in section 3 above, where cumulative deviations were lower when ACLs were derived using Table 1 (no tiers) as opposed to Table 2 (tiered). While each of the multivariate approaches described in this section could also be used to determine ACLs using Table 2, this was not explored here based on the expectation that cumulative deviations would be higher. When the CTC was tasked with translating Table 1 in 2019, a regression equation was developed to relate the 9806 AIs to the Phase II AIs from the new base-period calibration (BPC) model. That same equation is used here to convert AIs prior to 2020 to be consistent with the Phase II model. This is an important step, otherwise the parameters of the regression equation would be fit to 9806 AIs but would be used to predict AIs from the Phase II model. Additionally, both the pre- and post-season AIs are modeled on the log-scale to compress the variation at larger AI scales.

After converting AIs prior to 2020 into Phase II model units, the regression equation takes the form:

$$\log(Post\ AI) = \beta_0 + \beta_1 \log(Pre\ AI) + \beta_2 \log(CPUE)$$

This approach produced a positive deviation of 8% in 2019 and 0% in 2021, and a deviation greater than 10% only for 2020 (see Table I).

Table I. *Linear model (LM) parameters, forecasted pre-season abundance index (AI), and annual catch limits (ACLs) based on Table 1 for years 2019–2021. Summary values represent cumulative deviations for the total deviation and mean deviations for the percent deviation.*

Time series	LM Parameters			Forecasted AI		Table 1 ACL		Deviation	
	Intercept	log_Pre	log_CPUE	Year	AI	Forecasted	Post-season	Total	%
2001-2018	-0.19605	0.553	0.2107	2019	1.12	137,824	127,130	10,694	8.4%
2001-2019	-0.2063	0.5645	0.2122	2020	1.22	159,211	135,685	23,526	17.3%
2001-2020	-0.2162	0.5936	0.2081	2021	1.23	161,349	161,349	0	0.0%
Summary								***34,220***	***8.6%***

4.2 LM based on Chinook Model pre-season AI, Catch, and Effort data

This method is similar to Method 4.1. There are, however, some important differences described below. Instead of including a CPUE term in this regression, Catch and Effort are treated as separate variables and an interaction term between them is included. Additionally, both the pre- and post-season AIs are modeled on the log-scale to compress the variation at larger AI scales. The regression equation takes the form:

$$\log(Post\ AI) = \beta_0 + \beta_1 \log(Pre\ AI) + \beta_2 Catch + \beta_3 Effort + \beta_4 CatchxEffort$$

Both pre-season and post-season AI and ACL values used for this method were again based on Table 1. This approach produced a slightly negative deviation in 2019, a positive deviation in 2020, and no deviation in 2021. The cumulative deviation is +3,931 and all annual percent deviations are less than 10% (Table J).

Table J. *Pre- and post-season abundance indices (AIs), associated Table 1 annual catch limits (ACLs), and corresponding ACL deviations determined from a linear model (LM) based on Catch and Effort as predictors. Summary values represent cumulative deviations for the total deviation and mean deviations for the percent deviation.*

Year	**Pre-season AI**	**Post-season AI**	**Pre-season ACL**	**Post-season ACL**	**Deviation**	
					Total	**%**
2019	1.03	1.07	118,229	127,130	-8,901	-7.0%
2020	1.17	1.11	148,517	135,685	12,832	9.5%
2021	1.23	1.23	161,349	161,349	0	0.0%
Summary					***3,931***	**0.8%**

Table K. *Linear model (LM) parameters for multiplicative catch and effort model.*

Time series	**LM Parameters**				
	Intercept	**Pre-season AI**	**Catch**	**Effort**	**Catch x Effort**
2001–2018	1.06×10^{-1}	6.72×10^{-1}	5.27×10^{-5}	1.70×10^{-4}	3.61×10^{-8}
2001–2019	8.62×10^{-2}	6.65×10^{-1}	5.20×10^{-5}	1.45×10^{-4}	3.48×10^{-8}
2001–2020	9.45×10^{-2}	6.78×10^{-1}	5.20×10^{-5}	1.45×10^{-4}	3.48×10^{-8}

These model results could potentially be misinterpreted to suggest that the post-season AI will increase linearly with Catch. However, the interaction term with Effort acts to reduce the slope of the Catch-log(Post AI) relationship for increasing values of Effort. This can be seen in Figure 3 below. This interaction term has a similar effect to calculating CPUE whereby higher catches do not necessarily imply higher abundances once Effort is accounted for.

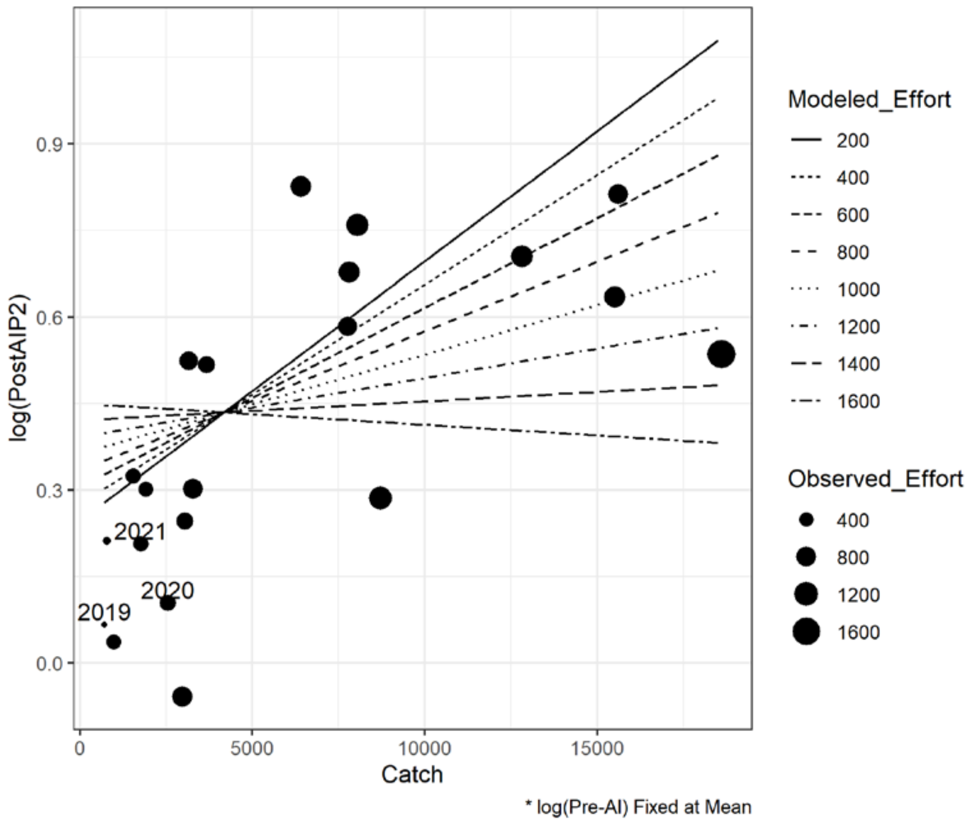


Figure 3. *Relationship between Catch and log(Post abundance index [AI]) for various levels of Effort. The log(pre-season AI) was fixed at the average value for these predictions. Predictions are from the 2021 analysis year model that utilizes data from 2001 to 2020.*

4.3 LM based on Chinook Model pre-season AI, CPUE, and Chinook Model one-year-ahead projected AI

This approach is similar to Methods 4.1 and 4.2 and has the following form:

$$Post\ AI = \beta_0 + \beta_1 \mathrm{Pr}\,e\ AI + \beta_2 log(CPUE) + \beta_3 Projection,$$

where the term '*Projection*' refers to the one-year-ahead projected AI from the previous year' calibration. The one-year-ahead projection refers to the output from the final PSC Chinook Model calibration from the previous April, which projects Chinook abundance a year ahead using default assumptions about Chinook vital rates. This differs from the pre-season AI by not using agency forecasts or any other quantities estimated after the previous April. Typically produced in April of the prior year. For more information about this approach please refer to ADF&G 7(b)(i) analyses (2022).

Table L. *Pre- and post-season abundance indices (AIs), annual catch limits (ACLs), and corresponding ACL deviations determined from a multivariate regression based on pre-season AI, one-year-ahead projected AI, and winter catch per unit effort (CPUE) as predictors. Summary values represent cumulative deviations for the total deviation and mean deviations for the percent deviation.*

Year	Pre-season AI	Post-season AI	Pre-season ACL	Post-season ACL	Deviation	
					Total	%
2019	1.01	1.07	116,820	127,130	-10,310	-8.1%
2020	1.13	1.11	139,920	135,685	4,235	3.1%
2021	1.12	1.23	137,780	161,349	-23,569	-14.6%
Summary					***-29,554***	***-6.5%***

Observations and Recommendations

This preliminary investigation provides alternatives to the current CPUE & Table 2 approach that decrease the likelihood of having two consecutive years with deviations in the pre-season to post-season ACLs greater than 10% in the SEAK AABM fishery (Table M). The simplest alternative would likely be to revert to using the PSC Chinook Model AIs and Table 1 to determine both pre- and post-season ACLs for the SEAK AABM fishery (Method 1), since this is the approach used for the other two AABM fisheries (NBC and WCVI). This approach produced ACL deviations of less than 10% for 2019 and 2020, and greater than 10% only for 2021, as well as one of the smallest 2019–2021 cumulative deviations.

The CPUE & Table 2 approach may be confounded by changes in abundance and distribution of the constituent stocks in the early winter troll fishery, along with being sensitive to potential changes in fleet behavior and an assumption of constant catchability, all of which have the capacity to deteriorate the CPUE-Abundance relationship.

Among the alternative approaches based on updated AI-CPUE time series, the variations relying on Table 1 (as opposed to Table 2) for pre-season AI forecasting were the most conservative (from the standpoint on not exceeding the ACL), producing negative deviations for 2019 and 2021, and therefore resulting in pre-season ACLs below post-season ACLs in these years. In particular, Method 3.3 produced the most negative deviation (21,387 under the post-season ACL in 2021), while Method 3.1 produced the third smallest cumulative deviation of all alternative approaches assessed.

The LM approach based on log-transformed pre-season AI and CPUE as predictors (Method 4.1) produced a deviation of 0% in 2021 and one of the smallest cumulative deviations for 2019–2021 (34,220 fish). A second LM approach, based on Catch and Effort treated as separate variables and an interaction term between them (Method 4.2) in place of CPUE, produced the smallest cumulative deviation (3,931) amongst all methods explored herein and also produced deviations smaller than 10% in all three years (2019–2021).

A parallel analysis by ADF&G (see ADF&G 7(b)(i) analyses 2022) looked at a similar suite of predictors combined using multiple regression. The major difference in approach was that the “best” model (Method 4.3) was selected by the standard deviation of the cross-validation prediction error over the years 2001–2021 (excluding 2006 and 2007). The cross-validation standard deviation of this model was 32,129. This can be contrasted to the LM approach that treated Catch and Effort as separate variables and included an interaction, where the size of the errors was -7%, 9.46% and 0% from 2019–2021; however, using this model the cross-validation error was 47,304. The range of cross-validation errors for all models that ADF&G explored (comparable to this approach of referencing Table 1 to determine ACLs) was 32,129–63,272, with a mean of 42,625. Comparatively, the LM with the catch and effort interaction did not perform well from a cross-validation standpoint.

There are some nuanced differences between cross-validation (the evaluation approach used by ADF&G) and expanding window retrospective evaluation (the evaluation approach used in this memo) that are important to understand. The major limitation of the expanding window retrospective evaluation is that there are only 3 years (2019–2021) that are used to calculate performance. There is the potential to look further back in time, but this limits the amount of data that a model can use and is not reflective of the data that are currently available. A 2019–2021 retrospective window was used in this memo as this period is most relevant to the current PST Agreement. The major advantage of the expanding window retrospective evaluation is that it tests the performance of the model exactly in the context in which it will be used (i.e., each year get a new data point, update the model and make a prediction). The model is being tested in a realistic way. Cross-validation is counterintuitive in that data from the future are used in constructing a model to “forecast” the left-out data point. However, note that the LM models used here assume that all the data are independent and identically distributed. In this context, the application of “future” data in cross-validation is appropriate. The major advantage of cross-validation is that there are n-1 (i.e., 2001–2021 = 21 - 1 = 20) errors that can be used to calculate the error. As a result of this larger sample size, this approach should improve the approximation of the center and distribution of the predictive error.

The best model from the ADF&G analysis had the following three predictors: CPUE and Model Pre-AI, plus the projected AI from the previous year’s CTC model calibration. Using this model was estimated to reduce a typical error in forecasting the post-season ACL from +/- 51,000 fish (current approach using Winter_CPUE only) to +/- 32,000 fish. Similarly, the CTC analysis found that if this model was used to predict the post-season AI for the years 2019–2021, the size of errors would be fairly low: -8.1%, 3.1%, and -14.6%, respectively.

Other approaches discussed by the CTC that could be considered in future investigations included: (a) methods based on concentration indices, (b) the use of correction factors based on deviations between winter CPUE-based power troll index (PTI) and summer CPUE-based PTI, (c) additional CPUE-based methods that rely on finer-scale data, (d) other multivariate-regression approaches, (e) depletion-based models that provide indices of abundance and (e) machine learning approaches on large multivariate datasets. Additionally, while exploration of approaches relying on individual harvester CPUE data are disallowed by the confidential nature of these data, there may be fruitful approaches using data disaggregated to a finer scale than boat days summed across the whole fleet and harvest over the whole season.

Despite using quite different methodologies, both the CTC and ADF&G analyses substantially agreed on the relative merits of the models examined. Both analyses found that models combining winter troll fishery catch rates with PSC Chinook Model outputs performed substantially better than using either data type in isolation. This is fortunate, as both methods contain unavoidable caveats. The CTC analysis compared performance across only the three most recent years, which is not enough to give high confidence that the differences seen will persist for future applications. The ADF&G analysis used PSC

Chinook Model outputs that spanned a significant revision in the model structure[1, 2]; prediction error estimates from the first part of the data, the majority, might not be completely representative of future errors using the revised PSC Chinook Model.

In light of the exploration and evaluation of alternative approaches to the current CPUE & Table 2 approach to determining SEAK AABM fishery pre-season ACLs, and, as per paragraph 7(b)(ii) provisions of Chapter 3 of the 2019 PST Agreement, the CTC recommends using one of two multivariate regressions (Method 4.2 or 4.3, Table M) to determine SEAK AABM fishery pre-season ACLs until the CPUE method review (outlined in paragraph 7(d) of Chapter 3 of the PST) can be conducted.

[1] CTC. 2021. 2019 Exploitation Rate Analysis and Model Calibration - Volume One. Pacific Salmon Commission Joint Chinook Technical Committee Report TCCHINOOK (21)-01, V1. Vancouver, BC.

[2] CTC. 2021. 2019 Exploitation Rate Analysis and Model Calibration - Volume 2: Appendix Supplement. Pacific Salmon Commission Joint Chinook Technical Committee Report TCCHINOOK (21)-01, V2. Vancouver, BC.

Table M. *Pre-season-to-post-season annual catch limit (ACL) percent deviations for all methods explored in this document, including the current catch per unit effort (CPUE) & Table 2 approach and the application of Chinook Model abundance indices (AIs) combined with Table 1. The table (Table 1 or Table 2) used to calculate the pre- and post-season ACLs is specified in the 'ACL Derivation' column. Percent deviation values are color-coded in green for single years with deviations < 10%, in yellow for single years with deviations > 10%, and in red for two consecutive years with deviations > 10%.*

Approach Type	Method	ACL Derivation	Year	Pre-to-Post Deviation	Cumulative Deviation
Current SEAK Approach	CPUE	Pre: Table 2 Post: Table 2	2019	0.0%	129,684
			2020	46.2%	
			2021	46.2%	
Same as NBC and WCVI	Method 1: Chinook Model	Pre: Table 1 Post: Table 1	2019	5.1%	39,481
			2020	3.2%	
			2021	17.8%	
Preserving original AI-CPUE relationship	Method 2: Non-tier CPUE Method	Pre: Table 2 (non-tiered) Post: Table 1	2019	15.1%	90,389
			2020	50.9%	
			2021	1.3%	
Updating AI-CPUE time series	Method 3.1	Pre: Table 1 Post: Table 2	2019	-9.4%	32,058
			2020	32.5%	
			2021	-0.3%	
	Method 3.1	Pre: Table 2 Post: Table 2	2019	0.0%	64,842
			2020	46.2%	
			2021	0.0%	
	Method 3.2	Pre: Table 1 Post: Table 2	2019	-1.8%	44,091
			2020	33.5%	
			2021	-0.3%	
	Method 3.2	Pre: Table 2 Post: Table 2	2019	0.0%	64,842
			2020	46.2%	
			2021	0.0%	
	Method 3.3	Pre: Table 1 Post: Table 1	2019	8.4%	40,895
			2020	38.0%	
			2021	-13.3%	
Multivariate	Method 4.1 LM (Chinook Model Pre + CPUE)	Pre: Table 1 Post: Table 1	2019	8.4%	34,220
			2020	17.3%	
			2021	0.0%	
	Method 4.2 LM (Chinook Model Pre + Catch + Effort + CatchxEffort)	Pre: Table 1 Post: Table 1	2019	-7.0%	3,931
			2020	9.5%	
			2021	0.0%	
	Method 4.3 Chinook Model Pre + CPUE + 1 Year Ahead Projection	Pre: Table 1 Post: Table 1	2019	-8.1%	-29,554
			2020	3.1%	
			2021	-14.6%	

Appendix A

This Appendix describes the technical details of deriving a non-tiered Table 2. This approach was motivated by maintaining the existing AI – CPUE relationship that was agreed to during the 2019 PST negotiations.

Background on the Original Table 2

The original Table 2 was formed on the basis of a power relationship between the first post-season AI (from the old version of the PSC Chinook Model utilizing the 9806 base period) and the winter-troll CPUE:

$$CPUE = 2.636\ Old\ AI^{\ 2.029} \qquad \text{(Equation 1)}$$

To form the tiers for Table 2, the original Table 1 breakpoints of 1.005, 1.2 and 1.5 were utilized and translated into CPUE breakpoints based on Equation 1. Then two additional tiers were added. The largest CPUE tier (≥ 20.5) tier was a result of the highest observed CPUE of 20.4. The largest AI in the time series was 2.2. A mid-point between 1.5 and 2.2 was then calculated and rounded down to 1.8. This value was then translated to a CPUE breakpoint based on Equation 1.

To determine the ACLs for each CPUE tier, the mid-point of the corresponding AI within the CPUE tier was calculated. The ACL for that AI mid-point was determined by the 2009 version of Table 1. Those ACLs were then reduced by 7.5% for AIs less than or equal to 1.8, 3.25% for AIs greater than 1.8 but less than or equal to 2.2, and 1.5% for AI values greater than 2.2.

Background on the Translated Table 2

The Phase II version of the Chinook Model was adopted by the PSC after the 2019 PST was published. This new model resulted in a different time series of AIs and hence the AIs associated with each CPUE tier needed to be translated. A catch neutral translation of Table 1 was developed based on a major axis regression:

$$Old\ AI = 0.0198 + 0.9544\ New\ AI \qquad \text{(Equation 2)}$$

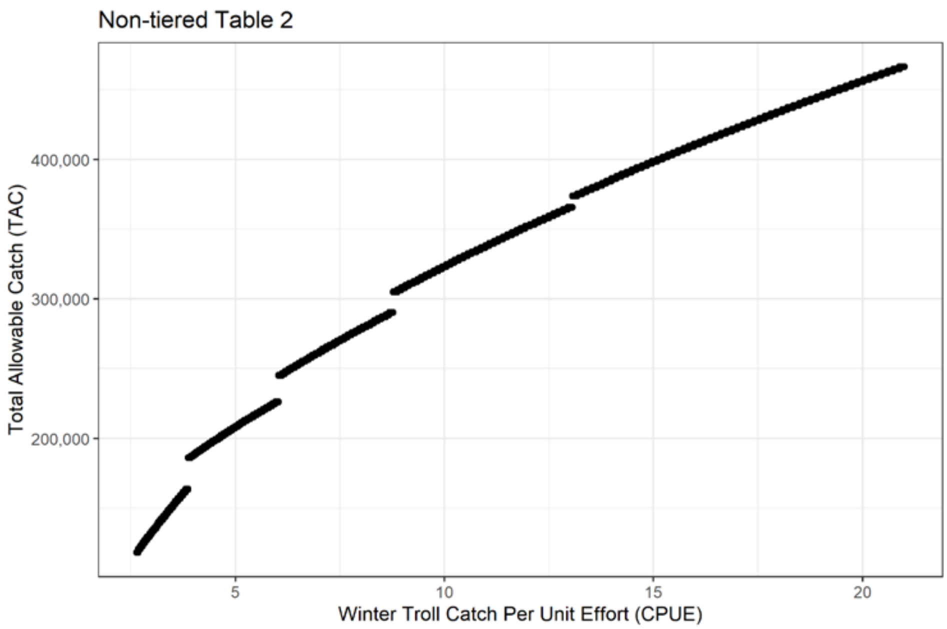
Solving this equation for *New AI* yields:

$$New\ AI = \frac{(Old\ AI - 0.0198)}{0.9544} \qquad \text{(Equation 3)}$$

The original Table 2 was then translated by keeping the CPUE based tiers and corresponding ACLs the same but translating the AI breakpoints based on Equation 3.

Deriving a Non-Tiered Table 2

Based on the following background, a non-tiered Table 2 can be generated by using Equation 1 and 3 to express the power relationship in Equation 1 in terms of the new AI. The 2019 translated Table 1 can then be referenced to determine the ACL for each CPUE. A plot of this non-tiered relationship is shown below:



Observations and Notes

The approach described above is an attempt to derive a non-tiered version of Table 2 without updating the power relationship in Equation 1 (i.e., use data from 2001 to 2021 to fit a new relationship between CPUE and the new AI) that was agreed to during negotiations.

One peculiarity of this approach is that the 2021 CPUE now belongs in the 3rd, instead of 4th, tier. This is explained by rounding errors in breakpoints. The old AI breakpoint of 1.205 was translated to a CPUE breakpoint of 3.8483 using Equation 1. This CPUE breakpoint was rounded down to 3.8. Also note that the same old AI breakpoint of 1.205 can be converted to a new AI breakpoint using Equation 3 resulting in a value of 1.2418 (which in the treaty was rounded to 1.245, the breakpoint between 1.24 and 1.25). The 2021 CPUE value was 3.85. This can be converted into a new AI using the approach described above. First convert this CPUE to the old AI, 1.2053, and then convert this to a new model AI, 1.2421. Note that in unrounded form this value is greater than the new model AI breakpoint of 1.2418. However, since AIs get rounded to the nearest hundredth, this value becomes 1.24 which is now less than the new AI breakpoint of 1.245.

Appendix B

Elements of the current CPUE approach, post-season AIs from CLB 2203 and updated regression, and recalculated ACLs based on Table 1 and Table 2 supporting analyses in Section 3.1.

Current Approach based on preseason CPUE tier catch limit						Postseason AI (Clb 2203)	Regression	Recalculated ACL	
Accounting Year	Boat Days	Chinook Catch	CPUE	CPUE Tier	Allowable Catch	Postseason AI (Clb 2203)	Regression Postseason AI	Table 1 ACL	Table 2 ACL
2001	1,057	8,721	8.25	5	266,585	1.20	1.57	246,553	266,585
2002	919	15,512	16.88	6	334,465	1.89	2.14	344,395	334,465
2003	783	15,607	19.93	6	334,465	2.25	2.29	373,801	372,921
2004	1,002	8,050	8.03	5	266,585	2.07	1.55	226,119	205,165
2005	941	7,812	8.3	5	266,585	1.83	1.58	248,005	266,585
2006	757	7,770	10.26	6	334,465	1.69	1.73	269,771	266,585
2007	453	1,553	3.43	3	140,323	1.20	1.08	129,269	140,323
2008	421	985	2.34	2	111,833	0.94	0.92	107,498	111,833
2009	226	783	3.46	3	140,323	1.14	1.08	129,269	140,323
2010	440	1,908	4.34	4	205,165	1.23	1.19	152,794	140,323
2011	596	3,678	6.17	5	266,585	1.43	1.39	204,687	205,165
2012	608	3,042	5	4	205,165	1.16	1.27	188,614	205,165
2013	719	3,163	4.4	4	205,165	1.51	1.2	154,933	140,323
2014	862	6,417	7.44	5	266,585	2.13	1.5	219,421	205,165
2015	955	12,821	13.43	6	334,465	2.07	1.94	314,040	334,465
2016	1,673	18,604	11.12	6	334,465	1.51	1.79	278,477	266,585
2017	781	3,286	4.21	4	205,165	1.11	1.18	150,656	140,323
2018	828	2,965	3.58	3	140,323	0.74	1.1	133,546	140,323
2019	210	709	3.38	3	140,323	0.99	1.07	127,130	140,323
2020	529	2,557	4.83	4	205,165	1.04	1.25	185,935	205,165
2021	460	1,772	3.85	4	205,165	1.23	1.13	139,962	140,323
2022	230	1,615	7.02	5	266,585		1.47	215,403	205,165

APPENDIX B: ADF&G ANALYSES RELATED TO CH. 3, 7(B)(I) TASK

Alaska Department of Fish and Game Analyses in Accordance with Management Entity Responsibilities under Chapter 3, Paragraph 7(b)(i)

Milo Adkison, David Leonard, and Randy Peterson

SUMMARY

The Southeast Alaska (SEAK) Treaty Chinook pre-season annual catch limit and catch has exceeded the post-season annual catch limit (ACL) in two consecutive years (2020 and 2021), triggering the provisions of Chapter 3 paragraph 7(b)(i) of the 2019 Pacific Salmon Treaty Agreement (PST). Paragraph 7(b) requires that Alaska Department of Fish and Game (ADF&G) as the management entity "…*take necessary actions to minimize variance between the pre-season and post-season catch limit*". In other words, ADF&G must improve its method for forecasting post-season limits such that it reduces the risk of exceeding post-season limits. The analysis presented here does that by: 1) assembling available datasets with potential to predict the post-season catch limit, 2) investigating the performance of combinations of the information to predict the post-season catch limit, and 3) reconsidering the structure of the tier system.

Seven historical data sets (including the CPUE data currently used) were explored over 19 years (2001–2021, except 2006 and 2007). In all, the prediction performances of 127 different models were investigated. Of these, the most accurate model predicting the post-season catch limit used a combination of three predictors-- winter troll catch per unit of effort (*Winter_CPUE*), the pre-season abundance index (AI) from the current PSC Chinook Model (*preseason_AI*), and a one-year-ahead projection from the previous PSC Chinook Model calibration (*projection*). In combination, this model far out-performed both the current, CPUE-based model and the alternative model using only the pre-season AI from the PSC Chinook Model.

The drawback to use of the "best" model is that the forecast, the pre-season ACL, and associated management strategy would be delayed from February to April 1, the date that the *preseason_AI* is available from the PSC Chinook Model. Using the *Winter_CPUE* in conjunction with the previous PSC Chinook Model calibration (*projection*) (i.e., removing the *pre-season AI* as one of the three predictors) would allow the ACL to continue to be set in February rather than delaying to April 1. This model would increase prediction error somewhat compared to the best model; however, this February forecast would still be more accurate than using the current methodology.

As expected with an unbiased predictor, the pre-season forecast of post-season ACL with most models exceeded the true value about 50% of the time, which means triggering paragraph 7(b) would be expected once in every four years if no tiers were applied. Conversely, consecutive underages would also be expected to occur once every four years.

We also explored three different configurations of tiers across all models investigated: 1) no tiers (Chapter 3, Table 1), 2) current tiers (Chapter 3, Table 2), and 3) current tiers split into 3. With tiers, some years had no forecast error, which would reduce the frequency of triggering paragraph 7(b)

somewhat. Although using tiers had little effect on the average forecast error, larger errors were more common than when tiers were not used.

Background

The winter troll CPUE-based pre-season forecast of Chinook abundance in the SEAK AABM, converted to a tier, is currently used to set the pre-season ACL. As the management entity, ADF&G is obligated to manage to a pre-season ACL and has successfully managed SEAK harvest to stay below the pre-season ACL since the 2019 PST Agreement was implemented. A post-season PSC Chinook Model AI, also converted to a tier, is compared to the SEAK Treaty pre-season ACL and catch post-season to assess fishery performance. Although there is currently no way to check the accuracy of the post-season AI as a measure of Chinook salmon abundance, it is the standard metric used for Treaty evaluations.

If there are two consecutive years where the Treaty pre-season ACL and catch exceeds the post-season ACL, Ch. 3, paragraph 7(b) requires actions by the management entity focused on reducing the likelihood of this recurring. For both 2020 and 2021 the pre-season forecast was for Tier 4, yielding a pre-season ACL of 205,165 Treaty Chinook, while the post-season AI was Tier 3, giving a post-season ACL of 140,323 Treaty Chinook (Table A). As the actual Treaty catch in both years was slightly below the pre-season ACL, in both years the catch was more than 60,000 fish above the post-season ACL.

This document is an investigation into methods for improving the pre-season forecast of the post-season AI and associated ACL. It is intended to serve as the technical underpinning of the ADF&G actions to minimize the variance between the pre-season and post-season catch limits required by Ch. 3, paragraph 7(b)(i).

Table A.– Pre-season CPUE, tier, annual catch limit (ACL), observed Treaty catch, and post-season AI, tier and ACLs. The Pre>Post and Obs>Post columns indicate years where the pre-season tier or observed catches exceeded the post-season tier or ACL, respectively.

	Pre-season				Post-season				
Year	CPUE	Tier	ACL	Observed	AI	Tier	ACL	Pre > Post	Obs > Post
2019	3.38	3	140,323	140,307	1.04	3	140,323	No	No
2020	4.83	4	205,165	204,624	1.11	3	140,323	Yes	Yes
2021	3.85	4	205,165	202,082	1.23	3	140,323	Yes	Yes

Methods to Investigate Alternative Forecasting Approaches

The task presented to ADF&G as the management agency under paragraph 7(b)(i) was to reduce the variation between the pre-season prediction of the model-generated post-season ACL, which isn't known until after the fisheries are closed. The analysis presented here does that by: 1) assembling available datasets with potential to predict the post-season catch limit, 2) evaluating the performance of combinations of the data to predict the post-season catch limit, and 3) reconsidering the structure of the tier system across three different configurations of tiers.

Information Assembly

We started by assembling any information available that provides a signal of Chinook abundance in the SEAK AABM fishery that could be used to predict the future value of the post-season AI and ACL. To be useful, information must be available prior to the major summer fisheries (i.e., the summer troll and sport fisheries), as changing the annual catch limit and associated regulations mid-season has allocative consequences. Data that would be available by February, the date of the current forecast based on winter troll fishery data, and by April, the date of the forecast from the PSC Chinook Model, were investigated. These data series fell into three categories: PSC Chinook Model outputs, SEAK troll catch rates, and the previous year's abundance of young/small Chinook (Table B).

In contrast to previous approaches, we investigated using multiple predictors simultaneously. We looked at using all possible combinations of our predictor variables to predict post-season AI; as we investigated 7 variables, there were a total of 127 models examined. Each set of predictors was combined using multiple linear regression; the assumption of linearity was verified by inspecting the scatterplots of predictors vs. the post-season AI (Figure 1). Based on this inspection, the early winter troll CPUE was log-transformed before use.

The forecast methodology specified in the Treaty was developed based on SEAK winter troll CPUE data from 2001 through 2015, the time series of data available at the time of the negotiation of the 2019 Treaty Agreement. In this investigation, data through 2021 were used, which should improve the confidence in any relationships found. However, because one variable, the PSC Chinook Model's prior year projection, was not available for 2006 and 2007, these two years were excluded from all analyses.

Table B.– Description of data sets explored and predictor variables used (details below).

Type	Predictor	Month Available	Rationale	Caveats
PSC model	Pre-season AI	April	PSC model summary of all data, including recent data and agency forecasts.	Many sources of uncertainty, all unquantified
PSC model	Projection from prior year	Feb	PSC model summary of all data, but prior to any data on the current year's abundance and forecasts are generated by the PSC model	Does not incorporate any data available after April of the previous year.
PSC model	Post-season AI from prior year	April	PSC model summary of all data, but prior to any data on the current year's abundance	Fewer sources of quantified uncertainty (e.g., does not rely on forecasts). A year out of date.
Young fish	Columbia River summer/fall jacks	Feb	Count of Chinook jacks at Bonneville Dam from Jun 1 – Dec 31 of previous year (= summer and fall runs)	Little uncertainty. But only represents one component of SEAK catch.
Catch rate	Early winter troll CPUE (log-transformed)	Feb	Empirical recent data	Little uncertainty. Stock composition differs from the annual averages
Catch rate	Prior Summer Power Troll Index (PTI)	Feb	Empirical estimate of abundance from the previous year	Little uncertainty. A year out of date.
Catch rate	Early winter troll driver stock index	Feb	Empirical recent data on three driver stocks, weighted to account for annual prevalence	Harvest of driver stocks and weighting introduces measurement uncertainty

Description of Data Series

PSC model pre-season AI (*preseason_AI*) = An output of the April PSC Chinook Model calibration, based on data from past years and agency forecasts of the current year's Chinook abundance. Typically produced in April of the current year. As the base period calibration was recently updated (TCCHINOOK (22)-02 V.1&2), values have been converted to this new calibration using major axis regression (CTC memo to CIG dated September 11, 2019) and may differ from originally published values.

PSC model projection from prior year (*projection*) = Output of PSC Chinook Model calibration from the previous April, which projected Chinook abundance a year ahead using default assumptions about Chinook vital rates. This differs from the pre-season AI by not using agency forecasts or any other quantities estimated after the previous April. Typically produced in April of the prior year. As the base period calibration was recently updated (TCCHINOOK (22)-02 V.1&2), values have been converted to this new calibration and may differ from originally published values. While the projection is calculated each year, in 2006 and 2007 the projections were not saved and are no longer available.

PSC model first post-season AI, prior year (*lag1_postseason_AI*) = An output of PSC Chinook Model calibration from the previous April that estimated the previous year's Chinook abundance. These are the first values, published several months after the fishery (estimates evolve in subsequent years after more data from incomplete broods accumulate). Typically produced in April of the prior year. As the base period calibration was recently updated (TCCHINOOK (22)-02 V.1&2), values have been converted to this new calibration and may differ from originally published values.

Columbia River summer/fall jacks (*CR_jacks*) = Count of jack Chinook salmon (fish that have spent only 1 year in the ocean) passing the Bonneville Dam fishway from June 1-Dec 31 of the previous year (data from github repository Ben-Cox/fpcDamCounts, per Mark Sorel, WDFW).

Early winter troll CPUE (*Winter_CPUE*) = A CPUE-based index of SEAK Chinook abundance in the winter, an indicator of the current year's abundance, but with a stock composition quite different from that seen in the major summer fisheries. Typically produced in January of the current year. The index is computed from fish ticket data collected in the SEAK District 113 early winter power troll fishery (ADF&G statistical weeks 41-48). Catch is the number of Chinook caught in the power troll fishery and effort is the number of power troll fishery boat days, which is the date fishing ends, minus the date fishing begins plus one (e.g., a boat that started and stopped fishing on the same day fished for 1 boat day).

Summer PTI (*lag1_summer_PTI*) = A CPUE-based index of Chinook abundance from the previous summer. Typically produced by August of the prior year. The index is computed from fish ticket data collected in the first half of the first retention summer power troll fishery (ADF&G statistical weeks 26-28) in the SEAK Northern Outside districts (113, 116, 154, 156, 157). Catch is the number of Chinook caught in the power troll fishery and effort is the number of permit holders who fished.

Winter troll driver stock index (*Winter_drivers*) = CPUE-based empirical recent data on driver stocks (stocks that contribute >5% to the SEAK catch annually). Typically, this information is available from coded-wire tag recoveries in January of the current year. This index transforms the winter troll CPUE by weighting catch components to account for winter-summer differences in prevalence. Rationale: If the CPUE is high, it indicates high Chinook abundance that may persist into the summer. And, if the stocks that are most common in the summer are a larger fraction of the winter catch than usual, that is an additional signal that summer abundance may be high.

Thus, the formula is:

Index = early winter troll CPUE * sum over driver stocks of (relative abundance * prevalence weight)

Using the quantities in Table C as calculated below:

Relative abundance = fraction of the driver stock in the winter troll catch in current year/average winter fraction from this stock

Prevalence weight = average fraction of the driver stock in annual troll catch/
average fraction of driver stock in winter troll catch

Table C.– Quantities used in calculating the Winter Driver Stocks index.

Driver Stock	Winter Fraction	Annual Fraction	Prevalence Weight
Interior Columbia Summer/Fall	0.283	0.102	0.36
West Vancouver	0.084	0.112	1.33
SEAK/TBR	0.277	0.662	2.38

Data Series Not Explored

Early winter plus late winter troll CPUE in SEAK has been previously examined as a potential predictor of post-season AI. Our preliminary analyses found that this data series had a correlation of 0.94 with the winter troll CPUE and was not a better predictor.

Fisheries performance data (FPD) is another variant on winter troll CPUE where the effort is based on surveying trollers about the number of hours fished rather than relying on fish ticket data for the duration of a fishing trip. Our preliminary analyses found that this data series had a correlation of 0.96 with the winter troll CPUE and was not a better predictor.

Table D.– Data series used in this analysis.

Year	PSC pre-season AI	PSC first post-season AI, prior year	PSC projection	Prior summer PTI	Early winter troll CPUE (before ln-transform)	Early winter troll driver stock index	Columbia River summer/fall jacks	First post-season AI (value predicted)
2001	*1.17*	*1.13*	*1.09*	*99*	*8.25*	*15.8*	*68,935*	*1.33*
2002	*1.8*	*1.33*	*1.551*	*108*	*16.88*	*50.2*	*89,219*	*1.89*
2003	*1.86*	*1.89*	*1.572*	*233*	*19.93*	*96.7*	*48,167*	*2.25*
2004	*1.95*	*2.25*	*1.467*	*298*	*8.03*	*50*	*61,088*	*2.14*
2005	*2.12*	*2.14*	*1.656*	*247*	*8.3*	*40.6*	*51,371*	*1.97*
2006	*1.75*	*1.97*	***Missing***[1]	*179*	*10.26*	*113.3*	*25,714*	*1.79*
2007	*1.65*	*1.79*	***Missing***[1]	*149*	*3.43*	*12.1*	*29,922*	*1.38*
2008	*1.1*	*1.38*	*1.436*	*147*	*2.34*	*15.2*	*67,115*	*1.04*
2009	*1.37*	*1.04*	*1.205*	*100*	*3.46*	*15.9*	*50,932*	*1.23*
2010	*1.39*	*1.23*	*1.289*	*117*	*4.34*	*7.9*	*152,207*	*1.35*
2011	*1.75*	*1.35*	*1.499*	*103*	*6.17*	*18.2*	*80,029*	*1.68*
2012	*1.57*	*1.68*	*1.457*	*140*	*5*	*32.5*	*135,084*	*1.27*
2013	*1.23*	*1.27*	*1.467*	*85*	*4.4*	*15.3*	*136,401*	*1.68*
2014	*2.68*	*1.68*	*1.813*	*144*	*7.44*	*16.6*	*137,227*	*2.21*
2015	*1.49*	*2.21*	*1.949*	*307*	*13.43*	*35*	*160,923*	*2.03*
2016	*2.13*	*2.03*	*1.467*	*230*	*11.12*	*19.9*	*100,268*	*1.71*
2017	*1.31*	*1.71*	*1.76*	*166*	*4.21*	*12.6*	*65,046*	*1.35*
2018	*1.1*	*1.35*	*1.237*	*100*	*3.58*	*14.8*	*48,349*	*0.94*
2019	*1.1*	*0.94*	*1.027*	*80*	*3.38*	*13*	*37,337*	*1.07*
2020	*1.13*	*1.07*	*1.017*	*110*	*4.83*	*16.2*	*53,304*	*1.11*
2021	*1.28*	*1.11*	*1.161*	*123*	*3.85*	*12.9*	*70,074*	*1.23*

[1]2006 and 2007 data were not used for cross-validation because values of the PSC Chinook Model projection were missing.

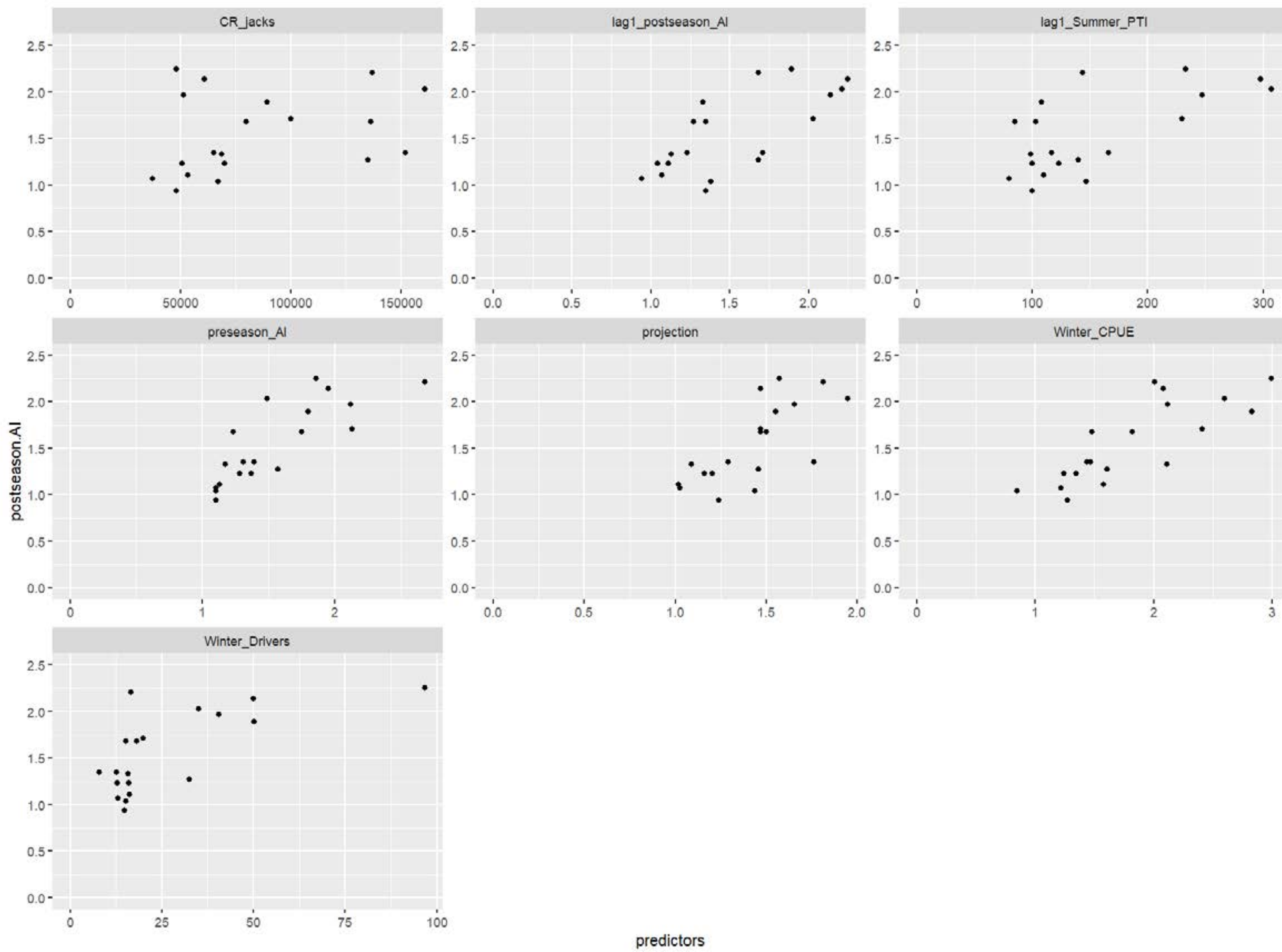


Figure 1.– Univariate plots of post-season AI vs. predictor variables explored in this analysis. Winter_CPUE is log-transformed in this figure and in analyses. Predictor variable names are from the descriptions of the data series above.

Tier Structures Explored

The PSC Chinook Model estimates an annual AI for SEAK to track the abundance of fish available to the fisheries. In SEAK, catch rates of Chinook are also used as indices of fish abundance. Management is abundance-based, with larger catch limits when Chinook are estimated to be more abundant.

The current approach is to set the same ACL for a range of predicted abundance, i.e., a catch tier, under the notion it is easier to predict which tier the AI will fall into rather than its exact value. While this is true, it ignores the consequences of forecasting the wrong tier; in such cases, the pre-season ACL can differ from the post-season value by tens of thousands of fish. Here, forecasts without tiers were examined, under the belief that the resultant frequent small errors have lesser consequences than occasional huge ones.

Under the current management system, the SEAK winter troll CPUE is translated into a pre-season ACL for the SEAK fisheries using a look-up table (Table 2 in Ch. 3 of the Treaty). This table was developed by analyses that used this CPUE-based approach as a predictor of the post-season AI (Appendix B to Annex IV, Chapter 3, Paragraphs 4 - 6). In evaluating performance, the Treaty requires that the first post-season AI from the PSC Chinook Model be translated to a post-season ACL using this same table for assessment of post-season fishery performance.

In our analyses, we examined removing tiers by translating both the pre-season forecast and the post-season AI to an ACL using Table 1 with linear interpolation between tier levels as specified in Chapter 3, Appendix C. We also examined an intermediate approach where each of the existing tiers was split into three.

2019 PST Agreement Chapter 3, Table 2 tiers were split into three according to the following steps:

(1) The highest and lowest tiers were not split.
(2) For all other tiers, the AI range was split into three equal parts.
(3) The ACL for the middle of the range was unchanged.
(4) The ACL for the upper third was increased by one-third of the distance to the ACL for the next tier.
(5) The ACL for the lower third was decreased by one third of the distance to the ACL of the preceding tier, except for tier two where it was decreased by one-third of the distance to the next highest tier, as the ACL for tier one in Table 2 is not specified.

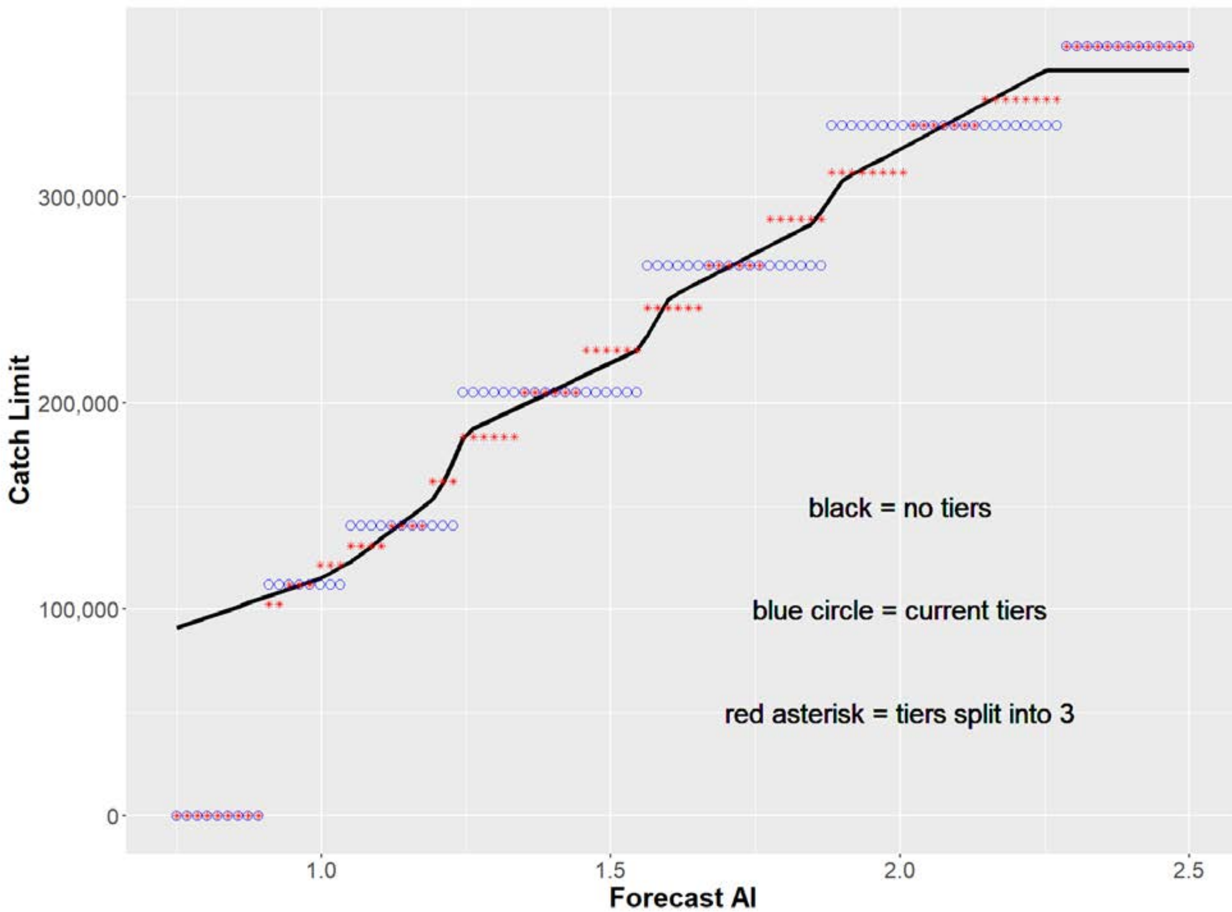


Figure 2.– The three methods of translating AI values to ACLs used in this analysis. Black line = no tiers (Table 1 with interpolation between tiers). Red dots = tiered values from Table 2 (current method). Blue asterisks = Table 2 tiers split into 3 sub-tiers.

Criteria for Evaluating Performance

The performance of each forecasting model/tier structure combination was evaluated using a method called "leave-one-out" cross-validation. This is a low-assumption approach that approximates performance forecasting a future unknown value by pretending that one of the values in our historical data is unknown and using the remaining data to predict it. That is, given the 19 years of data, a model was fit to 18 of those years and that fit was used to predict the year left out. This process was then repeated 19 times, leaving a different year out each time, resulting in 19 prediction errors (difference between the predicted value and the known value from the data). These differences together constituted a sample of the sizes of prediction errors we could expect in the future.

Technical note: The typical prediction error (PE) is represented here as the leave-one-out cross-validation prediction standard deviation (i.e., the square root of the average squared cross-validation forecast error) for each model. An alternative model selection criterion, the more commonly-used Akaike Information Criterion (AIC), which is also based on a prediction error criteria, is also reported. We calculated ∆AIC values for each model; the lower the value, the better the model fit.

For each model explored, we calculated the following measures of performance (Table E):

- PE for the post-season AI
- PE for the post-season ACL with no tiers applied to either the forecast or post-season values
- PE for the post-season ACL with tiers applied to both the forecast and post-season values (separate columns for tiers from Table 2 and the tiers split into three)
- Frequency of the forecast exceeding the post-season ACL by >10% when no tiers were applied
- Frequency of the forecast tier exceeding the post-season tier (separate columns for tiers from Table 2 and the tiers split into three)
- ∆AIC = the difference between the AIC value for the model and the lowest AIC among all models

For comparison purposes, we calculated a "baseline" PE for the post-season AI and the post-season AI translated into numbers of fish using the continuous translation. These baselines were simply the standard deviations of these quantities; i.e., the typical error that would result from using their mean values as a predictor.

RESULTS

Best model

All variables examined had strong relationships to the post-season AI (Figure 1). The two best single predictors of post-season AI and post-season catch limit were SEAK Winter Troll CPUE and the pre-season AI. Singly, they reduced error (PE) in predicting the post-season AI from the baseline value of 0.413 to 0.267 and 0.274, and the post-season catch limit PE from the baseline value of ~81,000 fish to 51,000 and 50,000, respectively.

The top-ranked model included these two predictors as well as the one-year-ahead projection (*projection*) from the PSC Chinook Model (Table E). The PE for this model was reduced to 0.183 in AI units and 32,000 in units of fish. This source of this reduction in the PE can be seen by comparing the magnitude of the cross-validation errors (Figure 3) and retrospective forecast errors (Figure 4) of the two best single-variable models (top two sub-panels) to those of this three-predictor model ("Best April Model" sub-panels, lower left).

The three predictors in the top model appeared in all of the top six models (Appendix A). None of the other variables considered appeared to improve forecasts more than marginally. Neither weighting the Winter CPUE to emphasize the abundance of three driver stocks nor using jack returns to the Columbia River appeared to have much predictive power.

For both this model and the best February model (below), all variables included substantially contributed to the predictive ability (Appendix B); no single variable dominated.

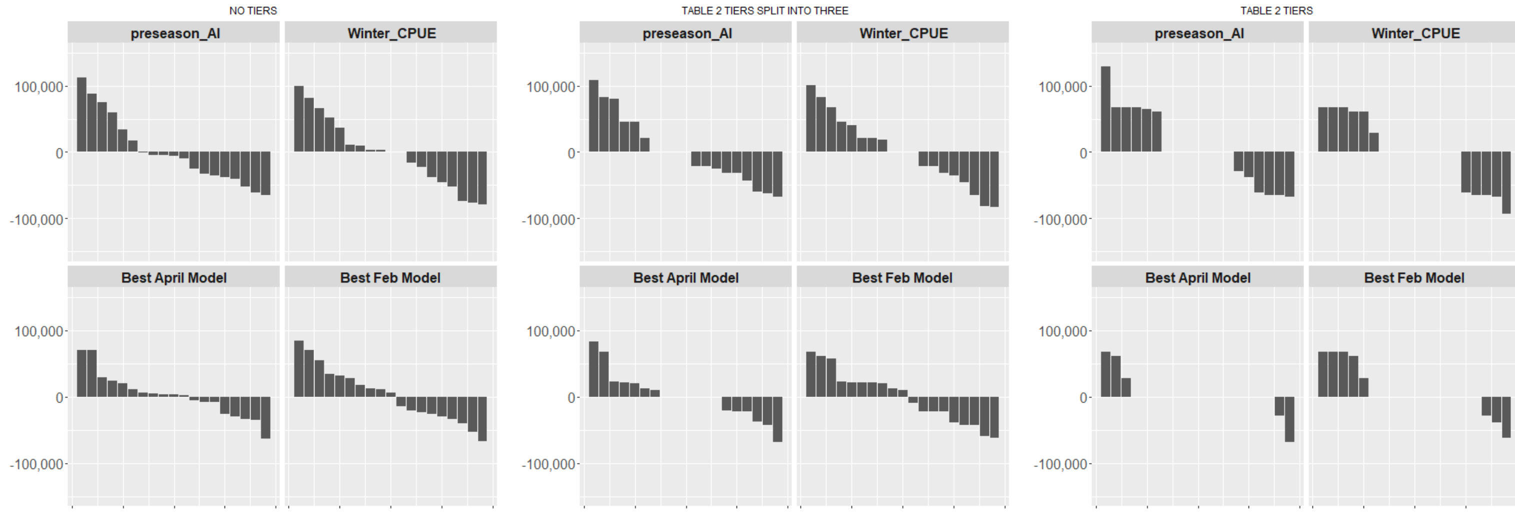


Figure 3.– Nineteen cross-validation errors in predicting the post-season ACL, sorted from highest to lowest, for each of four models. Left = no tiers, Middle = Table 2 tiers split into three tiers, Right = Table 2 tiers (see Figure 2).

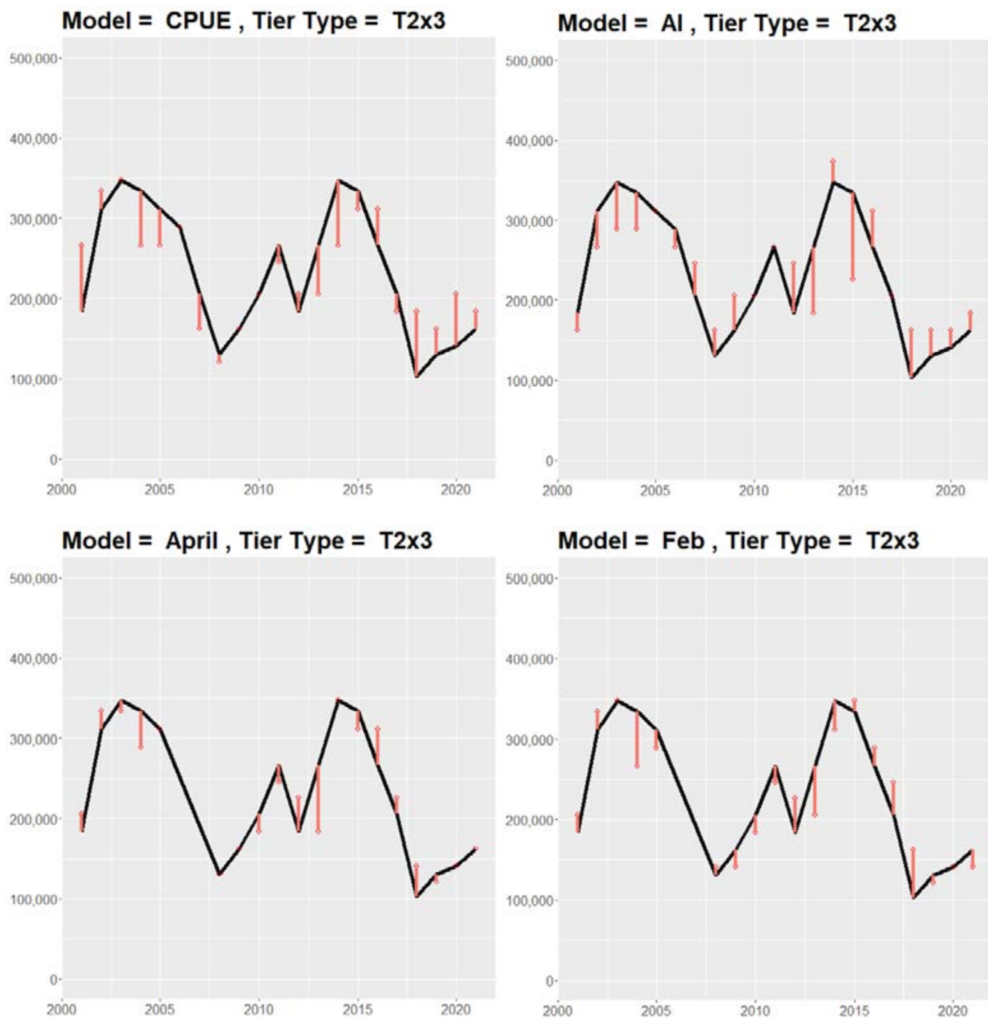


Figure 4.– Retrospective application of four models fit to the entire dataset (e.g., without cross-validation) using Table 2 split into 17 tiers. Solid black line = post-season ACL. Red dots = pre-season forecast, and red bars show the magnitude of the forecast error.

Table E.– Top model as ranked by prediction error (PE) plus all models that use subsets of the predictors in this model. Note that the highest ranked model available for February uses a two-variable subset of the variables used by the model ranked highest overall. Predictor variable names are from the descriptions of the data series above. Green = models with lowest no tier PE available in April and February, blue = current and previously employed one-predictor models. Complete results in Appendix A.

Date Available	*PE (AI units)*	*PE (fish, no tiers)*	*PE (fish, Table 2 tiers)*	*PE (fish, tiers split into 3)*	*10% over post-season*	*> 1 tier over post-season (Table 2)*	*> 1 tier over post-season (split into 3)*	*model predictors*
	0.413	**81,000**						**Baseline values (no model)**
April	**0.183**	**32,389**	**27,731**	**34,317**	**21%**	**11%**	**32%**	**preseason_AI projection Winter_CPUE**
April	0.205	38,550	48,124	41,348	16%	26%	47%	preseason_AI Winter_CPUE
Feb	**0.227**	**40,763**	**35,887**	**38,571**	**32%**	**16%**	**47%**	**projection Winter_CPUE**
April	0.261	48,861	50,918	48,829	26%	37%	42%	preseason_AI projection
Feb	0.267	51,179	50,094	51,124	26%	26%	42%	Winter_CPUE
April	0.274	50,136	55,059	49,886	26%	32%	47%	preseason_AI
Feb	0.321	63,367	61,552	59,152	32%	26%	32%	projection

Best model available by February

The best model that included only data available by February was simply the best April model minus the pre-season AI; i.e., the model containing the Winter Troll CPUE and the PSC Chinook Model's one-year-ahead projection (Table E). Without the pre-season AI, the PE in AI units increased from 0.183 to 0.227, while the PE in units of fish increased from 32,000 to 41,000 fish (no tiers case).

Effect of tiers

On average, using tiers to set the ACLs was not found to increase the PE of forecasts. With a few models the use of coarse tiers (Table 2) was estimated to improve performance and with others to dramatically worsen it; these extreme cases are likely caused by the large size of errors (e.g., > 60,000 fish difference between many tiers in Table 2) (Figure 3, far right).

Splitting tiers into three sub-tiers resulted in a higher frequency of instances of exceeding the post-season ACL (Table E, column 8 vs. column 7). However, the difference in ACL between adjacent tiers after splitting was less than 10%.

Cross-validation prediction errors using the current forecast method (predictor = SEAK Winter Troll CPUE, with tiers from Table 2 of Ch. 3 of the PST) suggested that a difference of at least one tier would occur more often than not; 11 of 19 cross-validation predictions of the post-season tier differed from the actual tier, with 6 over-predictions and 5 under-predictions (Figure 3, right panel, top right subpanel). Improving forecast accuracy by using better multivariate models reduced the frequency of tier differences (bottom two sub-panels).

A real-world example of how tiers can cause large discrepancies occurred in 2021 (Figure 5). In that year, the pre-season AI was 1.28, near the lower boundary of Tier 4, giving an ACL of 205,165. The post season AI was 1.23, near the upper boundary of Tier 3, giving an ACL of 140,323. The pre-season ACL differed from its post-season value by ~65,000 fish even though the pre-season and post-season AIs differed by only 0.05 units. This situation could also occur in the other direction if the pre-season ACL was a tier lower than the post-season ACL, which would result in a large forgone harvest opportunity.

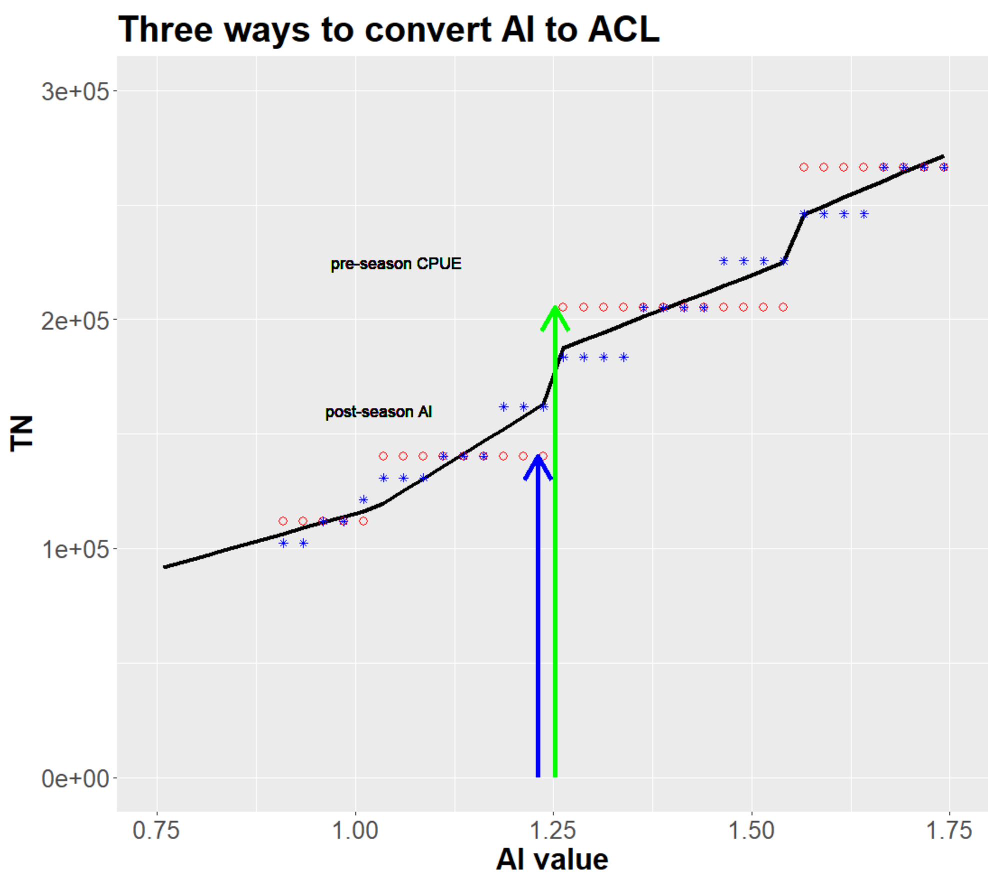


Figure 5.– The 2021 pre-season and post-season ACLs, and their conversion to ACLs. Black line = no tiers (Table 1 with interpolation between tiers). Red dots = tiered values from Table 2 (current method). Blue asterisks = Table 2 tiers split into 3 sub-tiers. Green arrow shows how the pre-season AI was converted to an ACL, the blue arrow the post-season conversion.

Without tiers, the pre-season ACL would have been 186,209 and the post-season ACL 161,349, a difference of only ~25,000 fish. Splitting the tiers in three, the pre-season ACL would have been 183,551 versus a post-season ACL of 161,937, an even smaller difference.

Discussion of Results

Table F.– Notable models, their predictors, and prediction error

Model	Predictors in model	PE (no tiers)
April best	preseason_AI, projection, Winter_CPUE	+/- 32,000 fish
February best	projection, Winter_CPUE	+/- 41,000 fish
Current	Winter_CPUE	+/- 51,000 fish
Former	preseason_AI	+/- 50,000 fish

Components of the best model

The "best" model had the lowest prediction error (PE) whether in units of AI or in fish, and whether the ACL for fish was calculated using a tier or not. This model included a direct measure of current fish abundance, the Winter Troll CPUE, and two PSC Chinook Model-based predictors of fish abundance, the pre-season AI and the projected AI from the previous year's calibration.

The complementary nature of the direct observations and the model-based estimates makes sense in retrospect. The model-derived measures integrate all pre-season data from multiple brood years and multiple component stocks, but strong model assumptions about mortality, distribution, etc. prevent the model from capturing the full range of potential variability in actual abundance. The Winter Troll CPUE can better capture annual fluctuations by directly measuring the current Chinook abundance in SEAK but is imperfect because the stock composition of the catch differs from the stock composition of the post-season AI.

In addition, the PSC Chinook Model-derived predictors have an inherent advantage in predicting the model-based post-season AI. Both the one-year-ahead projection and the pre-season AI use the exact equations and much of the same data as that used to calculate the post-season AI, the quantity being forecasted. Even if the post-season AI was a poor index of Chinook abundance, this structural similarity would favor the predictive abilities of the PSC Chinook Model-derived predictors.

February vs. April forecasts

The best April forecasts show a large reduction in PE for forecasting the post-season AI compared to the best available February forecast. A typical forecast error for April would be plus or minus 32,000 fish, while that for February is about 41,000. In years of poor PSC Chinook Model performance, such as that observed in 2014, 2015, 2016, and 2017, February and April forecasts can differ greatly.

The effect of tiers

An earlier analysis using all 21 years of data found that tiers, as expected, slightly increased the average PE. With the current analysis, which excluded 2006-2007, that was no longer true. The average PE was roughly comparable with and without tiers.

Regardless of the effect on average PE, tiers change the distribution of forecast errors. Without tiers, there is a forecast error every year. With tiers, there are years where the error is zero (about half the years with the current model – Figure 3) and years with larger errors. For the current system of setting ACLs, forecast errors of +/- 60,000 fish are expected every other year (Figure 3).

Increasing the accuracy of the forecast reduces the frequency of a discrepancy between the pre- and post-season tier (Figure 3, right, top vs. bottom sub-panels). Reducing the size of the tiers (Figure 3, middle) gives results intermediate between the current, coarse-tier approach (Figure 3, right) and the approach using no tiers at all (Figure 3, left).

Caveats

1. Heterogeneity in the time series: Cross-validation assumes that the same processes and statistical properties apply across the entire time series used. Thus, in fitting a model, the ordering of data is irrelevant. A complication for this analysis is the base period calibration of

the PSC Chinook Model that occurred in 2019. Thus, the abundance indices from 2020 and 2021 and the future values we want to predict might have different properties from the bulk of the data we used to compare the predictive abilities of our candidate models. Unfortunately, the short period (two years of model outputs) since recalibration precludes a rigorous investigation of the differences.

However, we believe that any differences would be slight. Although some fisheries and stocks were changed and/or split, the model equations and the data used are largely unchanged. PSC Chinook Model outputs have been recalibrated to account for the slight differences observed between pre- and post-recalibration outputs. Thus, we think that the base period calibration is unlikely to have large effects on the estimated predictive error, and even less effect on the relative errors of competing models.

2. Accuracy of PE estimates: The estimated magnitude of PE for each model is based on only 19 values. Small differences in estimated PE values between models may not reliably indicate that one has a better predictive ability than another. Nonetheless, the values are our best estimate of predictive ability, and the estimated 40% reduction in PE, from ~50,000 using single predictors to ~30,000 for the best model, is large enough to provide high confidence in a marked improvement in forecast accuracy.

Appendix A

Cross-validation statistics for all 127 models examined. Prediction error in AI units (AI-PE) and in units of fish when calculating ACL using Table 1 (T2_PE), Table 2 (T2_PE), or Table 2 split into 17 tiers (split_PE). Also, the frequency of the prediction being 10% above the post-season ACL when using Table 1 (over_ten), or at least one tier above when using Table 2 (over_T2) or Table 2 split into 17 tiers (over_split). Also, dAIC for the model fit to the full data set (dAIC) and the predictors included in each model.

AI_PE	T1_PE	T2_PE	split_PE	over_ten	over_T2	over_split	dAIC	preseason_AI	lag1_postseason_AI	projection	lag1_Summer_PTI	Winter_CPUE	Winter_Drivers	CR_jacks
0.274	50,136	55,059	49,886	26%	32%	47%	13.5	x						
0.314	60,724	57,469	61,320	26%	32%	47%	20.3		x					
0.321	63,367	61,552	59,152	32%	26%	32%	20.4			x				
0.341	67,208	69,307	67,075	26%	37%	53%	23.2				x			
0.267	51,179	50,094	51,124	26%	26%	42%	13.8					x		
0.368	65,266	65,474	64,483	37%	42%	47%	22.9						x	
0.448	85,298	82,744	88,592	37%	42%	53%	32.3							x
0.254	49,777	58,559	50,403	26%	37%	47%	11.2	x	x					
0.261	48,861	50,918	48,829	26%	37%	42%	10.5	x		x				
0.245	50,046	54,180	48,721	32%	26%	47%	9.7	x			x			
0.205	38,550	48,124	41,348	16%	26%	47%	3.3	x				x		
0.212	41,903	54,263	45,694	16%	32%	53%	5.7	x					x	
0.304	52,559	55,059	55,664	32%	32%	53%	14.9	x						x
0.319	62,761	63,119	61,324	37%	21%	32%	19.4		x	x				
0.337	64,328	55,510	65,497	32%	26%	42%	22.3		x		x			
0.236	45,306	41,957	43,450	32%	21%	37%	9.9		x			x		
0.284	55,688	53,810	55,518	21%	32%	42%	17.4		x				x	

0.328	61,900	57,469	62,709	32%	32%	47%	21.5		x					x
0.325	62,452	71,570	59,309	37%	37%	37%	19.2			x	x			
0.227	40,763	35,887	38,571	32%	16%	47%	6.5			x		x		
0.272	52,578	53,844	50,087	37%	32%	32%	12.9			x			x	
0.343	67,358	63,144	62,998	37%	26%	32%	22.3			x				x
0.253	50,033	51,880	47,514	32%	26%	42%	12.1				x	x		
0.314	60,696	63,256	63,750	21%	42%	47%	20.3				x		x	
0.360	66,811	70,011	69,144	32%	53%	58%	23.5				x			x
0.286	54,248	56,786	54,495	26%	32%	47%	15.3					x	x	
0.274	50,687	47,877	50,553	32%	32%	53%	14.4					x		x
0.324	61,155	65,284	56,955	26%	42%	47%	18.3						x	x
0.270	51,645	50,918	49,440	32%	37%	42%	11.5	x	x	x				
0.261	54,024	55,983	52,583	32%	32%	47%	11.5	x	x		x			
0.204	37,633	37,544	39,196	26%	11%	32%	3.1	x	x			x		
0.223	46,467	54,458	45,068	21%	26%	47%	6.2	x	x				x	
0.276	53,143	58,559	54,188	26%	37%	47%	12.8	x	x					x
0.247	49,492	56,674	47,137	32%	42%	47%	9.6	x		x	x			
0.183	32,389	27,731	34,317	21%	11%	32%	0.2	x		x		x		
0.198	38,915	40,281	39,631	26%	32%	42%	2.2	x		x			x	
0.285	52,854	50,918	53,547	26%	37%	42%	12.5	x		x				x
0.202	39,607	42,537	42,499	26%	21%	37%	2.5	x			x	x		
0.227	48,081	58,185	49,900	21%	32%	53%	5.6	x			x		x	
0.260	52,616	56,674	51,637	32%	37%	53%	10.9	x			x			x
0.208	39,455	48,693	43,794	16%	32%	47%	3.5	x				x	x	
0.218	40,747	45,518	44,002	21%	21%	32%	4.5	x				x		x
0.210	37,993	40,823	42,462	32%	26%	37%	2.9	x					x	x
0.348	65,341	70,007	63,651	37%	32%	37%	21.1		x	x	x			
0.258	49,024	46,560	45,985	32%	21%	47%	7.9		x	x		x		
0.281	54,310	54,041	54,840	42%	26%	32%	14.4		x	x			x	
0.343	66,021	63,119	63,380	42%	21%	32%	21.4		x	x				x
0.257	49,950	46,920	50,377	32%	26%	37%	11.6		x		x	x		
0.309	60,353	61,801	62,727	42%	26%	42%	18.9		x		x		x	

0.354	65,967	63,733	68,701	32%	37%	47%	23.5		x		x			x
0.249	47,365	44,260	46,919	32%	26%	42%	11.8		x			x	x	
0.253	48,773	50,641	46,591	37%	32%	32%	11.0		x			x		x
0.277	53,881	54,621	51,288	32%	21%	37%	15.4		x				x	x
0.261	47,560	48,645	48,813	32%	21%	47%	7.9			x	x	x		
0.285	54,875	54,041	52,695	37%	32%	37%	14.4			x	x		x	
0.351	65,914	71,570	62,959	37%	37%	37%	21.2			x	x			x
0.233	43,557	36,956	40,397	32%	21%	47%	7.6			x		x	x	
0.243	43,314	35,887	42,771	32%	16%	47%	8.5			x		x		x
0.284	54,207	52,363	52,987	42%	26%	32%	13.7			x			x	x
0.266	53,104	58,367	52,348	32%	32%	53%	14.1				x	x	x	
0.276	47,817	48,243	50,477	32%	37%	42%	12.6				x	x		x
0.301	56,935	60,850	57,012	26%	42%	42%	17.0				x		x	x
0.284	50,712	45,660	51,100	32%	32%	58%	14.5					x	x	x
0.251	49,778	54,894	49,276	26%	37%	47%	9.5	x	x	x	x			
0.214	37,227	27,731	37,138	21%	11%	32%	2.1	x	x	x		x		
0.214	41,662	43,187	42,659	26%	32%	42%	4.2	x	x	x			x	
0.292	54,948	55,237	55,676	32%	37%	42%	13.5	x	x	x				x
0.217	42,843	42,537	44,013	21%	21%	37%	4.5	x	x		x	x		
0.246	52,030	58,185	53,401	21%	32%	53%	7.5	x	x		x		x	
0.271	54,924	56,674	52,018	32%	37%	53%	12.5	x	x		x			x
0.220	41,043	39,564	44,310	16%	16%	32%	4.0	x	x			x	x	
0.215	41,171	40,630	39,666	26%	16%	26%	4.5	x	x			x		x
0.215	39,501	41,325	43,944	21%	21%	32%	4.2	x	x				x	x
0.206	38,130	37,544	37,116	21%	11%	37%	1.4	x		x	x	x		
0.213	43,185	50,493	44,752	21%	32%	42%	3.9	x		x	x		x	
0.265	52,780	56,674	50,893	32%	42%	47%	11.6	x		x	x			x
0.183	33,616	34,786	33,265	21%	16%	32%	0.0	x		x		x	x	
0.197	35,325	40,101	38,175	21%	16%	32%	2.2	x		x		x		x
0.201	39,418	41,343	41,702	26%	26%	32%	2.4	x		x			x	x
0.220	42,530	42,537	43,395	21%	21%	42%	3.5	x			x	x	x	
0.210	41,404	40,101	42,794	26%	16%	26%	3.5	x			x	x		x

0.215	40,570	50,691	44,731	21%	26%	37%	3.1	x			x		x	x
0.215	38,701	38,295	43,087	21%	21%	37%	2.5	x				x	x	x
0.289	51,143	54,595	51,617	32%	26%	47%	9.8		x	x	x	x		
0.304	57,416	54,756	59,043	37%	32%	32%	16.4		x	x	x		x	
0.388	68,738	70,007	67,507	37%	32%	37%	23.1		x	x	x			x
0.261	50,874	51,408	47,671	32%	32%	47%	9.3		x	x		x	x	
0.273	51,486	48,645	49,375	37%	26%	47%	9.9		x	x		x		x
0.293	56,698	58,883	56,530	42%	26%	32%	15.1		x	x			x	x
0.270	52,250	46,920	51,827	32%	26%	32%	13.4		x		x	x	x	
0.279	51,626	50,641	52,010	37%	32%	37%	12.9		x		x	x		x
0.304	59,219	60,527	58,435	42%	21%	37%	17.3		x		x		x	x
0.263	50,187	48,642	52,364	37%	26%	37%	12.2		x			x	x	x
0.265	48,882	42,256	46,376	32%	26%	53%	9.3			x	x	x	x	
0.279	49,395	48,645	48,902	37%	21%	47%	9.9			x	x	x		x
0.299	55,440	53,513	56,028	42%	32%	32%	15.1			x	x		x	x
0.251	46,816	39,551	43,607	37%	26%	47%	9.5			x		x	x	x
0.283	50,129	49,043	49,907	32%	42%	53%	13.6				x	x	x	x
0.214	40,891	43,036	41,904	11%	21%	53%	1.3	x	x	x	x	x		
0.209	44,049	50,283	43,314	21%	32%	47%	3.0	x	x	x	x		x	
0.268	52,643	54,894	51,641	26%	37%	47%	11.4	x	x	x	x			x
0.215	38,290	35,887	39,736	21%	21%	37%	2.0	x	x	x		x	x	
0.228	41,164	42,504	42,091	21%	21%	32%	4.1	x	x	x		x		x
0.217	42,139	41,343	43,287	26%	26%	32%	4.4	x	x	x			x	x
0.236	47,198	49,272	48,763	21%	32%	42%	5.5	x	x		x	x	x	
0.221	44,901	46,973	45,140	21%	26%	32%	5.4	x	x		x	x		x
0.231	46,626	54,492	49,714	26%	32%	47%	4.4	x	x		x		x	x
0.224	40,785	37,532	42,749	26%	16%	21%	3.6	x	x			x	x	x
0.210	38,920	43,018	41,177	21%	16%	37%	1.7	x		x	x	x	x	
0.218	40,942	40,101	37,997	21%	16%	37%	3.3	x		x	x	x		x
0.211	41,954	46,600	43,555	26%	26%	26%	3.9	x		x	x		x	x
0.200	36,306	34,480	37,514	16%	16%	32%	1.3	x		x		x	x	x
0.222	42,498	42,504	42,781	26%	16%	26%	2.8	x			x	x	x	x

0.298	54,017	57,269	52,125	32%	37%	53%	11.3		x	x	x	x	x	
0.324	53,738	54,595	51,617	37%	26%	47%	11.8		x	x	x	x		x
0.341	61,425	59,540	61,278	47%	32%	32%	17.0		x	x	x		x	x
0.280	53,607	51,408	49,433	42%	32%	47%	11.1		x	x		x	x	x
0.295	55,554	53,161	54,511	37%	21%	37%	14.0		x		x	x	x	x
0.284	51,455	44,543	48,947	37%	32%	47%	11.1			x	x	x	x	x
0.208	41,729	45,918	41,517	16%	26%	47%	1.2	x	x	x	x	x	x	
0.236	42,973	43,931	44,723	11%	26%	53%	3.3	x	x	x	x	x		x
0.219	45,280	49,413	46,322	21%	26%	37%	2.8	x	x	x	x		x	x
0.229	40,979	38,848	44,278	21%	21%	37%	3.3	x	x	x		x	x	x
0.234	46,078	49,272	46,903	26%	26%	42%	4.3	x	x		x	x	x	x
0.221	41,692	42,771	43,193	37%	16%	32%	2.9	x		x	x	x	x	x
0.340	58,675	62,938	57,902	42%	37%	47%	13.1		x	x	x	x	x	x
0.233	46,464	48,474	45,181	21%	32%	47%	2.2	x	x	x	x	x	x	x

Appendix B

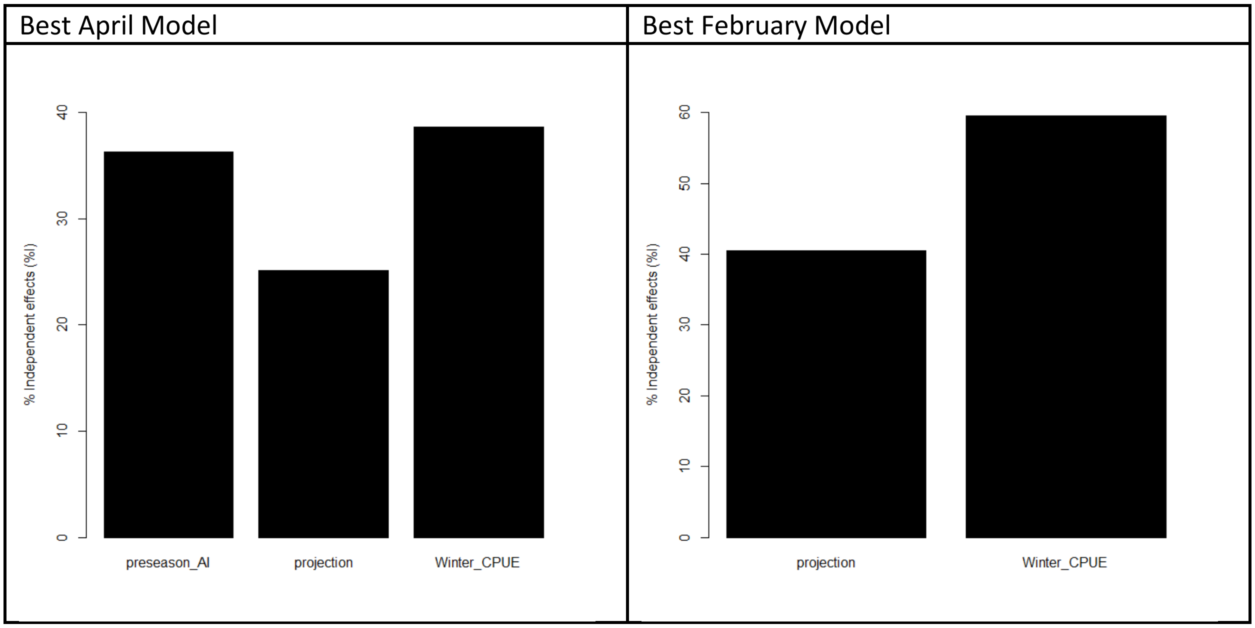


Figure B1. Hierarchical portioning results; i.e., the contribution of each explanatory variable to the adjusted R^2 value for the best April and February models

APPENDIX C: MEMO FROM CTC TO PSC: CH. 3, 7(B)(II) FOLLOW-UP TASKS FROM THE JANUARY 2023 PSC POST-SEASON MEETING

TO: Chinook Interface Group
FROM: Chinook Technical Committee
DATE: February 7, 2023
SUBJECT: CTC response to Chapter 3, subparagraph 7(b)(ii) follow-up tasks from the January 2023 PSC Post-Season Meeting
CC: National Correspondents

At the Pacific Salmon Commission (PSC) Post-Season Meeting held in January 2023, the Chinook Interface Group (CIG) reviewed the memo from the Chinook Technical Committee (CTC) to the PSC sent on January 6, 2023 regarding Chapter 3, subparagraph 7(b)(ii) of the 2019 Pacific Salmon Treaty (PST) Agreement and the analyses from the Alaska Department of Fish and Game (ADF&G) to the PSC sent on January 3, 2023 regarding Chapter 3, subparagraph 7(b)(i). Following discussion about the CTC memo and the ADF&G analyses, the CIG recommended that the CTC undertake the following tasks:

1. Resolve any differences and summarize the technical merits of selecting Method 4.2 or Method 4.3/ADF&G model.
2. Provide additional assessments that evaluate the performance of the two proposed models with and without tiers and summarize the technical merits of the use of tiers versus no tiers and identify any potential technical improvements to the tiers proposed by ADF&G.

The Commission approved these recommendations from the CIG. This memo contains the CTC response to the requests listed above. Note that any references to ‘Table 1’ or ‘Table 2’ in the following sections denote Table 1 or Table 2 in Chapter 3 of the 2019 PST Agreement, which are non-tiered and tiered harvest control rules, respectively.

Description of Proposed Technical Improvements to the Catch Limits in the ADF&G Proposed Tiers

The CTC reviewed the revised tier structure proposed by ADF&G and the catch limits associated with each tier (Table A). The tiers presented by ADF&G were calculated from the existing seven tiers by splitting the abundance index (AI) range for tiers two through six into three equal parts. For each new group of three tiers, the associated annual catch limits (ACLs) for each middle tier were unchanged from those in the existing Table 2, while the ACLs for each upper and lower tier were determined by adjusting their values 1/3 of the way to the next higher or lower tier, respectively.

The CTC supports the approach used to set the AI range for each of the new tiers but recommends an alternative approach to determining the ACLs for each tier, where the AI midpoint for each tier is translated into an ACL using the relevant formulas provided in Appendix C of Chapter 3 of the 2019 PST Agreement. This approach mimics that which was used to determine ACLs in the existing version of Table 2 (see Appendix B of Chapter 3 for more detail). These alternative proposed ACLs are provided in Table A. These ACLs better align with the AI/catch relationship defined in Table 1 and Appendix C of Chapter 3. A visual comparison of the original Table 2, ADF&G and CTC proposed revisions to Table 2, and Table 1 ACLs is shown in Figure A.

Table A. *Proposed revision to Table 2 tiers with ADF&G and CTC proposed catch limits.*

Tier	Abundance Index Range	AI Midpoint	ADF&G Proposed Catch Limits	CTC Proposed Catch Limits
1	Less than 0.895	NA	Commission Determination	Commission Determination
2	Between 0.895 and 0.945	0.920	102,336	107,498
3	Between 0.945 and 0.985	0.965	111,833	111,888
4	Between 0.985 and 1.035	1.010	121,330	116,278
5	Between 1.035 and 1.105	1.070	130,826	127,130
6	Between 1.105 and 1.175	1.140	140,323	142,101
7	Between 1.175 and 1.245	1.210	161,937	157,072
8	Between 1.245 and 1.345	1.295	183,551	191,963
9	Between 1.345 and 1.455	1.400	205,165	206,027
10	Between 1.455 and 1.555	1.505	225,638	220,091
11	Between 1.555 and 1.665	1.610	246,112	252,358
12	Between 1.665 and 1.765	1.715	266,585	267,594
13	Between 1.765 and 1.875	1.820	289,212	282,830
14	Between 1.875 and 2.015	1.945	311,838	314,799
15	Between 2.015 and 2.145	2.080	334,465	335,288
16	Between 2.145 and 2.285	2.215	347,284	355,778
17	Greater than 2.285	2.285	372,921	373,801

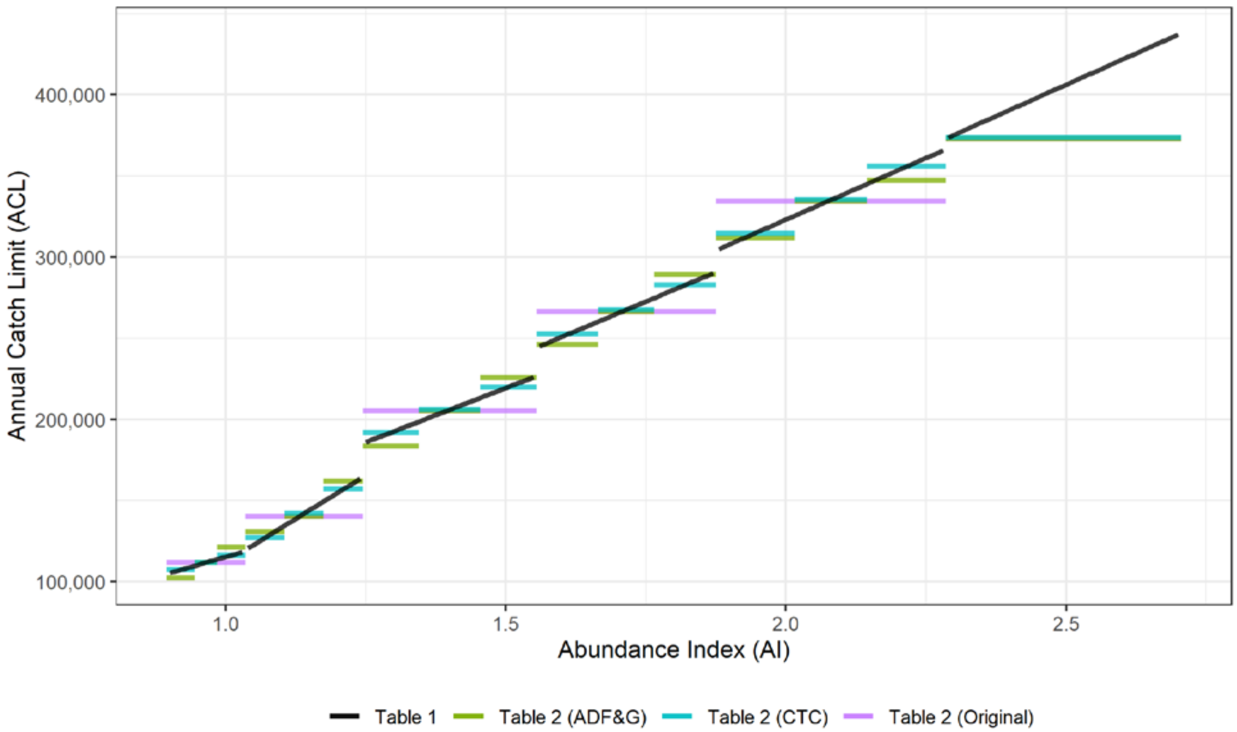


Figure B. *Visual Comparison of original and proposed versions of Table 2 ACLs, alongside Table 1 ACLs.*

Results

Prior to conducting additional analyses, the CTC conducted additional QA/QC to ensure all input information used to inform the models was accurate. During this process a few corrections were made to the time series of projections and pre- and post-season AIs used in the original analyses. All input data used to inform the models are included in Table B. Using these data, retrospective (Table C) and cross-validation (Table D) analyses were conducted using the same methods outlined in prior materials associated with the CTC analysis in response to subparagraph 7(b)(ii) and the ADF&G analysis in response to subparagraph 7(b)(i). For this exercise, analyses were limited to the two models recommended in the CTC's prior memo to the Commission dated January 6, 2023.

- ***Method 4.2*** (Linear model based on Chinook Model pre-season AI, catch, and effort data)

$$\log(Post\ AI) = \beta_0 + \beta_1 \log(Pre\ AI) + \beta_2 Catch + \beta_3 Effort + \beta_4 Catch * Effort$$

- ***Method 4.3*** (Linear model based on catch per unit effort (CPUE), Chinook Model pre-season AI, and one-year-ahead projected AI; note that this is the same as the ADF&G recommended model)

$$Post\ AI = \beta_0 + \beta_1 Pre\ AI + \beta_2 \log(CPUE) + \beta_3 Projection$$

The performance of each of these models was assessed under four different tier structures:

- Existing tier structure – 7 tiers defined in the current Table 2
- Expanded tier structure with ADF&G proposed ACLs – 17 tiers (Table A above)
- Expanded tier structure with CTC proposed ACLs – 17 tiers (Table A above)
- Non-tiered – ACLs defined by Table 1 and equations in Appendix C of Chapter 3

Table B. *Input data used to inform Methods 4.2 and 4.3. Pre-season abundance indices (AIs) are from the official calibration of the PSC Chinook Model in each year. Projection AIs are Chinook Model AI predictions from the prior year's Model calibration. Post-season AI values are first post-season AIs from the following year's Model calibration. Catch, effort, and catch per unit effort (CPUE) are values associated with the District 113 Winter Troll fishery during statistical weeks 41 – 48. See Appendix A for 4-digit pre-season and post-season AIs from the 9806 and Phase II version of the PSC Chinook Model.*

Year	Pre-season AI	Projection AI	Post-season AI	Catch	Effort	CPUE
2001	1.17	1.09	1.33	8,721	1,057	8.25
2002	1.80	1.55	1.89	15,512	919	16.88
2003	1.86	1.57	2.25	15,607	783	19.93
2004	1.95	1.47	2.14	8,050	1,002	8.03
2005	2.13	1.66	1.97	7,812	941	8.30
2006	1.75	NA[1]	1.79	7,770	757	10.26
2007	1.65	NA[1]	1.38	1,553	453	3.43
2008	1.10	1.44	1.04	985	421	2.34
2009	1.37	1.21	1.23	783	226	3.46
2010	1.39	1.29	1.35	1,908	440	4.34
2011	1.75	1.50	1.68	3,678	596	6.17
2012	1.57	1.46	1.27	3,042	608	5.00
2013	1.24	1.47	1.68	3,163	719	4.40
2014	2.68	1.81	2.29	6,417	862	7.44
2015	1.49	1.95	2.03	12,821	955	13.43
2016	2.13	1.47	1.71	18,604	1,673	11.12
2017	1.31	1.76	1.35	3,286	781	4.21
2018	1.10	1.24	0.94	2,965	828	3.58
2019	1.10	1.03	1.07	709	210	3.38
2020	1.13	1.02	1.11	2,557	529	4.83
2021	1.28	1.16	1.23	1,772	460	3.85

[1] One-year-ahead AI projections were unavailable for 2006 and 2007.

Table C. *Comparison of retrospective analysis results for 2019 – 2021 between Method 4.2 and Method 4.3/ADF&G model under four different tier structures. Pre-season abundance index (AI) represents the AI predicted by each model for each year. Total rows represent cumulative annual catch limits (ACLs) and pre/post deviation over the three-year period.*

Model	Year	Tier Structure	Pre-season		Post-season		ACL Deviation	
			AI	ACL	AI	ACL	Fish	%
Method 4.2 (catch x effort)	2019	Current Table 2 (7 tiers)	1.02	111,883	1.07	140,323	-28,440	-20.3%
		17 tiers w/ADFG ACLs		121,330		130,826	-9,496	-7.3%
		17 tiers w/CTC ACLs		116,278		127,130	-10,852	-8.5%
		Non-tiered (Table 1)		117,254		127,130	-9,876	-7.8%
	2020	Current Table 2 (7 tiers)	1.17	140,323	1.11	140,323	0	0.0%
		17 tiers w/ADFG ACLs		140,323		140,323	0	0.0%
		17 tiers w/CTC ACLs		142,101		142,101	0	0.0%
		Non-tiered (Table 1)		148,517		135,685	12,832	9.5%
	2021	Current Table 2 (7 tiers)	1.22	140,323	1.23	140,323	0	0.0%
		17 tiers w/ADFG ACLs		161,937		161,937	0	0.0%
		17 tiers w/CTC ACLs		157,072		157,072	0	0.0%
		Non-tiered (Table 1)		159,211		161,349	-2,138	-1.3%
	Total	Current Table 2 (7 tiers)		392,529		420,969	-28,440	-6.8%
		17 tiers w/ADFG ACLs		423,590		433,086	-9,496	-2.2%
		17 tiers w/CTC ACLs		415,451		426,303	-10,852	-2.5%
		Non-tiered (Table 1)		424,982		424,164	818	0.2%
Method 4.3/ADF&G Model (pre-season AI, projection, CPUE)	2019	Current Table 2 (7 tiers)	0.98	111,883	1.07	140,323	-28,440	-20.3%
		17 tiers w/ADFG ACLs		111,833		130,826	-18,993	-14.5%
		17 tiers w/CTC ACLs		111,888		127,130	-15,242	-12.0%
		Non-tiered (Table 1)		113,352		127,130	-13,778	-10.8%
	2020	Current Table 2 (7 tiers)	1.13	140,323	1.11	140,323	0	0.0%
		17 tiers w/ADFG ACLs		140,323		140,323	0	0.0%
		17 tiers w/CTC ACLs		142,101		142,101	0	0.0%
		Non-tiered (Table 1)		139,962		135,685	4,277	3.2%
	2021	Current Table 2 (7 tiers)	1.17	140,323	1.23	140,323	0	0.0%
		17 tiers w/ADFG ACLs		140,323		161,937	-21,614	-13.3%
		17 tiers w/CTC ACLs		142,101		157,072	-14,971	-9.5%
		Non-tiered (Table 1)		148,517		161,349	-12,832	-8.0%
	Total	Current Table 2 (7 tiers)		392,529		420,969	-28,440	-6.8%
		17 tiers w/ADFG ACLs		392,479		433,086	-40,607	-9.4%
		17 tiers w/CTC ACLs		396,090		426,303	-30,213	-7.1%
		Non-tiered (Table 1)		401,831		424,164	-22,333	-5.3%

Table D. *Cross-validation prediction errors for Method 4.2 and Method 4.3/ADF&G model under each of the four tier structures.*

Tier Structure	Method 4.2 (Pre AI, catch x effort)	Method 4.3/ADF&G Model (Pre AI, Projection, CPUE)[1]
Current Table 2 (7 tiers)	48,643	29,401
17 tiers w/ADFG catch limits	45,566	33,727
17 tiers w/CTC catch limits	45,873	31,128
Non-tiered (Table 1)	49,128	32,800

[1]Note that Method 4.3/ADF&G Model excluded the years 2006 and 2007 since there was no projection available for these years.

Recommendation and corresponding technical justification for which model

The linear models utilized in Methods 4.2 and 4.3 are similar. Both rely on forecast information from the Chinook Model and CPUE. There are differences in the mathematical transformations and how CPUE is expressed. An important distinction is that Method 4.3 relies on output from multiple calibrations of the Chinook Model. The pre-season AI is derived from the current year's model calibration and the projection AI is derived from the past year's model calibration. Method 4.2 does not rely on a projection AI component.

The CTC recommends using the model described under Method 4.3 (same as the ADF&G recommended model) to predict a pre-season AI for the Southeast Alaska (SEAK) fishery in 2023. Both models 4.2 and 4.3 represent an improvement over the existing catch per unit effort (CPUE) approach and the pre-season AI approach produced by the PSC Chinook Model. This was demonstrated in the memo from the CTC to the PSC sent on January 6, 2023. Method 4.2 performs better than Method 4.3 based on the results of the retrospective analysis, with cumulative deviations that ranged from -6.8% to 0.2% for Method 4.2, depending on the tier structure, compared to a range of -9.4% to -5.3% for Method 4.3 (Table C). However, it is important to consider that the retrospective analysis evaluates performance only over a three-year period, but does so in the way the model will be used for management. The prediction error resulting from the cross-validation analysis was higher for Method 4.2 than Method 4.3, with a range of 45,600 to 49,100 depending on tier structure for Method 4.2 compared to a range of 29,400 to 33,700 for Method 4.3 (Table D). The CTC recommends using Method 4.3 based on these lower prediction errors from the cross-validation analysis, which indicate that Method 4.3 is more likely to perform better on average. The CTC also recommends that, regardless of the model selected, the parameter values be updated annually to improve estimation by incorporating the latest data.

Recommendation and corresponding technical justification for which tiers

From a technical standpoint, the choice of tier structure does not appear to affect performance in any consistent way. There was no trend in the retrospective analysis where one tier structure consistently performed better across years or models (Table C). Further, the variability in cross-validation prediction errors across tier structures is minimal (Table D). Given this, the Commission may wish to favor other, non-technical factors when deciding which tier structure to implement for 2023. Should the Commission elect to implement the revised tier structure with 17 tiers, the CTC recommends using the ACLs proposed by the CTC, as they should be better aligned with the AI/catch relationship defined in Table 1 and Appendix C of Chapter 3.

In the event that the CIG decides to recommend moving away from the current 7-tier approach to either the expanded tier or non-tiered approach, they may also wish to consider the future criteria for triggering the actions in subparagraphs 7(b)(i) and 7(b)(ii) for the SEAK AABM fishery. Currently, these actions are triggered if both the pre-season ACL and catch exceed the post-season ACL by any amount for two consecutive years. The SEAK AABM fishery was not provided with the same 10% 'buffer' that was afforded to the two Canadian AABM fisheries because any exceedance was guaranteed to be greater than 10% given the Table 2 tier structure. Under the non-tiered and expanded tier structure, the pre-season ACL (and possibly catches) would possibly exceed the post-season ACL more frequently than under the current 7-tier structure, but exceedances of less than 10% would be possible. Thus, if recommending one of these alternative tier structures, the CIG may also wish to consider in what cases the SEAK AABM fishery would trigger 7(b).

Appendix A

The table below shows the source of AIs used in Method 4.2 and 4.3 based on a technical consensus between ADF&G and CTC members working on the 7(b) tasks. AIs from 2001 to 2019 were produced from the 9806 version of the PSC Chinook Model and were converted to Phase II model units via the equation: Phase II AI = (9806 AI - 0.019793) / 0.954424. Whenever possible, 9806 4-digit AIs were used to avoid rounding errors when converting to Phase II AIs.

Table A.1 *Projection (Proj), pre-season (Pre) and first post-season (Post) AIs from the 9806 and Phase II version of the PSC Chinook Model. The Method 4.2 and 4.3 AI column indicates the AIs used in these analyses.*

	9806 AI			Phase II AI			Method 4.2 and 4.3 AI			Calibration Version		
Year	**Proj**	**Pre**	**Post**	**Proj**	**Pre**	**Post**	**Proj**	**Pre**	**Post**	**Proj**	**Pre**	**Post**
2001	1.06	1.1387	1.2889				1.09	1.17	1.33	0021	0107	0206
2002	1.50	1.739	1.8247				1.55	1.80	1.89	0107	0206	0308
2003	1.52	1.7927	2.1663				1.57	1.86	2.25	0206	0308	0404
2004	1.42	1.8783	2.06				1.47	1.95	2.14	0308	0404	0506
2005	1.60	2.05	1.9025				1.66	2.13	1.97	0404	0506	0604
2006		1.6898	1.7322					1.75	1.79	0506	0604	0705
2007		1.5981	1.3366					1.65	1.38	0604	0705	0807
2008	1.39	1.0698	1.0108				1.44	1.10	1.04	0705	0807	0907
2009	1.17	1.329	1.1959				1.21	1.37	1.23	0807	0907	1007
2010	1.25	1.3497	1.3054				1.29	1.39	1.35	0907	1007	1106
2011	1.45	1.691	1.6227				1.50	1.75	1.68	1007	1106	1209
2012	1.41	1.5188	1.2361				1.46	1.57	1.27	1106	1209	1309
2013	1.42	1.2	1.6276				1.47	1.24	1.68	1209	UNK	1402
2014	1.75	2.5737	2.2031				1.81	2.68	2.29	UNK	1402	1601
2015	1.88	1.4455	1.9547				1.95	1.49	2.03	1402	1503a	1601
2016	1.42	2.0552	1.6527				1.47	2.13	1.71	1503a	1601	1702
2017	1.70	1.2699	1.3123				1.76	1.31	1.35	1601	1702	1804
2018	1.20	1.0743	0.9216				1.24	1.10	0.94	1702	1804	1905
2019	1.00	1.0716	1.0447				1.03	1.10	1.07	1804	1905	2000
2020	0.99				1.1311	1.1136	1.02	1.13	1.11	1905	2002	2104
2021				1.1610	1.2756	1.2269	1.16	1.28	1.23	2002	2104	2203

APPENDIX D: ADDITIONAL ANALYSES OF METHOD 4.2

***Table D1.** Pre- and post-season abundance indices (AIs), associated Table 1 annual catch limits (ACLs), and corresponding ACL deviations determined from Method 4.2 based on Catch and Effort as predictors. Summary values represent cumulative deviations for the total deviation and mean deviations for the percent deviation.*

Year	Pre-season AI	Post-season AI	Pre-season ACL	Post-season ACL	Deviation	
					Total	%
2019	1.02	1.07	117,254	127,130	-9,876	-8%
2020	1.17	1.11	148,517	135,685	12,832	10%
2021	1.22	1.23	159,211	161,349	-2,138	-1%
2022	1.12	1.04	137,824	120,714	17,110	14%

***Table D2.** Pre- and post-season abundance indices (AIs), associated Table 1 annual catch limits (ACLs), and corresponding ACL deviations determined from Method 4.2 based on Catch and Effort as predictors and including an AR(1) autocorrelation term. Summary values represent cumulative deviations for the total deviation and mean deviations for the percent deviation.*

Year	Pre-season AI	Post-season AI	Pre-season ACL	Post-season ACL	Deviation	
					Total	%
2019	0.99	1.07	114,327	127,130	-12,803	-10%
2020	1.10	1.11	133,546	135,685	-2,139	2%
2021	1.20	1.23	154,933	161,349	-6,416	-4%
2022	1.08	1.04	129,269	120,714	8,555	7%

APPENDIX E: EVALUATION OF THE POTENTIAL FOR SEAK AABM ACL BUFFERS FROM THE POINT OF VIEW OF PARITY AMONG THE THREE AABM FISHERIES

Chapter 3, subparagraph 7(b) of the 2019 PST Agreement identifies a 10% ACL buffer for NCB and WCVI AABM fisheries and none for the SEAK AABM because ACLs for NBC and WCVI are based on Table 1 whereas ACLs for SEAK are based on the seven tiers in Table 2 of the current Agreement. Tiers in Table 2 already represent a buffer system with ACLs for the SEAK AABM fishery based on the midpoints of the CPUE tiers and their corresponding AI tiers. Two relevant measurements of ACL buffer implicit in the tier system are: ACL deviations between contiguous-tier midpoints and ACL ranges (i.e., full ACL interval) within a single tier. If all tiers were the same size and if there were no breakpoints in the AI-ACL relationship, these two metrics would be identical. Table D1 shows that based on these two measurements, all tiers in Table 2 show midpoint ACL deviations and within-tier ranges greater than 10%.

***Table E1**. Midpoint ACL deviations between contiguous tiers and within-tier ranges in Table 2 of the current Agreement presented as percent differences.*

ai_min	ai_max	cpue_min	cpue_max	tier_7	acl_7_mid	acl_7_min	acl_7_max	Percent Difference (1 Tier deviation)	Full-Interval % Diff
0	0.895	0	1.99	1					
0.895	1.035	2	2.59	2	111,883	105,083	119,696	25.42%	13.91%
1.035	1.245	2.6	3.79	3	140,323	119,696	185,297	46.21%	54.81%
1.245	1.555	3.8	5.99	4	205,165	185,297	244,411	29.94%	31.90%
1.555	1.875	6	8.69	5	266,585	244,411	304,211	25.46%	24.47%
1.875	2.285	8.7	20.49	6	334,465	304,211	373,065	11.50%	22.63%
2.285	10	20.5	50	7	372,921	373,065			

The evaluation of these two ACL measurements under the new 17-tier system showed that ACL deviations between contiguous tiers (Table D2, 1 Tier Deviation Percent Difference is calculated from ACLs in two consecutive tiers derived from the midpoint AI) and within-tier ACL ranges (Table D3, Tier Interval Percent Difference is calculated from ACLs within a tier derived from the min and max AI) are smaller than 10% in most cases. The following conclusions can be derived from this evaluation:

- ACL between-tier deviations and within-tier ranges are tier-specific
- Tiers 5, 6, 7, 10 and 13 exhibit ACL 1-tier deviations or ranges greater than 10%
- The determination of buffers (trigger points) for the remaining tiers seems feasible

Elaborating on the last point above, given that current Treaty provisions for SEAK AABM catch are based on within-tier ACL midpoints, the tier-specific buffers would need to be discrete and based on tolerable tier deviations as determined by distances between contiguous ACL midpoints and therefore not exactly a 10% buffer. An example of how this buffer system could look, pending further review, is presented in Table D4.

Table E2. *Midpoint ACL deviations between contiguous tiers in the new 17-tier table presented as percent differences. Rows highlighted in green show cases with ACL deviations smaller than 10%; red rows show cases with ACL deviations greater than 10%.*

Tier	AI_mid	ACL_ctc	Percent Difference (1 Tier deviation)	Relative to 10% (1 Tier deviation)
1	NA			
2	0.920	107,498	4.1%	5.9%
3	0.965	111,888	3.9%	6.1%
4	1.010	116,278	9.3%	0.7%
5	1.070	127,130	11.8%	-1.8%
6	1.140	142,101	10.5%	-0.5%
7	1.210	157,072	22.2%	-12.2%
8	1.295	191,963	7.3%	2.7%
9	1.400	206,027	6.8%	3.2%
10	1.505	220,091	14.7%	-4.7%
11	1.610	252,358	6.0%	4.0%
12	1.715	267,594	5.7%	4.3%
13	1.820	282,830	11.3%	-1.3%
14	1.945	314,799	6.5%	3.5%
15	2.080	335,288	6.1%	3.9%
16	2.215	355,778	5.1%	4.9%
17	2.285	373,801		

Table E3*. Within-tier ACL ranges in the new 17-tier table presented as percent differences. Rows highlighted in green show cases with ACL ranges smaller than 10%; red rows show cases with ACL ranges greater than 10%.*

Tier	AI_min	AI_max	ACL_ctc_min	ACL_ctc_max	Tier-Interval % Diff	Tier-Interval Relative to 10%
1	0	0.895				
2	0.895	0.945	105,083	109,960	4.6%	5.4%
3	0.945	0.985	109,960	113,863	3.5%	6.5%
4	0.985	1.035	113,863	119,696	5.1%	4.9%
5	1.035	1.105	119,696	134,667	12.5%	-2.5%
6	1.105	1.175	134,667	149,638	11.1%	-1.1%
7	1.175	1.245	149,638	185,297	23.8%	-13.8%
8	1.245	1.345	185,297	198,692	7.2%	2.8%
9	1.345	1.455	198,692	213,426	7.4%	2.6%
10	1.455	1.555	213,426	244,411	14.5%	-4.5%
11	1.555	1.665	244,411	260,373	6.5%	3.5%
12	1.665	1.765	260,373	274,884	5.6%	4.4%
13	1.765	1.875	274,884	304,211	10.7%	-0.7%
14	1.875	2.015	304,211	325,459	7.0%	3.0%
15	2.015	2.145	325,459	345,190	6.1%	3.9%
16	2.145	2.285	345,190	373,065	8.1%	1.9%
17	2.285		373,065			

Table E4. *Example of potential tier-specific trigger points for SEAK AABM catch.*

Postseason Tier	ACL	Tolerable Tier deviation	Trigger point
1			
2	107,498	2	116,278
3	111,888	1	116,278
4	116,278	1	127,130
5	127,130	0	127,130
6	142,101	0	142,101
7	157,072	0	157,072
8	191,963	1	206,027
9	206,027	1	220,091
10	220,091	0	220,091
11	252,358	1	267,594
12	267,594	1	282,830
13	282,830	0	282,830
14	314,799	1	335,288
15	335,288	1	355,778
16	355,778	1	373,801
17	373,801		

APPENDIX F: SIMULATION OF THE EXPECTED FREQUENCY OF TRIGGERING 7B, HAVING A PRE-SEASON ACL > POST-SEASON ACL TWO YEARS IN A ROW WITHOUT TRIGGERING 7B, AND THE AVERAGE TWO-YEAR EXCEEDANCE IN BOTH CASES AS A FUNCTION OF THE TRIGGER CRITERIA

Flagged year = a year where the pre-season ACL exceeded the post-season ACL by more than allowed by the trigger criteria.

We looked at potential rules for flagging years so that when two years in a row were flagged, section 7(b) would be triggered.

Three flagging rules were explored:

a. PreACL exceeds PostACL by 1 tier

b. PreACL exceeds PostACL by 10%

c. PreACL exceeds the first tier that is more than 10% larger than the PostACL

For each flagging rule, we calculated:

1. the probability that 7(b) is triggered

2. the average two-year overage when 7(b) is triggered

3. the average two-year overage when there is an overage two years in a row but 7(b) is not triggered

The simulation had the following steps:

From cross-validation using the forecasting model 4.3, we calculated the standard deviation of the forecast residuals for AI. This value was 0.19

We calculated the range of historical values of the post-season AI over the period 2001-2022. These ranged from 0.95 to 2.29.

Then, we ran a 10,000-year simulation in which, for each year, we:

a. simulated post-season AI values using an AR1 process from a model fit to the observed post-season AI values (mean = 1.5137, ar1 = 0.6715, sd = 0.2972) and calculated the post-season ACL using the new 17-tier table

b. drew a random pre-season AI value by drawing a normal random number with mean = post-season AI and standard deviation = the cross-validation standard deviation, then calculated the pre-season ACL using the 17 tiers

c. checked whether the year would be flagged under each of our 3 rules

d. if it was, checked whether the previous year was also flagged, and if so, calculated the summed exceedance for the two years

e. checked if 7b was or was not triggered, and saved the summed exceedance for calculating either the "trigger" or "no-trigger" averages

At the end of the 10,000-year simulation, calculated the frequency and average exceedance for the "trigger" and "no-trigger" cases.

Results:

Because ACLs are set using the table of 17 tiers, the 1-tier flagging rule results in Table E1 show the expected frequency with which the pre-season ACL is expected to exceed the post-season ACL two years in a row, 14.2% of the time, or roughly every 7 years. When this occurs, the average sum of the two-year exceedances would be 39,463 fish.

Because the ACLs of most of the tiers differ by less than 10% from the ACL of the next tier, using a 10% difference as the criteria for flagging years means sometimes when the pre-season ACL exceeds the post-season ACL two years in a row, 7b would not be triggered, because in one or both years the difference would be less than 10%. Thus, the frequency of triggering 7b would be 7.1%, or roughly every 14 years. For the remaining 9.4% of years where there were two sequential exceedances, 7b would not be triggered; the average two-year exceedance in this case would be 28,667 fish.

The final rule we looked at would cause 7b to be triggered even less often, because shifting the criteria to the tier level above 10% means years would be flagged less often. Consequently, 7b would be triggered only 1.9% of the time, and when it was not triggered the two-year exceedance would average 34,706 fish.

Table F1. *Summary of simulation results.*

Amount that preACL must exceeds postACL to flag a year	a) 1 Tier	b) 10%	c) Next tier > 1.1 x postACL
Frequency of 7b (= 2 sequential flagged years)	14.2%	7.1%	1.9%
If 7b triggered, average amount over	39,463	50,395	69,595
Frequency of preACL > postACL in 2 sequential years, but 7b not triggered	0%	7.2%	12.3%
Average amount over in this case	*0	28,667	34,706

** Because ACLs come from the 17 tiers, the pre-season ACL can't be over the post-season ACL and not be one tier greater.*

APPENDIX G: APPRAISAL OF THE HISTORY OF SEAK AABM OVERAGES AND NBC AND WCVI UNDERAGES DURING THIS AGREEMENT (2019–2022)

An alternative way of exploring buffer parity for AABM ACLs is to examine the history of catch overages and underages during the elapsed time period (2019–2022) of the current Agreement. Table F1 shows that SEAK AABM overages have occurred in three of the four years elapsed during the current Agreement with the largest overage taking place in 2022 and characterized by an actual catch 70% greater than the post-season ACL. Due to these overages, a new ACL forecasting model (Method 4.3) and a new 17-tier table were introduced to determine the SEAK AABM catch limit in 2023. The real-world performance of this new system has not been evaluated yet. Thus, it is sensible to consider the incorporation of ACL buffers for SEAK once more is known about the performance of the new system.

Table F1 also shows the history of catch underages in the two Canadian AABM fisheries, NBC and WCVI. The largest underages occurred in 2020 and directly related to the impacts of COVID-19 on fishing activities. From this examination, it is clear that a 10% buffer for NBC and WCVI has been essentially immaterial during 2019–2022 and most likely will continue to be for the rest of this Agreement due to Canadian fishery plans designed to protect Chinook salmon stocks of concern. Hence another way to achieve parity for implementation of subparagraph 7(b) would be to explore reductions to the 10% buffer currently recognized for NBC and WCVI.

Table F2 shows an example of how reduced catch buffers for NBC and WCVI can be determined based on the principle of parity. This example draws from the last columns in Table D2 and Table D3, which show the percent balance for 10% parity from the perspective of between-tier ACL deviations and within-tier ACL intervals. The average of all tiers eligible for a balance relative to a 10% buffer (i.e., those highlighted in green) could be used to determine an ACL buffer for NBC and WCVI equivalent to the *de facto* buffers already included in the 17-tier system for SEAK. Both statistics produced ~4% averages.

Modifications to subparagraph 7(b) could be considered in the future, depending on performance of the new system (Method 4.3 & 17-tier table) in 2023. These modifications could be characterized either by adding discrete tier-specific ACL buffers for SEAK AABM catch or by reducing the 10% buffer for NBC and WCVI to an agreed lower level.

Table G1. *History of AABM fishery overages and underages during the current Agreement.*

SEAK				
Year	**Actual Catch**	**Postseason ACL**	**Actual - Postseason**	**Percent Deviation**
2019	140,307	140,323	-16	-0.01%
2020	204,624	140,323	64,301	45.82%
2021	202,082	140,323	61,759	44.01%
2022	238,621	140,323	98,298	70.05%
Cumulative	785,634	561,292	224,342	39.97%

NBC				
Year	**Actual Catch**	**Postseason ACL**	**Actual - Postseason**	**Percent Deviation**
2019	88,026	122,200	-34,174	-27.97%
2020	36,103	141,700	-105,597	-74.52%
2021	90,987	147,200	-56,213	-38.19%
2022	83,153	133,000	-49,847	-37.48%
Cumulative	298,269	544,100	-245,831	-45.18%

WCVI				
Year	**Actual Catch**	**Postseason ACL**	**Actual - Postseason**	**Percent Deviation**
2019	73,482	76,000	-2,518	-3.31%
2020	43,581	78,500	-34,919	-44.48%
2021	75,776	84,800	-9,024	-10.64%
2022	95,288	112,400	-17,112	-15.22%
Cumulative	288,127	351,700	-63,573	-18.08%

Table G2. *Example of how reduced catch buffers for NBC and WCVI can be determined based on the principle of parity. This example calculates the average percent balance (relative to 10%) based on between-tier ACL deviations and within-tier ACL intervals from SEAK's 17-tier table.*

	Between Tiers	**Within Tiers**
tier_17	**Relative to 10% (1-Tier deviation)**	**Tier-Interval 10% Balance**
1		
2	5.9%	5.4%
3	6.1%	6.5%
4	0.7%	4.9%
5	-1.8%	-2.5%
6	-0.5%	-1.1%
7	-12.2%	-13.8%
8	2.7%	2.8%
9	3.2%	2.6%
10	-4.7%	-4.5%
11	4.0%	3.5%
12	4.3%	4.4%
13	-1.3%	-0.7%
14	3.5%	3.0%
15	3.9%	3.9%
16	4.9%	1.9%
17		
Balance average	**3.91%**	**3.88%**