PACIFIC SALMON COMMISSION
JOINT CHINOOK TECHNICAL COMMITTEE REPORT

2022 PSC Chinook Model Calibration

TCCHINOOK (2022)-05

October 7, 2022

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List of Acronyms and Abbreviations[1]

AABM	Aggregate Abundance-Based Management	**IM**	Incidental Mortality
ACL	Annual Catch Limit	**ISBM**	Individual Stock-Based Management
ADF&G	Alaska Department of Fish & Game	**MAE**	Mean Absolute Error
AEQ	Adult Equivalent	**MAPE**	Mean Absolute Percent Error
AI	Abundance Index	**MASE**	Mean Absolute Scaled Error
AIC	Akaike Information Criterion	**MAT**	Maturity Factor
ARIMA	Auto Regressive Integrated Moving Average	**MATAEQ**	Maturation Adult Equivalent
AWG	Analytical Working Group of the Chinook Technical Committee	**MPE**	Mean Percent Error
BC	British Columbia	**MRE**	Mean Relative Error
BSE	Base Calibration File	**NA**	Not Available
BY	Brood Year	**NBC**	Northern British Colombia Dixon Entrance to Kitimat including Haida Gwaii
CBC	Central British Columbia	**NOAA**	National Oceanic and Atmospheric Administration
CEI	Ceiling File	**NWIFC**	Northwest Indian Fisheries Commission
CIOOS	Canadian Integration Ocean Observing System	**ODFW**	Oregon Department of Fish & Wildlife
CLB	Calibration	**OR**	Oregon
CNR	Chinook Non-retention	**PNV**	Proportion Non-Vulnerable
CPUE	Catch Per Unit Effort	**PSC**	Pacific Salmon Commission
CRITFC	Columbia River Inter-Tribal Fish Commission	**PST**	Pacific Salmon Treaty
CTC	Chinook Technical Committee	**QIN**	Quinault Indian Nation
CWT	Coded-Wire Tag	**RMSE**	Root Mean Squared Error
CY	Calendar Year	**ROM**	Ratio of Means
CYER	Calendar Year Exploitation Rate	**SACE**	Stock Aggregate Cohort Evaluation
DFO	Department of Fisheries and Oceans Canada	**SEAK**	Southeast Alaska Cape Suckling to Dixon Entrance
DIT	Double Index Tag	**SPFI**	Stratified Proportional Fishery Index
ENH	Enhancement File	**STK**	Stock Cohort Sizes File
ERA	Exploitation Rate Analysis	**SUS**	Southern United States
ETS	Exponentially Smoothed	**TBD**	To Be Determined
EV	Environmental Variable scalar	**TBR**	Transboundary Rivers
FCS	Forecast File	**UAF**	University of Alaska Fairbanks
FI	Fishery Index	**U.S.**	United States
FNC	First Nations Caucus	**USFWS**	US Fish & Wildlife Service
FP	Fishery Policy	**WA**	Washington
FSC	Food, Social and Ceremonial	**WCVI**	West Coast Vancouver Island excluding Area 20
HRI	Harvest Rate Index	**WDFW**	Washington Department of Fish and Wildlife
IDL	Interdam Loss		

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[1] Stock acronyms can be found in Table 1.1 and Appendix A.

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EXECUTIVE SUMMARY

The 2019 Pacific Salmon Treaty (PST) Agreement requires the Chinook Technical Committee (CTC) to annually report catch and escapement data and modeling results used to manage Chinook salmon fisheries and stocks harvested within the Treaty area (PST 2020). This report provides an overview of the annual Pacific Salmon Commission (PSC) Chinook Model calibration process and results, including post-season abundance indices (AIs) through 2021 and pre-season AIs through 2022 used for the management of aggregate abundance-based management (AABM) fisheries. Also included is an initial evaluation of AABM fishery performance as it relates to the terms of the 2019 PST Agreement, in addition to evaluations of model performance such as model error, stock composition of AIs, fishery indices, and stock forecasts of escapement or terminal run used as inputs to the PSC Chinook Model. The 2019 PST Agreement applies to all analyses and model calibration results for 2019 through 2028.

Aggregate Abundance-Based Management Abundance Indices and Associated Catches

Paragraphs 6(a) and (b) of the 2019 PST Agreement define abundance-based annual catch limits (ACLs) for the three AABM fisheries: Southeast Alaska (SEAK), Northern British Columbia (NBC), and West Coast Vancouver Island (WCVI). Each year, the annual PSC Chinook Model calibration provides the post-season AIs for the previous year and the pre-season AIs for the current year. Pre-season AIs are used to determine the ACLs in the upcoming fishing season for the NBC and WCVI AABM fisheries corresponding to Table 1 of Chapter 3 of the PST. The pre-season ACL for the SEAK AABM fishery is determined by the SEAK early winter District 113 troll fishery catch per unit effort (CPUE) metric. Per paragraph 6(a), *"annual catch limits are specified in Table 1 (catch limits specified at levels of the Chinook abundance index)"* based on annual calibrations of the PSC Chinook Model and "*Table 2 (catch limits for the SEAK AABM fishery and the catch per unit effort (CPUE)-based tiers), unless otherwise specified by the Commission"*.

Catch overages and underages in AABM fisheries are tracked relative to pre-season AIs (or CPUE metrics) and post-season AIs and their associated ACLs. Any overages relative to the pre-season ACLs must be paid back in the subsequent fishing year, per 2019 PST Agreement subparagraph 6(h)(i). If overages are observed in two successive years relative to post-season ACLs, then the PSC will request that the management entity responsible for the affected AABM fishery take steps to reduce the variance between the pre-season and post-season ACLs per subparagraph 7(b)(i) and the CTC must recommend a plan to the PSC to "*improve the performance of pre-season, in-season, and other management tools so that the deviations between the catches and post-season fishery limits to AABM fisheries are narrowed to a maximum level of 10%*" per subparagraph 7(b)(ii).

Abundance Indices for 2020–2022 for the Southeast Alaska (SEAK), Northern British Columbia (NBC), and West Coast Vancouver Island (WCVI) aggregate abundance-based management (AABM) fisheries. Post-season Indices for each year are from the first post-season calibration following the fishing year. Per paragraph 6(b) of the 2019 Pacific Salmon Treaty (PST)

Agreement, SEAK annual catch limits are set based on a catch per unit effort (CPUE) statistic, which is provided in parentheses following the abundance index (AI).

Year	SEAK Pre-season	SEAK Post-season	NBC Pre-season	NBC Post-season	WCVI Pre-season	WCVI Post-season
2020[1]	1.13 (4.83)	1.11	1.08	1.16	0.75	0.67
2021	1.28 (3.85)	1.23	1.27	1.21	0.76	0.73
2022	1.16 (7.02)		1.17		0.88	

[1] Pre-season AIs are from CLB 2002 (Phase II model configuration). During the 2021 Calibration process, an error was identified in some of the maturation rates used as inputs to CLB 2002. These errors were corrected in CLB 2003, which yielded 2020 pre-season AIs of 1.02, 1.00, and 0.69 for SEAK, NBC, and WCVI, respectively.

The pre-season and post-season Treaty catch limits by fishery for each year and actual Treaty catches (total catch minus any hatchery add-on and exclusion catch) are shown for AABM fisheries for 2020–2022 in the table below.

Pre-season annual catch limits (ACLs) (2020–2022), and post-season ACLs and actual catches (2020–2021) for aggregate abundance-based management (AABM) fisheries. Post-season values for each year are based on abundance indices (AIs) from the first post-season calibration following the fishing year.

Year	SEAK (Troll, Net, Sport) Pre-season ACL[1]	SEAK (Troll, Net, Sport) Post-season ACL	SEAK (Troll, Net, Sport) Actual Catch	NBC (Troll, Sport) Pre-season ACL	NBC (Troll, Sport) Post-season ACL	NBC (Troll, Sport) Actual Catch	WCVI (Troll, Sport) Pre-season ACL	WCVI (Troll, Sport) Post-season ACL	WCVI (Troll, Sport) Actual Catch
2020	205,165	140,323	204,624	133,000	141,700	36,183	87,000	78,500	43,581
2021	205,165	140,323	202,082	153,800	147,200	90,987	88,000	84,800	75,776
2022	266,585			142,800			100,700		

[1] Per paragraph 6(b) of the 2019 PST Agreement, this number represents the ACL based on a CPUE statistic.

Overages and underages in AABM fishery catches, relative to pre-season and post-season ACLs for a fishing year, can occur due to the operation of the in-season management system referred to herein as *management error*, errors in the pre-season calibration process (e.g., forecast error) or CPUE statistic referred to as *model error*, or a combination of the two referred to as *composite error*. The relative influence of each was evaluated by inspecting differences in actual landed catch and the pre- and post-season ACLs, as shown in the table below. In 2021, actual landed catch was less than the pre-season ACL by 3,083 fish (2%) in SEAK, 62,813 fish (41%) in NBC, and 12,224 fish (14%) in WCVI due to in-season management; thus, no payback was necessary for the 2022 fishing season per the terms of subparagraph 6(h)(i) of the 2019 PST Agreement. The lower catches in British Columbia are partly due to reduced effort due to the COVID-19 pandemic[2], where travel restrictions and lodge closures resulted in significantly reduced catch estimates for NBC AABM recreational fisheries, and partly due to domestic

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[2] Chinook Technical Committee. (January 6, 2022). *COVID-19 Impacts on Chapter 3 of the Pacific Salmon Treaty in 2020 and 2021* [Memorandum]. Pacific Salmon Commission.

constraints in both WCVI and NBC troll fisheries to protect stocks of concern such as Fraser Chinook.

In terms of the post-season ACLs for evaluation of the provisions of paragraph 7(b), 2021 actual catches were more than the post-season ACLs by 61,759 fish in SEAK (44%), and less than post-season ACLs by 56,213 (38%) in NBC and 9,024 (11%) in WCVI.

For the SEAK AABM fishery in 2020, both the pre-season ACL and the observed catch exceeded the post-season ACL. Similarly, in 2021, both the pre-season ACL and the observed catch exceeded the post-season ACL. As a result, in the SEAK AABM fishery there have now been two consecutive years where the pre-season ACL and the observed catch exceeded the post-season ACL. Per the provisions of the 2019 PST Agreement this requires further action, as identified in subparagraphs 7(b)(i) and 7(b)(ii).

For the NBC AABM fishery, the observed catch was 25% and 62% of the post-season ACL in 2020 and 2021, respectively. Since neither of these is greater than 110%, this does not require any further action regarding the NBC AABM fishery per subparagraphs 7(b)(i) and 7(b)(ii).

For the WCVI AABM fishery, the observed catch was 56% and 89% of the post-season ACL in 2020 and 2021, respectively. Since neither of these is greater than 110%, this does not require any further action regarding the WCVI AABM fishery per subparagraphs 7(b)(i) and 7(b)(ii) .

Summary of aggregate abundance-based management (AABM) fishery performance and deviations between pre- and post-season annual catch limits (ACLs) and actual catches for Southeast Alaska (SEAK), Northern British Columbia (NBC), and West Coast Vancouver Island (WCVI), 2020–2021.

Positive values indicate an overage and negative values indicate an underage. Colored cells indicate AABM fishery performance relative to Treaty obligations; cells shaded green indicate where a fishery met Treaty obligations and red cells indicate where a fishery exceeded Treaty obligations.

	Management Error Actual – Pre ACL		Model Error Pre ACL – Post ACL		Composite Error Actual – Post ACL	
Year	#	%	#	%	#	%
SEAK (Troll, Net, Sport)						
2020	-541	0%	64,842	46%	64,301	46%
2021	-3,083	-2%	64,842	46%	61,759	44%
NBC (Troll, Sport)						
2020	-96,817	-73%	-8,700	-6%	-105,597	-75%
2021	-62,813	-41%	6,600	4%	-56,213	-38%
WCVI (Troll, Sport)						
2020	-43,419	-50%	8,500	11%	-34,919	-44%
2021	-12,224	-14%	3,200	4%	-9,024	-11%

1. INTRODUCTION

Chapter 3 of the 2019 Pacific Salmon Treaty (PST) Agreement requires the Chinook Technical Committee (CTC) to annually report catch and escapement data and modeling results used to manage Chinook salmon fisheries and stocks harvested within the Treaty area (PST 2020). To fulfill this obligation, the CTC provides a series of annual reports to the Pacific Salmon Commission (PSC). This report provides an overview of the annual PSC Chinook Model calibration (CLB) process and results, including post-season abundance indices (AIs) through 2021 and pre-season AIs through 2022 used for coastwide management of Chinook stocks. Management includes both aggregate abundance-based management (AABM) fisheries and individual stock-based management (ISBM) fisheries. The PSC Chinook Model is assessed and adjusted (i.e., calibrated) each year, incorporating pre-season stock-specific abundance forecasts with the latest information on catches, exploitation rates generated through a cohort analysis, terminal runs, and escapements. Also included is an evaluation of AABM fishery performances as they relate to the terms of the 2019 PST Agreement (Section 3), PSC Chinook Model validation, evaluations of model error, and a summary of model improvements (Section 4) . The CTC uses the PSC Chinook Model to generate key components of the PSC's annual fishery management cycle. The Parties rely upon the PSC Chinook Model to generate annual indices of abundance for AABM fisheries, and to produce estimates of calendar year exploitation rates (CYER) in ISBM fisheries (Figure 1.1).

The pre-season AIs determine the annual catch limits (ACLs) for two of the three AABM fisheries: Northern British Columbia (NBC) and West Coast Vancouver Island (WCVI). Beginning in 2019, the pre-season ACL for the Southeast Alaska (SEAK) AABM fishery is determined by the SEAK early winter District 113 troll fishery catch per unit effort (CPUE) metric. These pre-season ACLs drive the in-season management of AABM fisheries and are used to evaluate fishery performance including management error. In addition to generating pre-season AIs, the PSC Chinook Model provides other information of immediate relevance to PSC management, most notably post-season AIs. The first post-season AI estimates are used to determine post-season fishery limits from which model error can be evaluated.

The results of the pre-season model calibration for 2022 are based on the CTC's annual exploitation rate analysis (ERA) using coded-wire tag (CWT) data through catch year 2021 (2020 for southern U.S. stocks) and coastwide data on catch, spawning escapements, and age structure through 2021, and forecast Chinook salmon returns expected in 2022. This report includes: (1) estimated post-season AIs for 1979 through 2021 and the pre-season AIs for 2022 for the AABM fisheries; (2) estimated stock composition for 1979–2021 and a projection for 2022 for the AABM and other fisheries; and (3) estimated fishery indices (harvest rates) for the AABM fisheries; (4) an evaluation of AABM fishery performance relative to the 2019 PST Agreement; and (5) a validation of the PSC Chinook Model and summary of model improvement activities.

More detailed results associated with the four sections of this report are included in nine appendices. Appendix A shows the relationship between the exploitation rate indicator stocks, escapement indicator stocks, model stocks, and PST Attachment I stocks. Appendix B through

Appendix F present additional output from the PSC Chinook Model calibration beyond the summaries presented in the main body of the report. Appendix B and Appendix C show the model estimates of stock composition in AABM, ISBM, and other sport and troll fisheries. Appendix D lists the incidental mortality (IM) rates used in the PSC Chinook Model. Appendix E gives the time series of total AIs for the AABM fisheries, and Appendix F provides a tabular summary of forecast error for PSC Chinook Model stocks. Calibration methodology is detailed in Appendix G. Issues with, and changes to PSC Chinook Model calibration, as well as their resolution, are detailed in Appendix H.
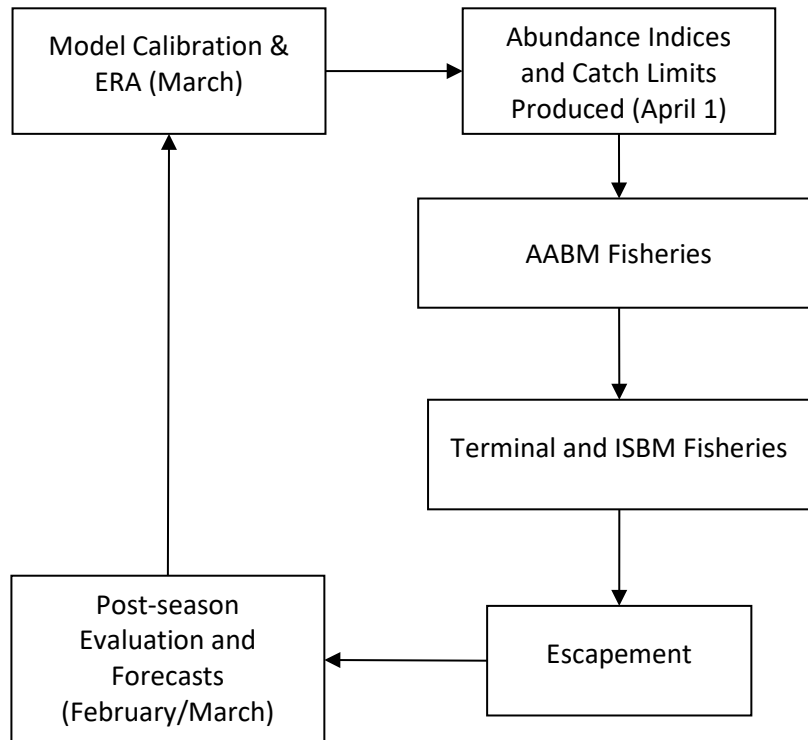
Figure 1.1.—Pacific Salmon Treaty (PST) Chinook management and fishery process.
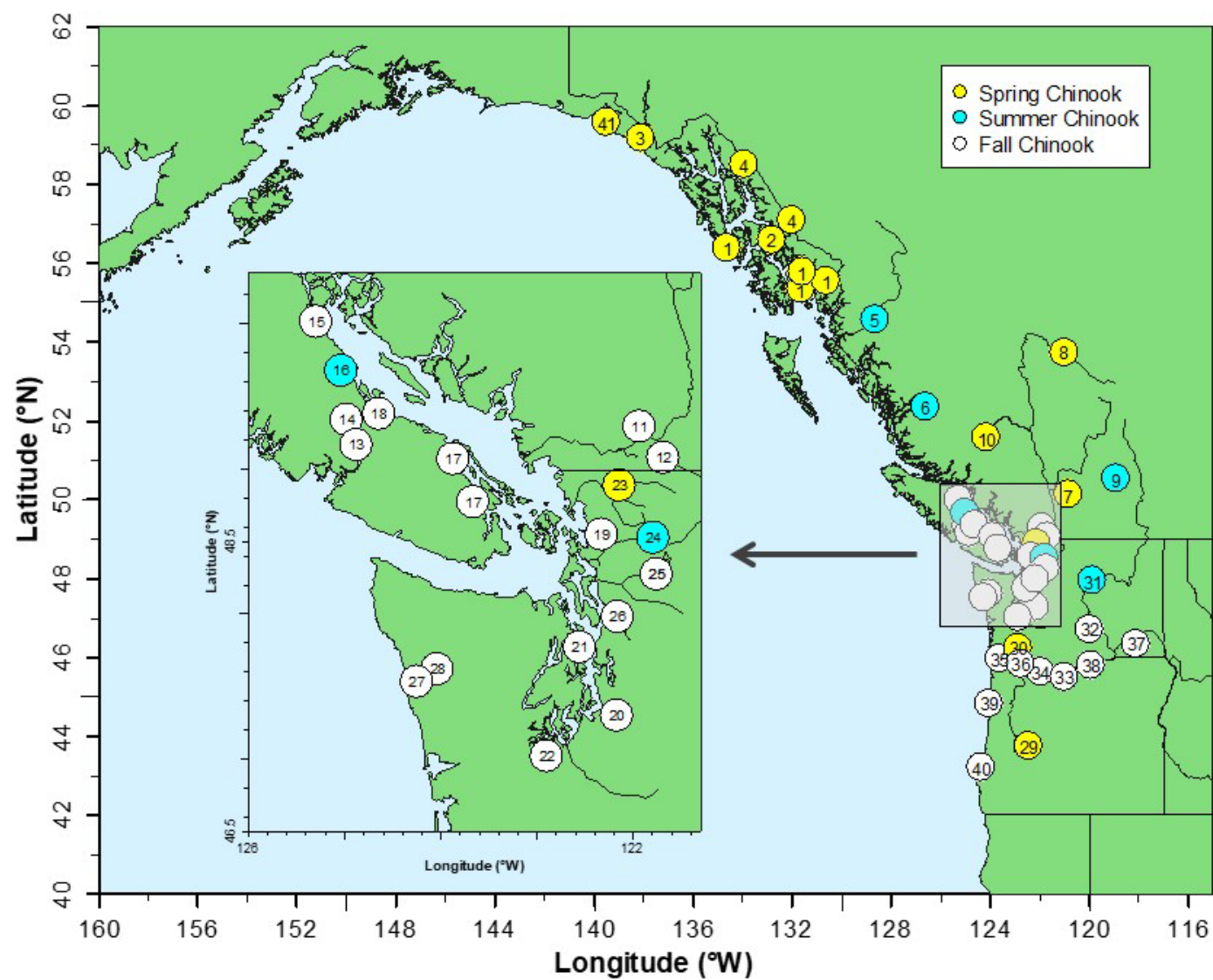
Figure 1.2.—Geographical locations of Phase II Pacific Salmon Commission Chinook Model stock groups.

Note: See Table 1.1 for the full stock names associated with each abbreviation and map indicator.

Table 1.1.—Stock groups used in the Phase II Pacific Salmon Commission Chinook Model, associated coded-wire tag (CWT) indicator(s), location, run type, smolt age, and map indicator.

Area	Model Stock	CWT Indicator	Run Type	Smolt Age	Map ID
Southeast Alaska	Southern Southeast Alaska (SSA)	Whitman Lake (AHC), Little Port Walter (ALP), Deer Mountain (ADM), Neets Bay (ANB)	Spring	Age 1	1
	Northern Southeast Alaska (NSA)	Crystal Lake (ACI)	Spring	Age 1	2
Transboundary	Alsek (ALS)	Wild – No indicator	Spring	Age 1	3
	Taku and Stikine (TST)	Wild Taku and Stikine Rivers	Spring	Age 1	4
	Yakutat Forelands (YAK)	Wild – No indicator	Spring	Age 1	41
North/Central British Columbia	Northern B.C. (NBC)	Kitsumkalum (KLM)	Summer	Age 0	5
	Central B.C. (CBC)	Atnarko (ATN)	Summer	Age 1	6
West Coast Vancouver Island	WCVI Hatchery (WVH)	Robertson Creek (RBT)	Fall	Age 0	13
	WCVI Natural (WVN)	Robertson Creek (RBT)	Fall	Age 0	14
Strait of Georgia	Upper Strait of Georgia (UGS)	Quinsam (QUI)	Fall	Age 0	15
	Middle Strait of Georgia (MGS)	Big Qualicum (BQR)	Fall	Age 0	18
	Puntledge Summers (PPS)	Puntledge (PPS)	Summer	Age 0	16
	Lower Strait of Georgia (LGS)	Cowichan (COW); Nanaimo (NAN)[1]	Fall	Age 0	17
Fraser River	Fraser Spring 1.2 (FS2)	Nicola (NIC)	Spring	Age 1	7
	Fraser Spring 1.3 (FS3)	Dome (DOM)[2]	Spring	Age 1	8
	Fraser Ocean-type 0.3 (FSO)	Lower Shuswap (SHU)	Summer	Age 0	9
	Fraser Summer Stream-type 1.3 (FSS)	Chilko (CKO)	Summer	Age 1	10
	Fraser Harrison Fall (FHF)	Harrison (HAR)	Fall	Age 0	11
	Fraser Chilliwack Fall Hatchery (FCF)	Chilliwack (CHI)	Fall	Age 0	12
North Puget Sound	Nooksack Spring (NKS)	Nooksack Spring Fingerling (NSF)	Spring	Age 0	23
	Nooksack Fall (NKF)	Samish Fall Fingerling[3] (SAM)	Summer/Fall	Age 0	19
	Skagit Wild (SKG)	Skagit Summer Fingerling (SSF)	Summer	Age 0	24
	Stillaguamish Wild (STL)	Stillaguamish Fall Fingerling (STL)	Summer/Fall	Age 0	25
	Snohomish Wild (SNO)	Snohomish Wild (SNO)	Summer/Fall	Age 0	26
South Puget Sound	Puget Sound Fingerling (PSF)	S. Puget Sound Fall Fingerling[3] (SPS)	Summer/Fall	Age 0	20
	Puget Sound Natural Fall (PSN)	S. Puget Sound Fall Fingerling[3] (SPS)	Summer/Fall	Age 0	21
	Puget Sound Yearling (PSY)	South Puget Sound Fall Yearling (SPY); University of Washington Accelerated (UWA)[4]	Summer/Fall	Age 1	22
Washington Coast	Washington Coast Natural (WCN)	Hoko Fall Fingerling (HOK)	Fall	Age 0	28
	Washington Coast Hatchery (WCH)	Queets Fall Fingerling (QUE); Tsoo-Yess Fall Fingerling (SOO)	Fall	Age 0	27
Columbia River	Lower Bonneville Hatchery (BON)	Columbia Lower River Hatchery[3] (LRH)	Fall Tule	Age 0	34
	Fall Cowlitz Hatchery (CWF)	Cowlitz Tule (CWF)	Fall Tule	Age 0	35
	Cowlitz Spring Hatchery (CWS)	Cowlitz Spring Hatchery (CWS)	Spring	Age 1	30
	Lewis River Wild (LRW)	Lewis River Wild (LRW)	Fall Bright	Age 0	36
	Spring Creek Hatchery (SPR)	Spring Creek Tule[3] (SPR)	Fall Tule	Age 0	33
	Willamette River Spring (WSH)	Willamette Spring[3] (WSH)	Spring	Age 1	29
	Mid-Columbia River Brights	Mid-Columbia River Brights (MCB)	Fall	Age 0	38
	Columbia River Summer (SUM)	Columbia Summers[5] (WA) (SUM)	Summer	Age 0/1	31
	Upriver Brights (URB)	Columbia Upriver Bright (URB)[1]	Fall Bright	Age 0	32
Snake River	Lyons Ferry (LYF)	Lyons Ferry[3,5] (LYF)	Fall Bright	Age 0	37
North Oregon Coast	North Oregon Coast (NOC)	Salmon (SRH)	Fall	Age 0	39
Mid Oregon Coast	Mid-Oregon Coast (MOC)	Elk River (ELK)	Fall	Age 0	40

[1] Tagged releases for the Nanaimo Fall stock were discontinued after the 2004 brood.

[2] Hatchery production of the Dome Creek stock was discontinued after the 2002 brood.

[3] Double index tags (DIT) associated with this stock.

[4] The last year included in the exploitation rate analysis for University of Washington Accelerated was 1984.

[5] Subyearlings have been CWT-tagged since brood year (BY) 1986, except for BYs 1993–1997.

2. PSC Chinook Model Calibration and Output

The annual calibration of the PSC Chinook Model provides pre-season AIs and post-season AIs for the previous year for the three AABM fisheries. The time series of pre-fishery abundances vulnerable to AABM fisheries produced by the PSC Chinook Model are the basis for the computation of AIs. AIs are a relative measure of abundance calculated as the ratio of AABM pre-fishery abundance in a given year and the average abundances during the 1979–1982 base period. The 2022 pre-season AIs are used to determine the ACLs of Treaty Chinook salmon in the NBC and WCVI AABM fisheries for 2022. The pre-season ACL for the SEAK AABM fishery was determined from the SEAK early winter District 113 Troll fishery CPUE metric. Post-season AIs are used to determine the previous season's ACLs (2021) for all three AABM fisheries and to evaluate PSC Chinook Model error. For additional calibration details, including key input data, procedures, and output data, see Appendix G. For details on improvements to the PSC Chinook Model, see Section 4.

2.1 Overview of 2021 Calibration Process

The CTC Analytical Work Group (AWG) met remotely in March 2022 to perform the PSC Chinook Model calibration. As in 2021, conducting the calibration remotely was challenging and a calibration was not produced during the initial meeting week. As was the case in 2020 and 2021, compiling maturity rates for the PSC Chinook Model was the primary impediment to completing the final calibration. Preliminary calibrations were produced after the initial meeting week and the AWG agreed to endorse calibration CLB 2203 which was subsequently accepted by the full CTC. In late March, the CTC produced its annual memo to the PSC detailing the 2021 post-season AIs and the 2022 pre-season AIs and ACLs for the AABM fisheries based on CLB 2203 and the SEAK early-winter troll fishery CPUE index (per the 2019 PST Agreement [PST 2020]; see details in section 3.1). PSC Chinook Model calibrations are named with the last two digits of the year (22) and the iteration of the calibration (03).

2.2 AABM Abundance Indices

The AABM fishery management regime relies on data for catches and incidental mortality, fishing effort, fishery impacts (CWT indices), and the AIs generated by the PSC Chinook Model. The PSC Chinook Model uses catch data (i.e., encountered fish that are either kept or released), escapement data, CWT recovery data, and abundance forecasts to predict the AI for the upcoming year and to estimate the time series of AIs since 1979 (including the post-season AIs).

The PST specifies that AABM fisheries are to be managed using pre-season AIs, where a fishery's AI corresponds to a specific ACL for each AABM fishery (Table 1 of Chapter 3 of the 2019 PST Agreement [PST 2020]). The 2019 PST Agreement continues the use of pre-season AIs for NBC and WCVI AABM fisheries but establishes a CPUE metric to set ACLs for the SEAK AABM fishery. Pre-season AIs that were used to establish ACLs are listed in Table 2.1 along with the CPUE metric used to set the pre-season SEAK ACLs beginning in 2019.

Post-season AIs are a better index of abundance for the AABM fisheries than are the pre-season AIs because they contain additional observed return data. Thus, the Treaty also establishes

post-season fishery limits (*a posteriori* limits to which the already prosecuted fishery is held accountable) based on the first post-season AI that is calculated each year, although as further catches from these cohorts are observed in subsequent years the AI estimates become even more accurate. Post-season AIs for 1999–2021 are listed in Table 2.1.

In response to coastwide conservation concerns, the 2009 PST Agreement called for reduced catches and associated harvest rates in the SEAK and WCVI AABM fisheries. AABM catches prescribed for 2009–2018 included negotiated reductions of 15% in SEAK and 30% in WCVI, but the NBC AABM fishery retained the same ACLs and harvest rates specified in the 1999 PST Agreement. Similarly, in response to coastwide concerns over Chinook productivity and an emerging concern over the viability of the Southern Resident Killer Whale population which has a diet mostly reliant on Chinook salmon (Ford et al. 1998, Hanson et al. 2010, Hanson et al. 2021), the 2019 PST Agreement called for additional reductions in catches and associated harvest rates in the SEAK and WCVI AABM fisheries. AABM catches prescribed for 2019–2028 include negotiated additional reductions of up to 7.5% in SEAK (based on CPUE tiers) and 12.5% in WCVI, but the NBC AABM fishery retained the same ACLs and harvest rates specified in the 1999 PST Agreement.

Table 2.1.—Abundance Indices (AIs) for 1999–2022 for the Southeast Alaska (SEAK), Northern British Columbia (NBC), and West Coast Vancouver Island (WCVI) aggregate abundance-based management (AABM) fisheries. Post-season values reported for each year are from the first post-season calibration following the fishing year.

| Year | SEAK | | NBC | | WCVI | |
	Pre-season	Post-season	Pre-season	Post-season	Pre-season	Post-season
1999	1.15	1.12	1.12	0.97	0.60	0.50
2000	1.14	1.10	1.00	0.95	0.54	0.47
2001	1.14	1.29	1.02	1.22	0.66	0.68
2002	1.74	1.82	1.45	1.63	0.95	0.92
2003	1.79	2.17	1.48	1.90	0.85	1.10
2004	1.88	2.06	1.67	1.83	0.90	0.98
2005	2.05	1.90	1.69	1.65	0.88	0.84
2006	1.69	1.73	1.53	1.50	0.75	0.68
2007	1.60	1.34	1.35	1.10	0.67	0.57
2008	1.07	1.01	0.96	0.93	0.76	0.64
2009	1.33	1.20	1.10	1.07	0.72	0.61
2010	1.35	1.31	1.17	1.23	0.96	0.95
2011	1.69	1.62	1.38	1.41	1.15	0.90
2012	1.52	1.24[1]	1.32	1.15[1]	0.89	0.76[1]
2013	1.20[1]	1.63	1.10[1]	1.51	0.77[1]	1.04
2014[2]	2.57	2.20	1.99	1.80	1.20	1.12
2015[2]	1.45	1.95	1.23	1.69	0.85	1.05
2016	2.06	1.65	1.70	1.39	0.89	0.70
2017	1.27	1.31	1.15	1.14	0.77	0.64
2018	1.07	0.92	1.01	0.89	0.59	0.59
2019[3]	1.07 (3.38)[5]	1.04	0.96	0.94	0.61	0.58
2020[4]	1.13 (4.83)[5]	1.11	1.08	1.16	0.75	0.67
2021	1.28 (3.85)[5]	1.23	1.27	1.21	0.76	0.73

	SEAK		NBC		WCVI	
Year	Pre-season	Post-season	Pre-season	Post-season	Pre-season	Post-season
2022	1.16 (7.02)[5]		1.17		0.88	

[1] Due to changes in calibration procedures (reviewed in section Appendix G), 2012 post-season (Calibration [CLB] 1309) and 2013 pre-season (CLB 1308) AIs are based on different calibrations; the procedures and assumptions CLB 1309 mirror those used during the 2012 pre-season calibration.

[2] Due to a disagreement over model calibration 1503, the Commission agreed to use CLB 1601 to estimate the 2014 and 2015 post-season AIs and 2016 pre-season AI.

[3] Post-season AIs are from CLB 2000–9806 (old model configuration).

[4] Pre-season AIs are from CLB 2002 (Phase II model configuration). During the 2021 Calibration process, an error was identified in some of the maturation rates used as inputs to CLB 2002. These errors were corrected in CLB 2003, which yielded 2020 pre-season AIs of 1.02, 1.00, and 0.69 for SEAK, NBC, and WCVI, respectively.

[5] Per paragraph 6(b) of the 2019 Pacific Salmon Treaty (PST) Agreement, the number in parentheses represents a catch per unit effort (CPUE) statistic used to determine the annual catch limit (ACL).

2.3 STOCK COMPOSITION OF ABUNDANCES AVAILABLE IN AABM FISHERIES, 1979–2020

Most catches in each AABM fishery are comprised of the small subset of geographically similar stocks or stock aggregates listed in Appendix A. Figure 2.1–Figure 2.3 show the post-season AIs (resulting from CLB 2203) partitioned into geographic stock groups (Table 2.2) using a combination of CWT and genetic data. In general, post-season AIs had peaks during the late 1980s (1987–1989), in 2003 and 2004, and in 2014 and 2015.

For additional stock composition information, see Appendix B which partitions catches by the 41 PSC Chinook Model stock stratification. For the percent stock composition of AIs partitioned by the 41 PSC Chinook Model stock stratification, please see the PSC website in the CTC Technical Reports section.

For additional fishery information, see Appendix C for model-generated stock composition estimates for all fisheries (AABM and ISBM).

Table 2.2.—Stock groupings comprising aggregate abundance-based management (AABM) fisheries.

SEAK/TBR	Southeast Alaska and Transboundary River stocks (Southern and Northern Southeast Alaska, Alsek, Taku and Stikine, and Yakutat Forelands)
NCBC	North and Central British Columbia stocks
WCVI	West Coast Vancouver Island stocks (hatchery and natural)
SG	Strait of Georgia stocks (Upper, Middle, Lower, and Puntledge Summers)
FR-early	Fraser River Early stocks (Fraser Spring 1.2 and 1.3, Fraser Summer Ocean-type 0.3 and Stream-type 1.3)
FR-late	Fraser River Late stocks (Harrison Fall, Chilliwack Fall Hatchery)
PSD	Puget Sound stocks (Nooksack Fall and Spring, Puget Sound Natural Fall, Puget Sound Fingerlings and Yearlings, Skagit Wild, Stillaguamish Wild, and Snohomish Wild)
WACST	Washington Coast stocks (hatchery and wild)
CR-sp&su	Columbia River Spring and Summer stocks (Willamette, Spring Cowlitz Hatchery, and Columbia Summers)
CR-bright	Columbia River Fall Bright stocks (Upriver, Mid-Columbia, Lewis River Wild, and Lyons Ferry)
CR-tule	Columbia River-Fall Tule stocks (Spring Creek, Lower Bonneville, and Fall Cowlitz Hatchery)
ORCST	North and Mid-Oregon Coast stocks

The major stock groups contributing to the SEAK AIs are Columbia River Fall Brights, WCVI, Oregon Coast, Fraser Early, SEAK/Transboundary Rivers, NCBC and Washington Coast (Figure 2.1). Since 1999, the average contribution to the SEAK AIs for these stock groups has been 47%, 25%, 16%, 13%, 11% and 11% respectively.

Figure 2.1.—Stock composition of the annual abundance indices for the Southeast Alaska (SEAK) Troll fishery from Calibration (CLB) 2203.

The major stock groups contributing to the NBC AIs are Columbia River Fall Brights, Oregon Coast, Fraser Early, Columbia Spring/Summer, Washington Coast and WCVI (Figure 2.2). Since 1999, the average contribution to the NBC AIs for these stock groups has been 31%, 31%, 19%, 15%, 15% and 15% respectively.

Figure 2.2.—Stock composition of the abundance indices for the Northern British Columbia (NBC) Troll fishery from Calibration (CLB) 2203.

The major stock groups contributing to the WCVI AIs are Columbia River Tules, Columbia River Brights, Puget Sound, Fraser Late and Columbia Spring/Summer (Figure 2.3). Since 1999, the average contribution to the WCVI AIs for these stock groups has been 21%, 20%, 17%, 8% and 7% respectively.

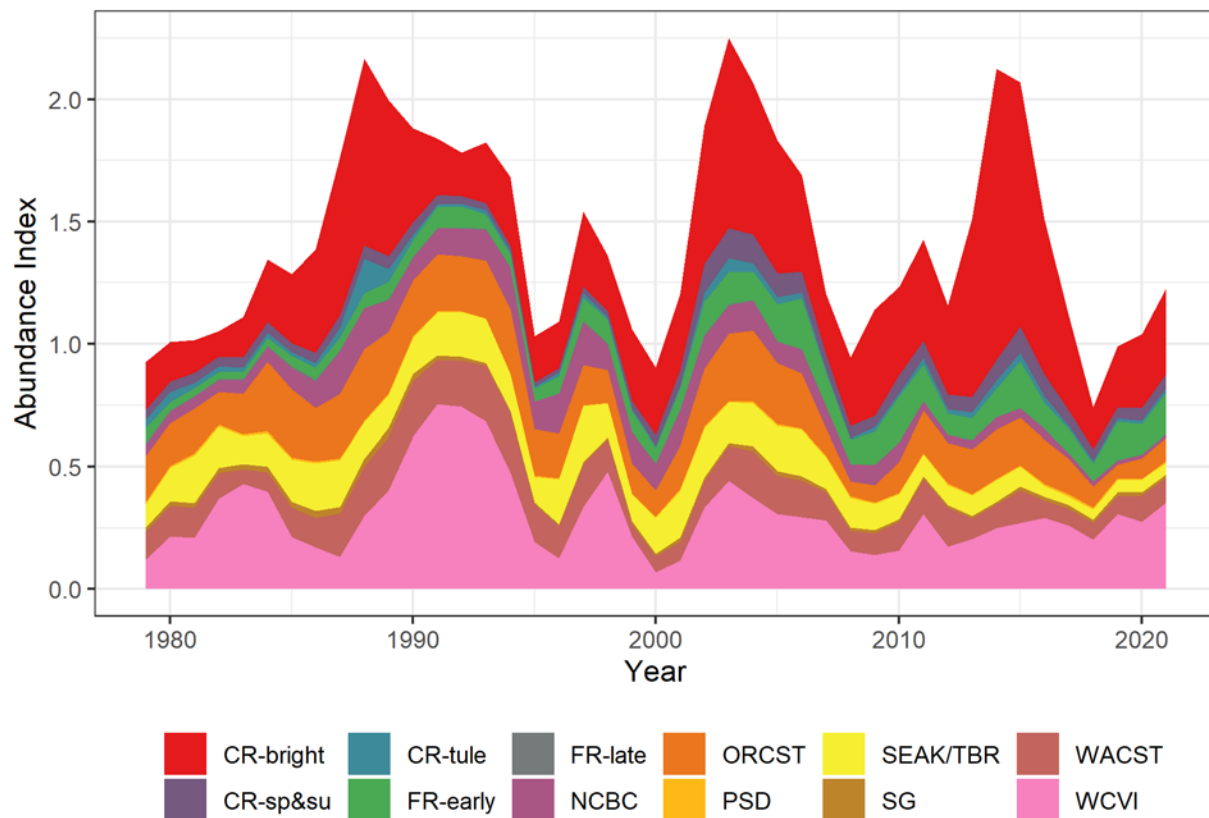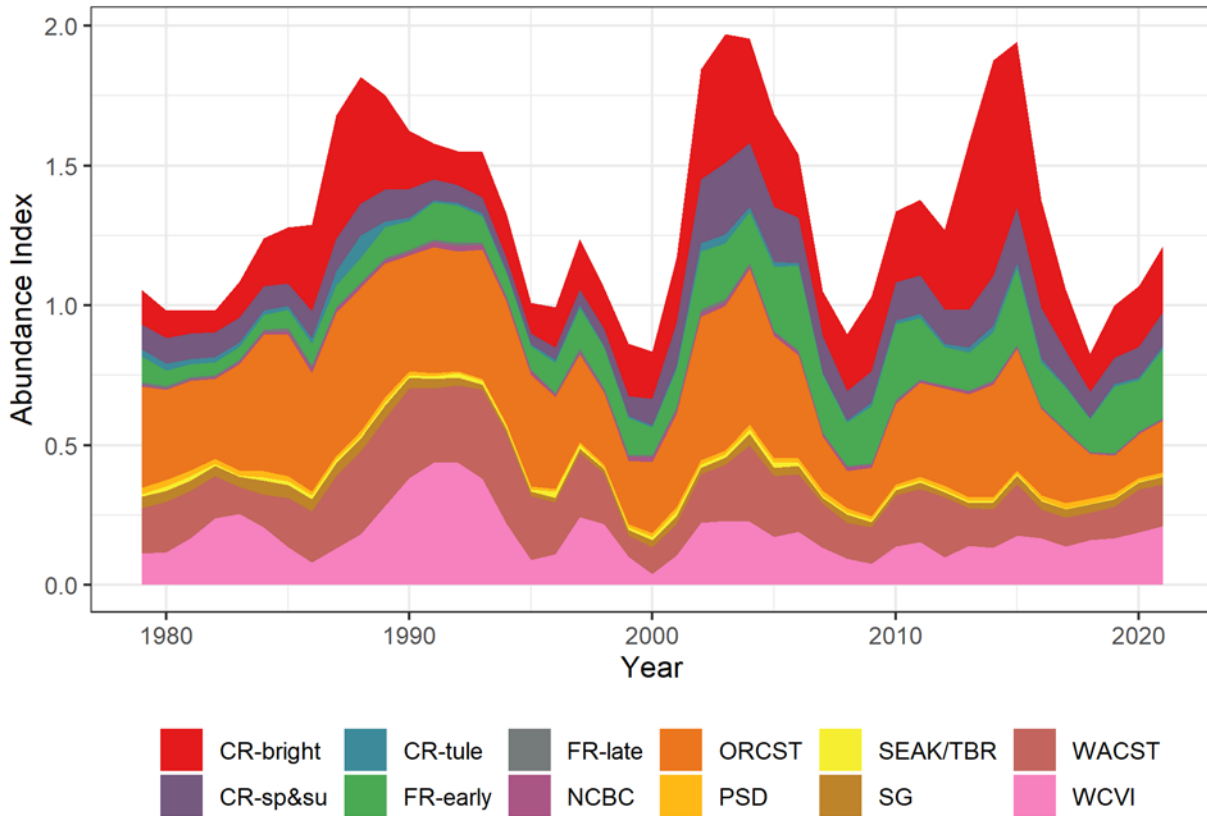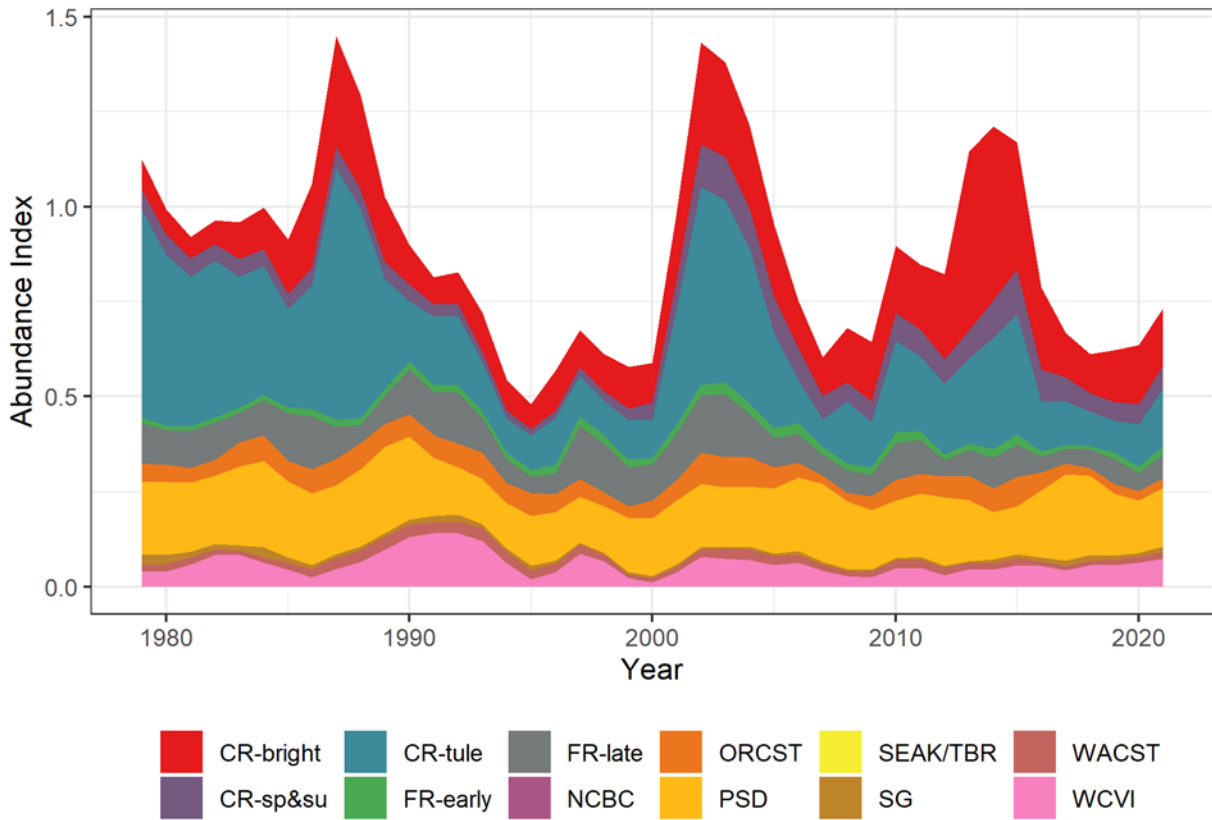*Figure 2.3.—Stock composition of the abundance indices for the West Coast Vancouver Island (WCVI) Troll fishery from Calibration (CLB) 2203.*

3. AABM FISHERY PERFORMANCE

The 2019 PST Agreement defines an AABM fishery as "*an abundance-based regime that constrains catch or total mortality to a numerical limit computed from either a pre-season forecast or an in-season estimate of abundance, from which a harvest rate index can be calculated, expressed as a proportion of the 1979 to 1982 base period*" per paragraph 3(a). The 2019 PST Agreement identified three such fisheries to be managed under an AABM regime for Chinook salmon: (1) SEAK troll, net, and sport, (2) NBC troll and Haida Gwaii sport, and (3) WCVI troll and outside sport. The CTC is tasked with annually evaluating AABM fishery performance relative to the obligations set forth in paragraphs 6 and 7 (Figure 3.1).

3.1 AABM MANAGEMENT FRAMEWORK

Paragraph 6(a) of the 2019 PST Agreement specifies that "*the SEAK, NBC, and WCVI AABM fisheries shall be abundance based with the annual catch limits specified in Table 1 (catch limits specified for AABM fisheries at levels of the Chinook abundance index)*" and "*Table 2 (catch limits for the SEAK AABM fishery and the catch per unit effort (CPUE)-based tiers)*". Under previous PST Agreements, ACLs for each of the three fisheries were determined from Table 1 in Chapter 3 of the 1999 and 2009 PST Agreements (PST 2000, 2010). In the 2009 and 2019 PST Agreements, the relationships between the AIs and the ACLs changed for SEAK and WCVI from the 1999 PST Agreement; thus, Table 1 has been revised for each successive PST Agreement to reflect these changes. Furthermore, the 2019 PST Agreement introduced a new process for determining SEAK ACLs: the early winter CPUE from the SEAK troll fishery in District 113 during statistical weeks 41–48 (October–November) determines the pre-season SEAK tier level and the associated ACLs using a newly added Table 2. The post-season tier level for SEAK is determined using Table 2 and the SEAK AI from the post-season calibration of the PSC Chinook Model.

The CTC is tasked with reporting AABM fishery performance for each fishing year relative to pre-season and post-season ACLs. The differences between actual catches and ACLs are the result of two processes (Table 3.2): 1) *management error*, defined here as the difference between the actual catch and the pre-season ACL; and 2) *model error*, which is the difference between the pre-season ACL and the post-season ACL. The term *management error* is used but it may be a misnomer in many situations as the deviations of actual catch from the pre-season ACLs may have been the result of deliberate actions. The combination of management error and model error is referred to as *composite error*. Composite error is calculated using the difference between the actual catch and the post-season ACL, or more simply adding model and management error together. Composite error is generally greatest when management error and model error are in the same direction. Low composite error can also be the result of management errors in the opposite direction of model errors, thereby cancelling out portions of these different deviations. The relative influence of each type of error on composite error is evaluated by inspecting model or management error over the total composite error.

Since the 2019 PST Agreement establishes a new method for setting SEAK AABM fishery limits, the Treaty calls for a comparison of the new CPUE-based approach and the existing PSC Chinook Model AI-based approach. Paragraph 7(d) states that the CTC will conduct "*up to two reviews of the CPUE-based approach*" with the "*first review occurring as soon as practical after*

the 2022 post-season AI is calculated and the second review as soon as practical after the 2025 post-season AI is calculated". The 2019 PST Agreement AABM management framework is diagrammed in Figure 3.1.
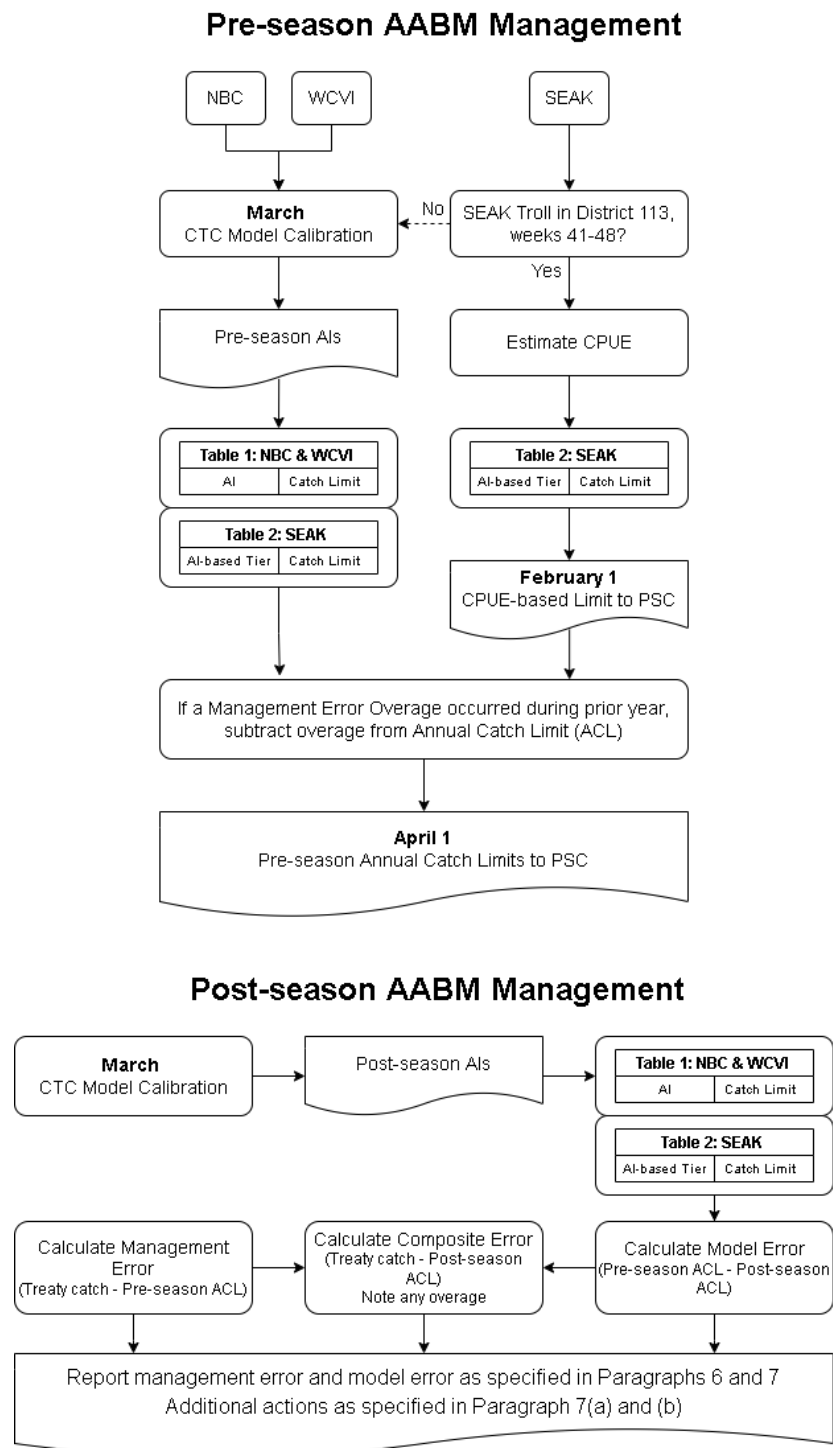
Figure 3.1.—Flow diagrams depicting the sequence of steps for pre-season (top) and post-season (bottom) aggregate abundance-based management (AABM) fisheries management framework under the 2019 Pacific Salmon Treaty (PST) Agreement.

3.2 ACTUAL CATCHES VS PRE-SEASON AND POST-SEASON ANNUAL CATCH LIMITS

In 2021, the actual landed catches in SEAK, NBC, and WCVI AABM fisheries were all below pre-season ACLs. Actual landed catch was less than the pre-season ACLs by 3,083 fish in SEAK, 62,813 fish in NBC, and 12,224 fish in WCVI. In terms of the post-season ACLs for evaluation of the provisions of the PST (PST 2020; paragraph 6(g)), 2021 actual catches were greater than the post-season ACL by 61,759 fish in SEAK, and less than the post-season ACL by 56,213 fish in NBC and 9,024 fish in WCVI. Pre-season ACLs, post-season ACLs, and actual catches are provided in Table 3.1.

Though management, model, and composite error are related concepts, they are considered and evaluated independently per Chapter 3 of the 2019 PST Agreement (Table 3.2). Zero or negative values for management and model error indicate that there were fewer fish caught than the modelled catch limits (pre- and post-season). Any errors that are positive indicate an "overage". For AABM fisheries in 2021, management error (the difference between actual catch and pre-season ACL, actual catch – pre-season ACL) was negative with catches in all three fisheries below the ACL. Percent differences of actual catch from the pre-season ACL ([actual catch – pre-season ACL]/pre-season ACL) were -2% in SEAK, -41% in NBC, and -14% in WCVI. The management error in NBC and WCVI was partially due to lower catches as a result of travel restrictions and decreased fishing effort of NBC AABM recreational fisheries due to the ongoing COVID-19 pandemic. Additionally, precautionary opening time restrictions were applied in WCVI and NBC fisheries to protect at-risk Fraser Chinook stocks and to provide increased availability of not-at-risk Chinook salmon for First Nations harvest opportunities.

Per paragraph 7(b), relative to post-season ACLs, "*overages are of particular concern*". Both model and composite error are used to monitor overages. Model error (the difference between actual catch and pre-season ACL, pre-season ACL – post-season ACL) ranged from 3,200 in WCVI to 64,842 in SEAK, with the post-season ACL lower in all three AABM fisheries. Percent differences of the pre-season ACL from the post-season ACL ([pre-season ACL – post-season ACL]/post-season ACL) were 46% in SEAK, 4% in NBC, and 4% in WCVI. Composite error (the difference between actual catch and post-season ACL, actual catch – post-season ACL) ranged from -56,213 in NBC to 61,759 in SEAK. Percent differences of actual catch from the post-season ACL ([actual catch – post-season ACL]/post-season ACL) were 44% in SEAK, -38% in NBC, and -11% in WCVI. In 2021, only the SEAK fishery experienced a composite error overage; the magnitude of this error is a function of the tiered catch limit management system that the SEAK AABM fishery operates under as defined in paragraph 6 and Table 2. The tiers are binned in 30,000–60,000 fish increments such that a mismatch between the pre-season and post-season ACL will necessarily result in a large model error. It is currently unknown whether COVID-related impacts on the collection of stock assessment data had an effect on model error.

Table 3.1.—Pre-season annual catch limits (ACLs) for 1999–2022, and post-season ACLs and actual catches for 1999–2021, for aggregate abundance-based management (AABM) fisheries: Southeast Alaska (SEAK), Northern British Columbia (NBC), and West Coast of Vancouver Island (WCVI). Post-season values for each year are from the first post-season calibration following the fishing year.

Year	SEAK (Troll, Net, Sport)			NBC (Troll, Sport)			WCVI (Troll, Sport)		
	Pre-season ACL	Post-season ACL	Actual Catch	Pre-season ACL	Post-season ACL	Actual Catch	Pre-season ACL	Post-season ACL	Actual Catch
1999	192,800	184,200	198,842	145,600	126,100	84,324	128,300	107,000	38,540
2000	189,900	178,500	186,493	130,000	123,500	32,048	115,500	86,200	88,617
2001	189,900	250,300	186,919	132,600	158,900	43,334	141,200	145,500	120,304
2002	356,500	371,900	357,133	192,700	237,800	149,831	203,200	196,800	157,920
2003	366,100	439,600	380,152	197,100	277,200	194,797	181,800	268,900	173,561
2004	383,500	418,300	417,019	243,600	267,000	241,508	192,500	209,600	215,252
2005	416,400	387,400	388,640	246,600	240,700	243,606	188,200	179,700	199,479
2006	346,800	354,500	360,094	223,200	200,000	215,985	160,400	145,500	145,511
2007	329,400	259,200	328,268	178,000	143,000	144,235	143,300	121,900	140,614
2008	170,000	152,900	172,905	124,800	120,900	95,647	162,600	136,900	145,726
2009	218,800	176,000	227,954	143,000	139,100	109,470	107,800	91,300	124,617
2010	221,800	215,800	230,611	152,100	160,400	136,613	143,700	142,300	139,047
2011	294,800	283,300	291,161	182,400	186,800	122,660	196,800	134,800	204,232
2012	266,800	205,100	242,821	173,600	149,500	120,307	133,300	113,800	135,210
2013	176,000	284,900	191,388	143,000	220,300	115,914	115,300	178,000	116,871
2014[1]	439,400	378,600	435,195	290,300	262,600	216,901	205,400	191,700	192,705
2015[1]	237,000	337,500	335,026	160,400	246,600	158,903	127,300	179,700	118,974
2016	355,600	288,200	350,939	248,000	183,900	190,181	133,300	104,800	103,093
2017	209,700	215,800	175,414	149,500	148,200	143,330	115,300	95,800	117,416
2018	144,500	118,700	127,776	131,300	115,700	108,976	88,300	88,300	85,330
2019[3]	140,323[2]	140,323	140,307	124,800	122,200	88,026	79,900	76,000	73,482
2020[4]	205,165[2]	140,323	204,624	133,000	141,700	36,183	87,000	78,500	43,581
2021	205,165[2]	140,323	202,082	153,800	147,200	90,987	88,000	84,800	75,776
2022	266,585[2]			142,800			100,700		

[1] Due to a disagreement over model calibration 1503, the Commission agreed to use output from Calibration (CLB) 1601 to estimate the catches associated with the 2014 and 2015 post-season abundance indices (Ais) and 2016 pre-season AIs.
[2] Per paragraph 6(b) of the 2019 Pacific Salmon Treaty (PST) Agreement, this number represents an ACL based on a catch per unit effort (CPUE) statistic.
[3] Post-season ACLs are based on AIs from CLB 2000–9806 (old model configuration).
[4] Pre-season ACLs are based on AIs from CLB 2002 (Phase II model configuration).

Table 3.2.—Summary of aggregate abundance-based management (AABM) fishery performance and deviations between pre- and post-season annual catch limits (ACLs) and actual catches for Southeast Alaska (SEAK), Northern British Columbia (NBC), and West Coast Vancouver Island (WCVI), 2019–2021.

Positive values indicate an overage and negative values indicate an underage. Colored cells indicate AABM fishery performance relative to Treaty obligations; cells shaded green indicate where a fishery met Treaty obligations and red cells indicate where a fishery exceeded Treaty obligations.

	Management Error Actual Catch – Pre ACL		Model Error Pre ACL – Post ACL		Composite Error Actual Catch – Post ACL	
Year	#	%	#	%	#	%
SEAK (Troll, Net, Sport)						
2019	-16	0%	0	0%	-16	0%
2020	-541	0%	64,842	46%	64,301	46%
2021	-3,083	-2%	64,842	46%	61,759	44%
NBC (Troll, Sport)						
2019	-36,774	-29%	2,600	2%	-34,174	-28%
2020	-96,817	-73%	-8,700	-6%	-105,597	-75%
2021	-62,813	-41%	6,600	4%	-56,213	-38%
WCVI (Troll, Sport)						
2019	-6,418	-8%	3,900	5%	-2,518	-3%
2020	-43,419	-50%	8,500	11%	-34,919	-44%
2021	-12,224	-14%	3,200	4%	-9,024	-11%

3.2.1 Southeast Alaska Aggregate Abundance-Based Management Fishery

Average management error was 1% for SEAK across the 1999–2018 time series and ranged between -16% and 41%. Average management error was 1% in the 1999–2008 time period and 2% across the 2009–2018 time period (Figure 3.2). The increase in the average management error in the 2009 PST Agreement period was driven by the large deviation in 2015 (41%). Model error ranged from -38% to 30% but averaged 3% to 5% for the time periods examined. Deviation of actual catch in SEAK from post-season ACLs (composite error) was largely driven by model error. SEAK management error was relatively small in all years except 2015 and was in the opposite direction of the model error in 7 of the 10 years between 2009–2018 (Figure 3.2). In 2021, management error was -2% and model error was 46% (Table 3.2).

Figure 3.2.— Performance of the Southeast Alaska aggregate abundance-based management (AABM) fishery from 1999–2021. The top panel compares pre- and post-season annual catch limits (ACLs) with the actual catch over time. Circles indicate actual catch while dashed lines indicate pre-season ACLs and solid lines indicate post-season ACLs. The bottom panel compares composite, management and model errors over time. The pink line indicates model error, the blue line indicates management error and the purple line indicates composite error.

3.2.2 Northern British Columbia Aggregate Abundance-Based Management Fishery

NBC actual catch was consistently below the pre-season ACL by an average of -22% from 1999–2018 (range -1% to -75%; Figure 3.3). The average NBC catch was -26% of the pre-season ACLs from 1999–2008 and -19% from 2009–2018. Negative management errors in NBC were the result of Canada's domestic efforts to protect at-risk Fraser River stream-type Chinook, to allow passage of Fraser River not-at-risk Chinook for First Nations food, social and ceremonial (FSC) purposes, and to limit exploitation of WCVI-origin Chinook. Management error in the NBC fishery was near zero from 2003 to 2006 and in 2015 and 2017; but catches were below the post-season ACL in all other years except 2005 to 2007 and 2016 (Figure 3.3). Management actions in NBC cancelled out any positive model errors in most years to an average of 0%

(1999–2018), which has widened in recent years to an average composite error of -47% (2019–2021) between the observed catch and the post-season ACL. In 2021, model error was 4% and conservative management actions combined with impacts from COVID-19 resulted in an actual catch 41% (management error) and 38% (composite error) below the pre- and post-season ACLs, respectively (Table 3.2).

Figure 3.3.— Performance of the Northern British Columbia aggregate abundance-based management (AABM) fishery from 1999–2021. The top panel compares pre- and post-season annual catch limits (ACLs) with the actual catch over time. Circles indicate actual catch while dashed lines indicate pre-season ACLs and solid lines indicate post-season ACLs. The bottom panel compares composite, management and model errors over time. The pink line indicates model error, the blue line indicates management error and the purple line indicates composite error.

3.2.3 West Coast Vancouver Island Aggregate Abundance-Based Management Fishery

Average management error in WCVI was -8% from 1999 to 2018 with more negative values in the beginning of the time series resulting in averages of -14% from 1999–2008 and -2% from 2009–2018 (Figure 3.4). The deviations of actual catch from the post-season ACL in WCVI (composite error) ranged from -64% to 52% across the 1999–2018 time period. Although management error in WCVI played a larger role than model errors in the deviation from the post-season ACL, model errors made up the largest component of the deviations. In 5 of 10 years during the 2009–2018 time series, the WCVI management and model errors occurred in a common direction. In 2010, 2014, 2018, and 2019 both model and management errors were small (Figure 3.4; Table 3.2). In 2021, management error was -14% and model error was 4%.
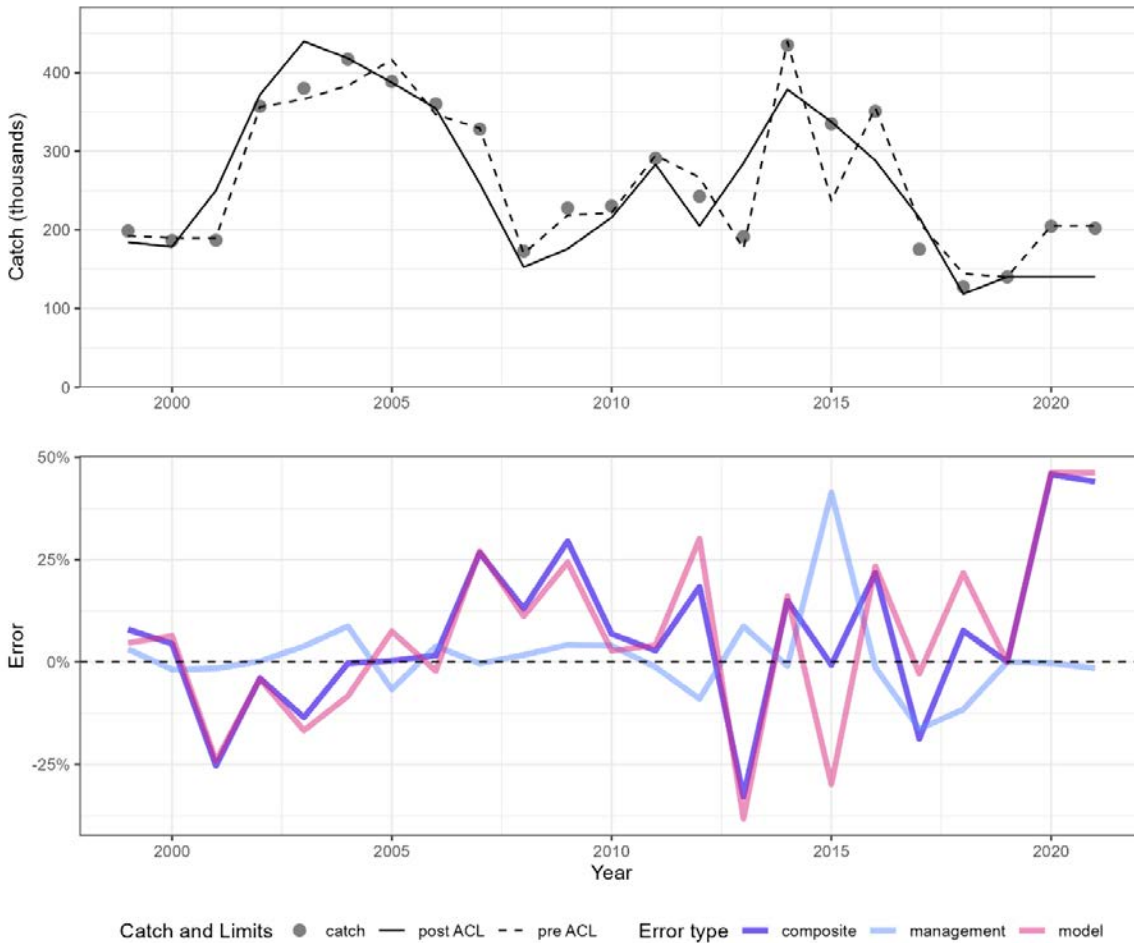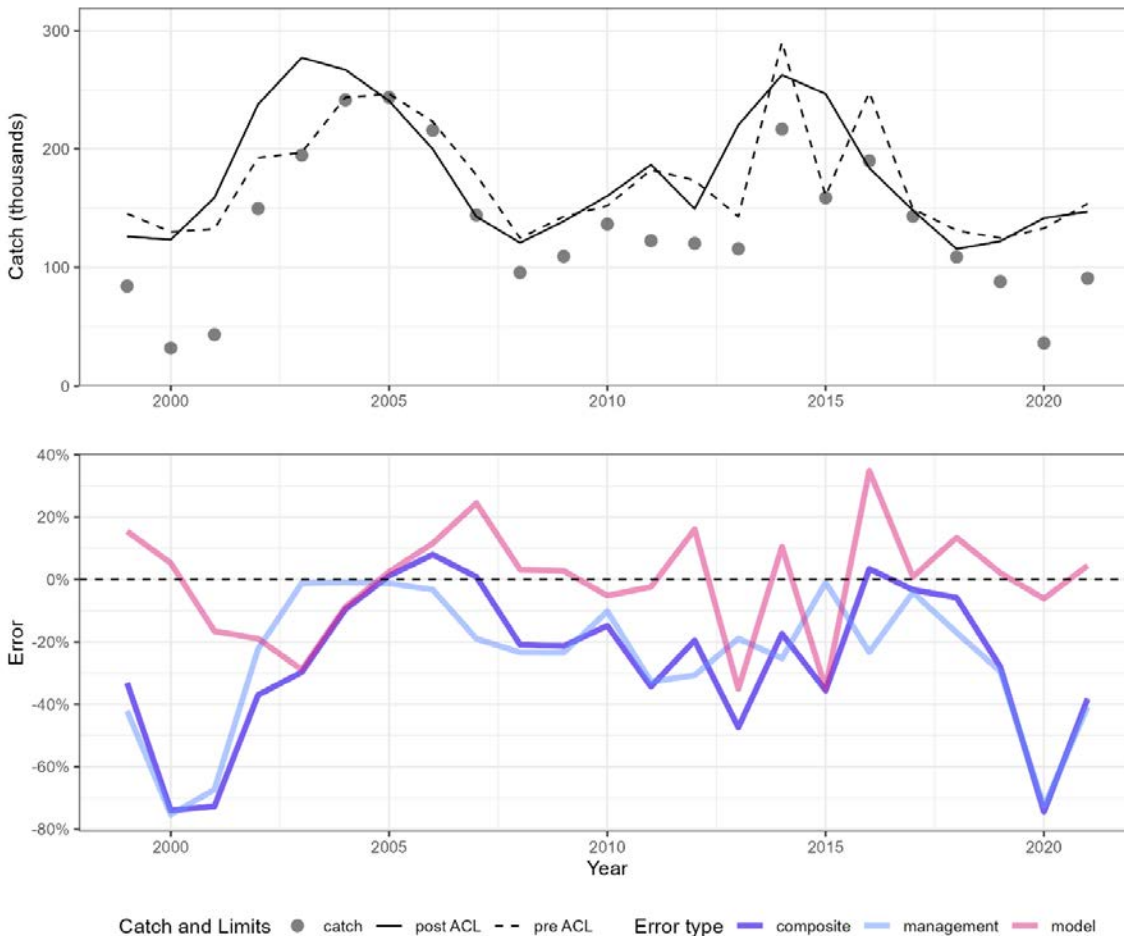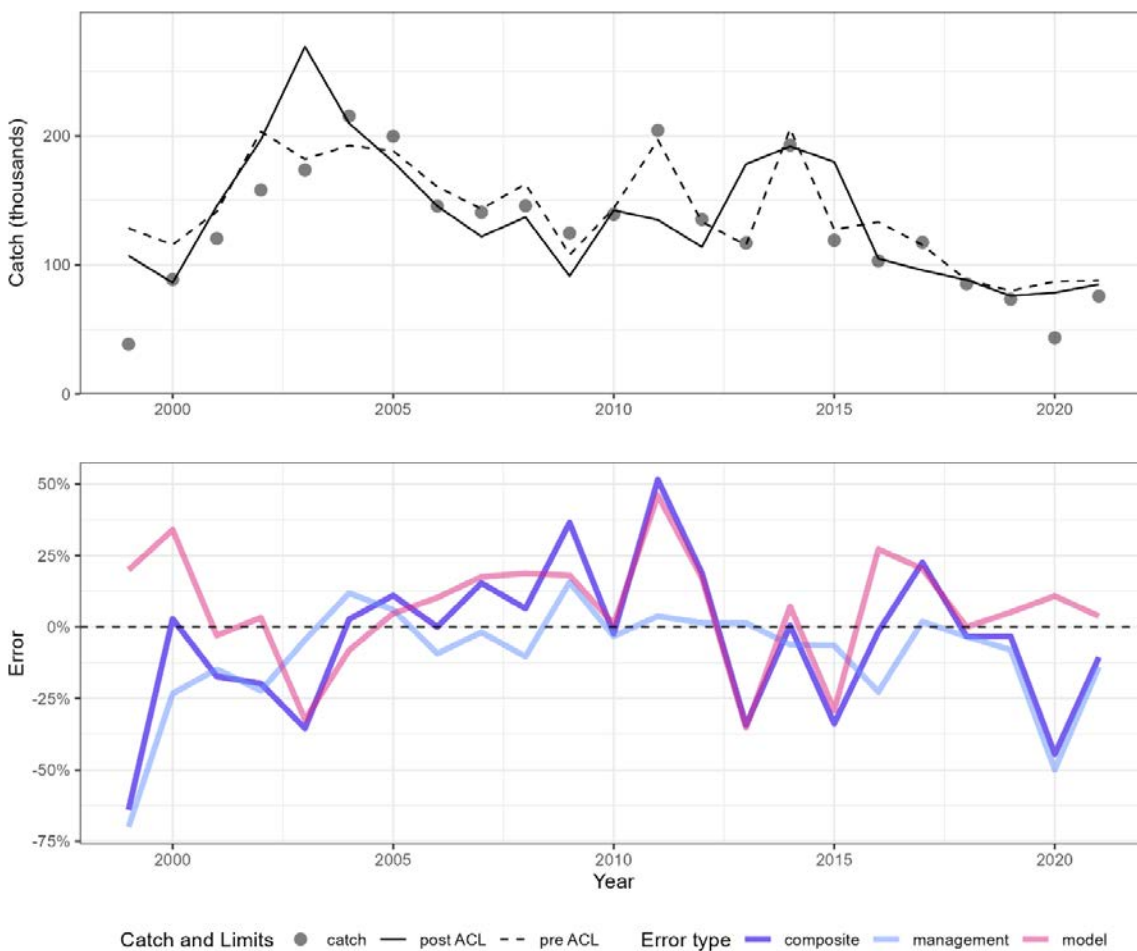

Figure 3.4.— Performance of the West Coast Vancouver Island aggregate abundance-based management (AABM) fishery from 1999–2021. The top panel compares pre- and post-season annual catch limits (ACLs) with the actual catch over time. Circles indicate actual catch while dashed lines indicate pre-season ACLs and solid lines indicate post-season ACLs. The bottom panel compares composite, management and model errors over time. The pink line indicates

model error, the blue line indicates management error and the purple line indicates composite error.

3.3 PERFORMANCE EVALUATION

Paragraph 7 of the 2019 PST Agreement defines the accountability provisions for AABM and ISBM fisheries. It describes a set of rules for evaluating fishery performance, stock status, models, management tools, and the effectiveness of the harvest reduction measures taken under the 2019 PST Agreement (Figure 3.1). It also contains conditional tasks in the event of overages. For AABM fisheries, paragraph 7 requires the CTC to conduct specific evaluations of pre-season and post-season deviations, make recommendations for reducing overages meeting specific criteria, and conduct up to two reviews of the CPUE approach to setting pre-season ACLs for the SEAK fishery.

Subparagraph 7(a)(i) requires the CTC to provide the Commission with "*the AABM fisheries pre-season limits, observed catches, and identify the extent of any exceedance (overage) of those limits for the prior fishing season (management error)*". In 2021, none of the three AABM fisheries had catches that exceeded pre-season ACLs. Management error data are provided in section 3.2 of this report.

Subparagraph 7(a)(ii) requires the CTC to provide the Commission with "*the AABM fisheries post-season limits for fisheries that occurred two years prior and any exceedance (overage) between the annual pre- and post-season limits from two years prior (model error)*". For 2020 and 2021, the pre-season limit exceeded the post-season limit in five of six cases, with SEAK having the largest of the exceedances in both 2020 and 2021 (46%; Table 3.3), the magnitude of which is largely a function of the tiered approach in Table 2 of Chapter 3 of the 2019 PST Agreement. Model error is described in detail in section 4.3 of this report.

Table 3.3.—Model error (calculated as (pre-season annual catch limit [ACL] – post-season ACL) / post-season ACL) for the past two years for aggregate abundance-based management (AABM) fisheries: Southeast Alaska (SEAK), Northern British Columbia (NBC), and West Coast Vancouver Island (WCVI).

Fishery	2020	2021
SEAK	46%	46%
NBC	-6%	4%
WCVI	11%	4%

Paragraph 7(b) defines "*AABM post-season fishery limits by using the first post-season Commission Chinook Model estimate*" and, when compared with actual catches, expresses that overages are of concern. It directs the CTC to provide an analysis of deviations from post-season limits. "*If, in two consecutive years, the NBC or WCVI 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 management agency action is requested by the Commission and the CTC is required to recommend a plan to the Commission 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%." In order to not exceed the post-season limits by more than 10% for NBC and WCVI AABM fisheries, the observed catch cannot be greater than 110% of the post-season ACL.

For the SEAK AABM fishery in 2020 and in 2021, both the pre-season ACL and the observed catch exceeded the post-season ACL. Thus, in the SEAK AABM fishery there have now been two consecutive years where the preseason ACL and the observed catch exceeded the post-season ACL (Table 3.3, Table 3.4). Per the provisions of the 2019 PST Agreement this requires further action, as identified in subparagraphs 7(b)(i) and 7(b)(ii).

For the NBC AABM fishery, the observed catch was 25% and 62% of the post-season ACL in 2020 and 2021, respectively. Since neither of these is greater than 110% this does not require any further action regarding the NBC AABM fishery per subparagraphs 7(b)(i) and 7(b)(ii).

For the WCVI AABM fishery, the observed catch was 56% and 89% of the post-season ACL in 2020 and 2021, respectively. Since neither of these is greater than 110%, this does not require any further action regarding the WCVI AABM fishery per subparagraphs 7(b)(i) and 7(b)(ii).

Table 3.4.—Composite error (calculated as (actual catch – post-season ACL) / post-season ACL) for the past two years for aggregate abundance-based management (AABM) fisheries: Southeast Alaska (SEAK), Northern British Columbia (NBC), and West Coast Vancouver Island (WCVI).

Fishery	2020	2021
SEAK	46%	44%
NBC	-75%	-38%
WCVI	-44%	-11%

4. PSC CHINOOK MODEL VALIDATION AND IMPROVEMENT

The reliability of model outputs, including abundance index predictions, are dependent on a number of factors including model parameters (e.g., base period exploitation rates), model structure (e.g., spatio-temporal fishery strata), and annual CWT, catch, and run-size inputs (forecast or post-season estimates) used for calibration. In the following sections, annual comparisons of model-based fishery indices (FI) versus CWT-based FIs, pre-season (forecast) versus post-season run size estimates, and pre-season versus post-season calibration AIs are presented.

4.1 EVALUATION OF FISHERY INDICES

FIs based on the PSC Chinook Model for all model stocks can be compared to FIs based on the estimates of landed catch or total mortality of CWT exploitation rate indicator stocks (Appendix G). Model- and CWT-based FIs use the same equation (see Appendix G); however, CWT estimates are more empirical. Model-based indices assume that the yearly pattern of exploitation in a fishery remains static compared to the base period (1979–1982) both temporally and spatially (with the exception of any yearly modifications achieved through stock and age-specific exploitation rate scalers) and that most of the change in exploitation can be

attributed to stock abundances and the magnitude of the catch.

CWT-based FIs can be constructed as a ratio of means (ROM) or as a stratified proportional fishery index (SPFI; CTC 2009). Results from the Harvest Rate Index Analysis (CTC 2009) indicated that the SPFI was unbiased and the most accurate estimator for most fishery, time, and area combinations. Therefore, a recommendation was made to use the SPFI estimator as the FI, not only for the SEAK troll fishery but also for the other two AABM troll fisheries. However, the CTC recently determined that the single time strata of data available for the NBC troll SPFI and a number of missing year-area data values for the WCVI troll SPFI made implementation of stratified FIs for these two AABM fisheries problematic. Therefore, in 2019, the CTC decided that ROMs were more appropriate FIs for the WCVI and NBC troll fisheries (CTC *in prep*.). Comparisons between the SPFI (SEAK) or the CWT-based ROM FIs (NBC and WCVI), and the model-based FIs are provided in this section.

4.1.1 Southeast Alaska Troll Fishery Exploitation Rate Indices

The SEAK Troll FI based on PSC Chinook Model estimates closely follows the trend of the CWT-based SPFI from 1979 through 1989 whether calculated using landed catch or total mortality (Figure 4.1 and Figure 4.2). Between 1990 and 2000, the model-based estimates using either the landed catch or total mortality FIs were lower than the CWT-based estimates for most years. However, since 2001, the model estimates have typically been higher. Since 1990, the model-based estimates show less year-to-year variability than the CWT-based indices. The CWT-based estimate was at a historic low in 2019 for both total mortality and landed catch. The model-based estimates were also low, though not outside the historic range of estimates.

Figure 4.1.—Estimated coded-wire tag (CWT)-based stratified proportional fishery index (SPFI) and Pacific Salmon Commission Chinook Model-based fishery indices for landed catch in the Southeast Alaska (SEAK) troll fishery through 2020.

Figure 4.2.—Estimated coded-wire tag (CWT)-based stratified proportional fishery index (SPFI) and Pacific Salmon Commission Chinook Model-based fishery indices for total mortality in the Southeast Alaska (SEAK) troll fishery through 2020.

4.1.2 Northern British Columbia Troll Fishery Indices

The model-based FIs for NBC troll fishery generally follow the same trend as the CWT-based ROM FIs (Figure 4.3 and Figure 4.4). In 2018, the CWT-based FI was much higher than the model-based FI for both landed catch and total mortality. In 2019 and 2020, the differences between both indices were smaller, though the CWT-based FI was still slightly higher in both years.
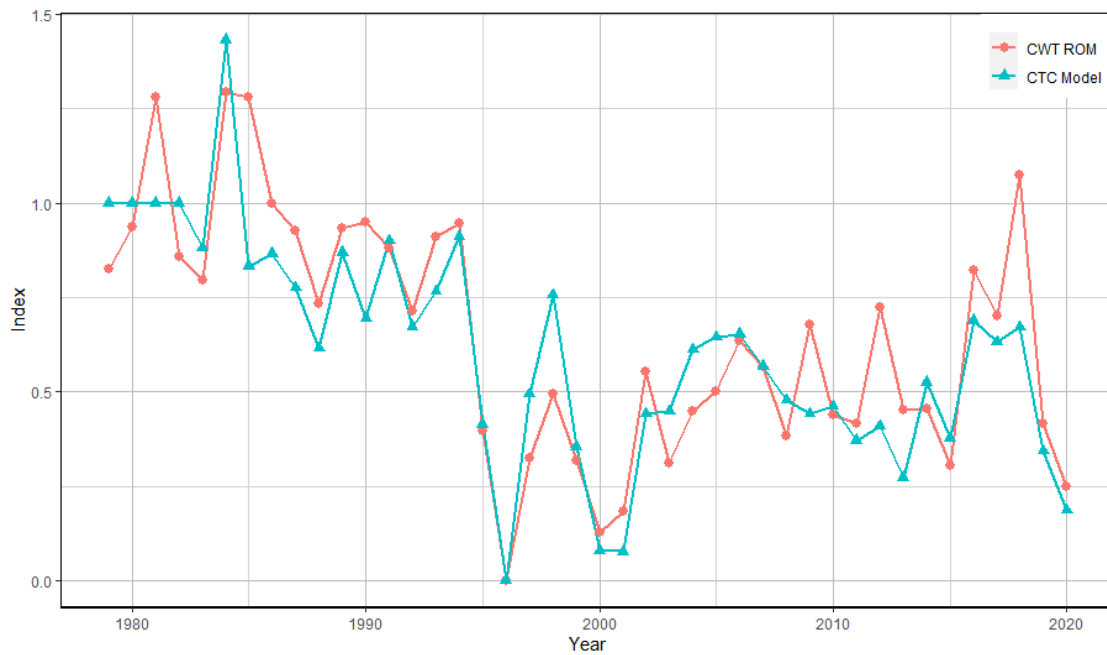
Figure 4.3.—Estimated coded-wire tag (CWT) ratio of means (ROM) and Pacific Salmon Commission Chinook Model fishery indices for landed catch in the Northern B.C. (NBC) troll fishery through 2020.
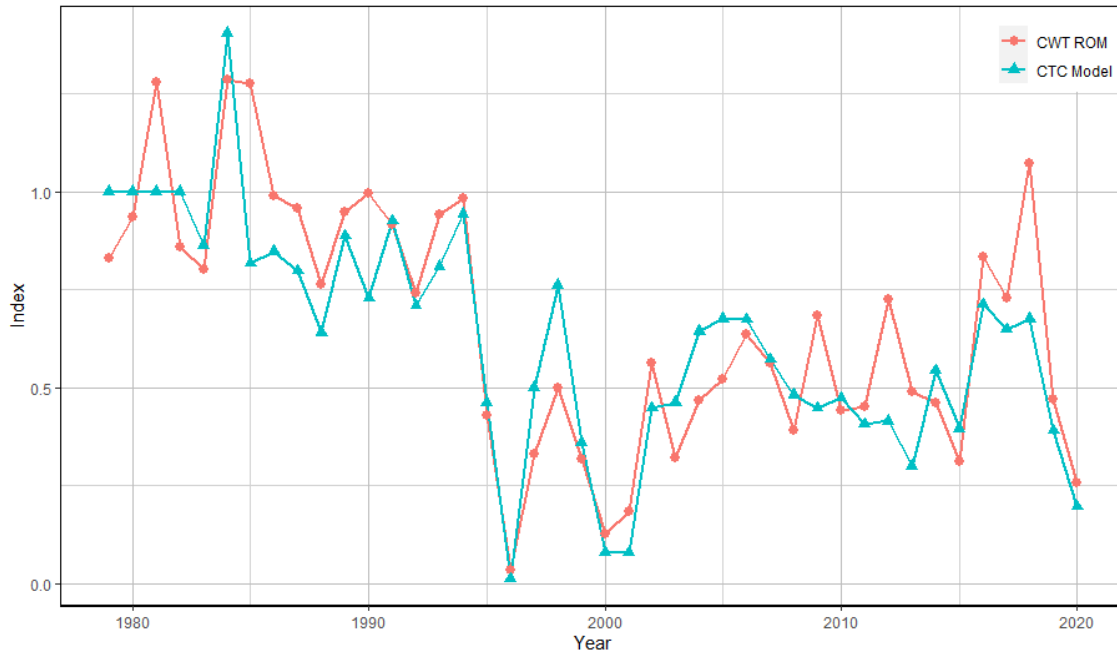
Figure 4.4.—Estimated coded-wire tag (CWT) ratio of means (ROM) and Pacific Salmon Commission Chinook Model fishery indices for total mortality in the Northern British Columbia (NBC) troll fishery through 2020.

4.1.3 West Coast Vancouver Island Troll Fishery Indices

For the WCVI troll fishery, correspondence between the model-based FI and the CWT-based ROM FI was very close from the start of the time series (1979) to the mid-1990s for both landed catch (Figure 4.5) and total mortality (Figure 4.6). Starting around 2000, model-based and CWT-based ROM FIs diverged noticeably, with the CWT-based FIs consistently exceeding the model-based FIs. This divergence is attributed to changes in the spatial and temporal conduct of the fishery (e.g., cessation of fishing in the summer period) to reduce impacts on B.C. stocks of conservation concern (e.g., Fraser River early return-timing stocks. The CWT-based FI has corresponded more closely with the model-based FI since 2009 (Figure 4.5 and Figure 4.6).
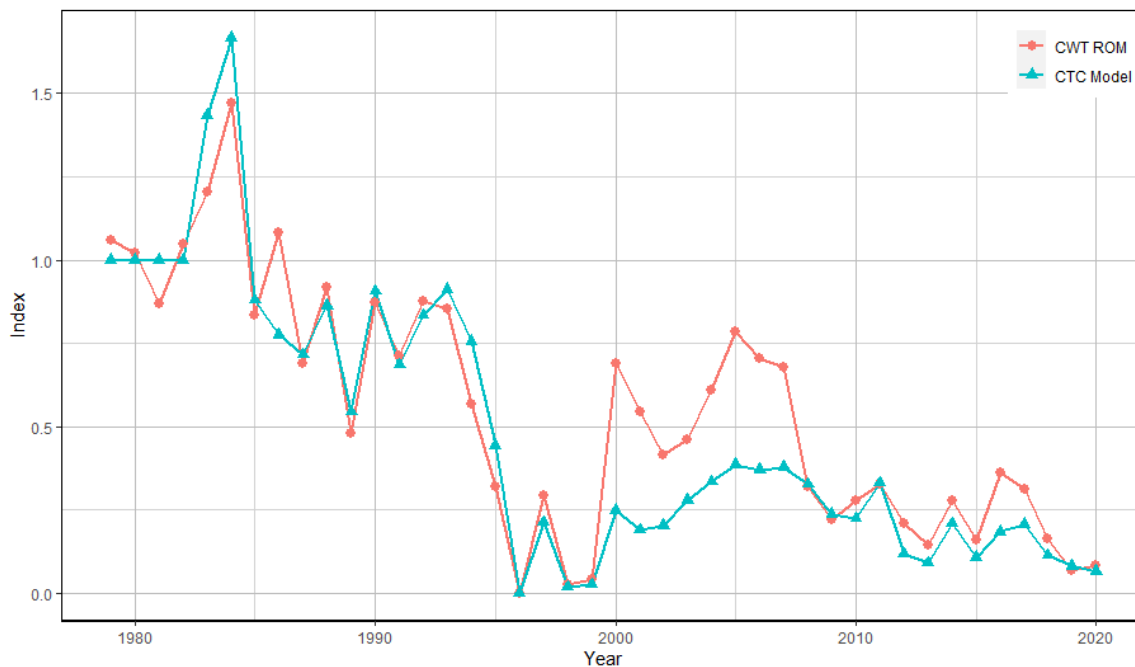
Figure 4.5.—Estimated coded-wire tag (CWT)-based ratio of means (ROM) fishery indices (FI) and model-based FI for landed catch in the West Coast Vancouver Island (WCVI) Troll fishery through 2020.
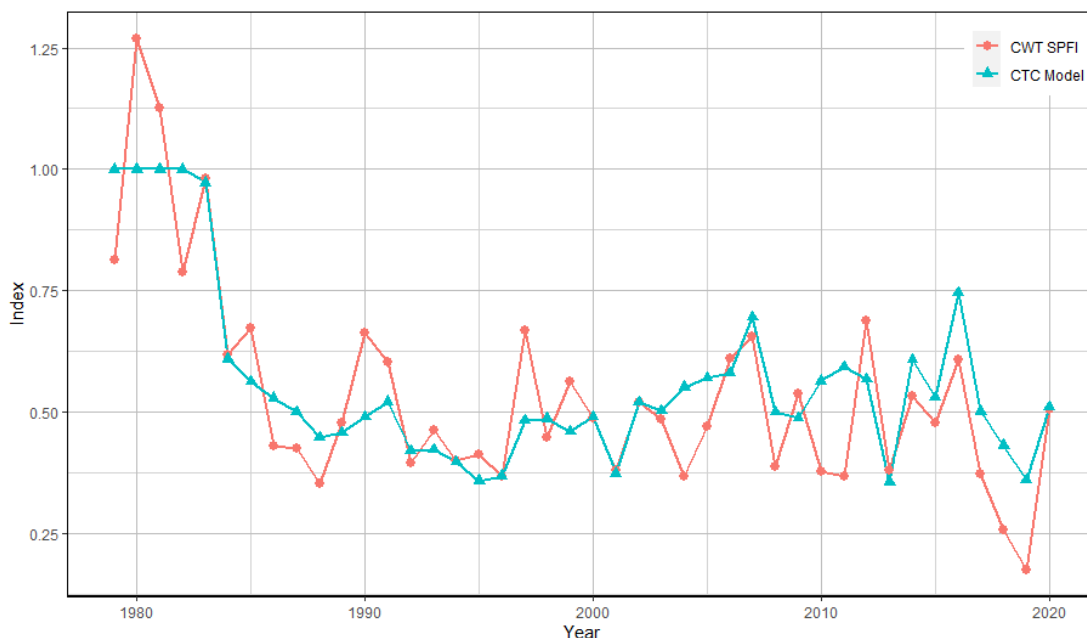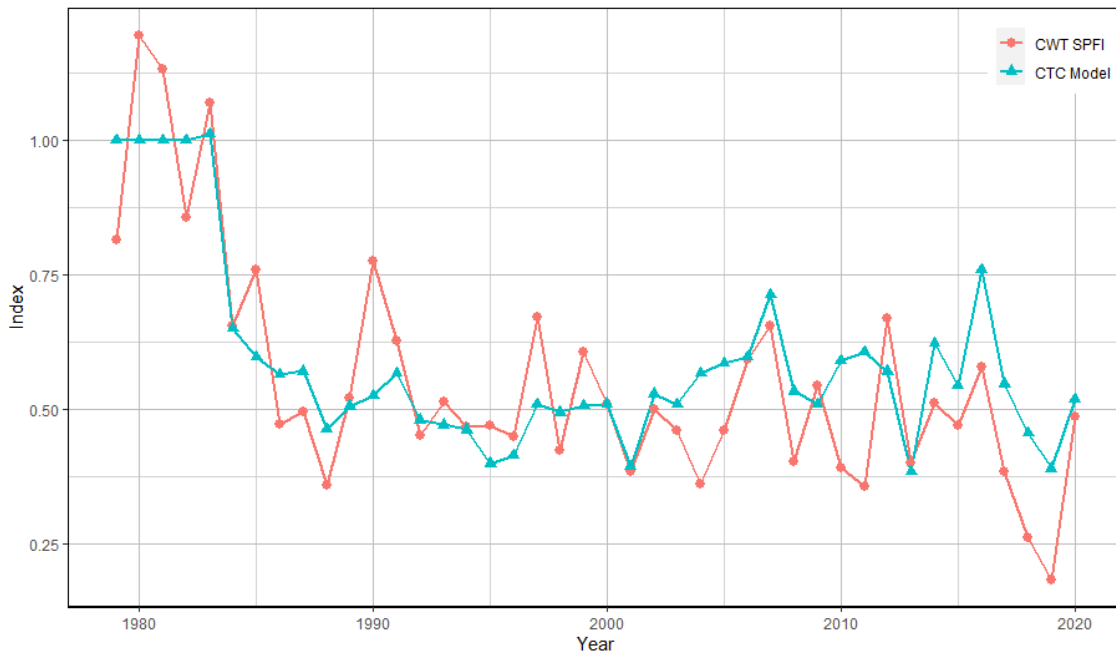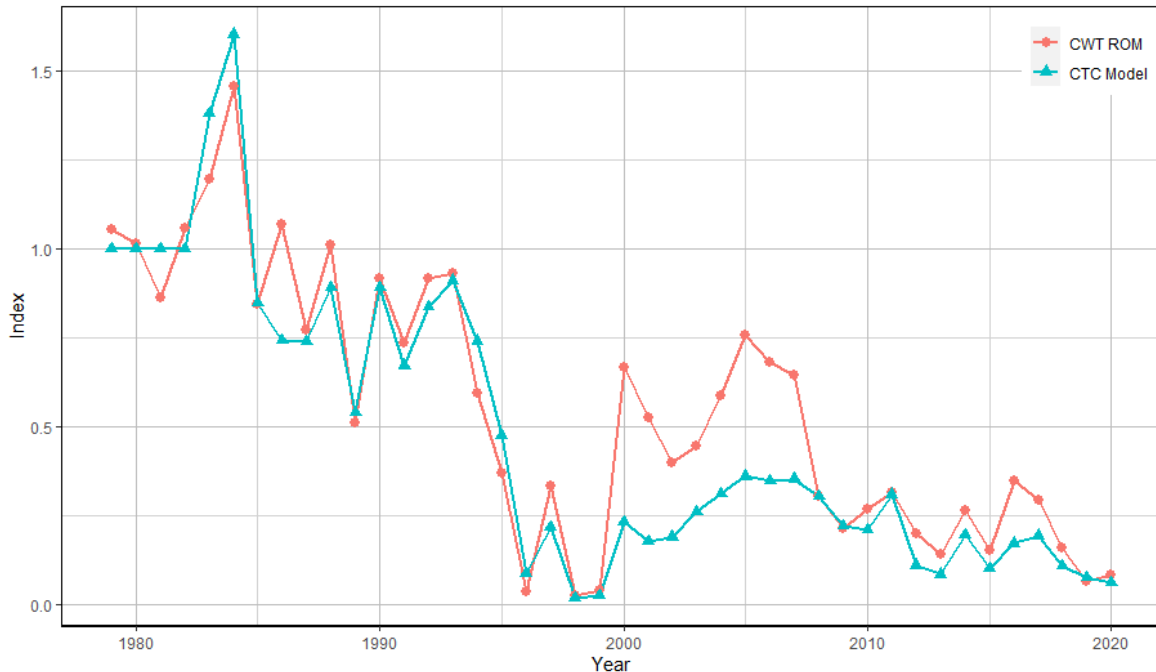
Figure 4.6.—Estimated coded-wire tag (CWT)-based ratio of means (ROM) fishery indices (FI) and Pacific Salmon Commission Chinook Model FI for total mortality in the West Coast Vancouver Island (WCVI) troll fishery through 2020.

4.1.4 Comparison of Fishery Indices

In Figure 4.1 and Figure 4.2 the model-based fishery indices generally track the CWT-based SPFI indices. However, there is a period of years from 2004 to 2011 where the model-based indices are mostly higher than the SPFIs. In Figure 4.3 and Figure 4.4 the model-based fishery indices generally track the CWT-based ROM indices, although from 2003 to 2008 the model-based indices are mostly higher than the ROMs. In Figure 4.5 and Figure 4.6 the model-based fishery indices generally track the CWT-based ROM indices, particularly in 2009 and 2019 where the CWT ROM and PSC Chinook Model were in agreement, with the exception of the years that roughly corresponds to the 1999 PST Agreement (PST 2000). During these years the WCVI CWT ROM indices are consistently higher that the model indices. This would seem to indicate that the temporal and/or spatial pattern of exploitation in the WCVI Troll fishery had changed compared to the base period which resulted in the discrepancies between the CWT ROM indices and the model-based indices. This is corroborated by an examination of the temporal distribution of catch in WCVI Troll which shows that the majority of the catch in years prior to 1998 occurred during the July to September time frame, whereas during 1998 and the years of the 1999 PST Agreement the catch shifted to other months of the year.

4.2 EVALUATION OF STOCK FORECASTS USED IN THE PSC CHINOOK MODEL

The ability of the PSC Chinook Model to accurately predict Chinook salmon ocean abundance in AABM fisheries depends on the ability of the model to predict the returns of Chinook salmon (in terms of ocean escapement or spawning escapement) in the forecast year. For each year's

model calibration, all available agency-produced forecasts for model stocks are inputs to the model. Thus, for model stocks with agency-produced forecasts, the variation between model forecasts and actual returns can be broken into two parts: the ability of the model to fit the agency-produced forecasts used as inputs, and the ability of the agency-produced forecasts to accurately predict the actual return of Chinook salmon in the upcoming year.

A summary of model-produced and agency-produced forecasts for 2020–present, including actual returns through 2021, is shown in Appendix F. For information regarding the relationship between the model indicator stocks, exploitation rate indicator stocks, and PST Attachment I stocks, see Appendix A. Note that with the transition to the Phase II PSC Chinook Model base period that occurred in 2020, the stock structure and number of stocks represented in the model have changed. Accordingly, the forecast and post-season return estimates included in Appendix F are now based on the Phase II model stock structure and begin in 2020. For information on forecasts and post-season returns prior to 2020, see Appendix G1 in CTC 2021a.

Overall, since transitioning to the Phase II model in 2020, the model forecasts have been similar to the agency-produced forecasts. This result is strongly influenced by the incorporation of the agency-produced forecasts into the model calibration procedure. The mean percent error (MPE) and mean absolute percent error (MAPE) for model forecasts relative to agency-produced forecasts were -0.3% and 12.3%, respectively, meaning that, on average, they were quite precise, and the model forecasts were close to but slightly lower than the agency-produced forecasts. For 2020–2021 (the only years with both forecasts and actual returns since transitioning to the Phase II model), the agency-produced forecasts were, on average, biased slightly low but fairly precise compared to the actual returns, with MPE of -3.8% and MAPE of 27.7%. Similarly, the MPE and MAPE for model forecasts relative to actual returns were -1.6% and 30.5%, respectively.

In the 2022 calibration of the PSC Chinook Model (CLB 2203) the post-season aggregate abundance for 2021 was slightly lower than the forecast (CLB 2104) for all three AABM fisheries. For SEAK, NBC, and WCVI the AIs decreased from pre-season estimates of 1.28, 1.27, and 0.76 to post-season estimates of 1.23, 1.21, and 0.73, respectively. This result can be largely attributed to the fact that for some of the larger stocks that contribute to these AABM fisheries, particularly those from the Columbia River and Oregon Coast, the agency-produced forecasts used as inputs to the calibration procedure were greater than the actual return (Figure 4.7, Figure 4.8, Appendix F). The overall effect of these over-forecasts, however, was somewhat offset by the under-forecasting that occurred for some of the other driver stocks (e.g., WVH, FSO). Figure 4.7 displays forecast error by stock arranged from north to south and allows for identification of regional trends in forecast performance. Figure 4.8 compares the agency-produced forecast with the actual return for each stock, ordered by the magnitude of the absolute difference. Agency-produced forecasts were supplied and used in the model calibration for all stocks with the exception of the five SEAK and transboundary (TBR) stocks, which used the forecast generated by the PSC Chinook Model (Figure 4.7).
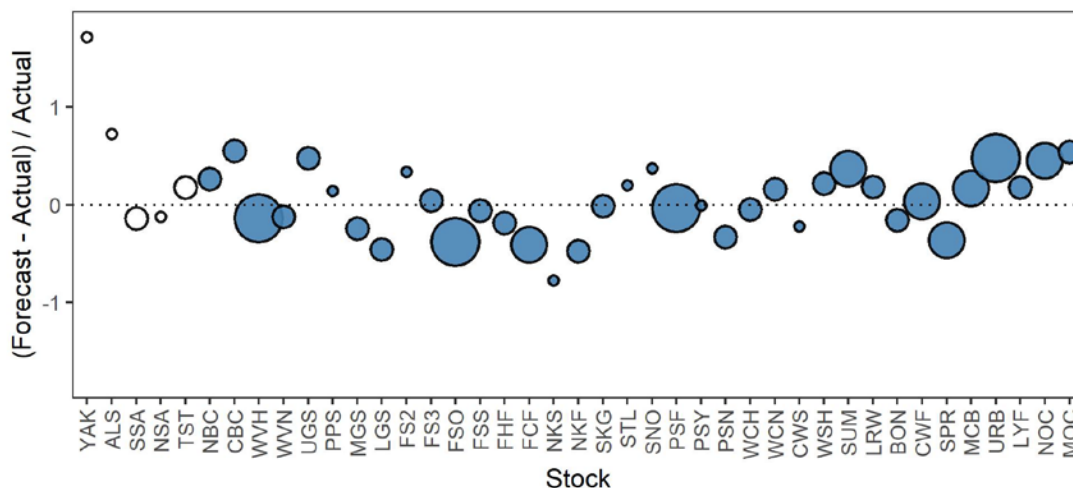
Figure 4.7.—2021 forecast error relative to the actual return for stocks represented in the Pacific Salmon Commission (PSC) Chinook Model.

Note: Points lying above the dashed horizontal line returned lower than forecast; points lying below the dashed horizontal line returned greater than forecast. Filled (blue) circles correspond to stocks with agency-produced forecasts; unfilled (white) circles correspond to stocks with forecasts generated by the PSC Chinook Model. The four symbol sizes correspond to categories of increasing relative stock size (based on average terminal run size: <10,000, 10,000–50,000, 50,000–100,000, and >100,000). Stocks are arranged along the x-axis from north to south and are defined according to the model stock acronyms in Appendix A.
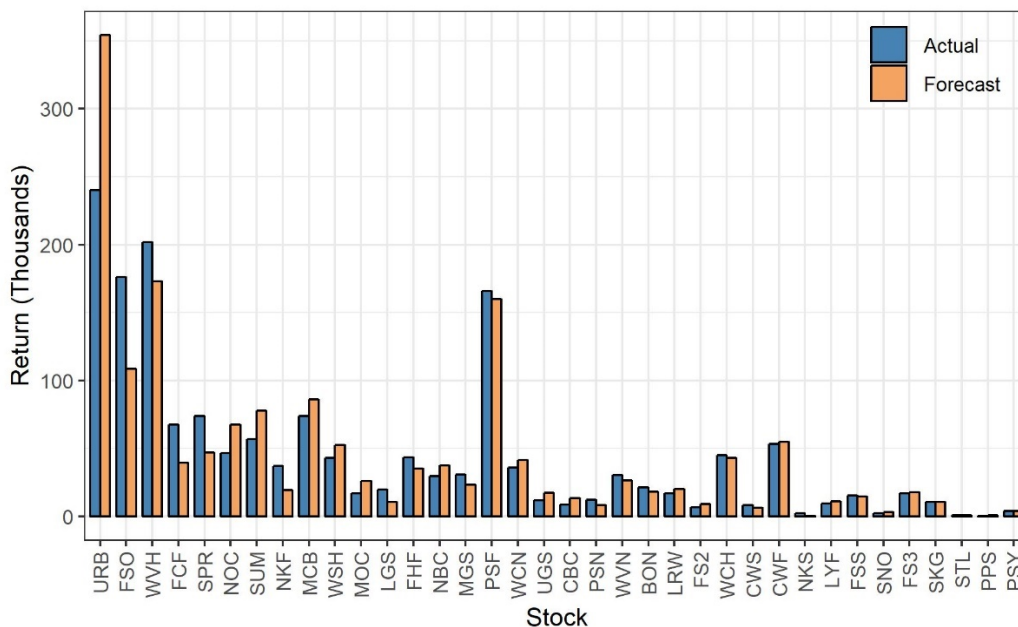
Figure 4.8.—Comparison of agency-produced forecasts to actual returns for Pacific Salmon Commission (PSC) Chinook Model stocks where an agency-produced forecast was supplied, 2021.

Note: Stocks are arranged from left to right along the x-axis based on the absolute value of the

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difference between the forecast and the actual return according to the model stock acronyms in Appendix A.

4.3 MODEL ERROR

For the purposes of this section of the report, model error will refer to the difference between model-generated pre-season AIs for each of the three AABM fisheries and the respective first post-season AIs produced in the following year's model calibration. The yearly percent deviations between pre-season and post-season AIs for the three AABM fisheries are illustrated in Figure 4.9. For each AABM fishery, the deviations between the pre-season and post-season AIs have varied considerably since 1999. The changes in AIs between pre- and post-season calibrations from 2012 to 2016 were among the largest observed (Figure 4.8) and resulted in large discrepancies (greater than 20% difference) between pre-season and post-season ACLs across the three AABM fisheries (Table 3.1). Model errors of this magnitude underscore the importance of routine model validation, as well as occasional targeted investigations and ongoing longer-term efforts to improve the PSC Chinook Model. Large deviations can compromise the utility of pre-season AIs for setting objectives for each of the fisheries, which provisions in the 2019 PST Agreement were intended to address. In 2021, model errors were relatively small across all three AABM fisheries.

The management framework for the three AABM fisheries relate fishery-specific catch and fishery indices to AIs using a proportionality constant that varies annually in reality but, as an input to the PSC Chinook Model, is assumed to be a static value. For the previous configuration of the model (referred to as 9806), the proportionality constant was based on the 1979–1997 average. Beginning in 2020, with the implementation of the Phase II configuration of the model, the proportionality constant is based on the 1999–2015 average. Uncertainty in the proportionality constant is not explicitly considered within the current AABM fishery regime; it is assumed to be stable in the long term.
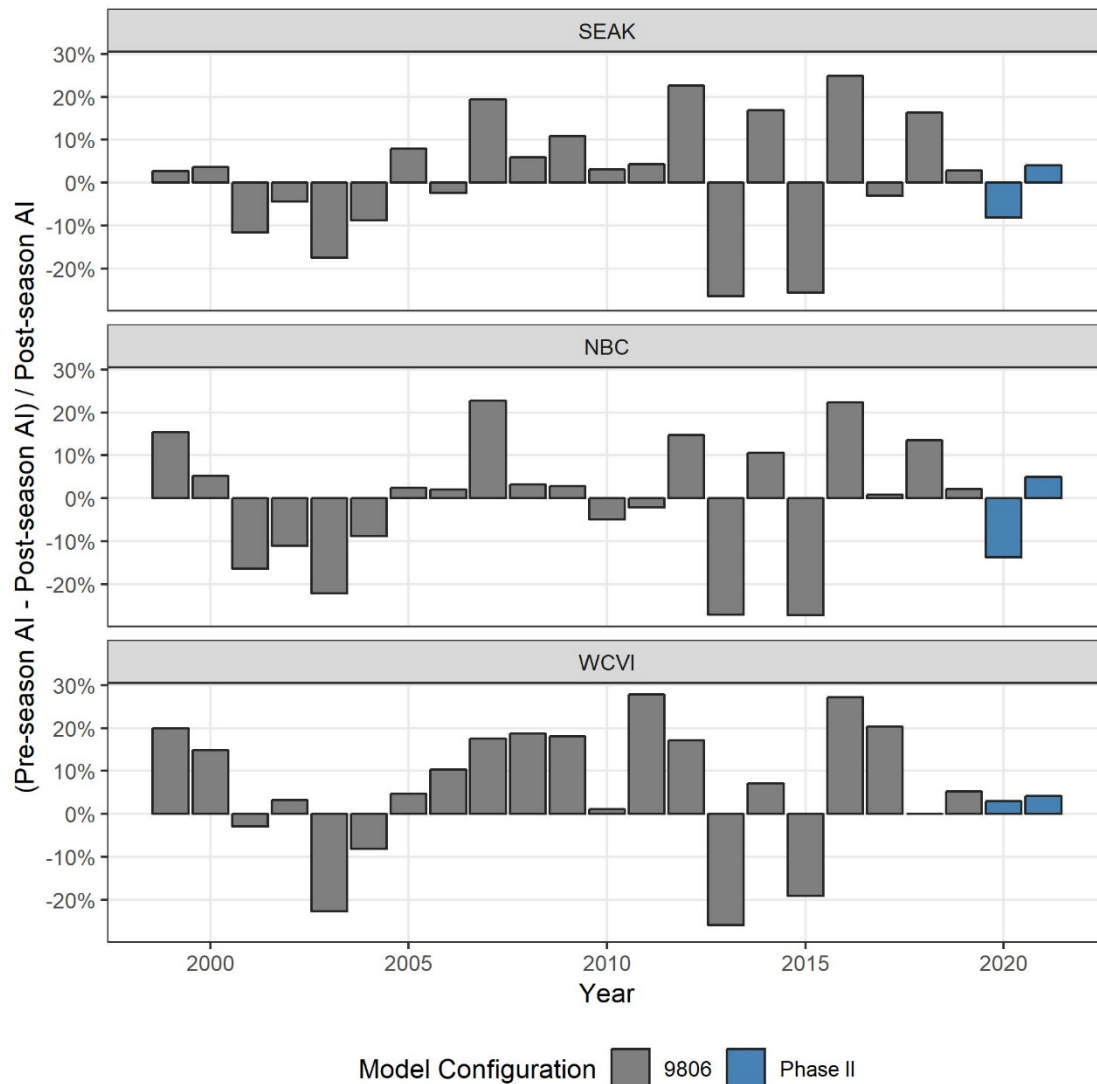
Figure 4.9.—Deviation between pre- and post-season abundance indices (AIs) for the three aggregate abundance-based management (AABM) fisheries, 1999–2021.

Note: Due to a disagreement over model calibration 1503, the Commission agreed to use CLB 1601 to estimate the 2014 and 2015 post-season AIs and 2016 pre-season AI.

Note: With the implementation of the Phase II model configuration beginning with the 2020 pre-season, the 2019 post-season AIs are based on CLB 2000-9806, which was conducted using the 9806 model configuration. The 2020 pre-season AIs in this figure are from CLB 2003, which is a corrected version of CLB 2002, the 2020 model calibration that was used for pre-season planning.

Note: Beginning in 2019, the SEAK AABM fishery transitioned to a CPUE index for management in place of the pre-season AI.

4.4 MODEL IMPROVEMENT ACTIVITIES

4.4.1 ForecastR

ForecastR relies on the open-source statistical software R (R Core Team 2020) to generate age-specific (or total abundance) forecasts of salmon escapement or terminal run using a variety of generic models and enabling users to perform interactive tasks with the help of a Graphical User Interface developed as a Shiny app. These tasks include: (a) the selection of forecasting approaches from a wide set of statistical and/or mechanistic models for forecasting terminal run and escapement; (b) the selection of several measures of retrospective forecast performance (e.g., mean relative error [MRE], mean absolute error [MAE], mean absolute percent error [MAPE], mean absolute scaled error [MASE], root mean squared error [RMSE]); (c) the comparison of forecasting models and model selection and ranking; and, (d) the reporting of forecasting results (point forecasts and interval forecasts) and diagnostics by producing detailed or summary reports.

The original design of ForecastR involved the generation of age-specific or total-abundance forecasts using several forecasting approaches, including: (i) simple and complex sibling regressions with the ability to include environmental/biological covariates; (ii) time series models such as auto regressive integrated moving average (ARIMA), exponential smoothing, and naïve models (based on preceding 1 year, 3 years or 5 years in abundance time series); and (iii) mechanistic models such as average return rate models that depend on auxiliary data such as the number of outmigrant juveniles, the number of hatchery fish released or the number of spawners in previous years. For both age-structured and non-age-structured data, Akaike Information Criterion (AIC)-based model selection takes place within model types (e.g., ARIMA and exponential smoothing) prior to model ranking across model types based on the abovementioned metrics of retrospective evaluation.

After five developmental phases, the latest release has successfully implemented all of the originally envisioned capabilities for this tool. Additional information about the project can be found in the GitHub site: https://github.com/SalmonForecastR. The latest release incorporated improvements and refinements to the Shiny app and incorporated Kalman-Filter sibling regressions, complex-sibling-regressions allowing the incorporation of environmental or biological variables, and the return-rate mechanistic module.

Utilizing an html-based Shiny application allows online forecasting exercises without users having ForecastR installed in their computers. The App can be accessed through two different servers: (https://psc1.shinyapps.io/ForecastR/ or https://solv-code.shinyapps.io/forecastr/). ForecastR has been used to produce agency forecasts for Canada and Oregon model stocks since 2016.

Development of database of candidate environmental covariates

Since ForecastR has gained the capability to include up to three environmental covariates, the AWG developed a database of candidate environmental covariates to be used in forecast modelling. The consideration for including a covariate in the database was the availability of a

yearly timeseries with geographic, temporal and biological relevance to the stocks of interest. The sources of data include data repositories run by the National Oceanic and Atmospheric Administration (NOAA), Fisheries and Oceans Canada (DFO), and the Canadian Integrated Ocean Observing System (CIOOS). The data have been then matched to a given stock based on proximity to sampling station. Thus far, the AWG has collected and explored the application of oceanic-atmospheric indices (e.g., Pacific Decadal Oscillation), temperature, salinity, zooplankton biomass and other biotic and abiotic indices. Additional environmental covariates are under development (e.g., NOAA Fisheries, Peterson et al. 2013, Warkentin et al. 2022) and could inform future forecast model improvements.

The environmental covariates can then be matched to average escapement or terminal run with a 0, 1 or 2-year time lag or lead from brood year or return year. For example, a 1-year time lag from brood year could represent oceanic conditions during the first year at sea, well-recognized as an important phase for survival (MacFarlane 2010). Up to three covariates can be utilized in ForecastR and used in the 'SigRegComplex' model. ForecastR evaluates the fit of each of the three environmental covariates and picks the model with the best fit for each age class. This model can then be compared against other models (e.g., Naïve, ARIMA) to determine if inclusion of covariates results in the improvement of model performance.

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LIST OF APPENDICES

APPENDIX A: RELATIONSHIP BETWEEN EXPLOITATION RATE INDICATOR STOCKS, ESCAPEMENT INDICATOR STOCKS, AND MODEL STOCKS IN THE PACIFIC SALMON TREATY

LIST OF APPENDIX A TABLES

Appendix A1– Indicator stocks for Transboundary (TBR) Rivers and Southeast Alaska (SEAK).

Region	Run	Attachment I stock	Escapement Indicator (PSC Management Objective)	Exploitation Rate Indicator/Acronym		Model Stock/Acronym	
Transboundary Rivers (TBR)	Spring	Yes	Taku (19,000–36,000)	Taku	TAK	Taku and Stikine	TST
		Yes	Stikine (14,000–28,000)	Stikine	STI		
		Yes	Alsek (3,500–5,300)	NA	NA	Alsek	ALS
Southeast Alaska (SEAK)		Yes	Situk (500–1,000)	NA	NA	Yakutat Forelands	YAK
		Yes	Chilkat (1,750–3,500)	Chilkat Northern Southeast Alaska	CHK, NSA[1]	Northern Southeast Alaska	NSA
		Yes	Unuk (1,800–3,800)	Unuk Southern Southeast Alaska	UNU, SSA[2]	Southern Southeast Alaska	SSA

[1]NSA is an aggregate of Crystal Lake (ACI) and Douglas Island Pink and Chum (DIPAC)/Macaulay (AMC) hatcheries.
[2]SSA is an aggregate of Little Port Walter (ALP), Neets Bay (ANB), Whitman Lake (AHC), and Deer Mountain (ADM) hatcheries.

Appendix A2– Indicator stocks for Northern British Columbia (NBC), Central British Columbia (CBC), and West Coast Vancouver Island (WCVI).

Region	Run	Attachment I stock	Escapement Indicator (PSC Management Objective)	Exploitation Rate Indicator/Acronym		Model Stock /Acronym	
Northern BC (NBC)	Summer	No	Nass	Kitsumkalum (Deep Creek Hatchery)	KLM	Northern BC	NBC
		Yes	Skeena (TBD)				
Central BC (CBC)	Fall	No	Wannock	Atnarko (Snootli Hatchery)	ATN	Central BC	CBC
	Summer	No	Chuckwalla and Killbella				
		Yes	Atnarko (5,009)				
West Coast Vancouver Island (WCVI)	Fall	Yes	North West Vancouver Island Aggregate (Colonial-Cayeagle, Tashish, Artlish, Kaouk) (TBD)	Robertson Creek Hatchery	RBT (adj)[1]	West Coast Vancouver Island Natural	WVN
		Yes	South West Vancouver Island Aggregate (Bedwell/Ursus, Megin, Moyeha) (TBD)				
		No	West Coast Vancouver Island Aggregate (14 Streams)	Robertson Creek Hatchery	RBT	West Coast Vancouver Island Hatchery	WVH

[1]Coded-wire tag indicator stocks and fishery adjustments described in CTC 2021b.

Appendix A3– Indicator stocks for Fraser River and Strait of Georgia.

Region	Run	Attachment I stock	Escapement Indicator (PSC Management Objective)	Exploitation Rate Indicator/Acronym		Model Stock /Acronym	
Fraser River	Spring	Yes	Nicola (TBD)	Nicola (Spius Creek Hatchery)	NIC	Fraser Spring 1.2	FS2
		No	NA	Dome (Penny Creek Hatchery)	DOM[2]	Fraser Spring 1.3	FS3
		Yes	Chilcotin (TBD)	Lower Chilcotin (in development)	LCT		
	Summer	Yes	Lower Shuswap (12,300)	Lower Shuswap (Shuswap Falls Hatchery)	SHU	Fraser Summer Ocean-type 0.3	FSO
		No	NA	Middle Shuswap (Shuswap Falls Hatchery)	MSH		
		Yes	Chilko (TBD)	Chilko (in development)	CKO	Fraser Summer Stream-type 1.3	FSS
	Fall	No	NA	Chilliwack Hatchery	CHI	Fraser Chilliwack Fall Hatchery	FCF
		Yes	Harrison (75,100)	Harrison (Chehalis Hatchery)	HAR	Fraser Harrison Fall	FHF
North Strait of Georgia	Fall	No	TBD	Quinsam Hatchery	QUI	Upper Strait of Georgia	UGS
		Yes	East Vancouver Island North (TBD)		QUI (adj)[1]		
		Yes	Phillips	Phillips (Gillard Pass Hatchery)	PHI		
South Strait of Georgia	Fall	No	Cowichan (6,500)	Big Qualicum Hatchery	BQR	Middle Strait of Georgia	MGS
		Yes		Cowichan Hatchery	COW	Lower Strait of Georgia	LGS
		No		Nanaimo Hatchery	NAN		
	Summer	No		Puntledge Hatchery	PPS	Puntledge Hatchery	PPS

[1]Coded-wire tag indicator stocks and fishery adjustments described in CTC 2021b.
[2]DOM was discontinued as an exploitation rate indicator stock as of brood year (BY) 2004 but is still included as part of the annual exploitation rate analysis (ERA).

Appendix A4– Indicator stocks for Puget Sound.

Region	Run	Attachment I stock	Escapement Indicator (PSC Management Objective)	Exploitation Rate Indicator/Acronym		Model Stock /Acronym	
Northern Puget Sound	Spring	Yes	Nooksack Spring (TBD)	Nooksack Spring Fingerling (Kendall Creek Hatchery)	NSF	Nooksack Spring	NKS
	Spring	Yes	Skagit Spring (690)	Skagit Spring Fingerling (Marblemount Hatchery)	SKF	NA	NA
	Fall	No	NA	Samish Fall Fingerling (Samish Hatchery)	SAM	Nooksack Fall	NKF
	Summer/ Fall	Yes	Skagit Summer/Fall (9,202)	Skagit Summer Fingerling (Marblemount Hatchery)	SSF	Skagit Summer/Fall	SKG
	Fall	Yes	Stillaguamish (TBD)	Stillaguamish Fall Fingerling (Whitehorse Hatchery)	STL	Stillaguamish	STL
	Summer	Yes	Snohomish (TBD)	Skykomish Fingerling (Wallace Hatchery)	SKY	Snohomish	SNO
Central Puget Sound	Fall	No	Lake Washington		UWA	Puget Sound Natural Fingerling	PSN
		No	Green	Green River Fingerling[1] (Soos Creek Hatchery)	GRN[1]		
Hood Canal		No	NA	George Adams Hatchery Fall Fingerling	GAD	Puget Sound Hatchery Fingerling	PSF
Southern Puget Sound (SPS)	Fall	No	NA	SPS Fall Fingerling[1]	SPS[1]		
		No	NA	Nisqually Fall Fingerling (Clear Creek Hatchery)	NIS		
		No	NA	SPS Fall Yearling	SPY	Puget Sound Hatchery Yearling	PSY
	Spring	No	NA	White River Hatchery Spring Yearling	WRY	NA	NA

[1]SPS is aggregate from Soos Creek (Green R), Grovers, and Issaquah hatcheries. The Soos Creek (GRN tag group) are included in the SPS exploitation rate indicator.
[2]SPY was discontinued as an exploitation rate indicator stock as of brood year (BY) 2013.

Appendix A5– Indicator stocks for the Washington Coast.

Region	Run	Attachment I stock	Escapement Indicator (PSC Management Objective)	Exploitation Rate Indicator/Acronym		Model Stock /Acronym	
Juan de Fuca		No	NA	Elwha Fall Fingerling (Lower Elwha Hatchery)	ELW	NA	NA
Washington Coast (WAC)	Fall	Yes	Hoko (TBD)	Hoko Fall Fingerling (Hoko Falls Hatchery)	HOK	NA	NA
		Yes	Queets Fall (2,500)	Queets Fall Fingerling (Salmon River brood stock)	QUE (adj)[2]	WA Coastal Wild	WCN
		Yes	Grays Harbor Fall (13,326)				
		Yes	Quillayute Fall (3,000)				
		Yes	Hoh Fall (1,200)				
		No	NA			WA Coastal Hatchery	WCH
		No	NA	Tsoo-Yess Fall Fingerling (Makah National Fish Hatchery)	SOO	NA	NA
	Spring	No	Grays Harbor Spring[1]	NA	NA	NA	NA
	Spring/ Summer	No	Queets Spring/Summer (700)[1]	NA	NA	NA	NA
	Summer	No	Quillayute Summer[1]	NA	NA	NA	NA
	Spring/ Summer	No	Hoh Spring/Summer (900)[1]	NA	NA	NA	NA

[1] Escapement indicator stock is not included in the Washington Coastal model stocks.
[2] Coded-wire tag indicator stocks and fishery adjustments described in CTC 2021b.

Appendix A6– Indicator stocks for Columbia River and Oregon Coast.

Region	Run	Attachment I stock	Escapement Indicator (PSC Management Objective)	Exploitation Rate Indicator/Acronym		Model Stock /Acronym	
Columbia River	Spring	No	NA	Cowlitz/Kalama/Lewis Springs	CWS	Cowlitz Spring Hatchery	CWS
		No	NA	Willamette Spring (Hatchery Complex)	WSH	Willamette River Hatchery	WSH
	Summer	Yes	Mid-Columbia Summers (12,143)	Columbia Summers (Wells Hatchery)	SUM	Columbia River Summers	SUM
	Fall	No	NA	Columbia Upriver Brights (Priest Rapids Hatchery)	URB	Mid-Columbia Brights	MCB
		Yes	Upriver Brights (40,000)			Columbia Upriver Brights	URB
				Hanford Wild	HAN		
		No	NA	Lyons Ferry Fingerling	LYF	Lyons Ferry Hatchery	LYF
		No	NA	Lyons Ferry Yearling	LYY		
		Yes	Lewis (5,700)	Lewis River Wild	LRW	Lewis River	LRW
		Yes	Coweeman (TBD)	Cowlitz Hatchery Fall Tule	CWF	Cowlitz Hatchery	CWF
		No	NA	Spring Creek National Fish Hatchery	SPR	Spring Creek	SPR
		No	NA	Lower River Hatchery (Big Creek Hatchery)	LRH	Bonneville Hatchery	BON
North Oregon Coast (NOC)	Fall	Yes	Nehalem (6,989)	Salmon River Hatchery (adj)	SRH (adj)[1]	North Oregon Coast	NOC
		Yes	Siletz (2,944)				
		Yes	Siuslaw (12,925)				
Mid-Oregon Coast (MOC)		Yes	South Umpqua (TBD)	Elk River Hatchery (adj)	ELK (adj)[1]	Mid-Oregon Coast	MOC
		Yes	Coquille (TBD)				

[1]Coded-wire tag indicator stocks and fishery adjustments described in CTC 2021b.

APPENDIX B: MODEL STOCK COMPOSITION ESTIMATES FOR THE AGGREGATE ABUNDANCE-BASED MANAGEMENT AND INDIVIDUAL STOCK-BASED MANAGEMENT FISHERIES IN 2021 AND THE 1985–2019 AVERAGE

This appendix shows the model stock composition estimates of catch for the three AABM fisheries (Appendix B1, Appendix B2 and Appendix B3) and all ISBM fisheries by country (Appendix B4 and Appendix B5). These estimates are based on summing the 41 model stock contributions for each model fishery aggregate, expressed as a percentage of the total catch.

The estimated stock composition may not reflect the true stock composition for several reasons:

1. The yearly catch estimates by stock are influenced by the base period stock composition in a fishery which may not reflect the current stock composition in the fishery, amongst the 41 model stocks.
2. The distribution of certain stocks may have changed over time.
3. The 41 model stocks do not represent all production available to a fishery.

For example, in the SEAK fishery a substantial component (over 20%) of the catch is comprised of Alaska hatchery fish, most of which do not count as treaty catch and are not included in Appendix B1. Also, in the sport fishery portion of the present NBC AABM fishery, the base period data used is from fisheries which were located near shore and do not represent the current stock composition of the sport fishery which is located offshore.

Hence, these tables do not necessarily portray the true stock composition of the total catch of the fisheries in Appendix B1 to Appendix B5. Genetic stock composition estimates are available for most of these fisheries in select years, which provide more accurate accounting of contributions by stocks or stock groups.

LIST OF APPENDIX B TABLES

Appendix B1–Southeast Alaska aggregate abundance-based management (AABM) troll, net, and sport fisheries.

FISHERY:	SOUTHEAST ALASKA AABM TROLL NET AND SPORT				
	2021	Average (1985–2020)			
Model Stock	% of Fishery Catch	% of Fishery Catch	% of Stock Catch	% of Stock Total Return	Associated Escapement Indicator Stocks[1]
Upriver Brights	18.79%	18.90%	21.50%	11.87%	Upriver Brights
WCVI Hatchery	21.86%	15.71%	28.56%	13.39%	NA
North Oregon Coast	6.86%	9.40%	21.92%	11.89%	Nehalem
					Siletz
					Siuslaw
Northern BC	1.69%	7.42%	67.30%	13.18%	Skeena
Fraser Summer Ocean-type 0.3	15.24%	7.34%	31.74%	12.15%	Lower Shuswap
WA Coastal Wild	5.30%	5.77%	33.67%	15.70%	Grays Harbor Fall
					Queets Fall
					Quillayute Fall
					Hoh Fall
Mid Columbia River Brights	6.39%	5.42%	19.31%	11.10%	Not Represented
Taku and Stikine	1.23%	4.39%	53.03%	9.91%	Taku
					Stikine
Southern SE AK	2.58%	3.91%	96.69%	32.13%	Unuk
WA Coastal Hatchery	4.13%	3.51%	32.65%	13.57%	NA
Columbia River Summer	4.76%	3.24%	18.21%	9.83%	Mid-Columbia Summers
Northern SE AK	1.08%	2.70%	99.63%	45.98%	Chilkat
Yakutat Forelands	0.00%	2.21%	0.00%	34.60%	Situk
WCVI Natural	3.55%	2.22%	30.64%	16.19%	NWVI Natural Aggregate
					SWVI Natural Aggregate
Mid-Oregon Coast	1.11%	2.00%	10.64%	5.48%	South Umpqua
					Coquille
Upper Georgia Strait	0.91%	1.16%	40.91%	13.48%	East Vancouver Island North
					Phillips
Willamette River Spring	0.71%	0.95%	6.35%	2.68%	NA
Fall Cowlitz Hatchery	0.71%	0.85%	3.12%	1.62%	NA
Central BC	0.24%	0.62%	28.81%	6.89%	Atnarko
Lewis River Wild	0.84%	0.59%	16.05%	5.62%	Lewis
Middle Georgia Strait	0.75%	0.41%	9.71%	3.10%	NA

Harrison Fall	0.29%	0.32%	1.83%	0.53%	Harrison
Puget Sound Fingerling	0.24%	0.19%	0.38%	0.21%	NA
Fraser Summer Stream-type 1.3	0.10%	0.16%	3.29%	1.05%	Chilko
Skagit Wild	0.14%	0.11%	3.79%	1.32%	Skagit Summer/Fall
Spring Cowlitz Hatchery	0.05%	0.08%	1.58%	0.82%	NA
Alsek	0.10%	0.08%	46.37%	2.74%	Alsek
Lower Georgia Strait	0.10%	0.11%	3.03%	1.25%	Cowichan
Lyons Ferry	0.11%	0.07%	1.93%	1.18%	Not Represented
Nooksack Fall	0.05%	0.06%	0.30%	0.20%	Not Represented
Puget Sound Natural Fall	0.02%	0.02%	0.33%	0.18%	NA
Chilliwack Fall Hatchery	0.03%	0.02%	0.19%	0.07%	NA
Nooksack Spring	0.03%	0.02%	4.87%	1.65%	Nooksack Spring
Puget Sound Yearlings	0.00%	0.01%	0.25%	0.16%	NA
Fraser Spring 1.2	0.00%	0.01%	0.45%	0.14%	Nicola
Puntledge Summers	0.01%	0.01%	5.83%	1.72%	NA
Snohomish Wild	0.00%	0.01%	1.03%	0.23%	Snohomish
Stillaguamish Wild	0.00%	0.00%	1.02%	0.39%	Stillaguamish
Fraser Spring 1.3	0.00%	0.00%	0.00%	0.00%	Chilcotin
Lower Bonneville Hatchery	0.00%	0.00%	0.00%	0.00%	NA
Spring Creek Hatchery	0.00%	0.00%	0.00%	0.00%	NA

[1] NA = a hatchery stock; Not represented = a wild stock without an escapement indicator.

Appendix B2– Northern British Columbia aggregate abundance-based management (AABM) troll and sport fisheries.

FISHERY:	NORTHERN BRITISH COLUMBIA AABM TROLL AND SPORT				
	2021	Average (1985–2020)			
Model Stock	% of Fishery Catch	% of Fishery Catch	% of Stock Catch	% of Stock Total Return	Associated Escapement Indicator Stocks[1]
North Oregon Coast	18.93%	20.76%	31.38%	17.75%	Nehalem
					Siletz
					Siuslaw
Upriver Brights	20.66%	16.99%	12.51%	7.07%	Upriver Brights
Fraser Summer Ocean-type 0.3	15.76%	12.20%	33.98%	14.17%	Lower Shuswap
WCVI Hatchery	8.25%	10.32%	10.77%	5.40%	NA
WA Coastal Wild	6.13%	7.75%	28.29%	13.91%	Grays Harbor Fall
					Queets Fall
					Quillayute Fall
					Hoh Fall
Mid-Oregon Coast	3.95%	6.56%	21.76%	11.49%	South Umpqua
					Coquille
Columbia River Summer	8.39%	6.23%	22.73%	12.78%	Mid-Columbia Summers
WA Coastal Hatchery	4.83%	4.75%	28.45%	12.50%	NA
Mid Columbia River Brights	4.10%	3.62%	8.97%	5.35%	Not Represented
Willamette River Spring	1.65%	2.14%	9.19%	4.06%	NA
WCVI Natural	1.32%	1.37%	10.98%	6.23%	NWVI Natural Aggregate
					SWVI Natural Aggregate
Upper Georgia Strait	0.53%	0.95%	20.48%	7.33%	East Vancouver Island North
					Phillips
Fall Cowlitz Hatchery	0.73%	0.88%	2.08%	1.12%	NA
Middle Georgia Strait	1.01%	0.64%	9.71%	3.26%	NA
Fraser Summer Stream-type 1.3	0.29%	0.48%	6.04%	2.04%	Chilko
Northern BC	0.10%	0.47%	2.92%	0.60%	Skeena
Puget Sound Fingerling	0.57%	0.47%	0.63%	0.36%	NA
Taku and Stikine	0.17%	0.46%	3.64%	0.64%	Taku
					Stikine
Lewis River Wild	0.42%	0.38%	5.97%	2.25%	Lewis
Central BC	0.17%	0.32%	9.53%	2.35%	Atnarko
Lyons Ferry	0.46%	0.32%	6.22%	3.97%	Not Represented

Spring Cowlitz Hatchery	0.17%	0.29%	3.63%	1.96%	NA
Skagit Wild	0.29%	0.29%	6.12%	2.20%	Skagit Summer/Fall
Harrison Fall	0.14%	0.26%	0.81%	0.25%	Harrison
Chilliwack Fall Hatchery	0.26%	0.23%	1.11%	0.44%	NA
Lower Georgia Strait	0.37%	0.23%	2.57%	1.25%	Cowichan
Southern SE AK	0.11%	0.19%	3.01%	1.00%	Unuk
Nooksack Fall	0.06%	0.09%	0.27%	0.18%	Not Represented
Puget Sound Natural Fall	0.03%	0.05%	0.41%	0.23%	NA
Lower Bonneville Hatchery	0.02%	0.05%	0.22%	0.11%	NA
Puntledge Summers	0.02%	0.05%	10.83%	3.44%	NA
Nooksack Spring	0.05%	0.05%	6.80%	2.47%	Nooksack Spring
Spring Creek Hatchery	0.03%	0.04%	0.07%	0.06%	NA
Fraser Spring 1.2	0.01%	0.03%	0.52%	0.17%	Nicola
Snohomish Wild	0.01%	0.03%	1.96%	0.47%	Snohomish
Stillaguamish Wild	0.01%	0.02%	2.11%	0.86%	Stillaguamish
Northern SE AK	0.00%	0.02%	0.17%	0.08%	Chilkat
Puget Sound Yearlings	0.00%	0.01%	0.04%	0.03%	NA
Alsek	0.00%	0.00%	0.00%	0.00%	Alsek
Fraser Spring 1.3	0.00%	0.00%	NaN	0.00%	Chilcotin
Yakutat Forelands	0.00%	0.00%	0.00%	0.00%	Situk

[1] NA = a hatchery stock; Not represented = a wild stock without an escapement indicator.

Appendix B3– West Coast Vancouver Island aggregate abundance-based management (AABM) troll and sport fisheries.

FISHERY:	WEST COAST VANCOUVER ISLAND AABM TROLL AND SPORT				
	2021	Average (1985–2020)			
Model Stock	% of Fishery Catch	% of Fishery Catch	% of Stock Catch	% of Stock Total Return	Associated Escapement Indicator Stocks[1]
Puget Sound Fingerling	12.56%	13.13%	18.02%	10.86%	NA
Upriver Brights	19.12%	13.54%	10.32%	5.99%	Upriver Brights
Spring Creek Hatchery	11.83%	10.61%	20.51%	15.92%	NA
Fall Cowlitz Hatchery	7.19%	8.23%	21.72%	12.18%	NA
Lower Bonneville Hatchery	4.43%	6.52%	32.65%	18.78%	NA
Harrison Fall	2.49%	5.72%	18.87%	6.16%	Harrison
WCVI Hatchery	5.32%	5.28%	5.68%	3.03%	NA
Chilliwack Fall Hatchery	6.33%	5.22%	25.02%	10.65%	NA
Mid Columbia River Brights	5.01%	4.26%	11.00%	6.81%	Not Represented
Columbia River Summer	4.55%	3.74%	16.72%	9.68%	Mid-Columbia Summers
North Oregon Coast	5.08%	3.97%	6.36%	3.60%	Nehalem
					Siletz
					Siuslaw
Nooksack Fall	1.86%	2.93%	10.55%	7.05%	Not Represented
Puget Sound Natural Fall	1.11%	2.42%	22.00%	12.96%	NA
Mid-Oregon Coast	1.53%	1.78%	6.77%	3.70%	South Umpqua
					Coquille
WA Coastal Wild	1.08%	1.52%	5.95%	2.95%	Grays Harbor Fall
					Queets Fall
					Quillayute Fall
					Hoh Fall
Puget Sound Yearlings	0.30%	1.36%	14.03%	9.29%	NA
Fraser Summer Stream-type 1.3	0.74%	1.33%	17.38%	6.07%	Chilko
Lyons Ferry	1.28%	1.08%	20.35%	13.73%	Not Represented
WA Coastal Hatchery	0.94%	0.97%	6.18%	2.77%	NA
Skagit Wild	0.83%	0.94%	21.60%	8.17%	Skagit Summer/Fall
Lewis River Wild	0.82%	0.82%	14.98%	5.85%	Lewis
Willamette River Spring	0.64%	0.80%	3.67%	1.65%	NA
Spring Cowlitz Hatchery	0.50%	0.76%	9.70%	5.61%	NA
Fraser Summer Ocean-type 0.3	1.15%	0.71%	2.26%	0.98%	Lower Shuswap

Lower Georgia Strait	1.50%	0.73%	9.72%	4.73%	Cowichan
WCVI Natural	0.84%	0.55%	5.61%	3.34%	NWVI Natural Aggregate
					SWVI Natural Aggregate
Middle Georgia Strait	0.61%	0.38%	5.77%	2.02%	NA
Snohomish Wild	0.08%	0.18%	18.47%	4.62%	Snohomish
Fraser Spring 1.2	0.08%	0.18%	4.23%	1.43%	Nicola
Stillaguamish Wild	0.06%	0.13%	18.19%	7.77%	Stillaguamish
Nooksack Spring	0.10%	0.10%	16.21%	5.94%	Nooksack Spring
Fraser Spring 1.3	0.03%	0.06%	1.00%	0.26%	Chilcotin
Puntledge Summers	0.01%	0.02%	7.32%	2.28%	NA
Upper Georgia Strait	0.01%	0.02%	0.56%	0.21%	East Vancouver Island North
					Phillips
Central BC	0.01%	0.01%	0.37%	0.09%	Atnarko
Northern SE AK	0.00%	0.00%	0.06%	0.02%	Chilkat
Yakutat Forelands	0.00%	0.00%	NaN	0.00%	Situk
Taku and Stikine	0.00%	0.00%	0.00%	0.00%	Taku
					Stikine
Alsek	0.00%	0.00%	0.00%	0.00%	Alsek
Northern BC	0.00%	0.00%	0.00%	0.00%	Skeena
Southern SE AK	0.00%	0.00%	0.00%	0.00%	Unuk

[1] NA = a hatchery stock; Not represented = a wild stock without an escapement indicator.

Appendix B4– Canada individual stock-based management (ISBM) net and sport fisheries.

FISHERY:	CANADA ISBM TROLL NET AND SPORT				
	2021	Average (1985–2020)			
Model Stock	% of Fishery Catch	% of Fishery Catch	% of Stock Catch	% of Stock Total Return	Associated Escapement Indicator Stocks[1]
WCVI Hatchery	43.49%	29.46%	54.58%	26.14%	NA
Harrison Fall	2.61%	7.63%	39.15%	13.38%	Harrison
Puget Sound Fingerling	6.62%	6.17%	13.02%	7.69%	NA
Fraser Summer Stream-type 1.3	1.24%	3.50%	67.84%	22.63%	Chilko
Fraser Summer Ocean-type 0.3	7.59%	5.96%	28.20%	11.23%	Lower Shuswap
Nooksack Fall	4.41%	5.31%	29.04%	19.40%	Not Represented
Lower Georgia Strait	7.68%	5.13%	76.82%	43.37%	Cowichan
Chilliwack Fall Hatchery	5.01%	4.26%	36.01%	16.90%	NA
WCVI Natural	5.85%	4.06%	52.42%	28.45%	NWVI Natural Aggregate
					SWVI Natural Aggregate
Fraser Spring 1.3	0.63%	3.80%	83.87%	22.91%	Chilcotin
Northern BC	0.40%	3.59%	29.78%	5.96%	Skeena
Middle Georgia Strait	5.68%	3.36%	72.42%	29.89%	NA
Fraser Spring 1.2	0.29%	3.14%	86.83%	31.07%	Nicola
Upriver Brights	0.88%	2.48%	3.49%	2.11%	Upriver Brights
Fall Cowlitz Hatchery	1.05%	1.56%	5.96%	3.25%	NA
Columbia River Summer	1.21%	1.55%	11.60%	6.40%	Mid-Columbia Summers
Central BC	0.65%	1.27%	61.20%	14.67%	Atnarko
Upper Georgia Strait	0.38%	1.14%	38.06%	14.93%	East Vancouver Island North
					Phillips
Skagit Wild	0.93%	1.06%	37.42%	14.04%	Skagit Summer/Fall
Puget Sound Natural Fall	0.50%	0.99%	14.53%	8.24%	NA
Puget Sound Yearlings	0.24%	0.85%	14.24%	9.49%	NA
Spring Creek Hatchery	1.17%	0.83%	2.69%	2.07%	NA
Mid Columbia River Brights	0.27%	0.67%	3.96%	2.69%	Not Represented
Lower Bonneville Hatchery	0.33%	0.50%	3.83%	2.08%	NA
North Oregon Coast	0.01%	0.32%	0.88%	0.50%	Nehalem
					Siletz
					Siuslaw
Snohomish Wild	0.10%	0.23%	35.62%	8.71%	Snohomish
Nooksack Spring	0.27%	0.23%	57.60%	20.89%	Nooksack Spring

Puntledge Summers	0.11%	0.19%	76.02%	29.76%	NA
Lewis River Wild	0.13%	0.17%	4.31%	1.70%	Lewis
Stillaguamish Wild	0.08%	0.16%	35.75%	15.01%	Stillaguamish
WA Coastal Wild	0.05%	0.13%	0.85%	0.43%	Grays Harbor Fall
					Queets Fall
					Quillayute Fall
					Hoh Fall
Spring Cowlitz Hatchery	0.05%	0.11%	2.16%	1.15%	NA
WA Coastal Hatchery	0.04%	0.09%	0.89%	0.43%	NA
Lyons Ferry	0.04%	0.05%	2.67%	1.94%	Not Represented
Willamette River Spring	0.00%	0.03%	0.22%	0.11%	NA
Mid-Oregon Coast	0.00%	0.01%	0.06%	0.03%	South Umpqua
					Coquille
Southern SE AK	0.00%	0.01%	0.30%	0.10%	Unuk
Northern SE AK	0.00%	0.00%	0.05%	0.02%	Chilkat
Taku and Stikine	0.00%	0.00%	0.00%	0.00%	Taku
					Stikine
Alsek	0.00%	0.00%	0.00%	0.00%	Alsek
Yakutat Forelands	0.00%	0.00%	NaN	0.00%	Situk

[1] NA = a hatchery stock; Not represented = a wild stock without an escapement indicator.

Appendix B5– U.S. individual stock-based management (ISBM) troll, net, and sport fisheries.

FISHERY:	US ISBM TROLL NET AND SPORT				
	2021	**Average (1985–2020)**			
Model Stock	**% of Fishery Catch**	**% of Fishery Catch**	**% of Stock Catch**	**% of Stock Total Return**	**Associated Escapement Indicator Stocks[1]**
Upriver Brights	25.36%	17.80%	52.17%	29.05%	Upriver Brights
Puget Sound Fingerling	16.76%	13.31%	67.96%	39.01%	NA
Spring Creek Hatchery	13.83%	10.65%	76.73%	58.67%	NA
Fall Cowlitz Hatchery	5.04%	6.95%	67.12%	36.70%	NA
North Oregon Coast	4.32%	6.67%	39.45%	21.28%	Nehalem
					Siletz
					Siuslaw
Mid Columbia River Brights	9.12%	6.11%	56.76%	33.53%	Not Represented
Willamette River Spring	2.62%	5.21%	80.57%	36.64%	NA
Mid-Oregon Coast	1.92%	4.66%	60.77%	31.87%	South Umpqua
					Coquille
Nooksack Fall	3.61%	4.56%	59.85%	38.91%	Not Represented
Lower Bonneville Hatchery	2.27%	3.51%	63.30%	34.81%	NA
Harrison Fall	1.18%	3.23%	39.34%	12.78%	Harrison
Columbia River Summer	4.18%	2.40%	30.74%	17.02%	Mid-Columbia Summers
WA Coastal Wild	1.36%	2.22%	31.24%	14.64%	Grays Harbor Fall
					Queets Fall
					Quillayute Fall
					Hoh Fall
Puget Sound Yearlings	0.51%	1.99%	71.43%	45.89%	NA
Puget Sound Natural Fall	0.96%	1.94%	62.73%	34.92%	NA
Chilliwack Fall Hatchery	2.01%	1.94%	37.67%	15.57%	NA
Spring Cowlitz Hatchery	0.73%	1.79%	82.93%	46.30%	NA
WA Coastal Hatchery	0.89%	1.52%	31.83%	13.66%	NA
Lewis River Wild	0.95%	0.99%	58.69%	23.38%	Lewis
Lyons Ferry	0.85%	0.88%	68.82%	44.96%	Not Represented
Skagit Wild	0.33%	0.36%	31.08%	10.94%	Skagit Summer/Fall
Fraser Summer Ocean-type 0.3	0.49%	0.32%	3.82%	1.52%	Lower Shuswap
Fraser Spring 1.3	0.10%	0.26%	15.13%	3.88%	Chilcotin
Lower Georgia Strait	0.25%	0.19%	7.87%	3.87%	Cowichan
Snohomish Wild	0.05%	0.12%	42.92%	10.44%	Snohomish

Fraser Summer Stream-type 1.3	0.06%	0.11%	5.44%	1.90%	Chilko
WCVI Hatchery	0.11%	0.09%	0.40%	0.18%	NA
Stillaguamish Wild	0.04%	0.08%	42.95%	17.89%	Stillaguamish
Fraser Spring 1.2	0.02%	0.08%	7.97%	2.55%	Nicola
Middle Georgia Strait	0.07%	0.04%	2.40%	0.82%	NA
Nooksack Spring	0.03%	0.02%	14.52%	5.18%	Nooksack Spring
WCVI Natural	0.01%	0.01%	0.35%	0.18%	NWVI Natural Aggregate
					SWVI Natural Aggregate
Northern SE AK	0.00%	0.00%	0.09%	0.04%	Chilkat
Central BC	0.00%	0.00%	0.09%	0.02%	Atnarko
Puntledge Summers	0.00%	0.00%	0.00%	0.00%	NA
Northern BC	0.00%	0.00%	0.00%	0.00%	Skeena
Yakutat Forelands	0.00%	0.00%	NaN	0.00%	Situk
Taku and Stikine	0.00%	0.00%	0.00%	0.00%	Taku
					Stikine
Alsek	0.00%	0.00%	0.00%	0.00%	Alsek
Upper Georgia Strait	0.00%	0.00%	0.00%	0.00%	East Vancouver Island North
					Phillips
Southern SE AK	0.00%	0.00%	0.00%	0.00%	Unuk

[1] NA = a hatchery stock; Not represented = a wild stock without an escapement indicator.

APPENDIX C: FIGURES OF PACIFIC SALMON COMMISSION CHINOOK MODEL-GENERATED STOCK COMPOSITION OF ACTUAL LANDED CATCH FOR ALL (AGGREGATE ABUNDANCE-BASED MANAGEMENT AND INDIVIDUAL STOCK-BASED MANAGEMENT) MODEL FISHERIES, 1979–2021

Stock composition in the AABM and ISBM fisheries are estimated using the PSC Chinook Model. Assumptions of the estimation procedure are described in Appendix B. The relative contribution of a model stock to a model fishery is computed as:

$$P_{F,S,Y} = \frac{Q_{F,S,Y}}{\sum_S Q_{F,S,Y}}$$

where $Q_{F,S,Y}$ is model landed catch by fishery F, stock S, and year Y. Landed catch stock composition is computed:

$$C_{F,S,Y} = C_{F,Y} * P_{F,S,Y}$$

where $C_{F,Y}$ is the landed catch by fishery F and year Y. Since the PSC Chinook Model does not include the Alaska Hatchery Add-on, the landed catch stock composition is adjusted to include this harvest:

$$C_{F,S=AK,Y} = C_{F,S=AK,Y} + A_{F,S=AK,Y}$$

where $A_{F,S=AK,Y}$ is the Alaska Hatchery Add-on by fishery F and year Y for the SEAK and TBR stock groups. Results with and without the Alaska Hatchery Add-on are reported. Stock group definitions in each figure correspond to the following model stock aggregations:

SEAK/TBR	Southeast Alaska and Transboundary River stocks (Southern and Northern SE AK, Alsek, Taku and Stikine, and Yakutat Forelands)
NCBC	North and Central British Columbia stocks
WCVI	West Coast Vancouver Island stocks (hatchery and natural)
SG	Strait of Georgia stocks (Upper, Middle, Lower, and Puntledge Summers)
FR-early	Fraser River Early stocks (Fraser Spring 1.2 and 1.3, Fraser Summer Ocean-type 0.3 and Stream-type 1.3)
FR-late	Fraser River Late stocks (Harrison Fall, Chilliwack Fall Hatchery)
PSD	Puget Sound stocks (Nooksack Fall and Spring, Puget Sound Natural Fall, Puget Sound Fingerlings and Yearlings, Skagit Wild, Stillaguamish Wild, and Snohomish Wild)
WACST	Washington Coast stocks (hatchery and wild)
CR-sp&su	Columbia River Spring and Summer stocks (Willamette, Spring Cowlitz Hatchery, and Columbia Summers)
CR-bright	Columbia River Fall Bright stocks (Upriver, Mid-Columbia, Lewis River Wild, and Lyons Ferry)
CR-tule	Columbia River-Fall Tule stocks (Spring Creek, Lower Bonneville, and Fall Cowlitz Hatchery)
ORCST	North and Mid-Oregon Coast stocks

LIST OF APPENDIX C FIGURES

Appendix C1— Pacific Salmon Commission Chinook Model estimates of landed catch stock composition for Alaska troll with (upper) and without (lower) Alaska hatchery add-on and terminal exclusion, 1979–2021.
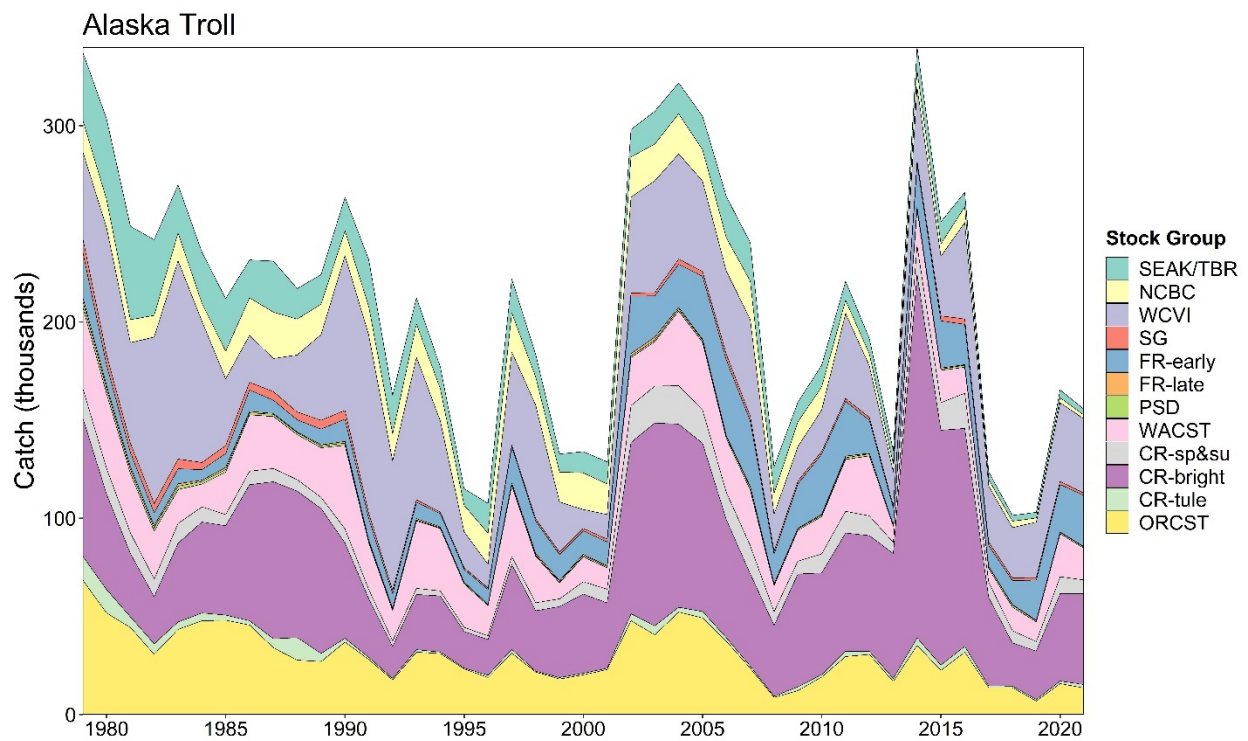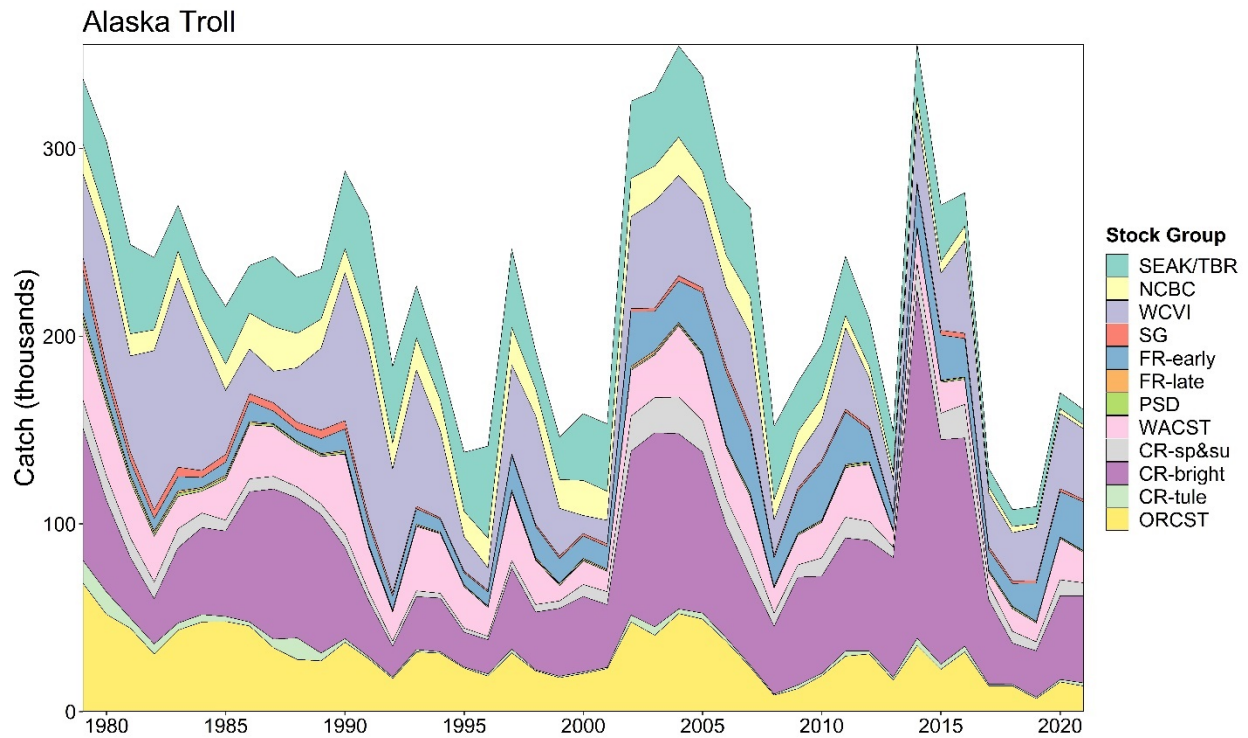
Appendix C2— Pacific Salmon Commission Chinook Model estimates of landed catch stock composition for Alaska Yakutat Terminal Net, 1979–2021.
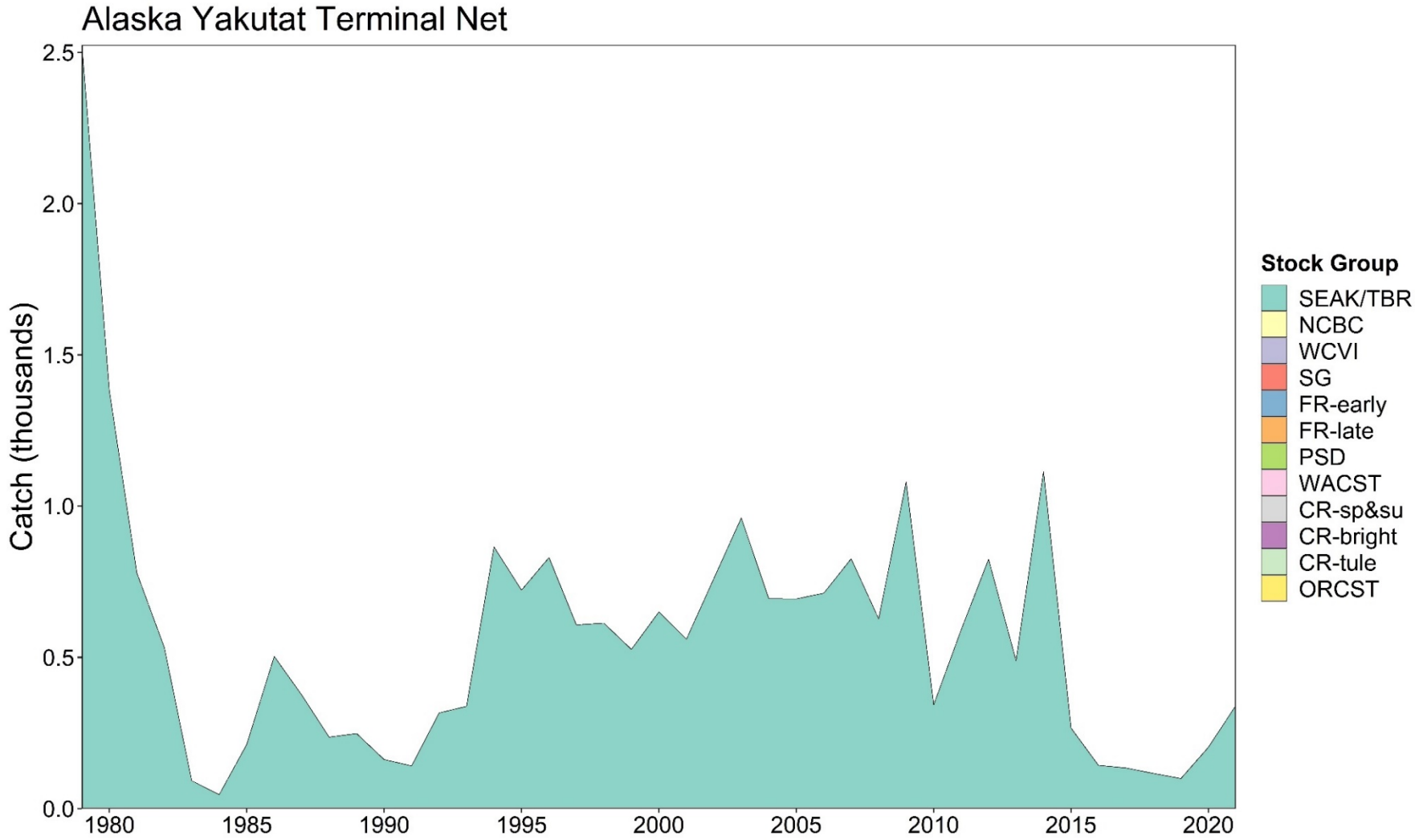
Appendix C3— Pacific Salmon Commission Chinook Model estimates of landed catch stock composition for North British Columbia Troll, 1979–2021.

North British Columbia Troll

Appendix C4— Pacific Salmon Commission Chinook Model estimates of landed catch stock composition for Central British Columbia Troll, 1979–2021.

Central British Columbia Troll

West Coast Vancouver Island Troll

South of Falcon Troll
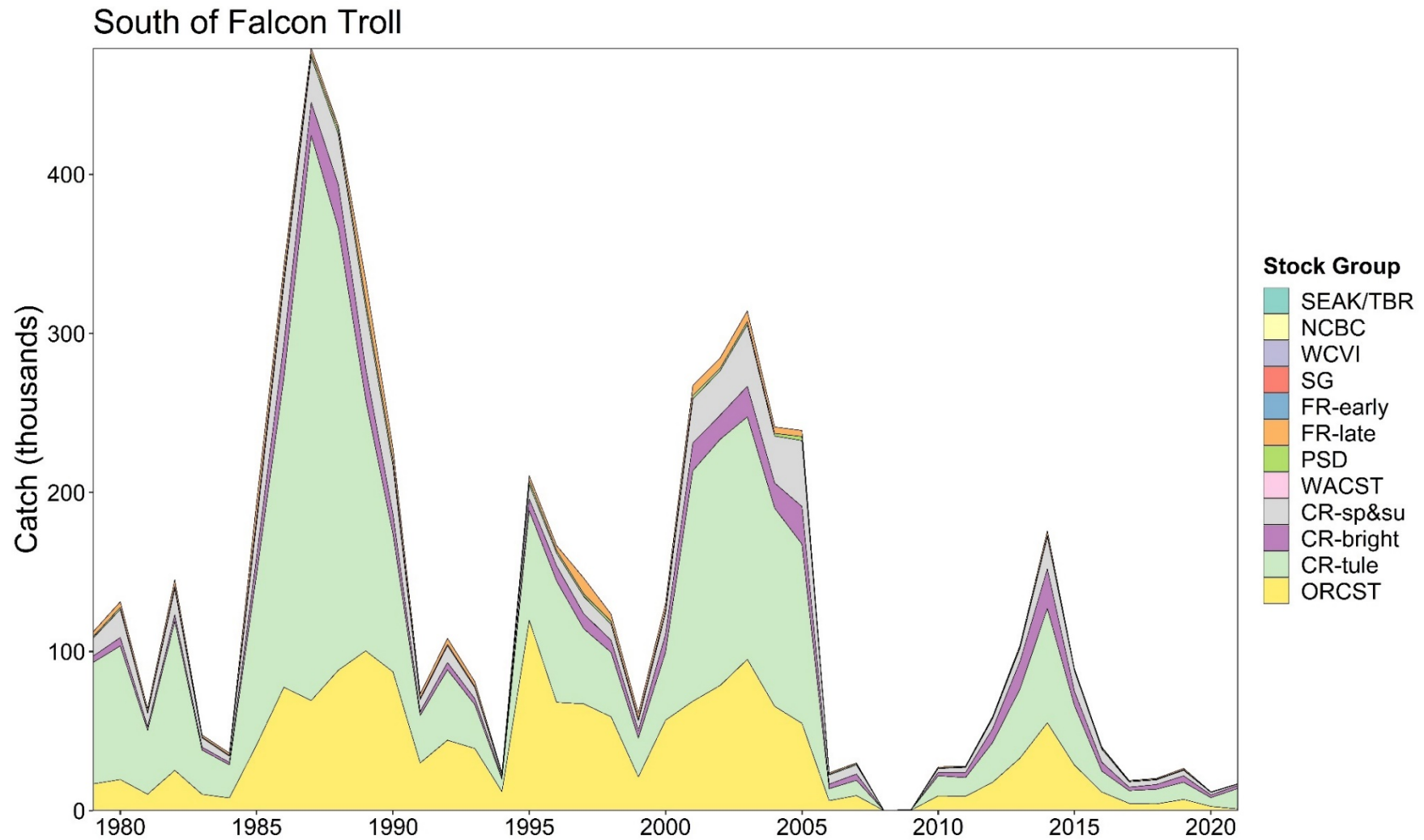
Appendix C8— Pacific Salmon Commission Chinook Model estimates of landed catch stock composition for Strait of Georgia Troll, 1979–2021.

Georgia Strait Troll

Appendix C9— Pacific Salmon Commission Chinook Model estimates of landed catch stock composition for Alaska net with (upper) and without (lower) hatchery add-on and terminal exclusion, 1979–2021.

Appendix C10— Pacific Salmon Commission Chinook Model estimates of landed catch stock composition for North British Columbia Net, 1979–2021.

North British Columbia Net
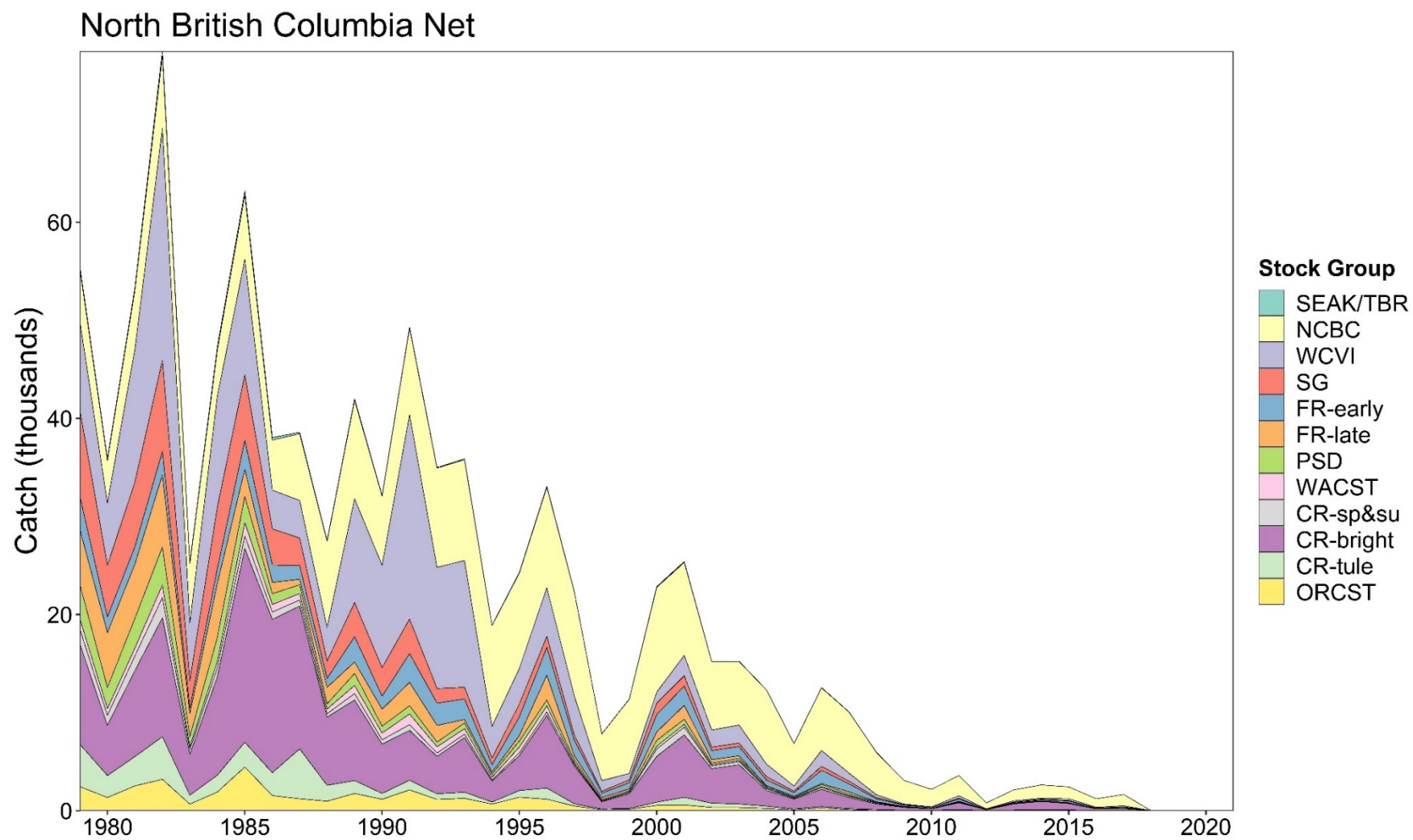
Appendix C11— Pacific Salmon Commission Chinook Model estimates of landed catch stock composition for Central British Columbia Net, 1979–2021.

Central British Columbia Net

Appendix C12— Pacific Salmon Commission Chinook Model estimates of landed catch stock composition for West Coast Vancouver Island Net, 1979–2021.

West Coast Vancouver Island Net

Stock Group
- SEAK/TBR
- NCBC
- WCVI
- SG
- FR-early
- FR-late
- PSD
- WACST
- CR-sp&su
- CR-bright
- CR-tule
- ORCST

Juan De Fuca Net

Stock Group
- SEAK/TBR
- NCBC
- WCVI
- SG
- FR-early
- FR-late
- PSD
- WACST
- CR-sp&su
- CR-bright
- CR-tule
- ORCST

Appendix C14— Pacific Salmon Commission Chinook Model estimates of landed catch stock composition for Puget Sound North Net, 1979–2021.

Appendix C15— Pacific Salmon Commission Chinook Model estimates of landed catch stock composition for Puget Sound Other Net, 1979–2021.

Puget Sound Other Net
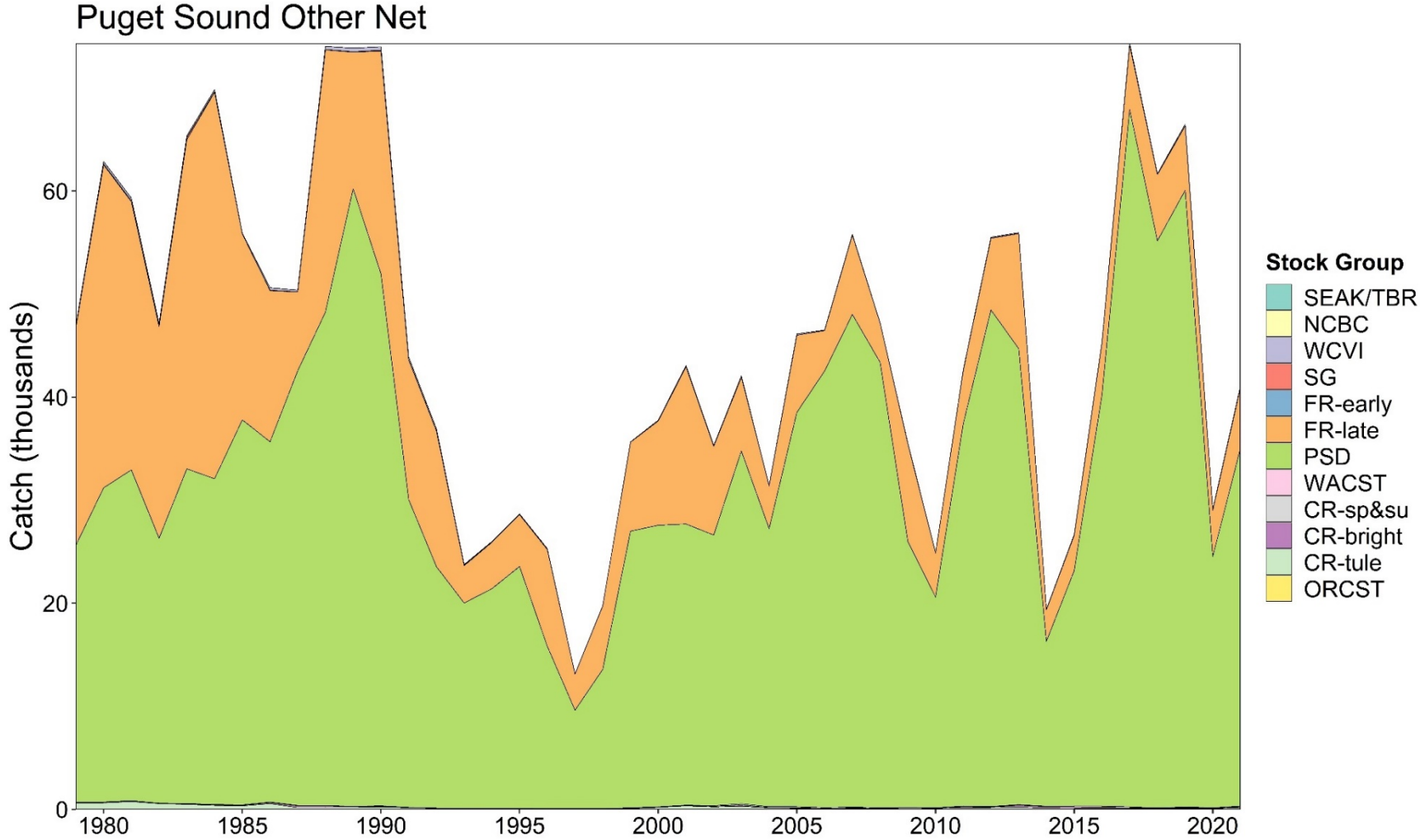
Appendix C16— Pacific Salmon Commission Chinook Model estimates of landed catch stock composition for Washington Coast Net, 1979–2021.

Appendix C17— Pacific Salmon Commission Chinook Model estimates of landed catch stock composition for Columbia River Net, 1979–2021.

Columbia River Net

Appendix C18— Pacific Salmon Commission Chinook Model estimates of landed catch stock composition for Alaska Transboundary River Terminal Net, 1979–2021.

Appendix C19— Pacific Salmon Commission Chinook Model estimates of landed catch stock composition for Canada Transboundary River Freshwater Net, 1979–2021.

British Columbia Transboundary Freshwater Net

Appendix C20— Pacific Salmon Commission Chinook Model estimates of landed catch stock composition for Central British Columbia Freshwater Net, 1979–2021.

Central British Columbia Freshwater Net

Appendix C21— Pacific Salmon Commission Chinook Model estimates of landed catch stock composition for Strait of Georgia Freshwater Net, 1979–2021.

Georgia Strait Freshwater Net

Stock Group
SEAK/TBR
NCBC
WCVI
SG
FR-early
FR-late
PSD
WACST
CR-sp&su
CR-bright
CR-tule
ORCST

Appendix C22— Pacific Salmon Commission Chinook Model estimates of landed catch stock composition for Puget Sound Freshwater Net, 1979–2021.

Puget Sound Freshwater Net

Appendix C23— Pacific Salmon Commission Chinook Model estimates of landed catch stock composition for Washington Coast Freshwater Net, 1979–2021.

Washington Coast Freshwater Net

Appendix C24— Pacific Salmon Commission Chinook Model estimates of landed catch stock composition for Johnstone Strait Net, 1979–2021.

Johnstone Strait Net

Appendix C25— Pacific Salmon Commission Chinook Model estimates of landed catch stock composition for Fraser Net, 1979–2021.

Appendix C26— Pacific Salmon Commission Chinook Model estimates of landed catch stock composition for Alaska sport with (upper) and without (lower) Alaska hatchery add-on and terminal exclusion, 1979–2021.
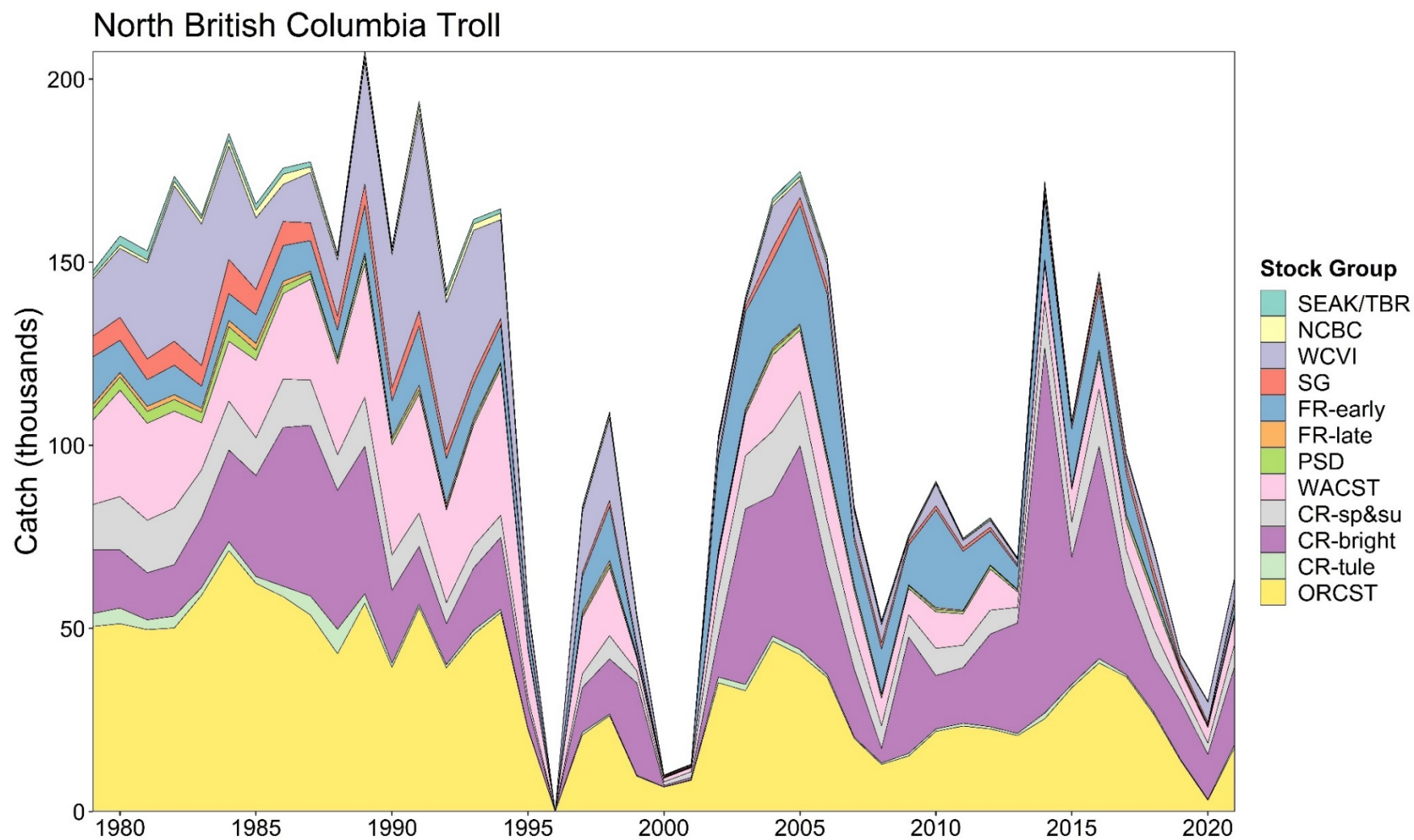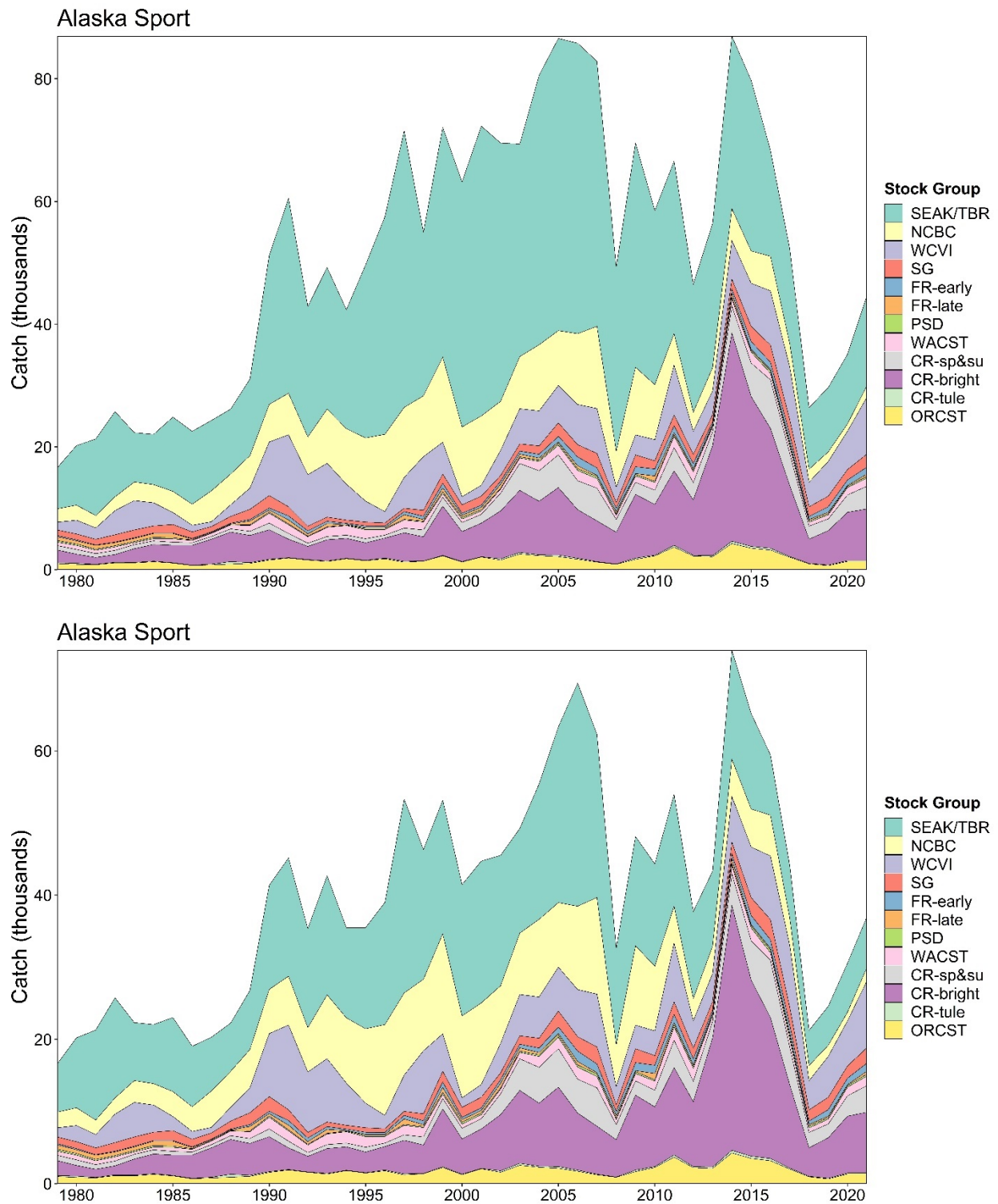
Appendix C28— Pacific Salmon Commission Chinook Model estimates of landed catch stock composition for North British Columbia AABM Sport, 1979–2021.

North British Columbia AABM Sport

Stock Group
- SEAK/TBR
- NCBC
- WCVI
- SG
- FR-early
- FR-late
- PSD
- WACST
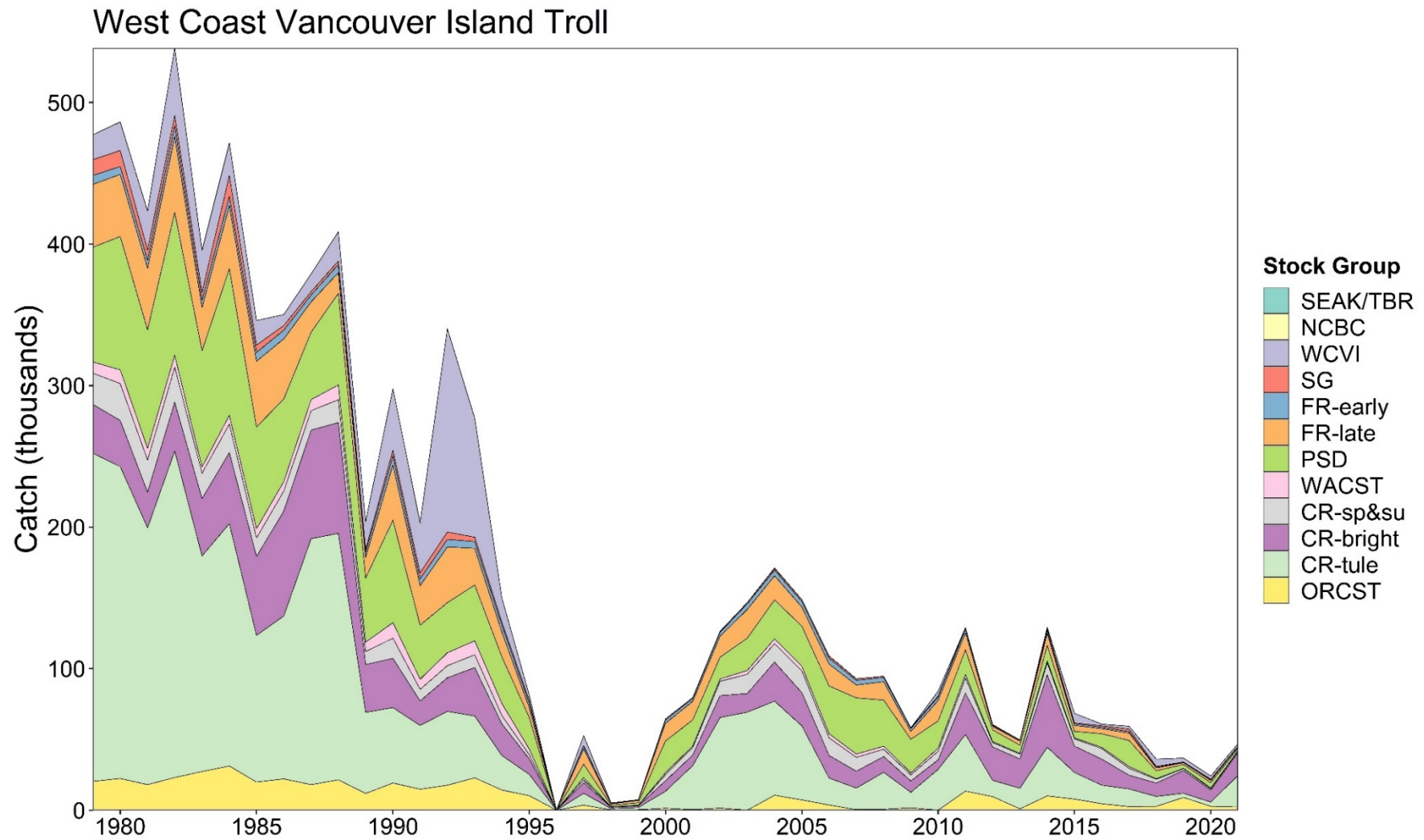- CR-sp&su
- CR-bright
- CR-tule
- ORCST

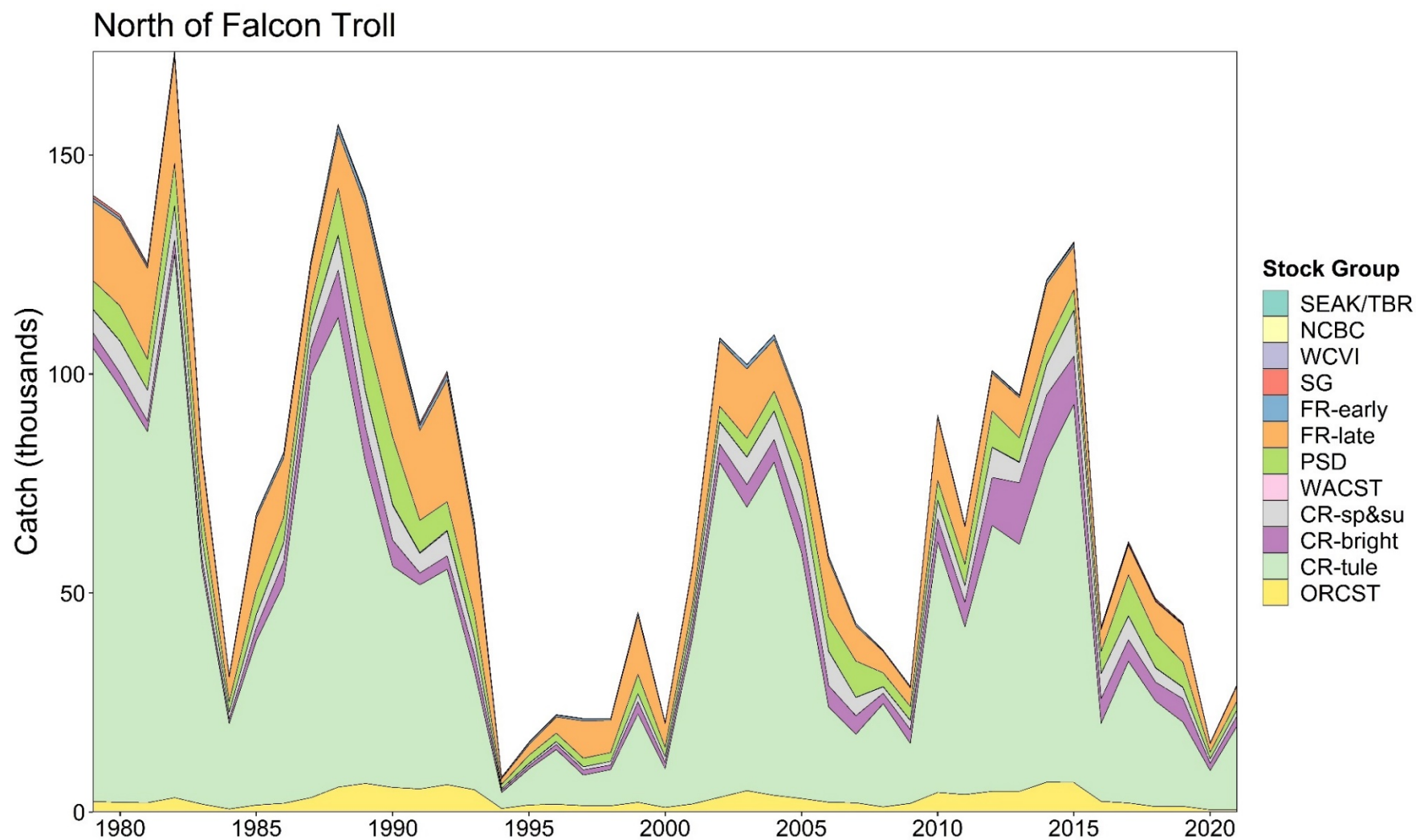*Appendix C29— Pacific Salmon Commission Chinook Model estimates of landed catch stock composition for North British Columbia ISBM Sport 1979–2021.*
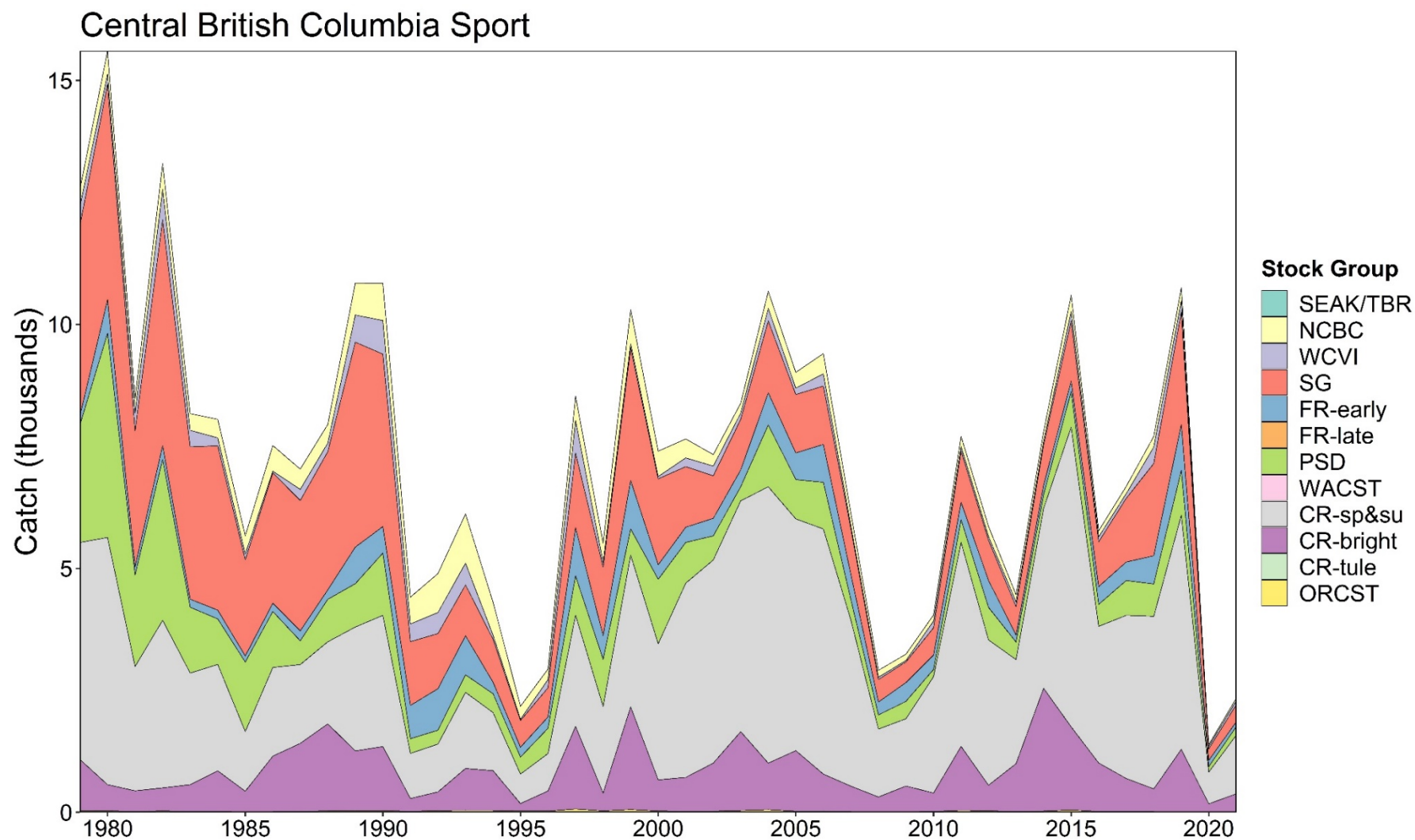
North British Columbia ISBM Sport
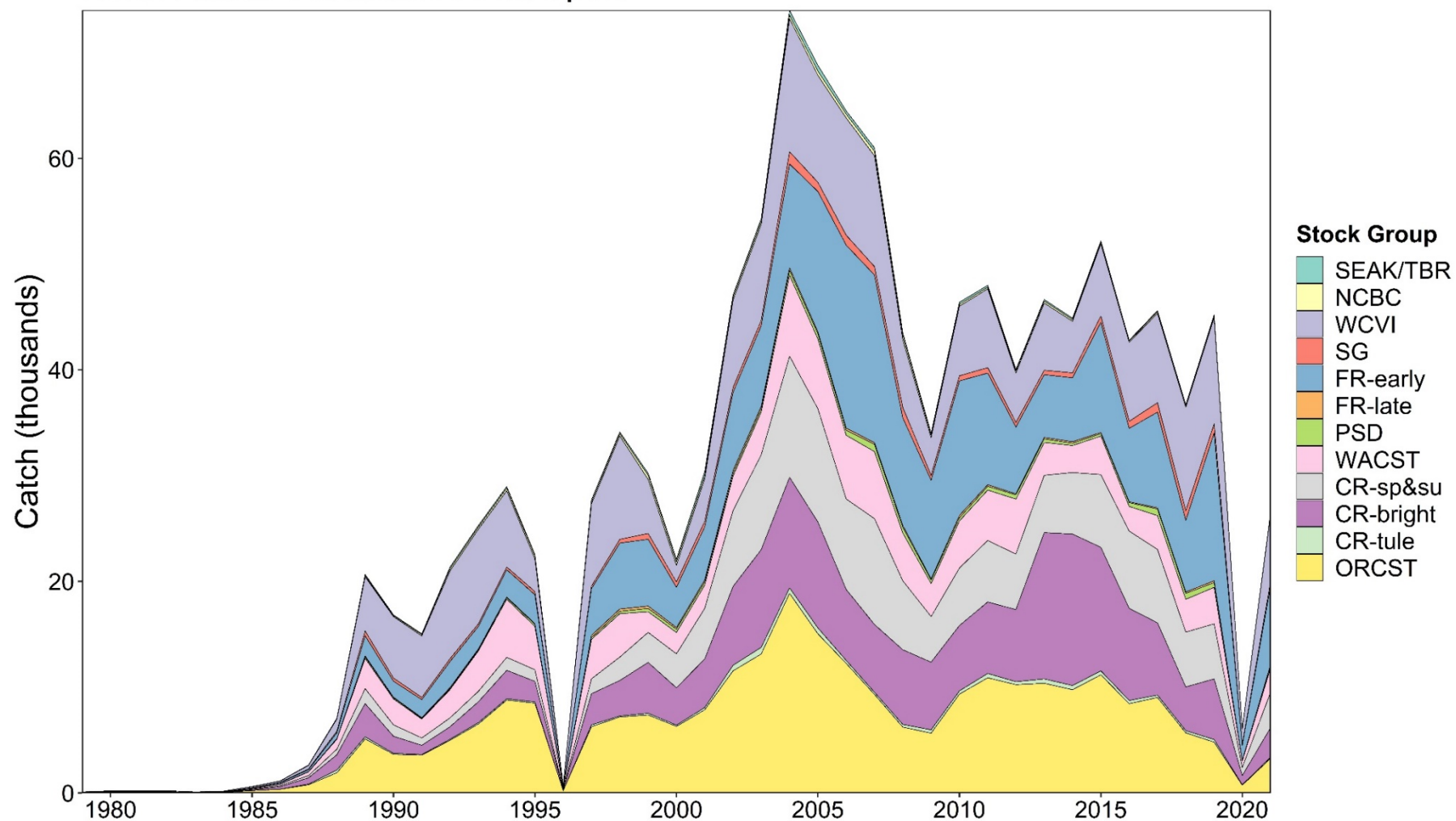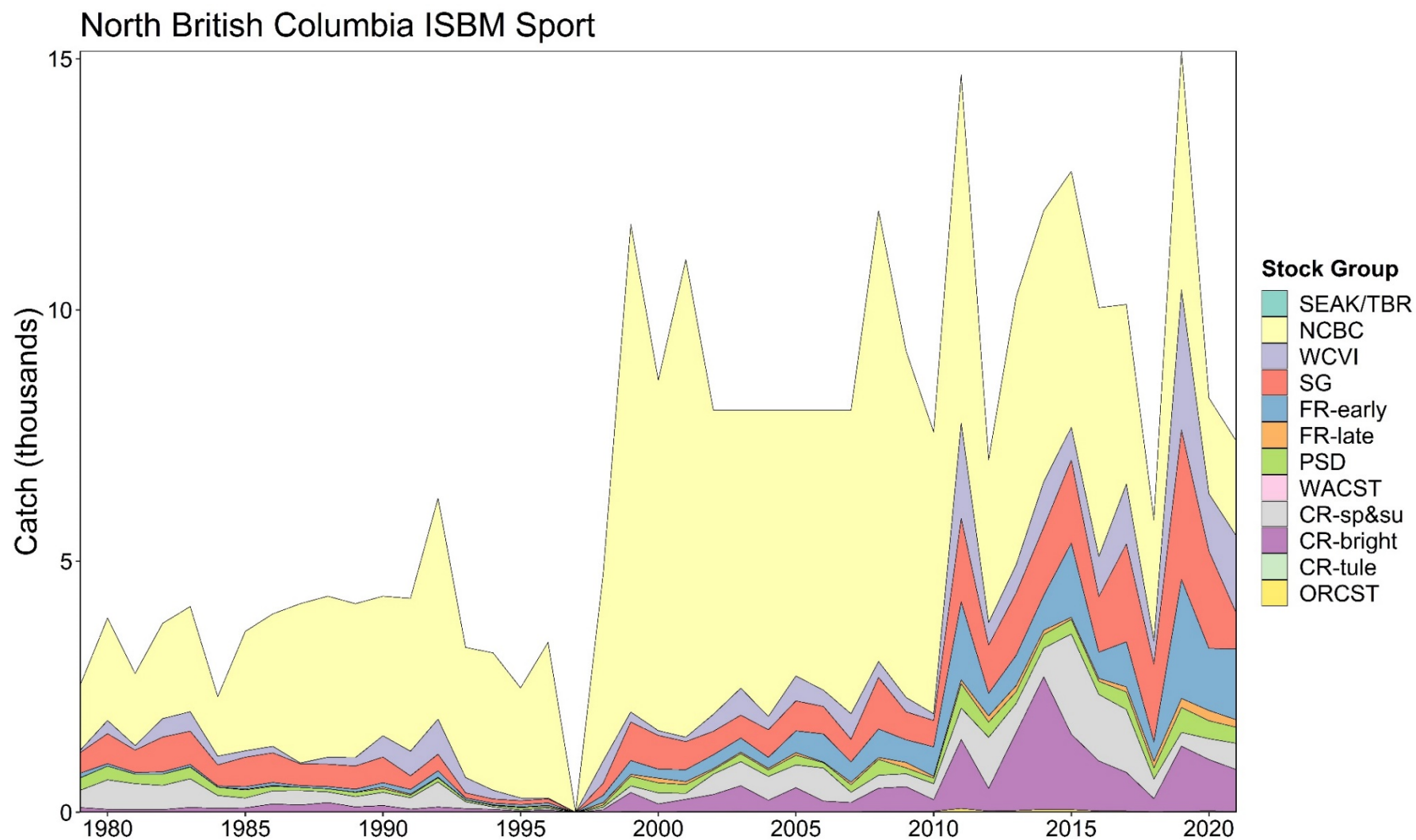
Appendix C30— Pacific Salmon Commission Chinook Model estimates of landed catch stock composition for West Coast Vancouver Island AABM Sport, 1979–2021.


West Coast Vancouver Island AABM Sport
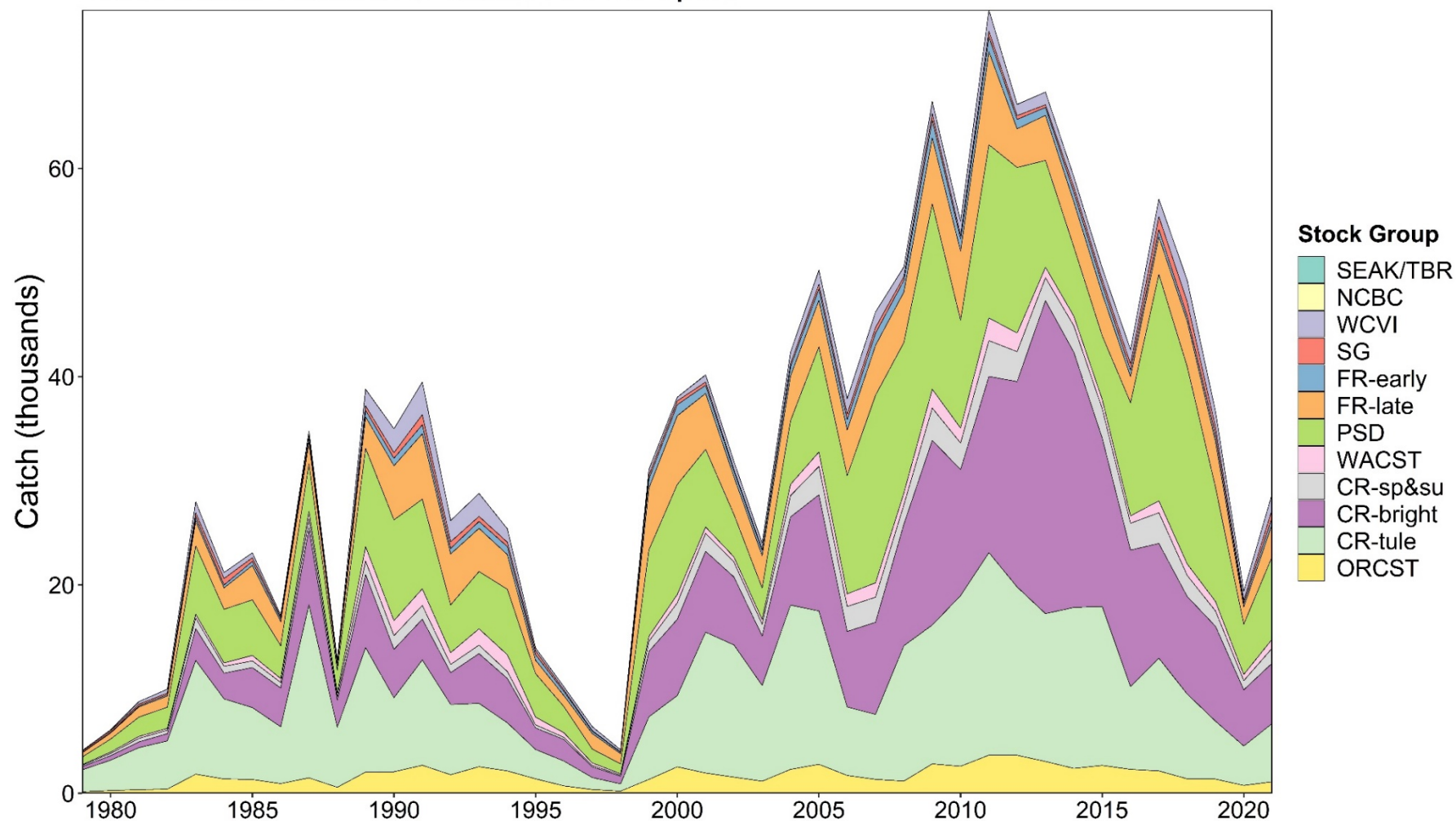
Appendix C31— Pacific Salmon Commission Chinook Model estimates of landed catch stock composition for West Coast Vancouver Island ISBM Sport, 1979–2021.

West Coast Vancouver Island ISBM Sport

Stock Group
- SEAK/TBR
- NCBC
- WCVI
- SG
- FR-early
- FR-late
- PSD
- WACST
- CR-sp&su
- CR-bright
- CR-tule
- ORCST
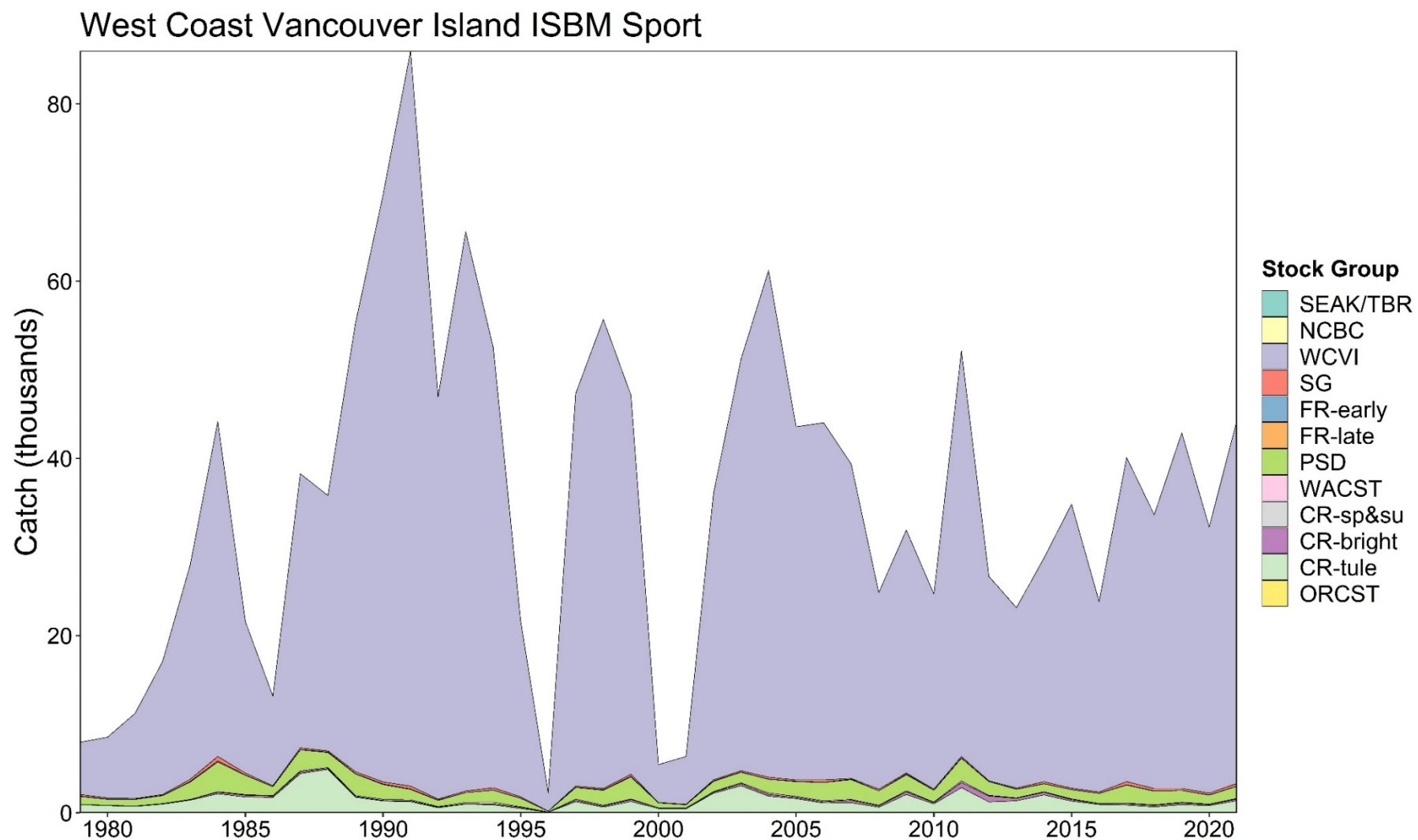
Appendix C32— Pacific Salmon Commission Chinook Model estimates of landed catch stock composition for North of Falcon Sport, 1979–2021.
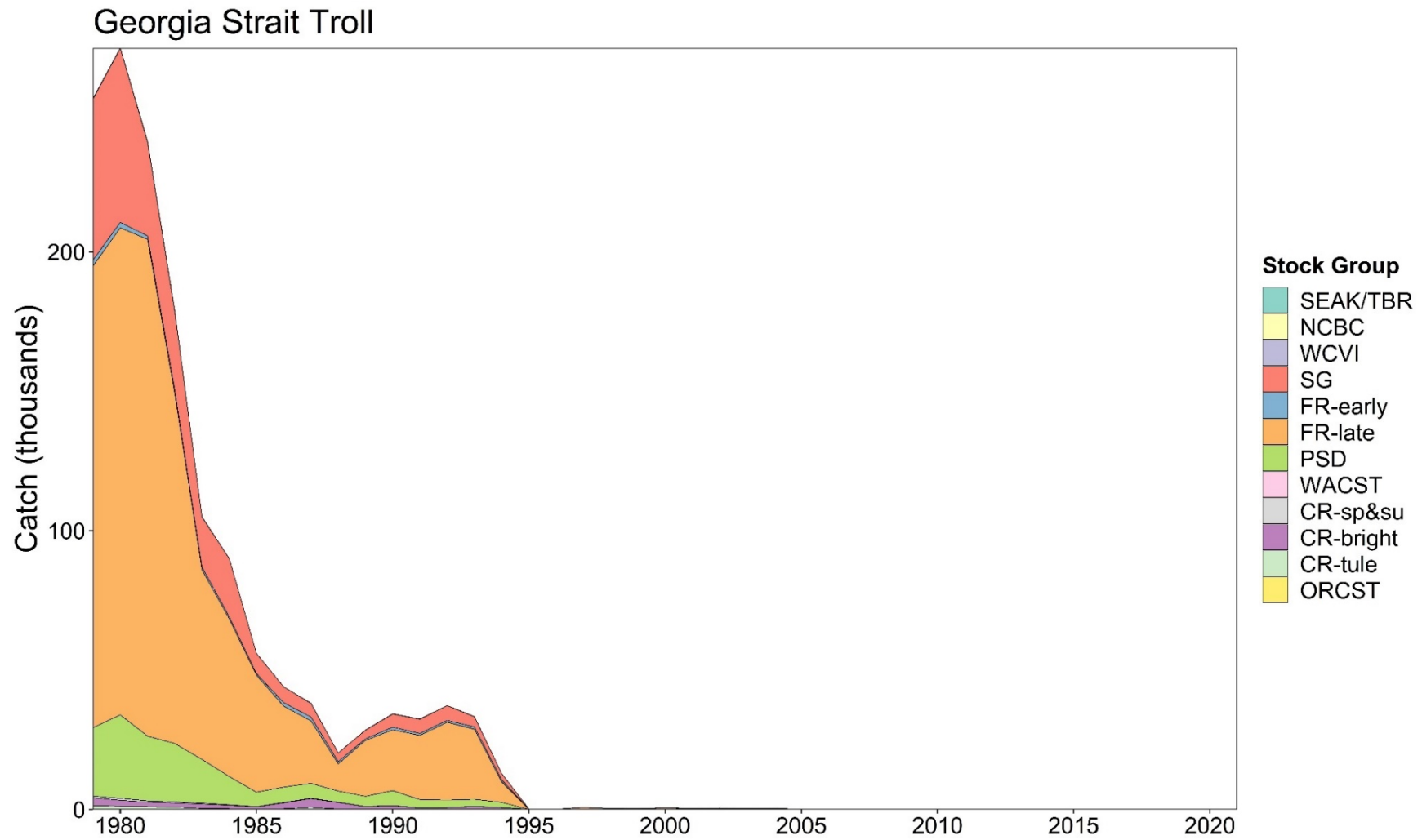

North of Falcon Sport
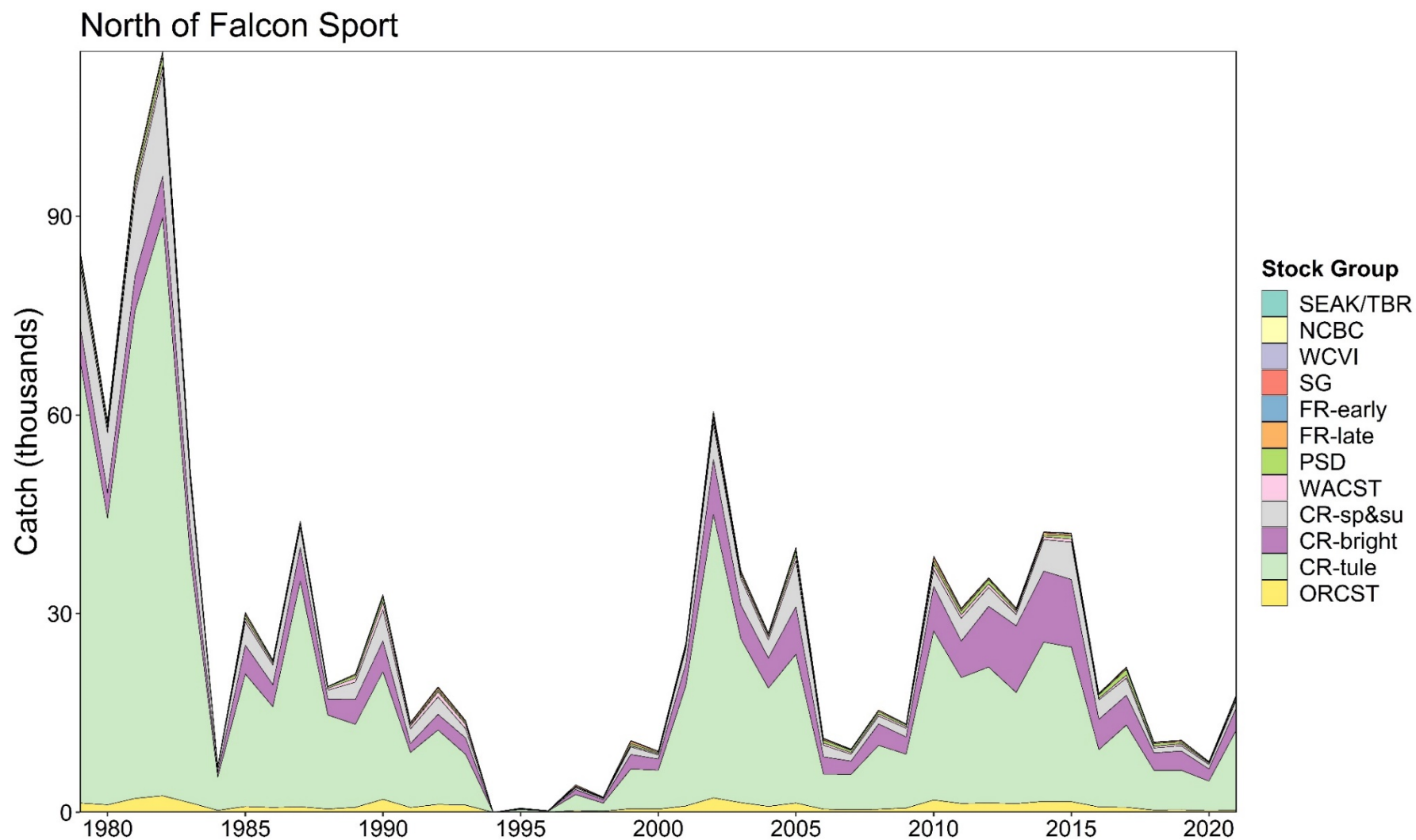
Appendix C33— Pacific Salmon Commission Chinook Model estimates of landed catch stock composition for South of Falcon Sport, 1979–2021.
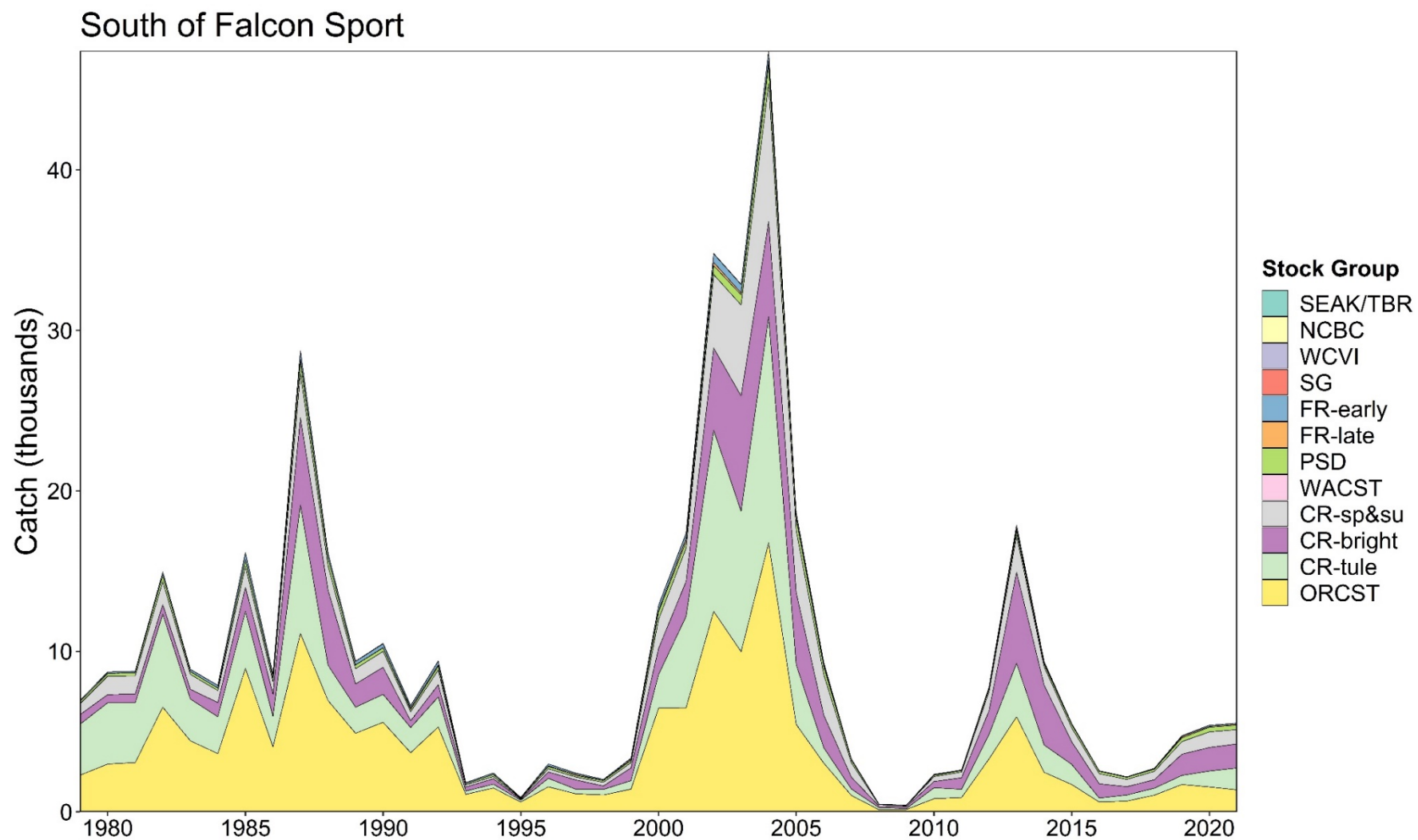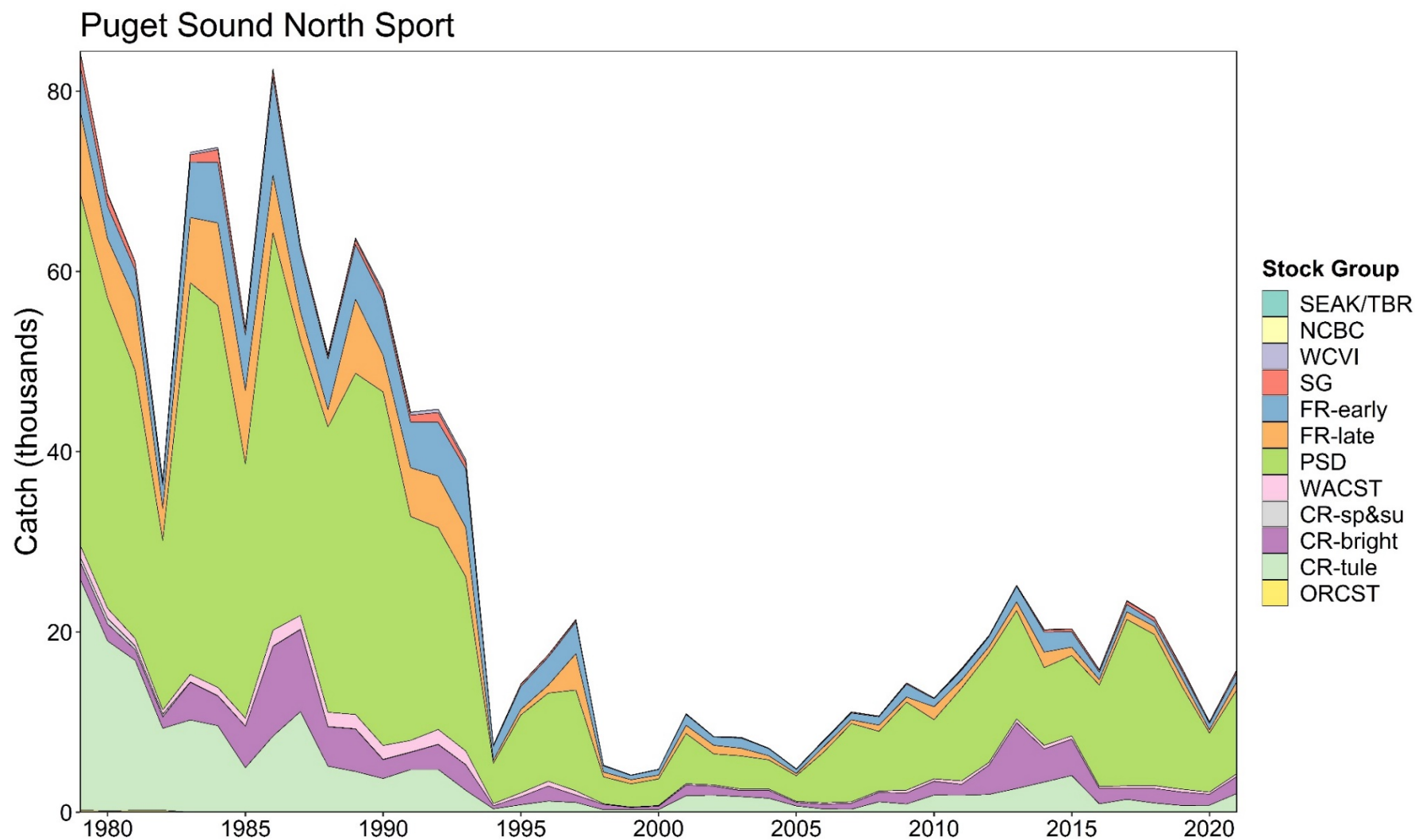
Appendix C35— Pacific Salmon Commission Chinook Model estimates of landed catch stock composition for Puget Sound Other Sport, 1979–2021.

Puget Sound Other Sport
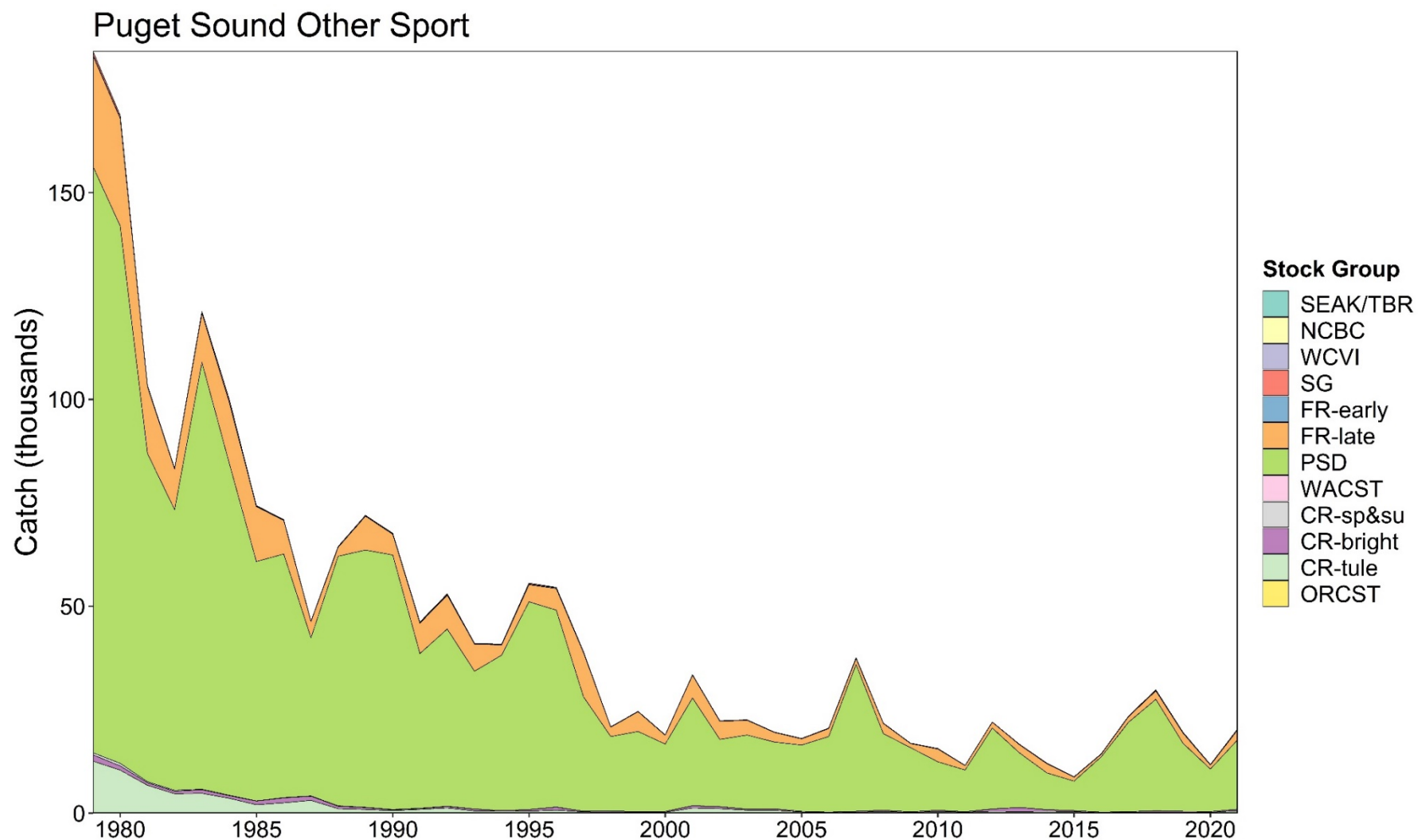
Appendix C36— Pacific Salmon Commission Chinook Model estimates of landed catch stock composition for Terminal Yukon Alsek Freshwater Net, 1979–2021.
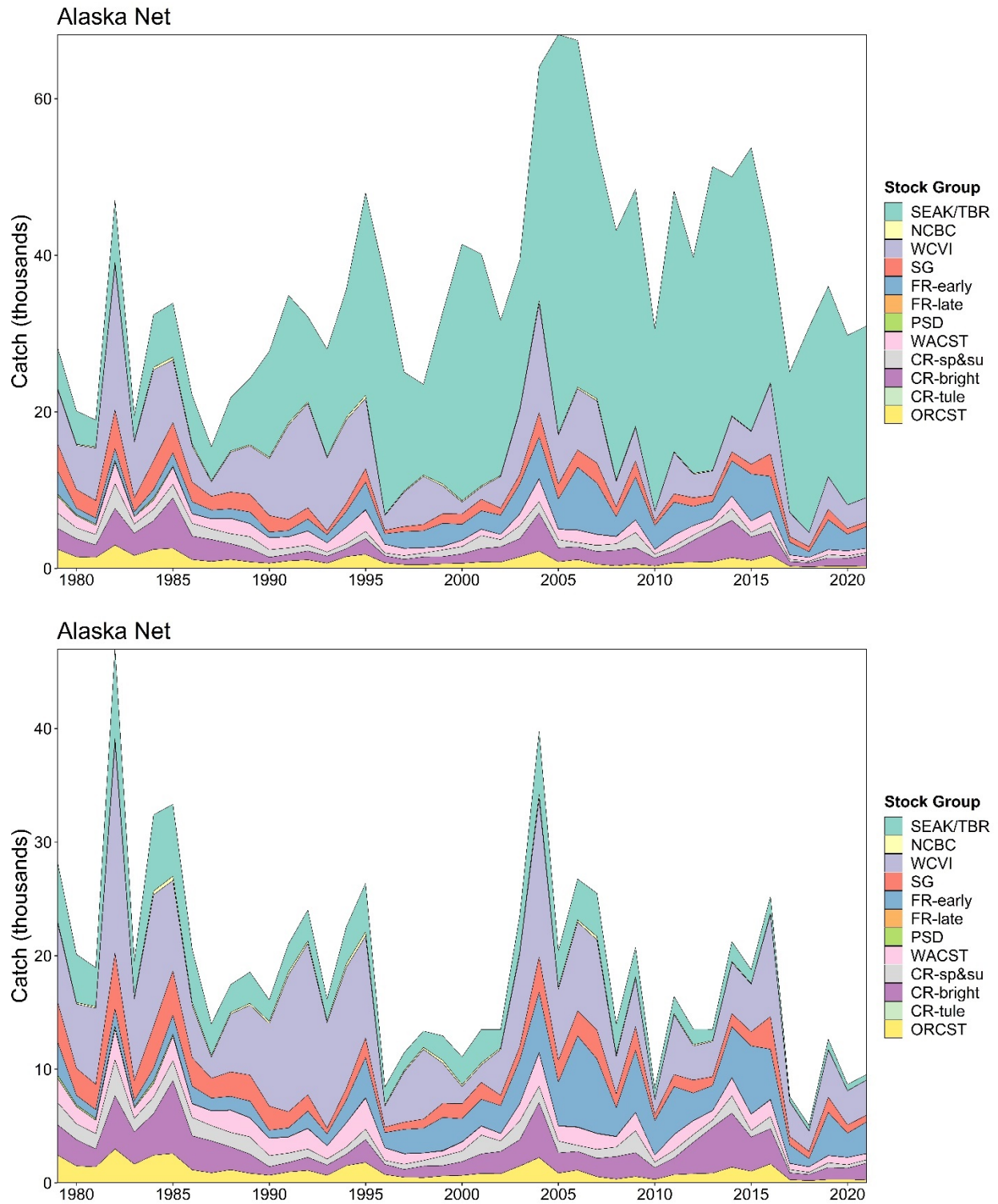

Yukon Yakutat Freshwater Net
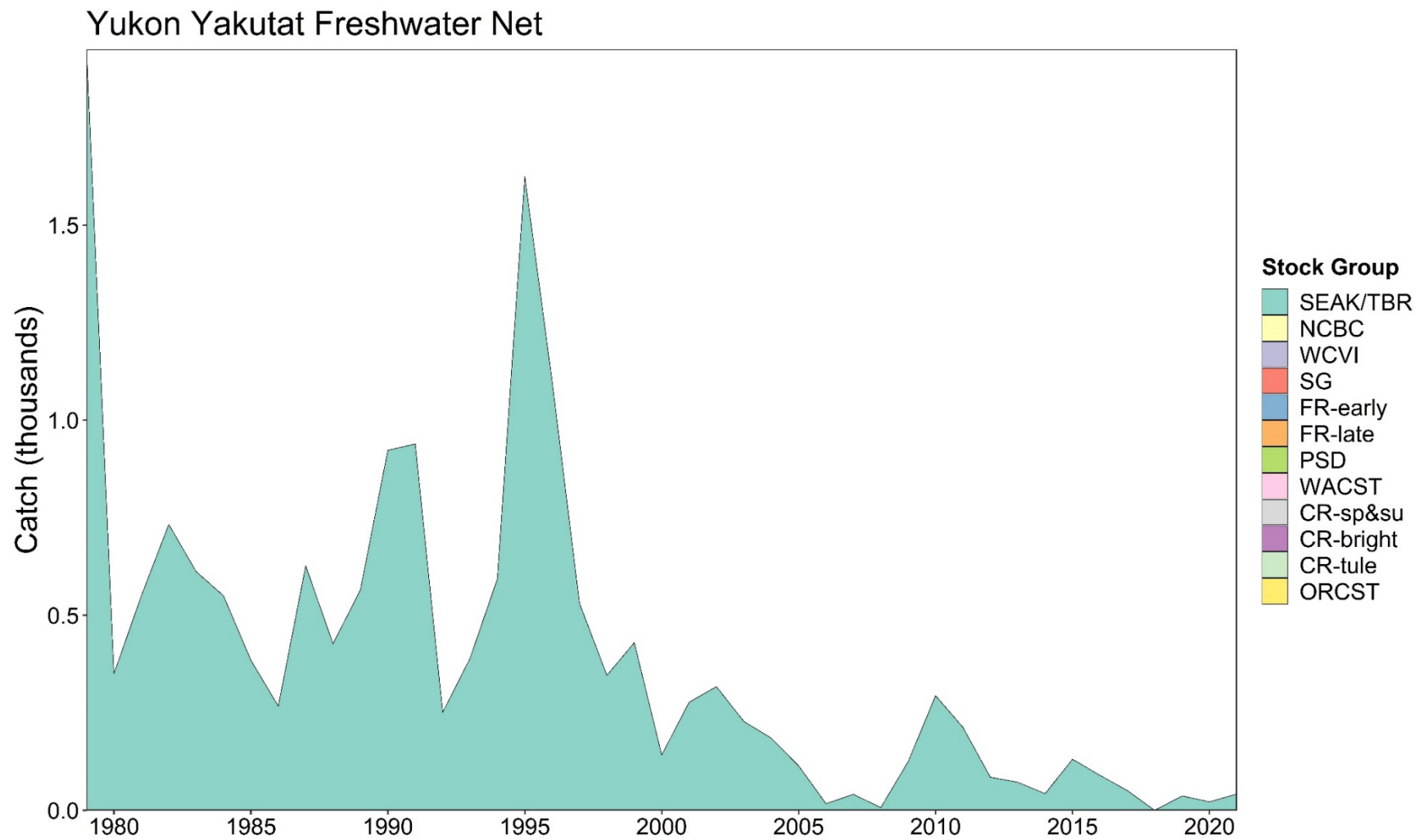
Appendix C37— Pacific Salmon Commission Chinook Model estimates of landed catch stock composition for Strait of Georgia Sport, 1979–2021.
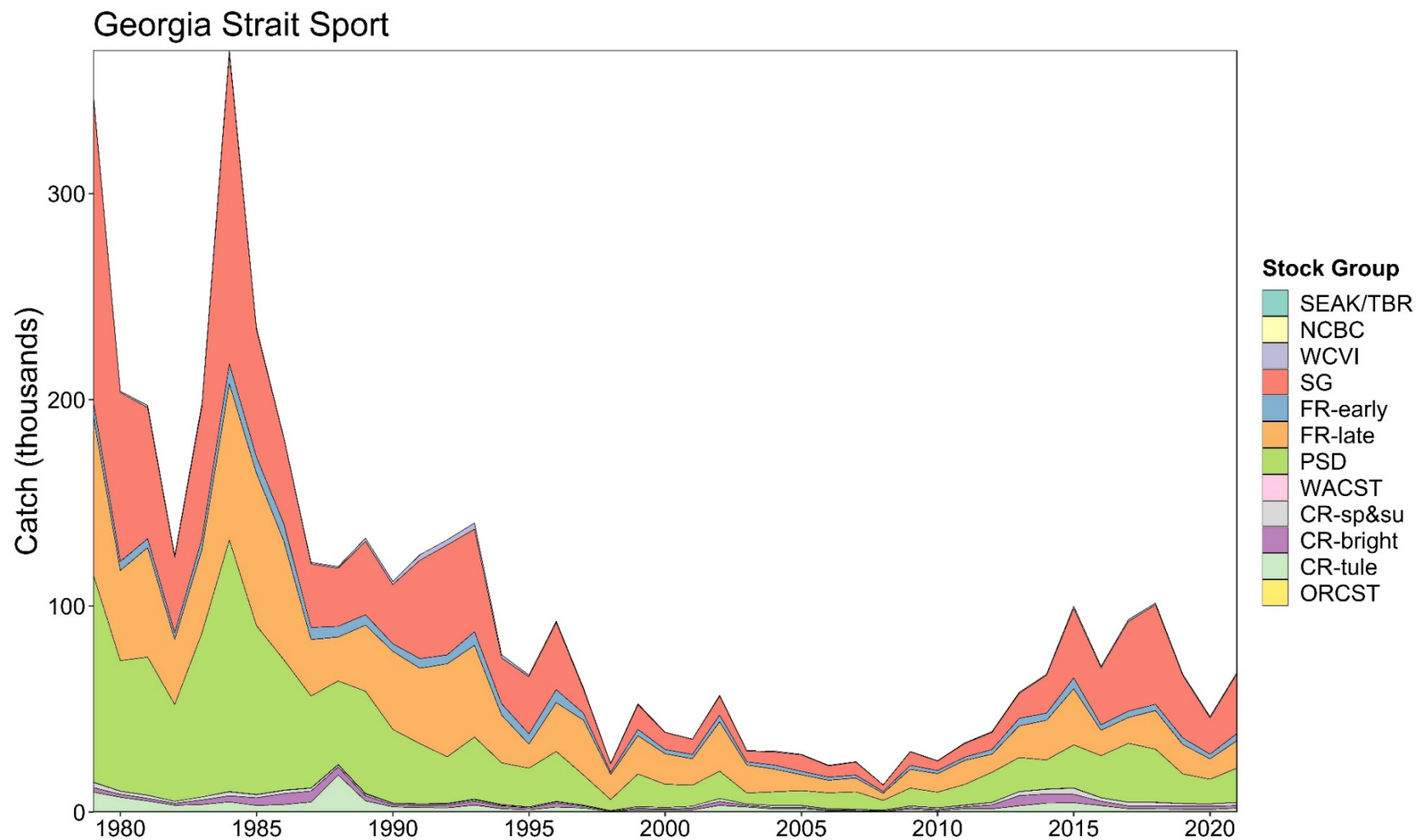
Appendix C38— Pacific Salmon Commission Chinook Model estimates of landed catch stock composition for British Columbia Juan De Fuca Sport, 1979–2021.

British Columbia Juan De Fuca Sport

Stock Group
- SEAK/TBR
- NCBC
- WCVI
- SG
- FR-early
- FR-late
- PSD
- WACST
- CR-sp&su
- CR-bright
- CR-tule
- ORCST

Appendix C39— Pacific Salmon Commission Chinook Model estimates of landed catch stock composition for Columbia River Sport, 1979–2021.

Columbia River Sport
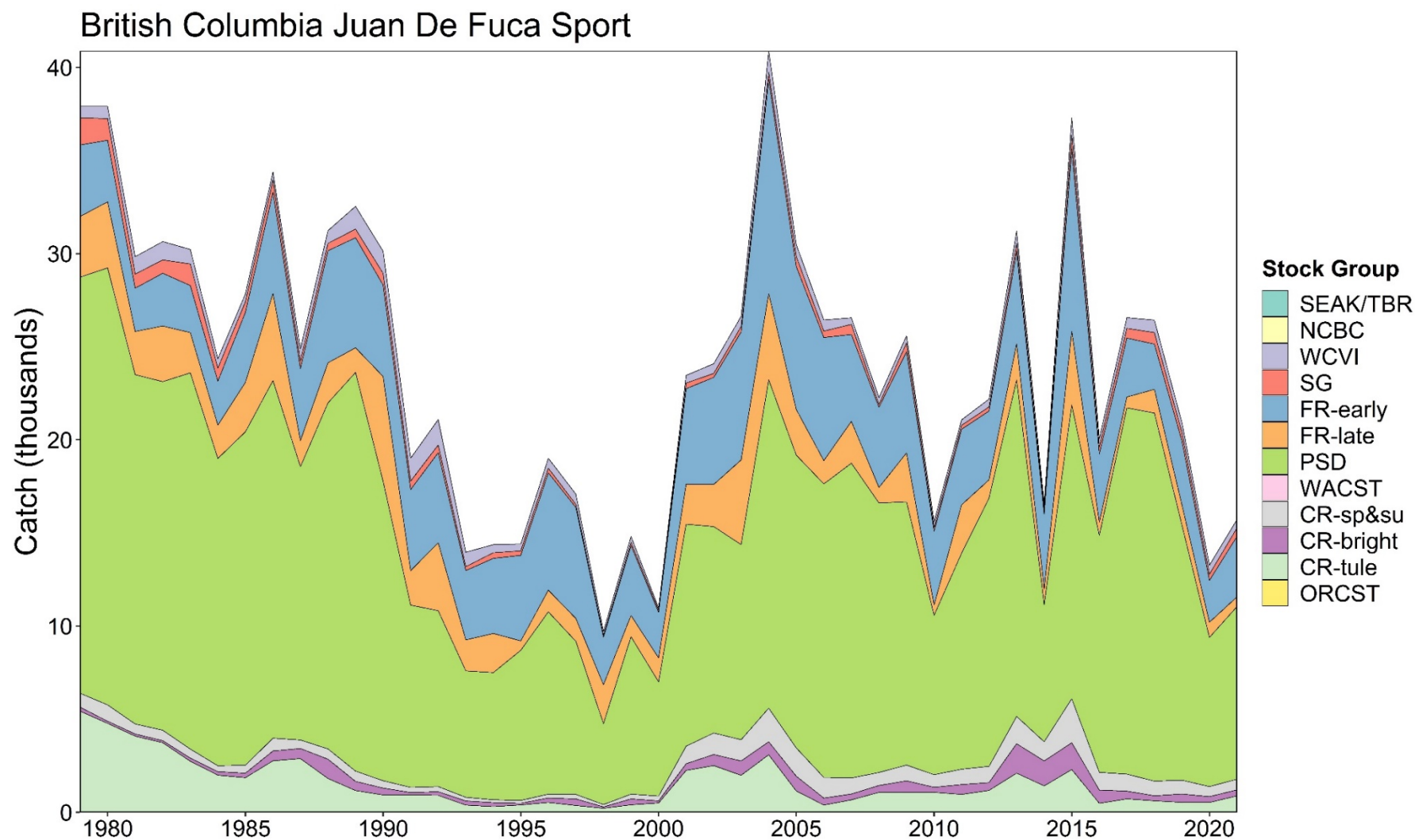
Stock Group
- SEAK/TBR
- NCBC
- WCVI
- SG
- FR-early
- FR-late
- PSD
- WACST
- CR-sp&su
- CR-bright
- CR-tule
- ORCST
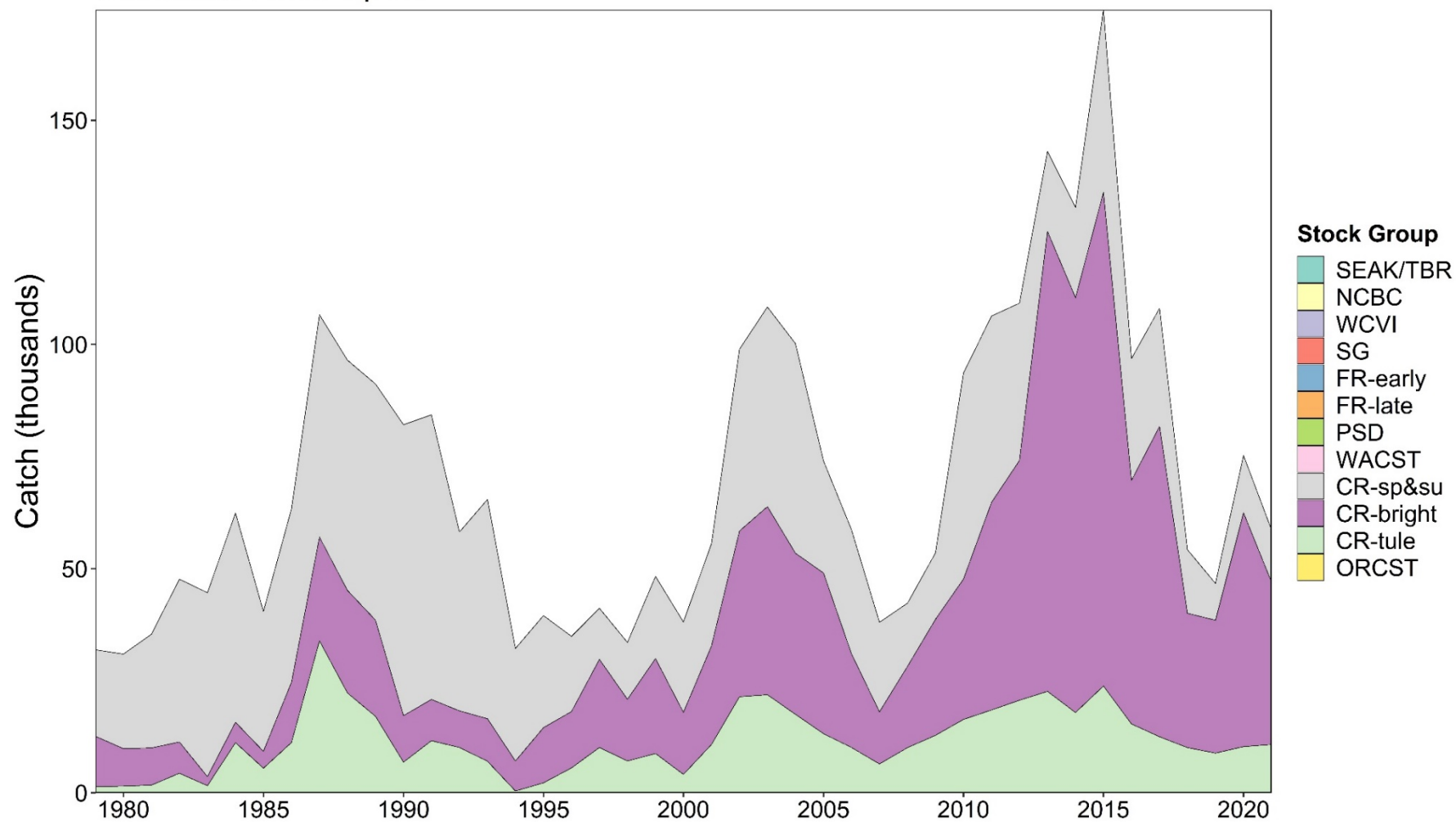
Appendix C40— Pacific Salmon Commission Chinook Model estimates of landed catch stock composition for Alaska Transboundary River Terminal Sport, 1979–2021.

Alaska Transboundary Terminal Sport
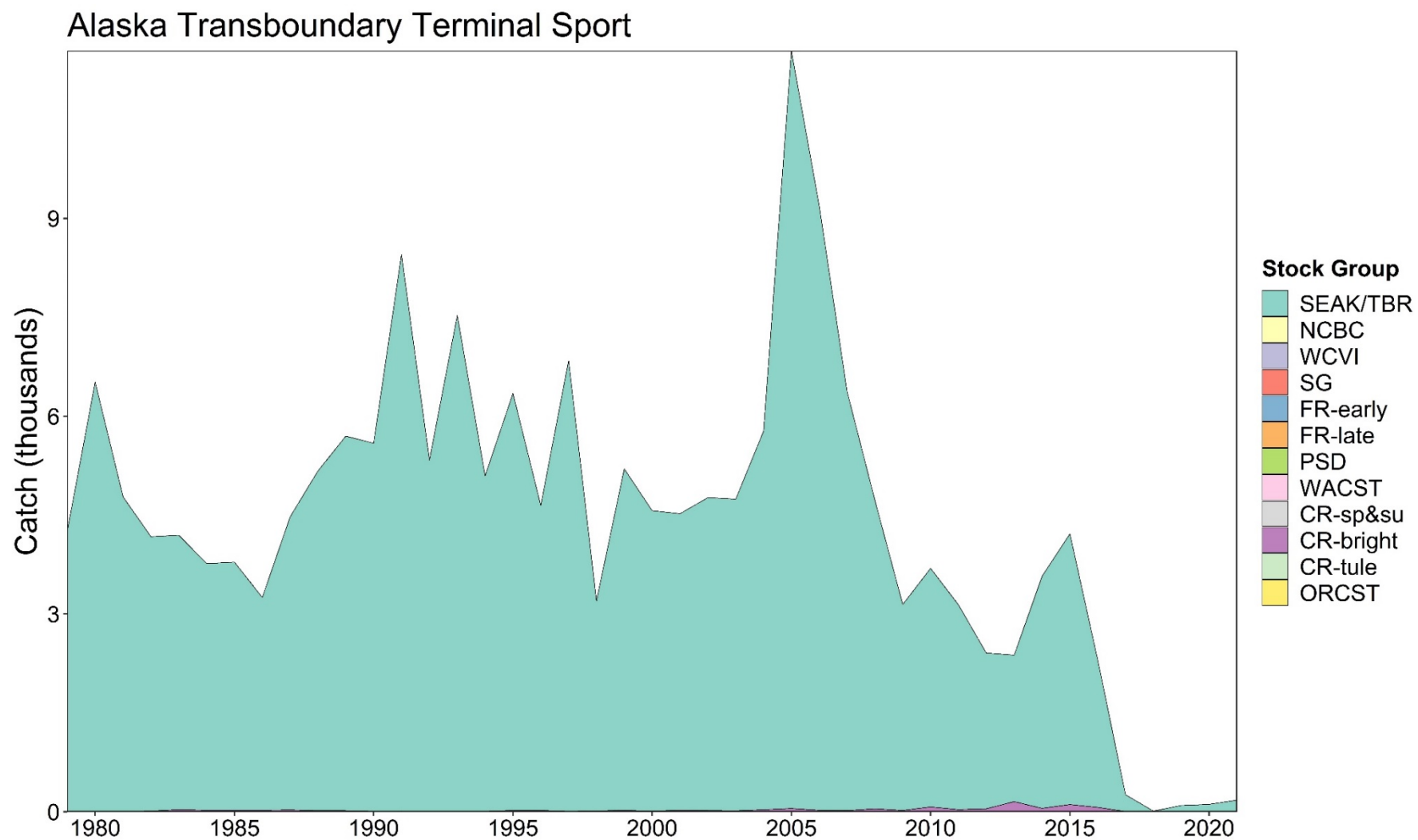
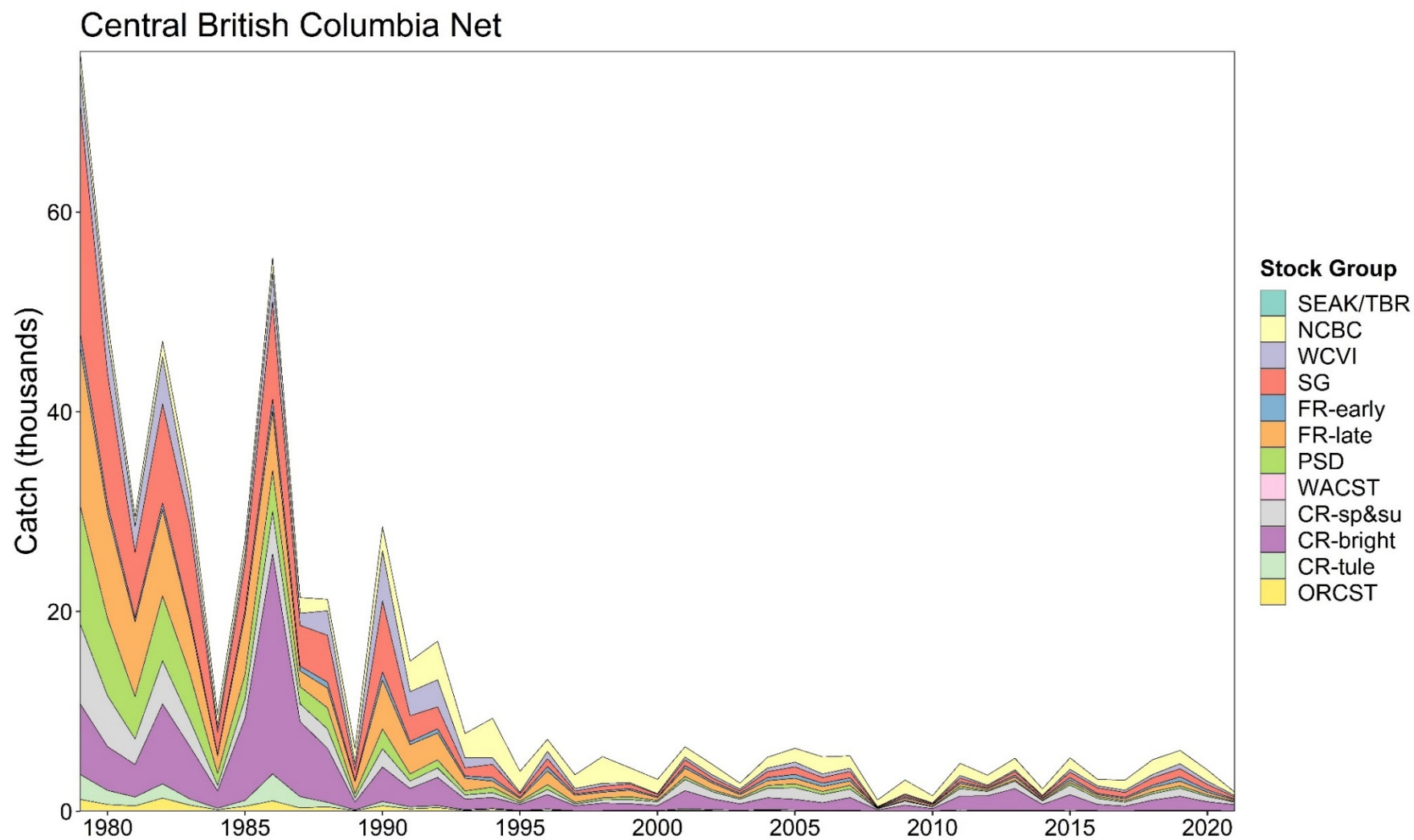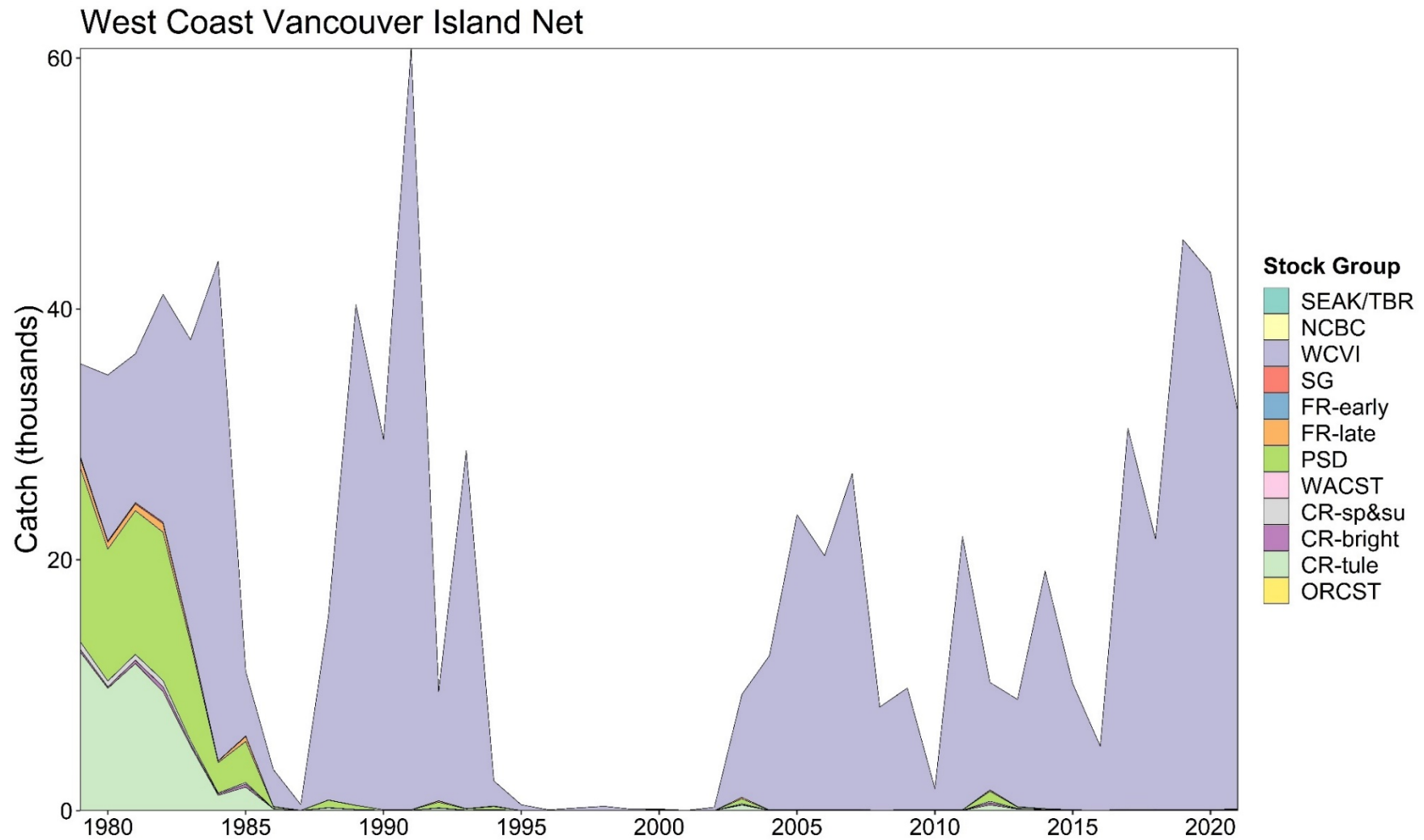*Appendix C41— Pacific Salmon Commission Chinook Model estimates of landed catch stock composition for North British Columbia Freshwater Sport, 1979–2021.*
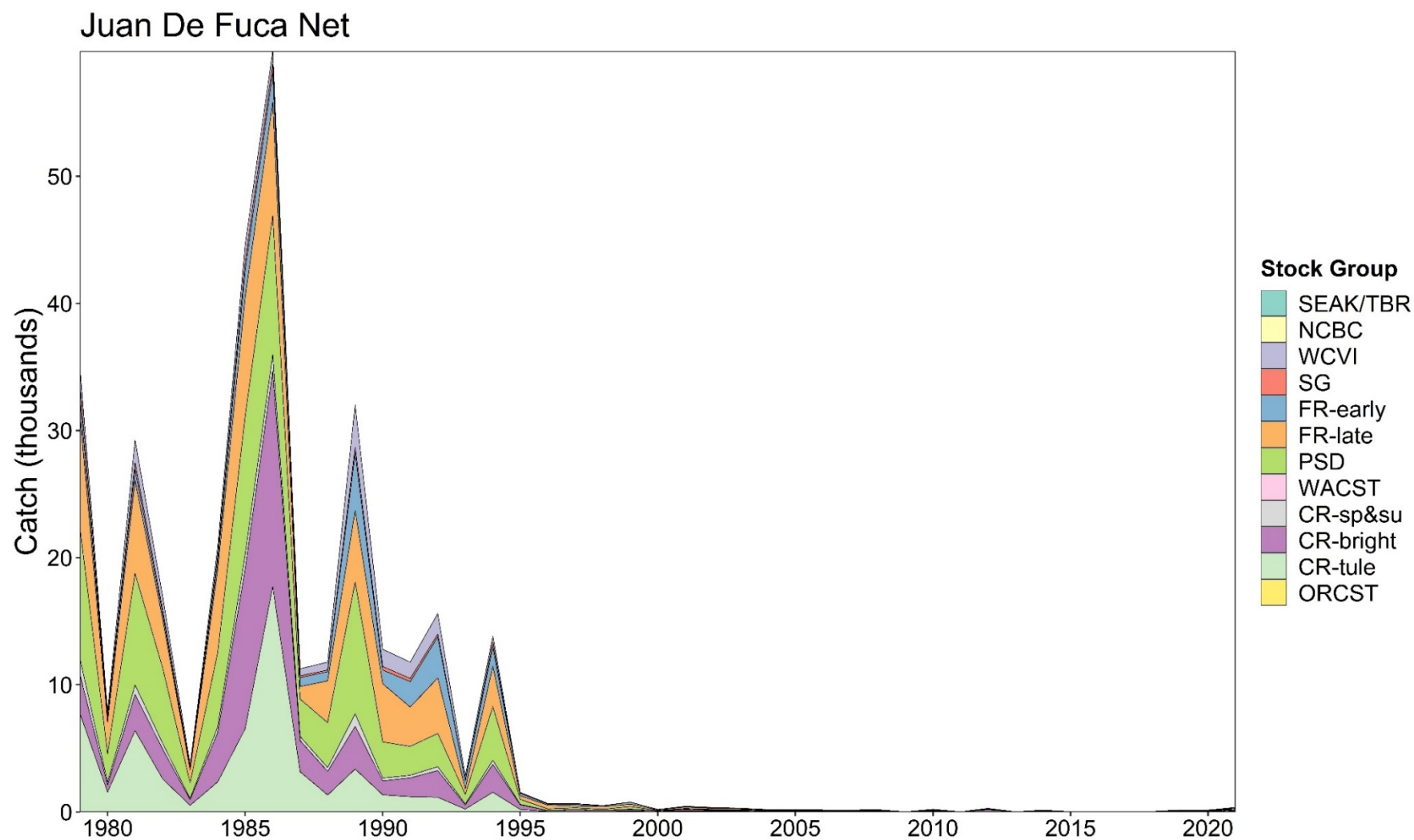

North British Columbia Freshwater Sport

Central British Columbia Freshwater Sport

Stock Group
- SEAK/TBR
- NCBC
- WCVI
- SG
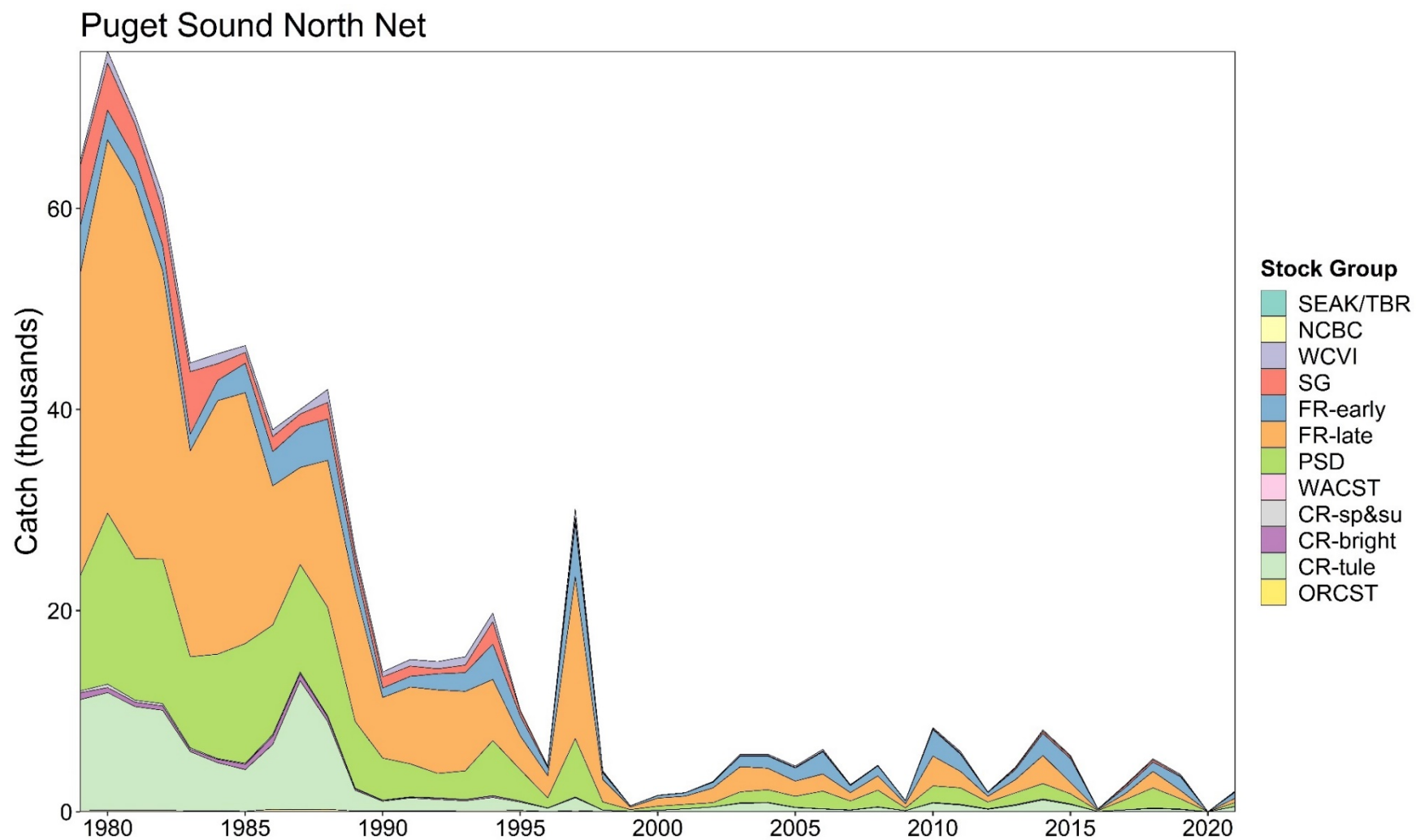- FR-early
- FR-late
- PSD
- WACST
- CR-sp&su
- CR-bright
- CR-tule
- ORCST
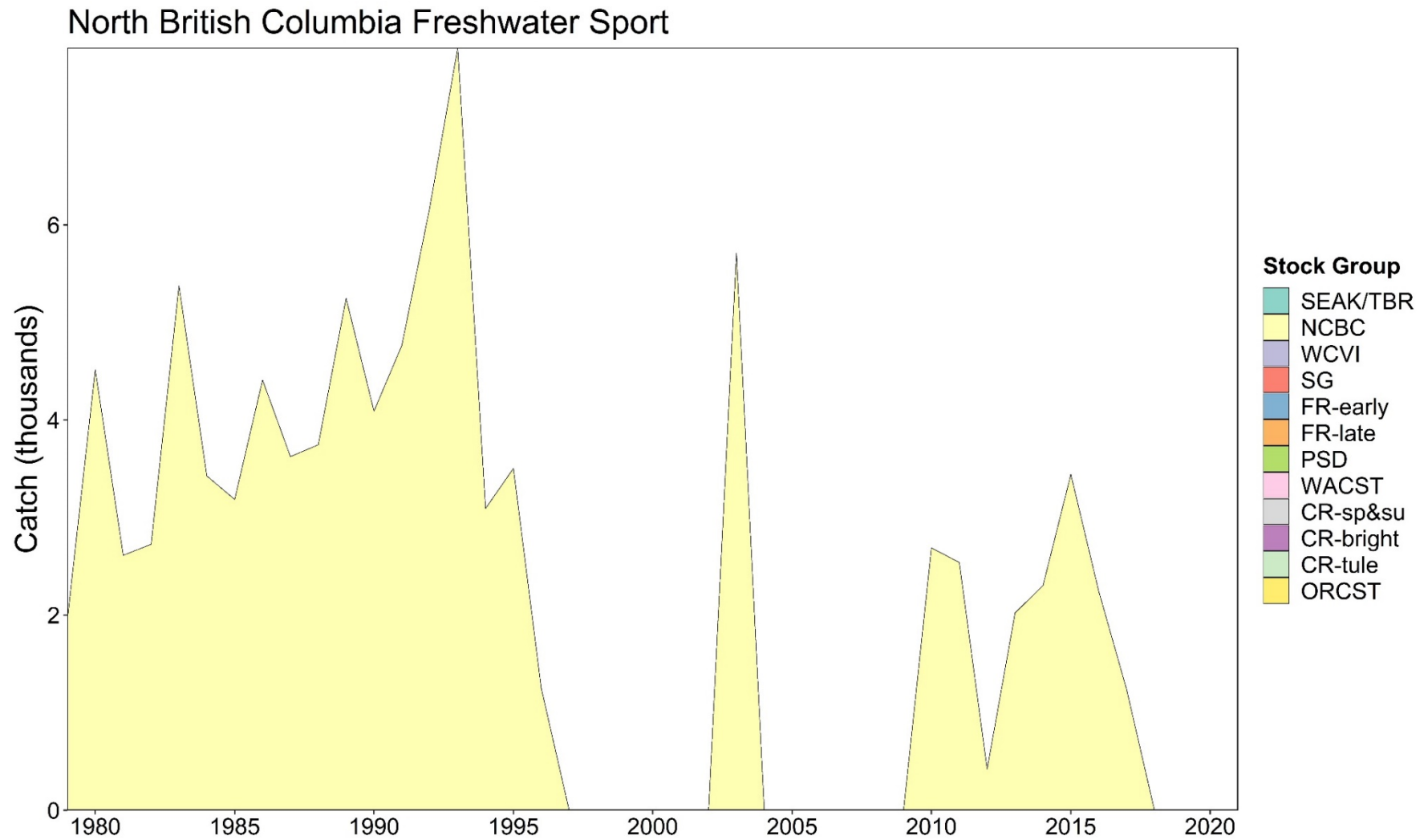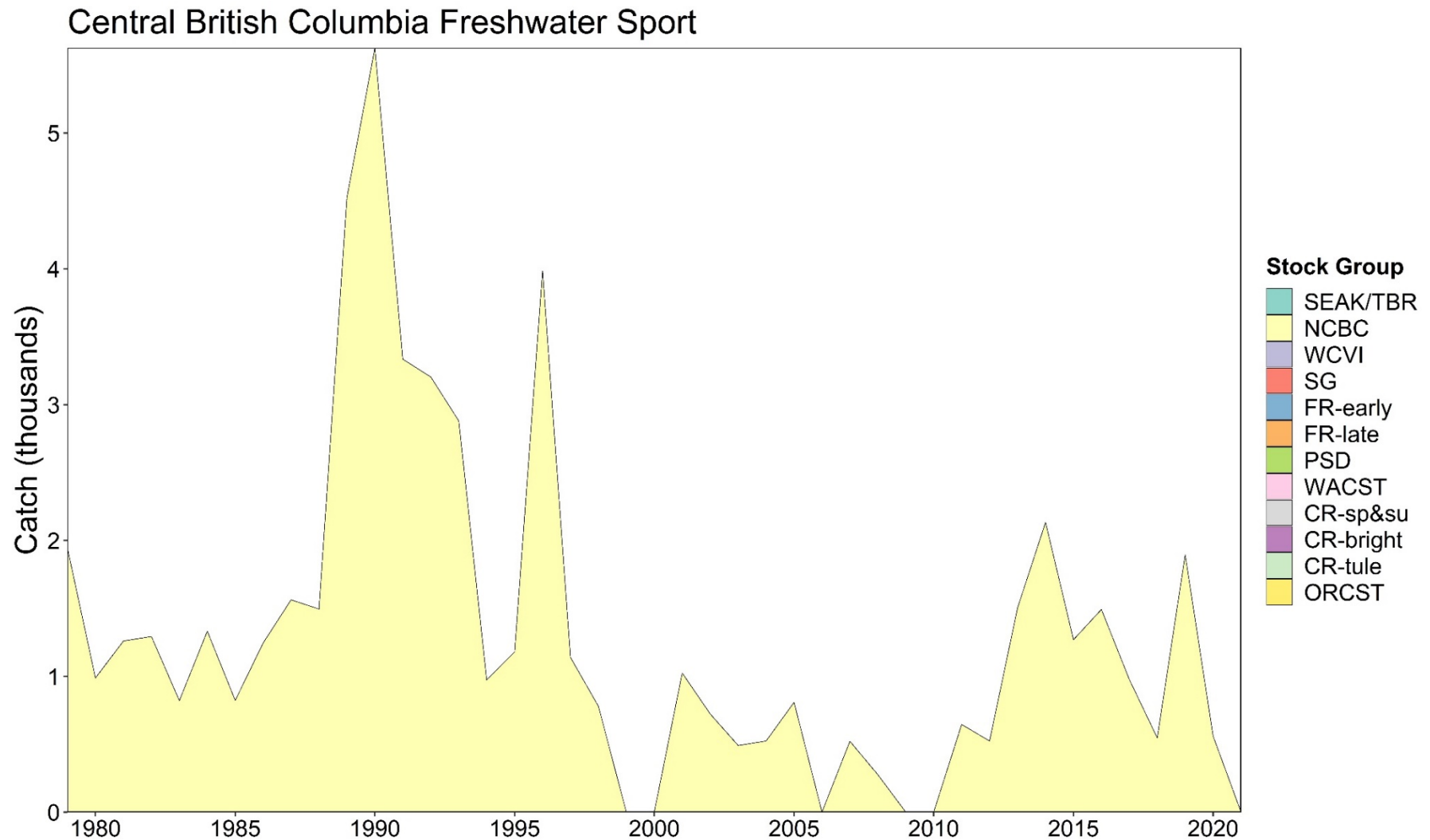
Appendix C43— Pacific Salmon Commission Chinook Model estimates of landed catch stock composition for West Coast Vancouver Island Freshwater Sport, 1979–2021.

West Coast Vancouver Island Freshwater Sport

Stock Group
- SEAK/TBR
- NCBC
- WCVI
- SG
- FR-early
- FR-late
- PSD
- WACST
- CR-sp&su
- CR-bright
- CR-tule
- ORCST
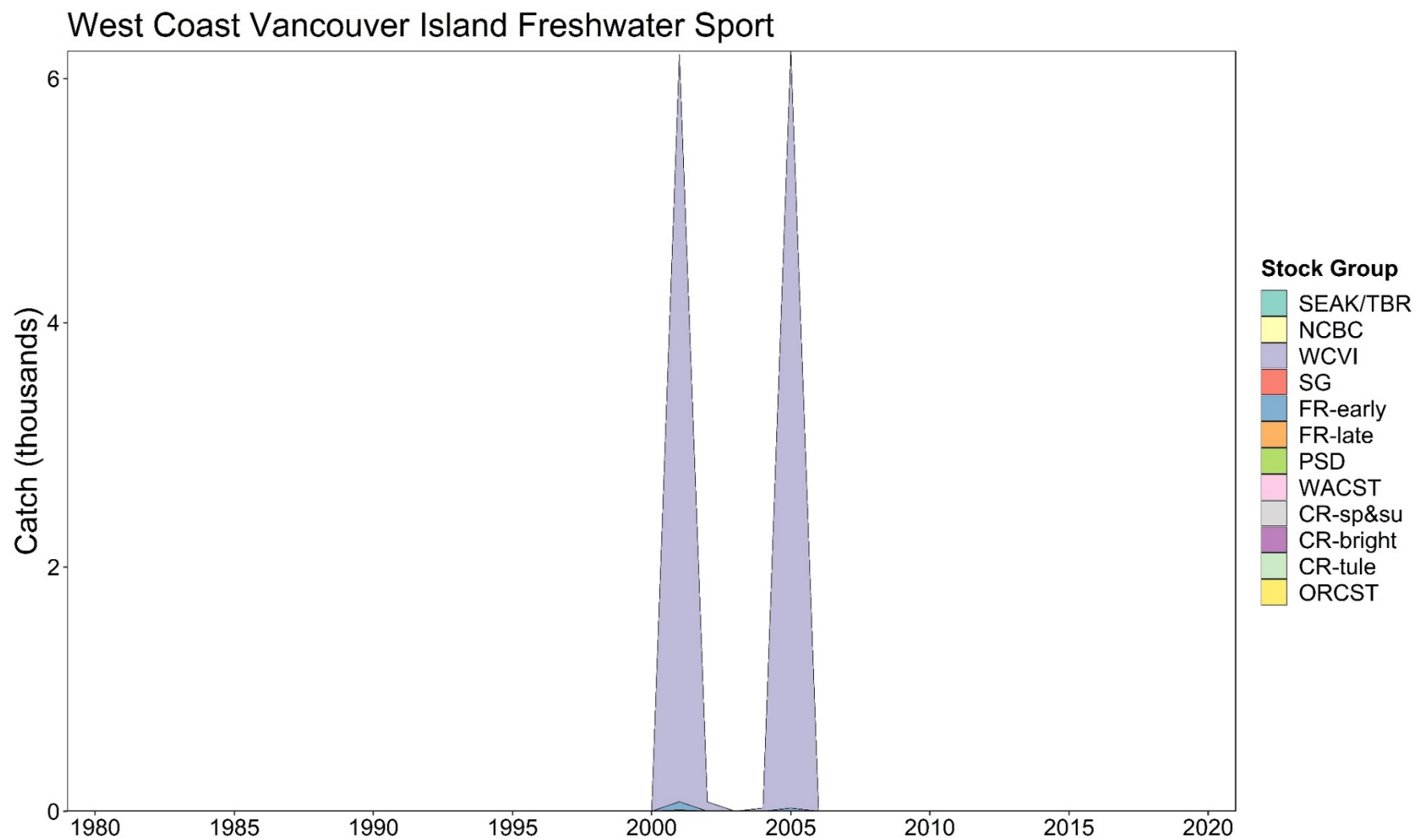
Appendix C44— Pacific Salmon Commission Chinook Model estimates of landed catch stock composition for Fraser River Freshwater Sport, 1979–2021.
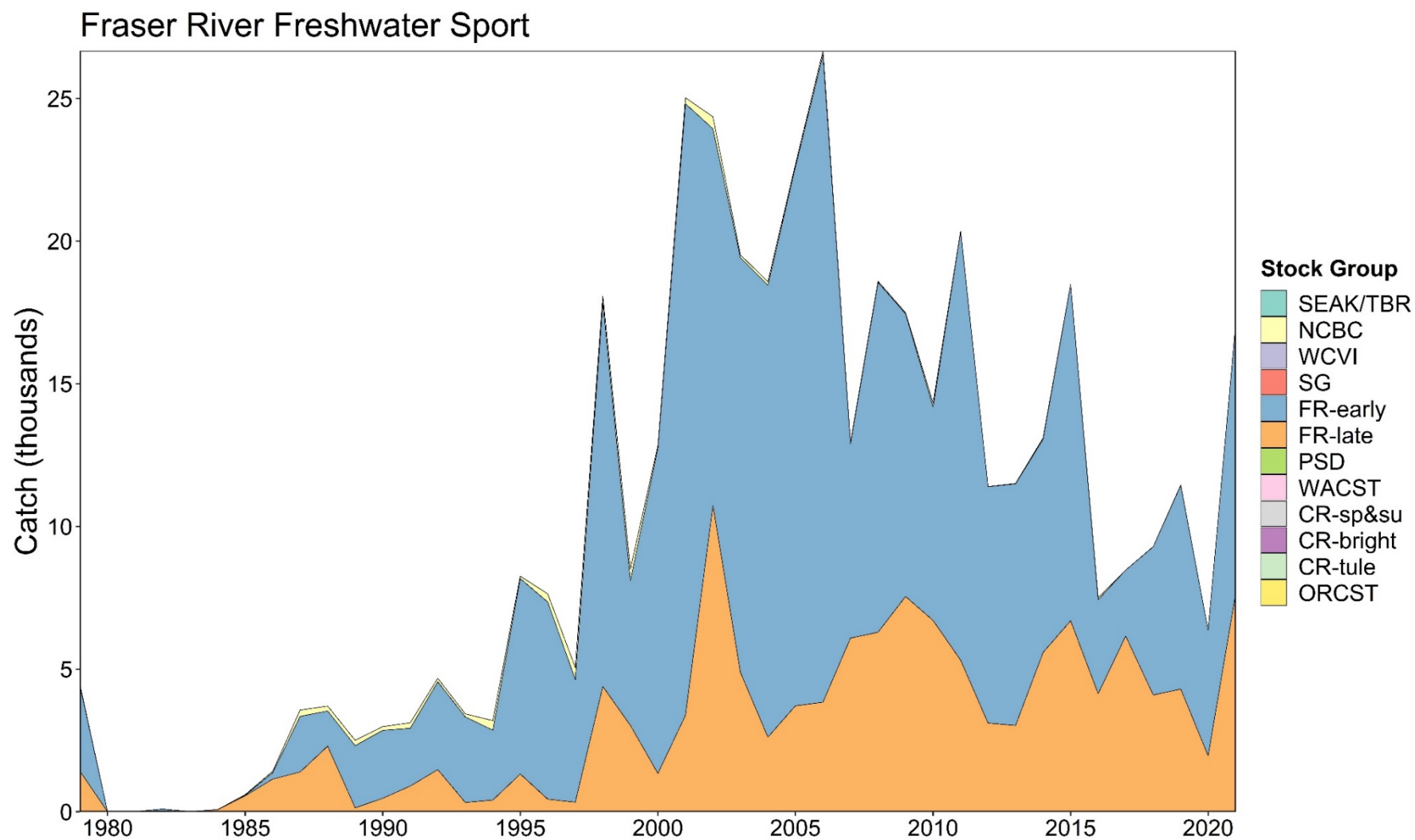
Appendix C45— Pacific Salmon Commission Chinook Model estimates of landed catch stock composition for Strait of Georgia Freshwater Sport, 1979–2021.

Georgia Strait Freshwater Sport
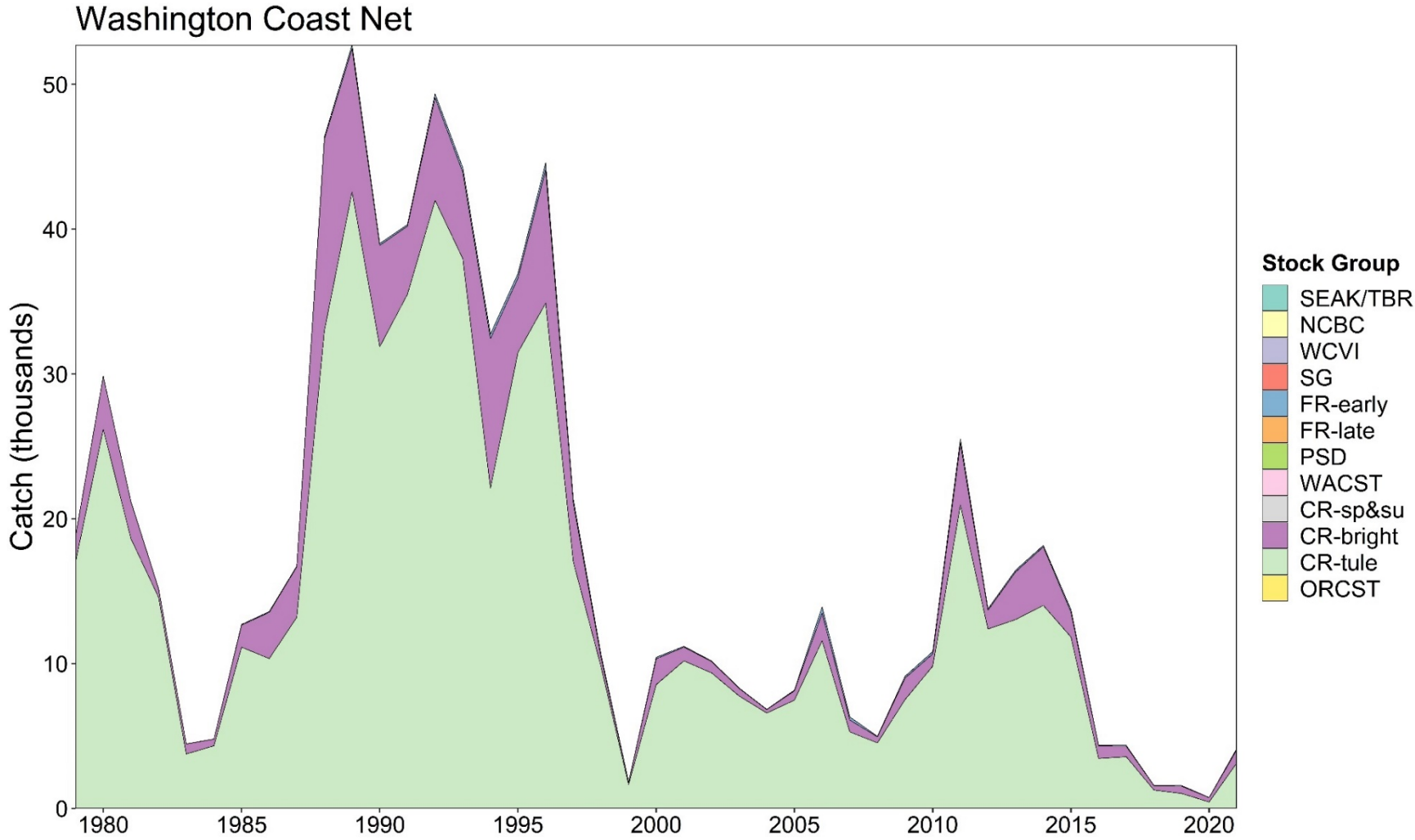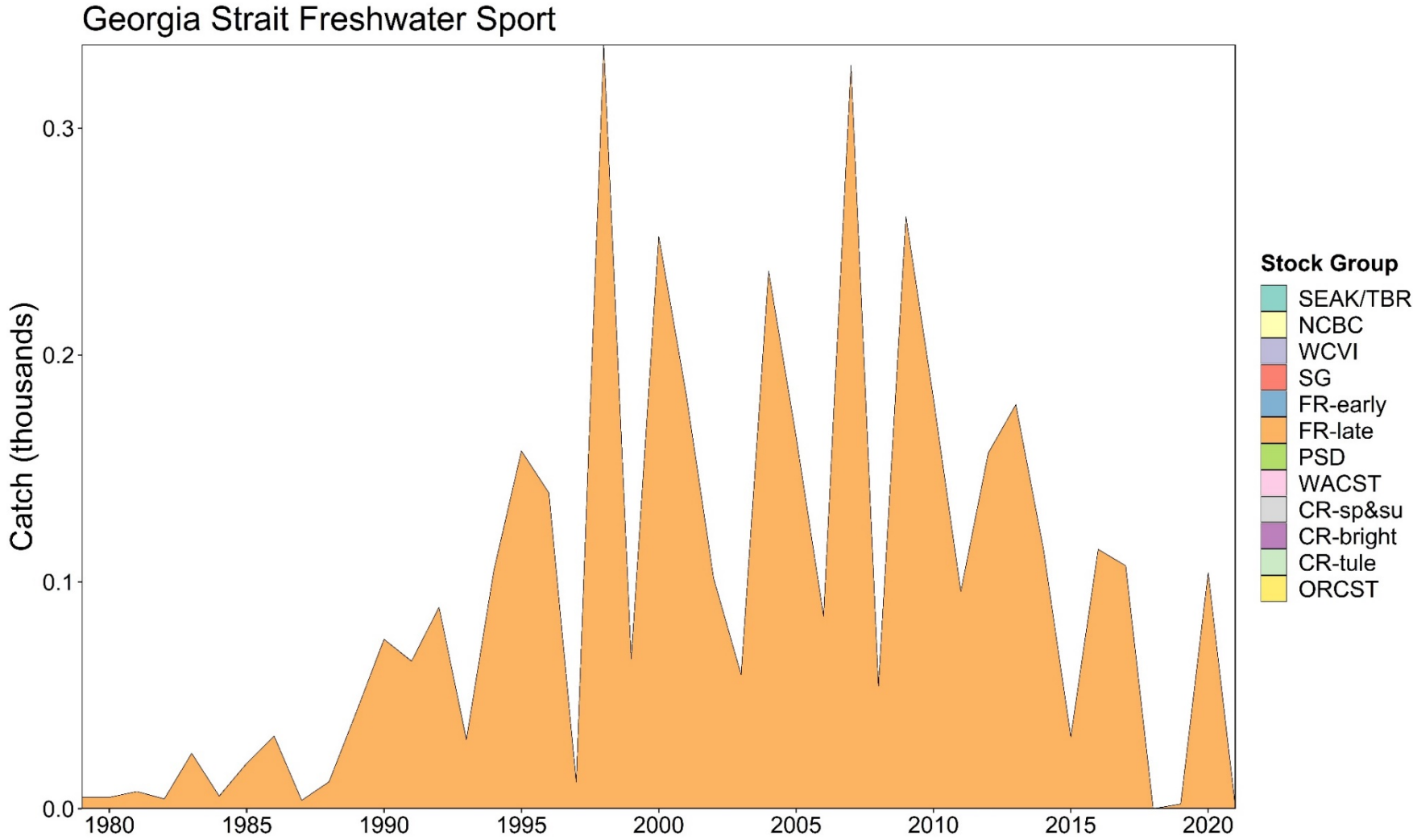
Appendix C46— Pacific Salmon Commission Chinook Model estimates of landed catch stock composition for Puget Sound Freshwater Sport, 1979–2021.
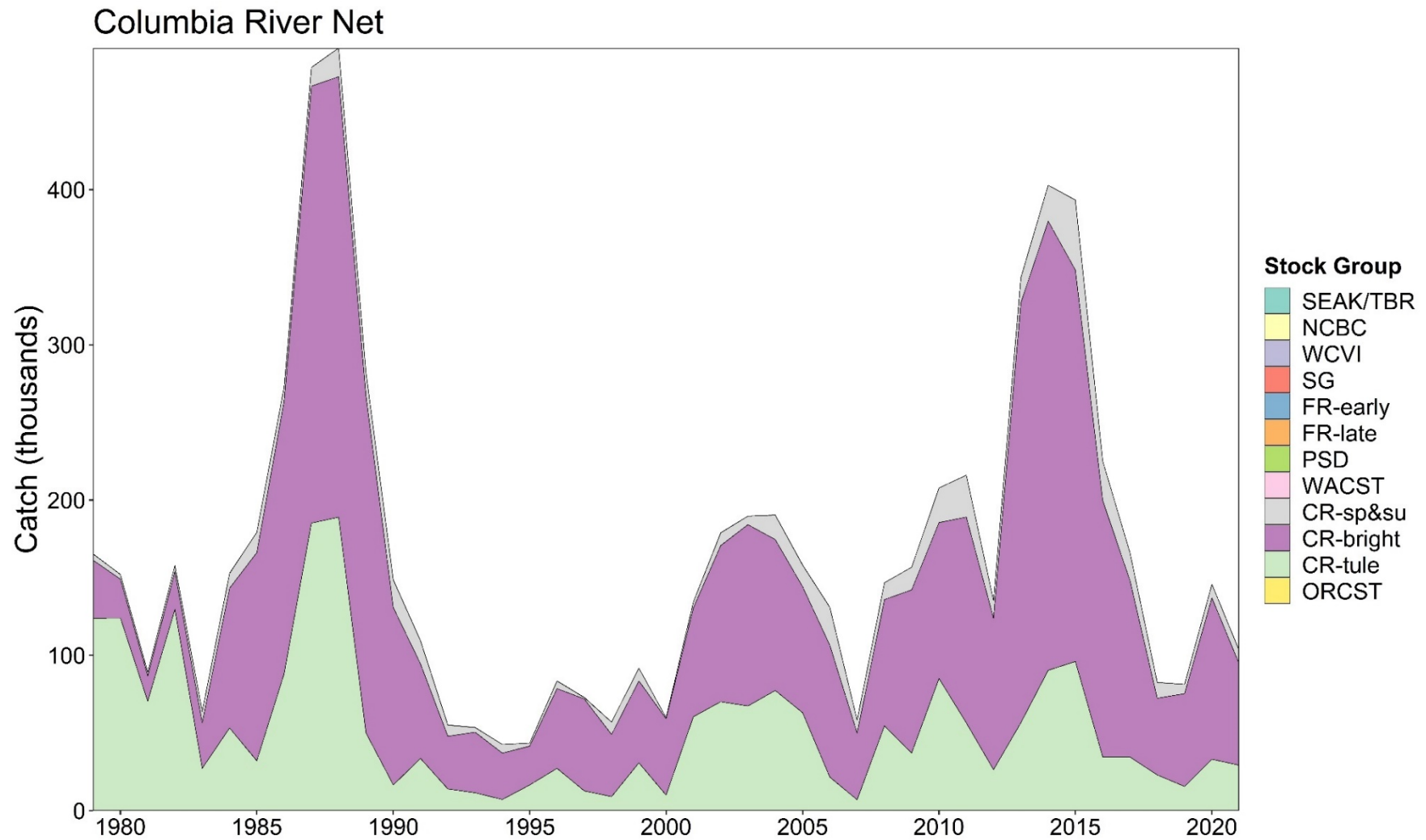
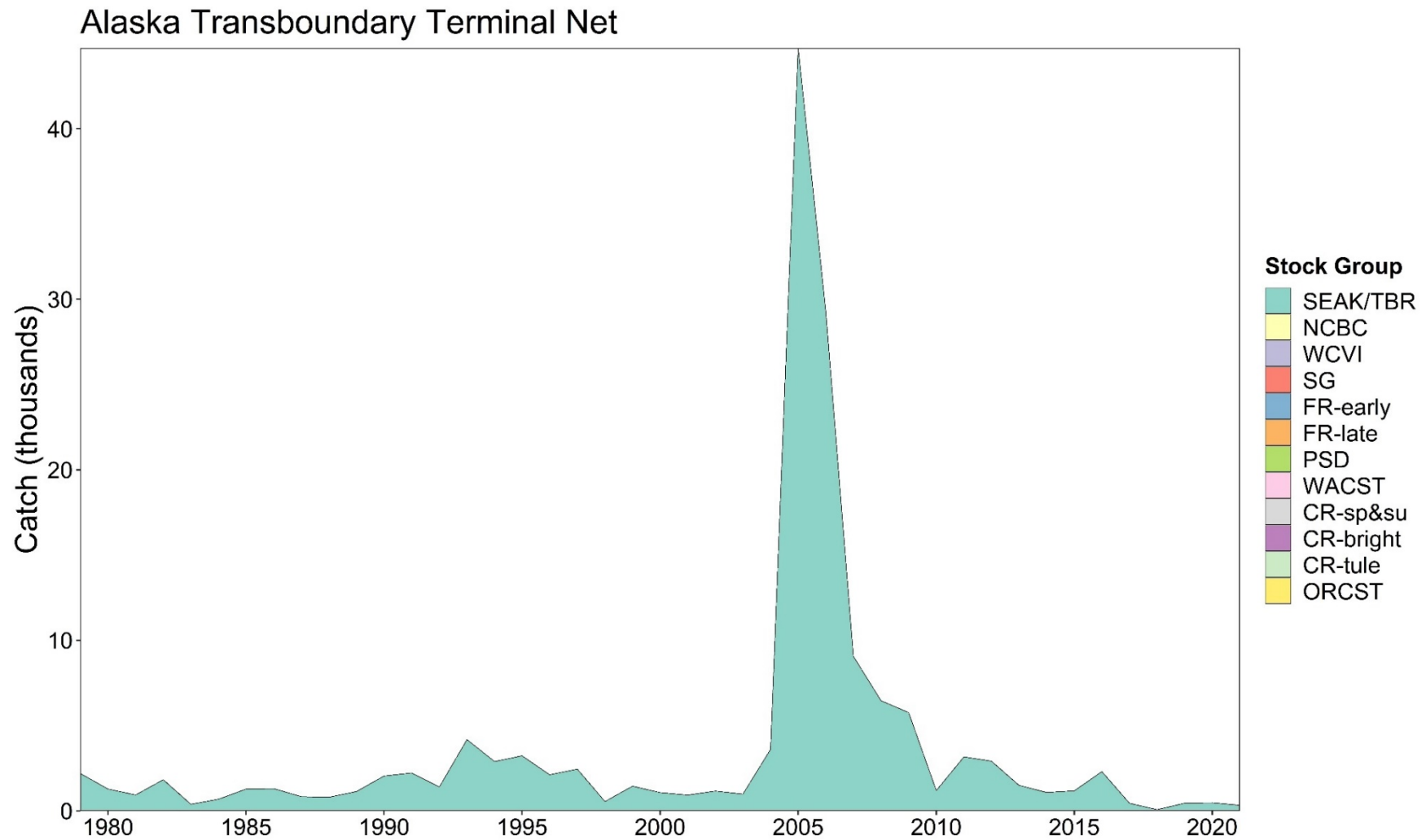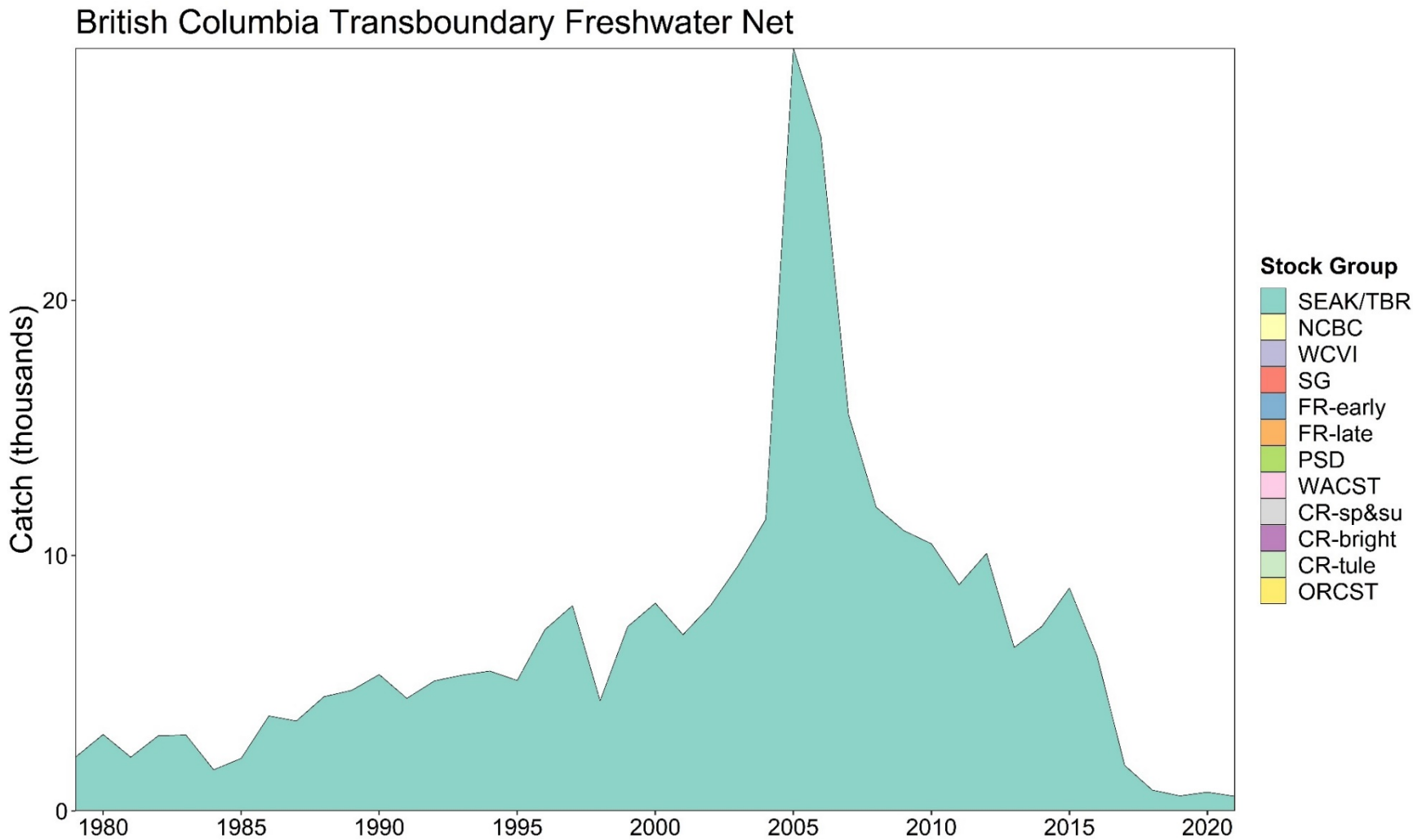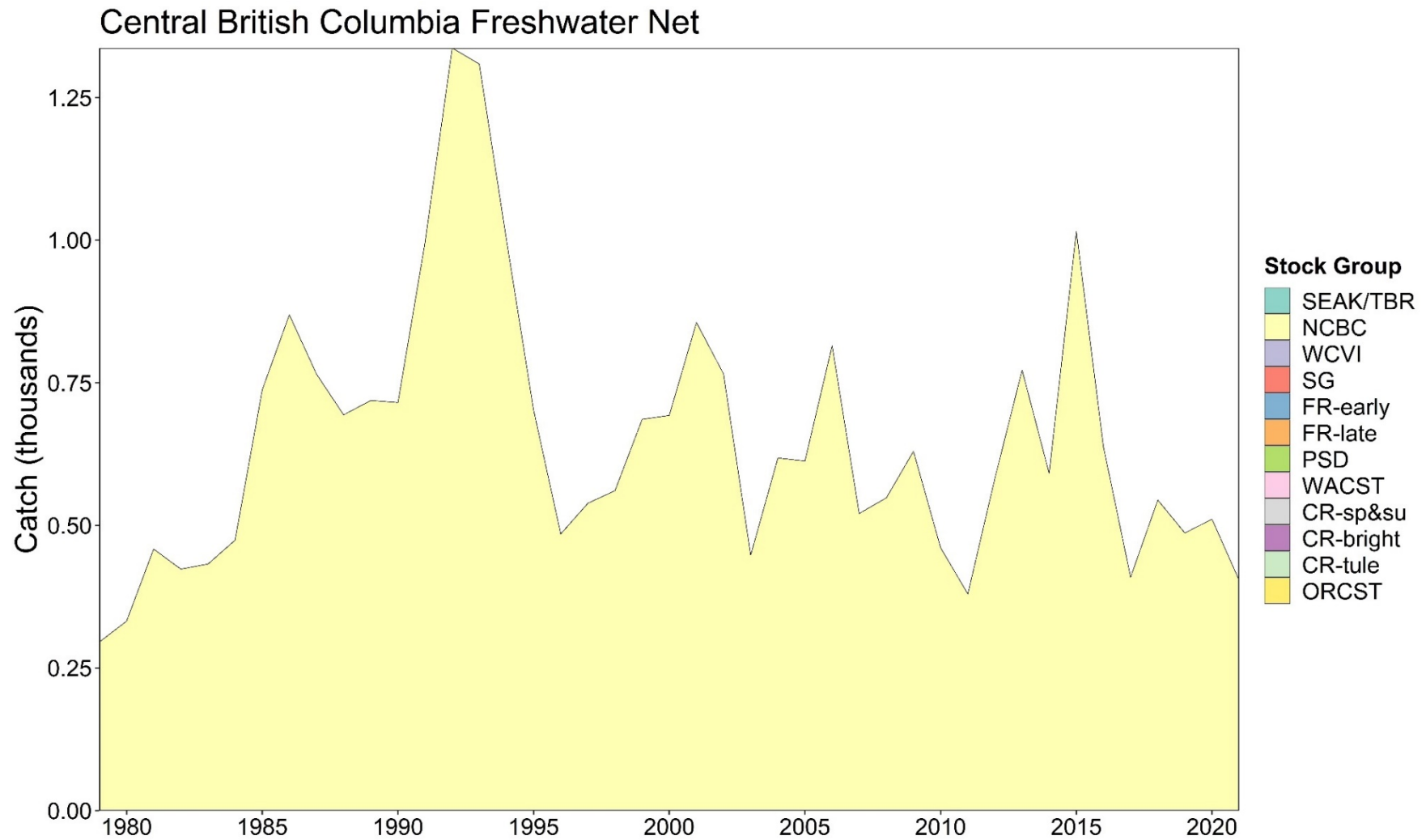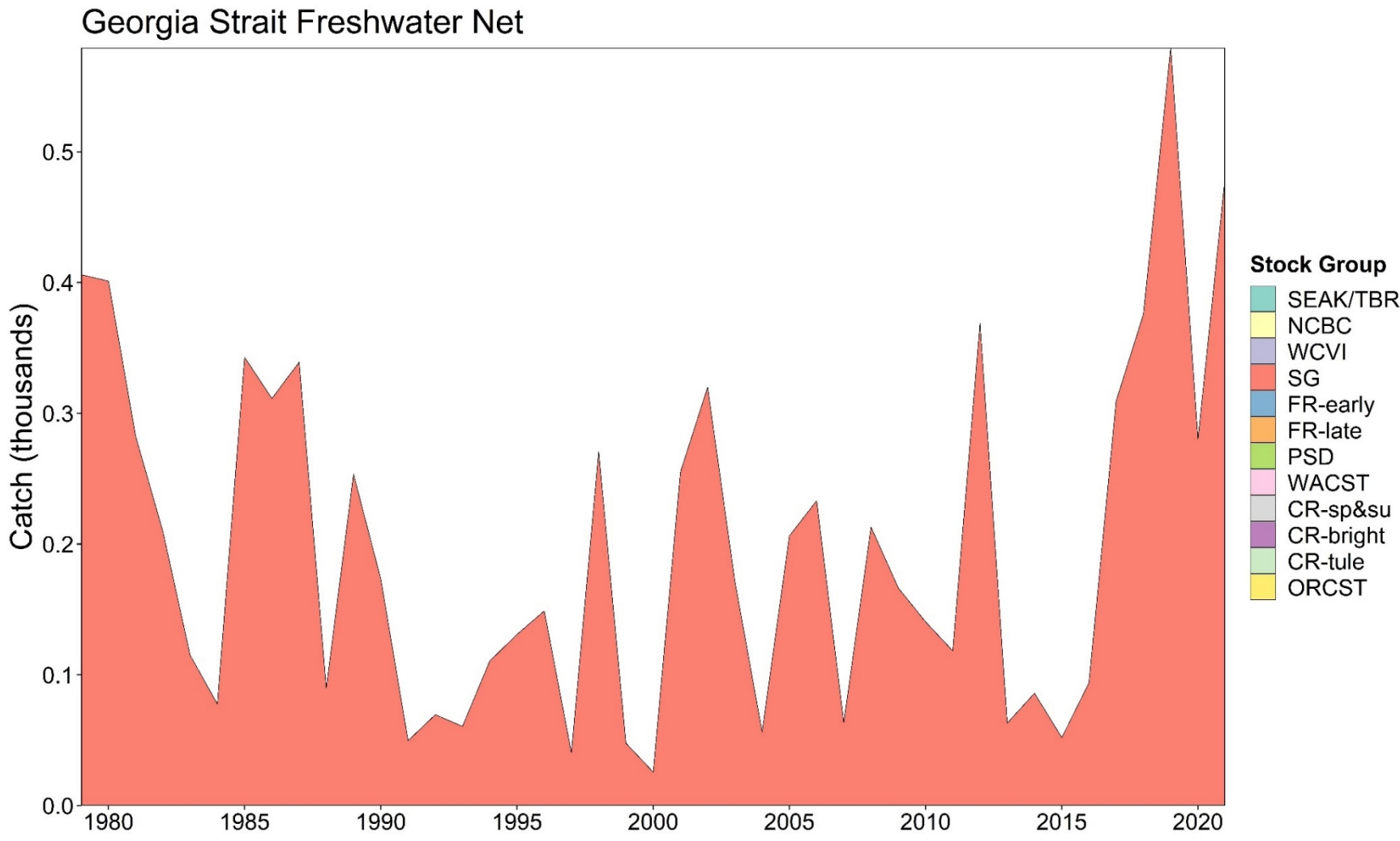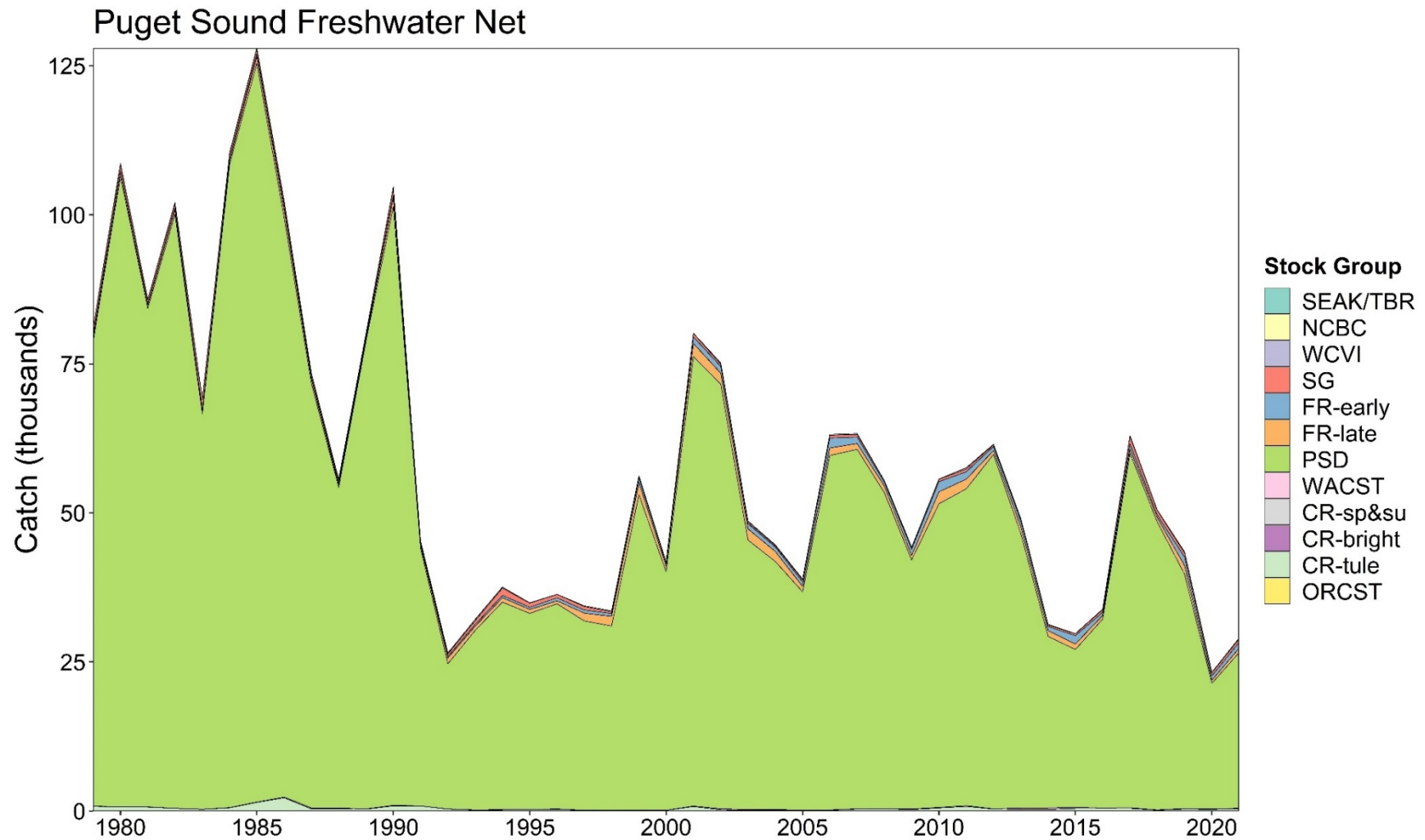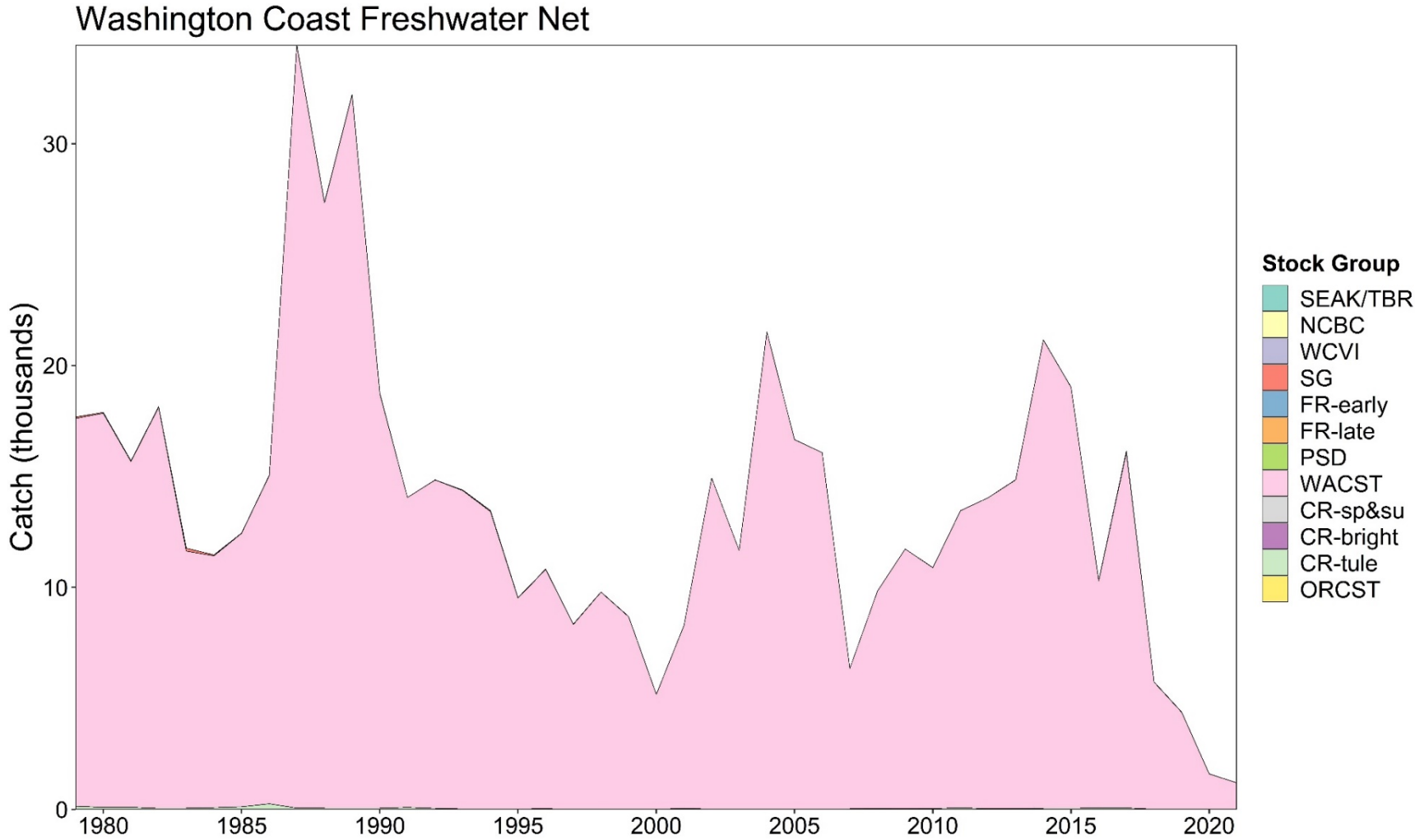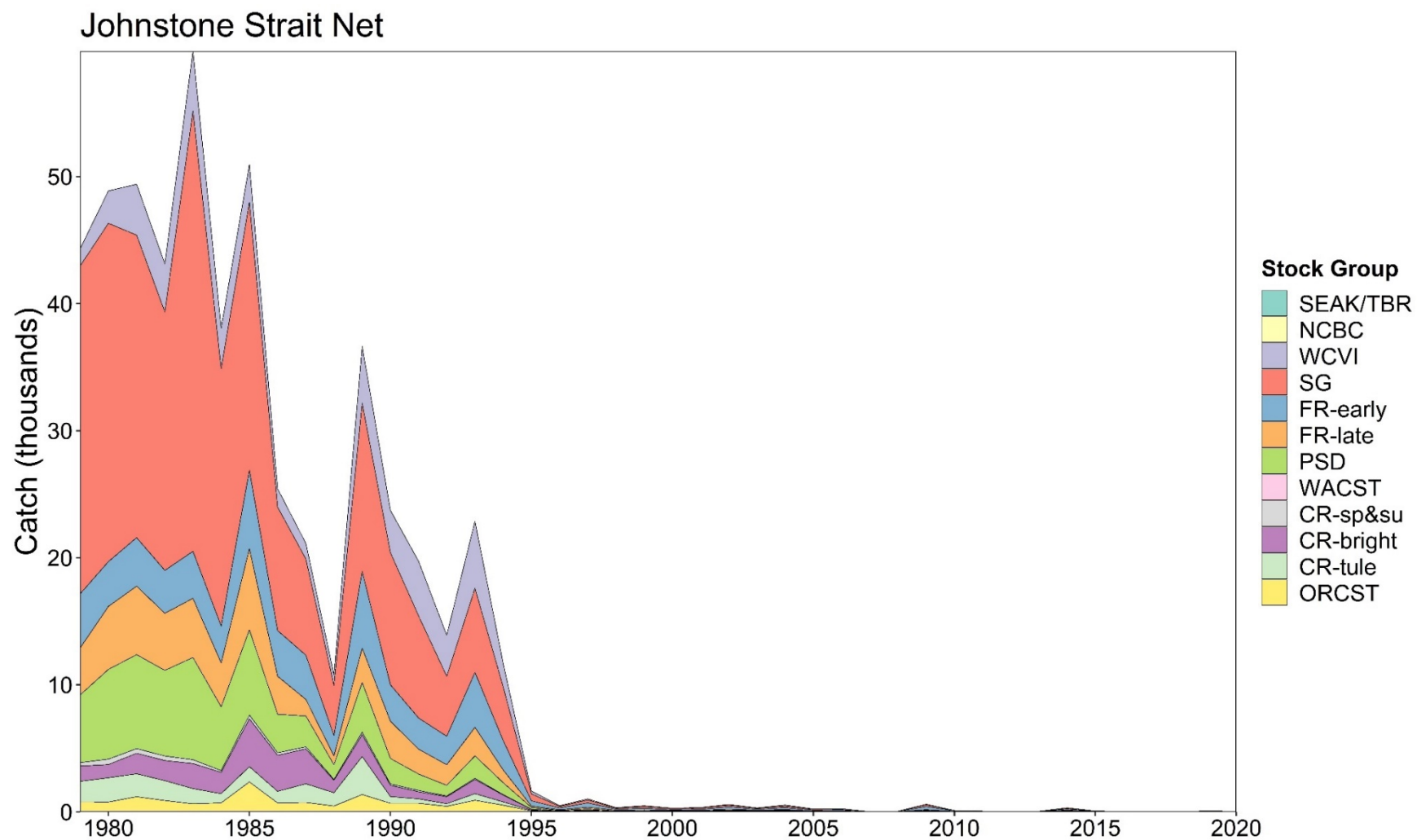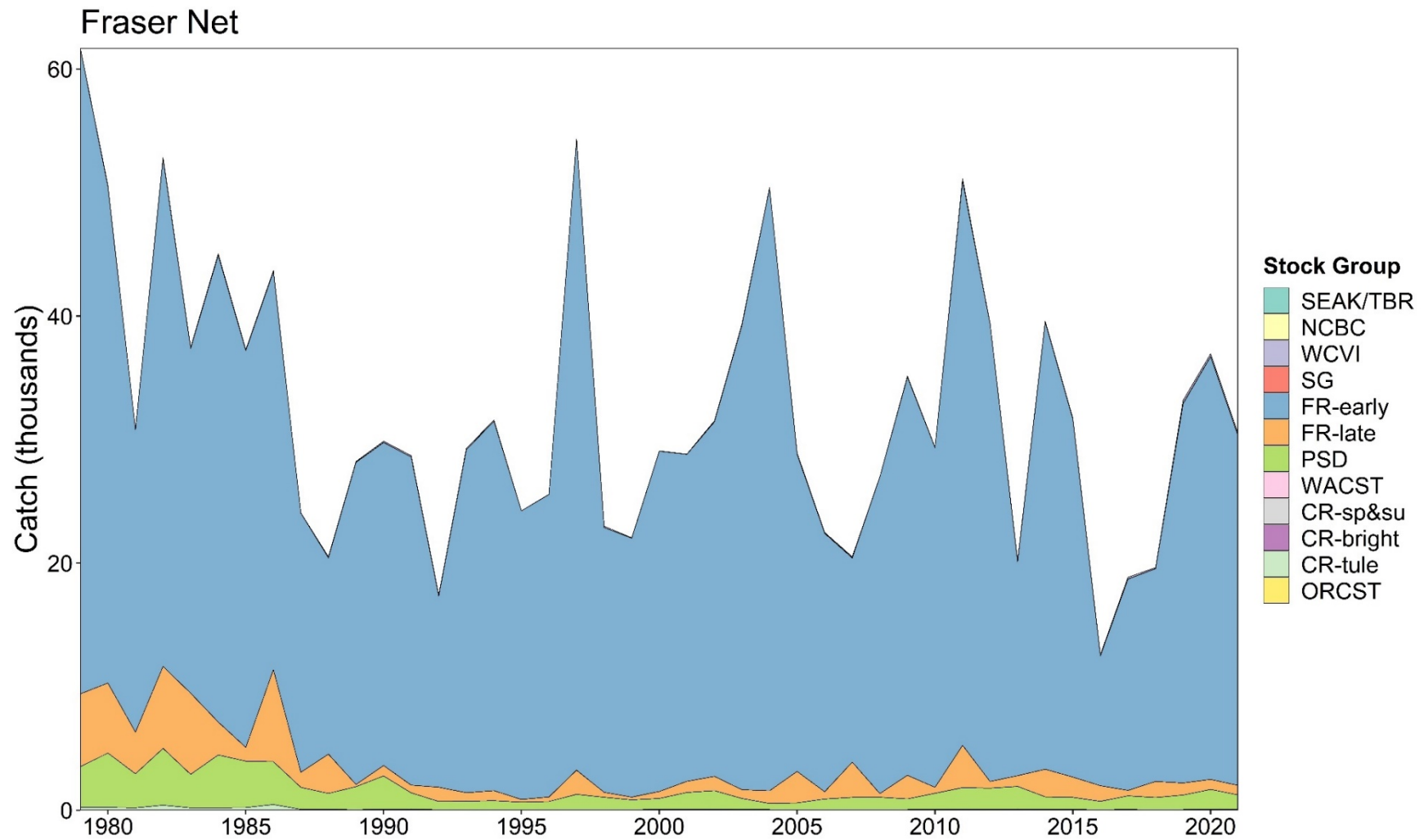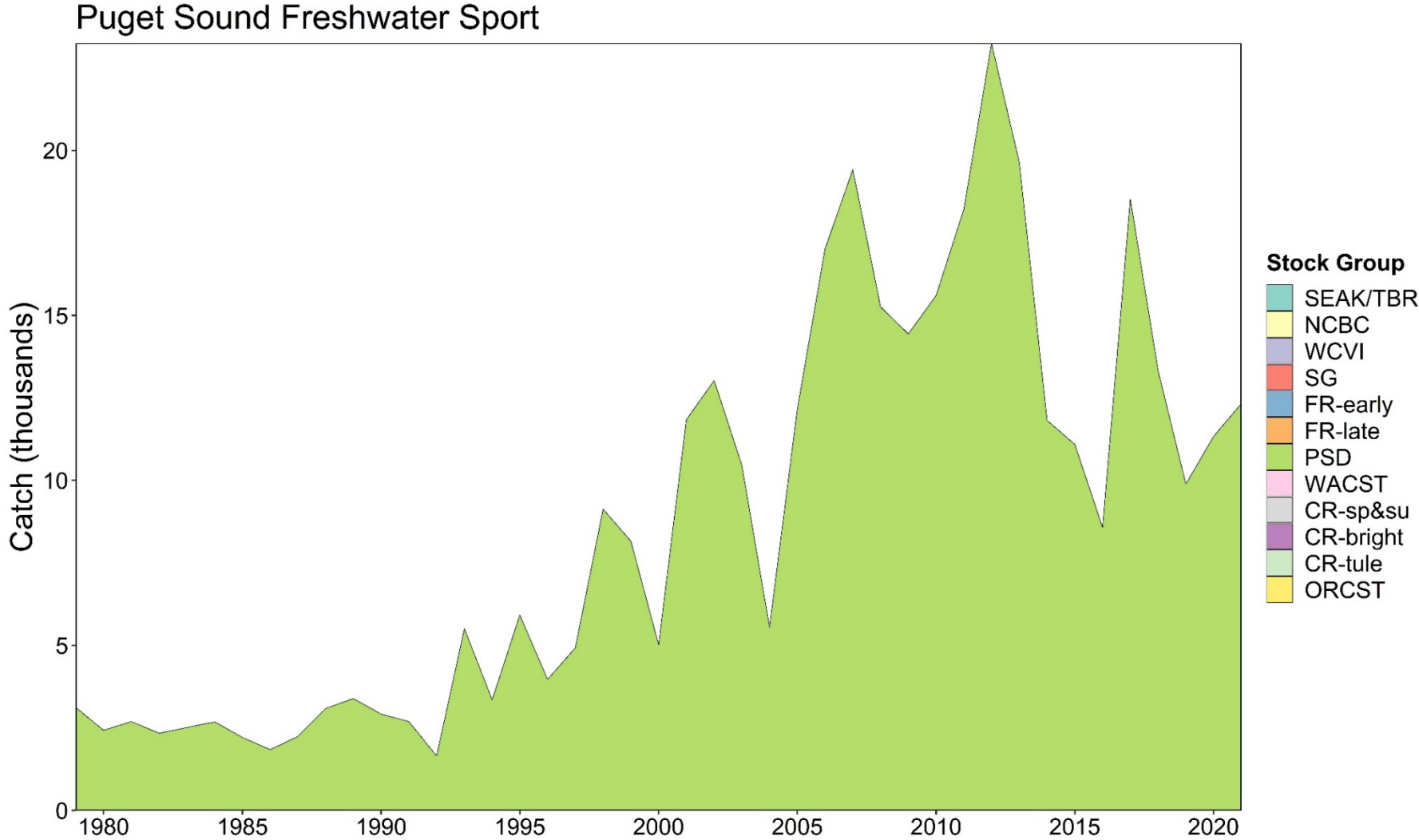*Appendix C47— Pacific Salmon Commission Chinook Model estimates of landed catch stock composition for South of Falcon Freshwater Sport, 1979–2021.*
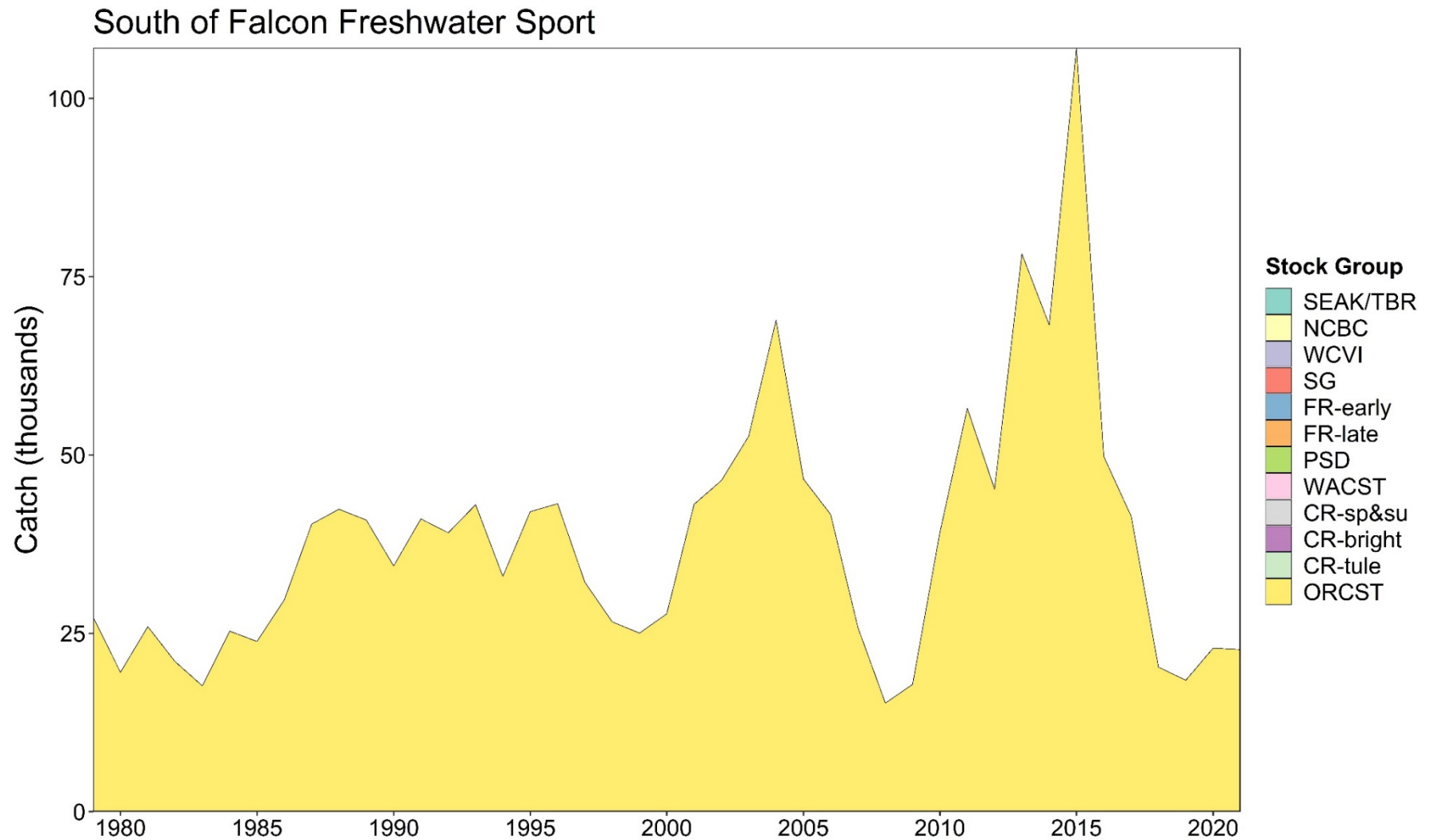
APPENDIX D: INCIDENTAL MORTALITY RATES APPLIED IN THE PACIFIC SALMON COMMISSION CHINOOK MODEL

Appendix D— Incidental mortality rates applied in the Phase II Pacific Salmon Commission (PSC) Chinook Model. Rates in original Model were applied to all years. In the current Model, rates in some fisheries vary in accordance to changes in management regulations.

| Fishery Number | Fishery | Rates applied in Model CLB 2203 | | | Applicable Years |
		Sublegal Rate	Legal Rate	Dropoff	
1	Alaska Troll	0.255	0.211	0.008	All
2	Alaska Yakutat Terminal Net	0.9	0.9	0	All
3	North Troll	0.255	0.211	0.017	1979–1995
3	North Troll	0.22	0.185	0.016	1996–Current
4	Central Troll	0.255	0.211	0.017	1979–1995
4	Central Troll	0.22	0.185	0.016	1996–Current
5	West Coast Vancouver Island Troll	0.255	0.211	0.017	1979–1997
5	West Coast Vancouver Island Troll	0.22	0.185	0.016	1998–Current
6	North of Falcon Troll	0.255	0.211	0.017	1979–1983
6	North of Falcon Troll	0.22	0.185	0.016	1984–Current
7	South of Falcon Troll	0.255	0.211	0.017	1979–1983
7	South of Falcon Troll	0.22	0.185	0.016	1984–Current
8	Strait of Georgia Troll	0.255	0.211	0.017	1979–1985, 1987–1997
8	Strait of Georgia Troll	0.22	0.185	0.016	1986, 1998–Current
9	Alaska Net	0.9	0.9	0	All
10	North Net	0.9	0.9	0	All
11	Central Net	0.9	0.9	0	All
12	West Coast Vancouver Island Net	0.9	0.9	0	All
13	Juan de Fuca Net	0.9	0.9	0	All
14	Puget Sound North Net	0.9	0.9	0	All
15	Puget Sound Other Net	0.9	0.9	0	All
16	Washington Coast Net	0.9	0.9	0	All
17	Columbia River Net	0.9	0.9	0	All
18	Alaska Transboundary River Terminal Net	0.9	0.9	0	All
19	Canada Transboundary River Freshwater Net	0.9	0.9	0	All
20	Central B.C. Freshwater Net	0.9	0.9	0	All
21	Strait of Georgia Freshwater Net	0.9	0.9	0	All
22	Fraser Freshwater Net	0.9	0.9	0	All
23	Puget Sound Freshwater Net	0.9	0.9	0	All
24	Washington Coast Freshwater Net	0.9	0.9	0	All
25	Johnstone Strait Net	0.9	0.9	0	All
26	Fraser Net	0.9	0.9	0	All

Appendix D continued. Incidental mortality rates applied in the Phase II PSC Chinook Model. Rates in original Model were applied to all years. In the current Model, rates in some fisheries vary in accordance to changes in management regulations.

| Fishery Number | Fishery | Rates applied in Model CLB 2203 | | | Applicable Years |
		Sublegal Rate	Legal Rate	Dropoff	
27	Alaska Sport	0.123	0.123	0.036	All
28	Central B.C. Sport	0.123	0.123	0.036	All
29	North B.C. AABM Sport	0.123	0.123	0.036	All
30	North B.C. ISBM Sport	0.123	0.123	0.036	All
31	West Coast Vancouver Island AABM Sport	0.123	0.123	0.069	All
32	West Coast Vancouver Island ISBM Sport	0.123	0.123	0.069	All
33	North of Falcon Sport	0.123	0.123	0.069	All
34	South of Falcon Sport	0.123	0.123	0.069	All
35	Puget Sound North Sport	0.123	0.123	0.145	All
36	Puget Sound Other Sport	0.123	0.123	0.145	All
37	Canada Yakutat Freshwater Net	0.9	0.9	0	All
38	Strait of Georgia Sport	0.322	0.322	0.069	1979–1981
38	Strait of Georgia Sport	0.123	0.123	0.069	1982–Current
39	B.C. Juan de Fuca Sport	0.322	0.322	0.069	All
40	Columbia River Sport	0.123	0.123	0.069	All
41	Alaska Transboundary River Terminal Sport	0.123	0.123	0.069	All
42	North B.C. Freshwater Sport	0.123	0.123	0.069	All
43	Central B.C. Freshwater Sport	0.123	0.123	0.069	All
44	West Coast Vancouver Island Freshwater Sport	0.123	0.123	0.069	All
45	Fraser River Freshwater Sport	0.123	0.123	0.069	All
46	Strait of Georgia Freshwater Sport	0.123	0.123	0.069	All
47	Puget Sound Freshwater Sport	0.123	0.123	0.069	All
48	South of Falcon Freshwater Sport	0.123	0.123	0.069	All

APPENDIX E: TIME SERIES OF ABUNDANCE INDICES

Appendix E— Time series of abundance indices from 1979–2022 for aggregate abundance-based management troll fisheries as estimated by PSC Chinook Model calibrations Calibration (CLB) 2203.

Year	Alaska Troll	North Troll	West Coast Vancouver Island Troll
1979	0.93	1.05	1.12
1980	1.01	0.98	0.99
1981	1.02	0.98	0.92
1982	1.05	0.98	0.96
1983	1.11	1.08	0.96
1984	1.35	1.24	1.00
1985	1.28	1.28	0.91
1986	1.39	1.29	1.06
1987	1.76	1.68	1.45
1988	2.17	1.82	1.29
1989	2.00	1.75	1.02
1990	1.88	1.63	0.90
1991	1.84	1.58	0.81
1992	1.78	1.55	0.83
1993	1.82	1.55	0.72
1994	1.68	1.33	0.55
1995	1.03	1.01	0.48
1996	1.09	0.99	0.57
1997	1.54	1.24	0.67
1998	1.36	1.06	0.61
1999	1.06	0.86	0.58
2000	0.90	0.84	0.59
2001	1.20	1.17	0.98
2002	1.89	1.85	1.43
2003	2.25	1.97	1.38
2004	2.07	1.95	1.21
2005	1.83	1.69	0.95
2006	1.69	1.54	0.75
2007	1.20	1.05	0.60
2008	0.94	0.90	0.68
2009	1.14	1.03	0.64
2010	1.23	1.34	0.90
2011	1.43	1.38	0.85
2012	1.16	1.27	0.82
2013	1.51	1.58	1.14
2014	2.13	1.88	1.21
2015	2.07	1.94	1.17
2016	1.51	1.38	0.79
2017	1.11	1.06	0.67
2018	0.74	0.82	0.61
2019	0.99	1.00	0.62
2020	1.04	1.07	0.63
2021	1.23	1.21	0.73
2022	1.16	1.17	0.88

APPENDIX F: PACIFIC SALMON COMMISSION CHINOOK MODEL FORECAST PERFORMANCE

Data in Appendix F1 are used to evaluate PSC Chinook Model and Agency Forecasts. The following terminology is used:

- Model Forecast. The model forecast for a stock is from that year's calibration (e.g., 2022 is from CLB 2203). These data do not change from year-to-year and can be found in a given year's model calibration out files. [source: stage 2 checkCLB.out file]
- Agency Forecast. The Agency forecast (FCS) for a stock is what was provided to the CTC for use with that year's model calibration. These data do not change from year-to-year and can be found in a given year's model calibration input file. [source: OCNyear.FCS files]
- Post-season Return. The post-season return is the most up to date estimate of either the terminal return or the escapement, depending on how the stock is reported in the FCS file. Historic estimates can change from one year to the next based on agencies updating of catch and/or escapement data and estimates. [source: checkCLB.out or FCS file]

In the Appendix F1 tables, the column labeled '*Model/Agency*' shows the ratio of the model prediction and the agency forecast as a percentage. The column labeled '*Agency/Post-season*' shows the ratio of the agency forecast and the actual return as a percentage. The column labeled '*Model/Post-season*' shows the ratio of the model prediction and the actual return as a percentage. A value of 100% would indicate that the predicted and actual values were the same.

With the transition to the Phase II PSC Chinook Model base period, the stock structure and number of stocks represented in the model have changed. As 2020 represents the first year that this model was used for preseason planning, Appendix F1 below contains model and agency forecasts, in addition to post-season returns for Phase II model stocks from 2020 to present. For information on forecasts and post-season returns prior to 2020, see Appendix F1 in CTC 2021a.

The figures in Appendix F2 display forecast error relative to the post-season ("actual") returns over time where information is available for each stock. Stocks are listed geographically from north to south. Gray shading indicates that an agency provided forecast was used for that particular stock/year, where orange shading indicates that the forecast used was model-based. The shape of the symbol denotes whether the 9806 model (circle) or the Phase II model (diamond) was used. Values in red indicate instances where the error value for a given stock/year exceeded the upper limit of the y-axis. Information used in these figures for 2020 to present can be found in Appendix F1. For information on forecast performance for years prior to 2020, see Appendix F1 in CTC 2021a.

With the change to model stock structure that occurred, it becomes difficult to represent stock-specific forecast performance across the transition to the Phase II model. Listed below are three categories of Phase II model stocks as they relate to the 9806 model configuration, which

will help with interpretation of the Appendix F2 figures. For information on Phase II model stock acronyms, see Appendix A. For information on 9806 model stock acronyms, see Appendix A in CTC 2021d.

1. *Stocks that were added to the Phase II model that were not represented in the 9806 model configuration (e.g., YAK, ALS, TST, MOC).* In these cases, forecasts are only available beginning in 2020, as they do not exist for these stocks prior to implementation of the Phase II model.
2. *Stocks that were split from a single 9806 model stock into two or more component stocks in the Phase II model (e.g., AKS split into NSA and SSA, NTH split into NBC and CBC, etc.).* In these cases, there are multiple panels, with one that shows performance through 2019 for the 9806-model stock (acronym in brackets followed by the corresponding Phase II model stocks in parentheses; e.g., "[AKS] (NSA+SSA)"), followed by others that present values beginning in 2020 for each of the corresponding Phase II model stocks.
3. *Stocks that were unchanged between the two models.* In these cases, the entire time series (1999 – present) is contained within a single panel. Since there were instances where the stock acronym did change, the Phase II model stock acronym is followed by the 9806 model stock acronym in brackets (e.g., NOC [ORC]).

LIST OF APPENDIX F TABLES

Appendix F1– Forecasts and post-season returns for Phase II model stocks, 2020 to present.
(Page 1 of 4)

Stock Name	Year	Model Forecast	Agency Forecast	Post-season Return	Model/ Agency	Agency/ Post-season	Model/ Post-season
Yakutat Forelands[1]	2020	4,377	NA	4,113	NA	NA	106%
(YAK)	2021	5,460	NA	2,011	NA	NA	272%
	2022	3,005	NA	NA	NA	NA	NA
	AVG	NA	NA	NA	NA	NA	189%
Alsek[1]	2020	10,787	NA	5,241	NA	NA	206%
(ALS)	2021	9,526	NA	5,523	NA	NA	172%
	2022	10,073	NA	NA	NA	NA	NA
	AVG	NA	NA	NA	NA	NA	189%
Southern SEAK[1]	2020	9,252	NA	9,211	NA	NA	100%
(SSA)	2021	10,599	NA	12,308	NA	NA	86%
	2022	11,705	NA	NA	NA	NA	NA
	AVG	NA	NA	NA	NA	NA	93%
Northern SEAK[1]	2020	3,232	NA	5,175	NA	NA	62%
(NSA)	2021	3,343	NA	3,812	NA	NA	88%
	2022	3,271	NA	NA	NA	NA	NA
	AVG	NA	NA	NA	NA	NA	75%
Transboundary Rivers[1]	2020	38,347	NA	37,681	NA	NA	102%
(TST)	2021	33,300	NA	28,297	NA	NA	118%
	2022	25,833	NA	NA	NA	NA	NA
	AVG	NA	NA	NA	NA	NA	110%
Northern BC[1]	2020	20,691	34,971	29,515	59%	118%	70%
(NBC)	2021	21,483	37,577	29,764	57%	126%	72%
	2022	15,697	31,007	NA	51%	NA	NA
	AVG	NA	NA	NA	56%	122%	71%
Central BC[1]	2020	6,785	11,463	14,262	59%	80%	48%
(CBC)	2021	8,066	13,438	8,663	60%	155%	93%
	2022	5,639	10,003	NA	56%	NA	NA
	AVG	NA	NA	NA	59%	118%	70%
WCVI Hacthery[2]	2020	163,921	152,227	189,043	108%	81%	87%
(WVH)	2021	196,007	172,955	201,948	113%	86%	97%
	2022	216,396	197,795	NA	109%	NA	NA
	AVG	NA	NA	NA	110%	83%	92%
WCVI Natural[2]	2020	25,671	22,531	29,846	114%	75%	86%
(WVN)	2021	29,472	26,511	30,203	111%	88%	98%
	2022	29,705	26,762	NA	111%	NA	NA
	AVG	NA	NA	NA	112%	82%	92%
Upper Georgia Strait[1]	2020	5,227	11,779	18,886	44%	62%	28%
(UGS)	2021	7,786	17,196	11,641	45%	148%	67%
	2022	4,543	10,756	NA	42%	NA	NA
	AVG	NA	NA	NA	44%	105%	47%
Puntledge River Summer[1]	2020	646	563	412	115%	137%	157%
(PPS)	2021	590	569	499	104%	114%	118%
	2022	581	516	NA	113%	NA	NA
	AVG	NA	NA	NA	110%	125%	138%

Appendix F1– Forecasts and post-season returns for Phase II model stocks, 2020 to present. (Page 2 of 4)

Stock Name	Year	Model Forecast	Agency Forecast	Post-season Return	Model/ Agency	Agency/ Post-	Model/ Post-
Middle Georgia Strait[1]	2020	24,214	23,595	22,005	103%	107%	110%
(MGS)	2021	23,027	23,283	30,916	99%	75%	74%
	2022	30,630	27,283	NA	112%	NA	NA
	AVG	NA	NA	NA	105%	91%	92%
Lower Georgia Strait[2]	2020	14,779	14,821	13,099	100%	113%	113%
(LGS)	2021	7,692	10,576	19,522	73%	54%	39%
	2022	22,072	21,917	NA	101%	NA	NA
	AVG	NA	NA	NA	91%	84%	76%
Fraser Early Spring 1.2[2]	2020	6,105	6,220	9,123	98%	68%	67%
(FS2)	2021	9,080	9,138	6,845	99%	133%	133%
	2022	8,081	8,293	NA	97%	NA	NA
	AVG	NA	NA	NA	98%	101%	100%
Fraser Early Spring 1.3[2]	2020	19,142	23,332	17,661	82%	132%	108%
(FS3)	2021	17,605	17,588	16,876	100%	104%	104%
	2022	17,024	16,876	NA	101%	NA	NA
	AVG	NA	NA	NA	94%	118%	106%
Fraser Early Summer 0.3[1]	2020	119,340	114,566	147,983	104%	77%	81%
(FSO)	2021	128,148	108,611	176,053	118%	62%	73%
	2022	136,667	128,800	NA	106%	NA	NA
	AVG	NA	NA	NA	109%	70%	77%
Fraser Early Summer 1.3[2]	2020	10,044	10,737	14,418	94%	74%	70%
(FSS)	2021	14,446	14,490	15,398	100%	94%	94%
	2022	15,593	15,398	NA	101%	NA	NA
	AVG	NA	NA	NA	98%	84%	82%
Fraser Late Natural (Harrison) [1]	2020	53,584	59,745	43,499	90%	137%	123%
(FHF)	2021	30,852	35,150	43,286	88%	81%	71%
	2022	60,347	68,388	NA	88%	NA	NA
	AVG	NA	NA	NA	89%	109%	97%
Fraser Late Hatchery (Chilliwack)	2020	44,589	31,077	44,721	143%	69%	100%
(FCF)	2021	36,766	39,593	67,663	93%	59%	54%
	2022	75,171	77,109	NA	97%	NA	NA
	AVG	NA	NA	NA	111%	64%	77%
Nooksack Spring[1]	2020	1,510	1,479	2,385	102%	62%	63%
(NKS)	2021	769	499	2,204	154%	23%	35%
	2022	1,962	1,789	NA	110%	NA	NA
	AVG	NA	NA	NA	122%	42%	49%
Nooksack/Samish Fall[2]	2020	15,764	16,858	22,233	94%	76%	71%
(NKF)	2021	18,313	19,412	37,170	94%	52%	49%
	2022	33,279	31,436	NA	106%	NA	NA
	AVG	NA	NA	NA	98%	64%	60%
Skagit Summer/Fall Wild[2]	2020	14,031	12,877	11,171	109%	115%	126%
(SKG)	2021	11,305	10,461	10,625	108%	98%	106%
	2022	14,114	12,508	NA	113%	NA	NA
	AVG	NA	NA	NA	110%	107%	116%

Stock Name	Year	Model Forecast	Agency Forecast	Post-season Return	Model/ Agency	Agency/ Post-season	Model/ Post-season
Stillaguamish Summer/Fall (STL)	2020	727	762	1,443	95%	53%	50%
	2021	922	876	732	105%	120%	126%
	2022	897	890	NA	101%	NA	NA
	AVG	NA	NA	NA	100%	86%	88%
Snohomish Summer/Fall Wild[2] (SNO)	2020	2,556	2,978	2,418	86%	123%	106%
	2021	2,939	2,922	2,126	101%	137%	138%
	2022	2,397	2,423	NA	99%	NA	NA
	AVG	NA	NA	NA	95%	130%	122%
Puget Sound Fingerling[2,3] (PSF)	2020	206,668	186,117	105,515	111%	176%	196%
	2021	159,464	160,088	165,813	100%	97%	96%
	2022	175,935	161,554	NA	109%	NA	NA
	AVG	NA	NA	NA	107%	136%	146%
Puget Sound Yearling[2,3] (PSY)	2020	4,604	4,059	2,240	113%	181%	206%
	2021	4,163	4,030	4,053	103%	99%	103%
	2022	4,584	3,770	NA	122%	NA	NA
	AVG	NA	NA	NA	113%	140%	154%
Puget Sound Natural[2,3] (PSN)	2020	7,731	7,132	9,749	108%	73%	79%
	2021	8,980	8,225	12,255	109%	67%	73%
	2022	11,149	8,427	NA	132%	NA	NA
	AVG	NA	NA	NA	117%	70%	76%
Washington Coastal Hatchery[2] (WCH)	2020	29,135	32,802	48,762	89%	67%	60%
	2021	40,339	42,953	45,059	94%	95%	90%
	2022	53,794	44,440	NA	121%	NA	NA
	AVG	NA	NA	NA	101%	81%	75%
Washington Coastal Natural[2] (WCN)	2020	30,576	30,130	53,590	101%	56%	57%
	2021	46,314	41,395	35,782	112%	116%	129%
	2022	49,667	41,036	NA	121%	NA	NA
	AVG	NA	NA	NA	111%	86%	93%
Cowlitz Spring[2] (CWS)	2020	3,738	3,843	3,984	97%	96%	94%
	2021	6,076	6,384	8,201	95%	78%	74%
	2022	9,356	8,994	NA	104%	NA	NA
	AVG	NA	NA	NA	99%	87%	84%
Willamette Spring[2] (WSH)	2020	43,814	43,430	47,327	101%	92%	93%
	2021	51,482	52,400	43,148	98%	121%	119%
	2022	51,436	52,918	NA	97%	NA	NA
	AVG	NA	NA	NA	99%	107%	106%
Columbia River Summer[2] (SUM)	2020	36,194	38,300	65,494	95%	58%	55%
	2021	73,414	77,600	56,800	95%	137%	129%
	2022	65,264	57,500	NA	114%	NA	NA
	AVG	NA	NA	NA	101%	98%	92%
Lewis River Wild[2] (LRW)	2020	22,290	19,700	35,397	113%	56%	63%
	2021	27,614	20,000	16,935	138%	118%	163%
	2022	13,078	10,842	NA	121%	NA	NA
	AVG	NA	NA	NA	124%	87%	113%

Appendix F1– Forecasts and post-season returns for Phase II model stocks, 2020 to present. (Page 4 of 4)

Stock Name	Year	Model Forecast	Agency Forecast	Post-season Return	Model/ Agency	Agency/ Post-season	Model/ Post-season
Lower Bonneville Hatchery[2] (BON)	2020	14,940	16,500	18,099	91%	91%	83%
	2021	17,207	18,100	21,472	95%	84%	80%
	2022	19,145	17,800	NA	108%	NA	NA
	AVG	NA	NA	NA	98%	88%	81%
Fall Cowlitz Hatchery[2] (CWF)	2020	34,100	34,500	59,704	99%	58%	57%
	2021	48,767	55,000	53,232	89%	103%	92%
	2022	46,920	55,200	NA	85%	NA	NA
	AVG	NA	NA	NA	91%	81%	74%
Spring Creek Hatchery[2] (SPR)	2020	46,779	47,500	52,273	98%	91%	89%
	2021	46,242	46,780	73,659	99%	64%	63%
	2022	96,292	96,654	NA	100%	NA	NA
	AVG	NA	NA	NA	99%	77%	76%
Mid-Columbia Bright[2] (MCB)	2020	78,988	78,200	109,813	101%	71%	72%
	2021	84,306	86,200	73,893	98%	117%	114%
	2022	85,351	78,938	NA	108%	NA	NA
	AVG	NA	NA	NA	102%	94%	93%
Columbia Upriver Bright[2] (URB)	2020	212,281	220,600	299,031	96%	74%	71%
	2021	338,574	354,218	239,947	96%	148%	141%
	2022	253,488	230,360	NA	110%	NA	NA
	AVG	NA	NA	NA	101%	111%	106%
Snake River Wild[2] (LYF)	2020	12,984	10,902	12,282	119%	89%	106%
	2021	12,485	10,991	9,342	114%	118%	134%
	2022	11,559	10,965	NA	105%	NA	NA
	AVG	NA	NA	NA	113%	103%	120%
North Oregon Coast[1] (NOC)	2020	55,940	44,809	76,901	125%	58%	73%
	2021	68,923	67,593	46,697	102%	145%	148%
	2022	53,675	49,343	NA	109%	NA	NA
	AVG	NA	NA	NA	112%	102%	110%
Mid-Oregon Coast[1] (MOC)	2020	25,427	28,140	26,511	90%	106%	96%
	2021	25,514	25,900	16,839	99%	154%	152%
	2022	16,784	19,118	NA	88%	NA	NA
	AVG	NA	NA	NA	92%	130%	124%

[1]Forecast unit is escapement.
[2] Forecast unit is terminal run.
[3] Puget Sound post-season returns for the most recent year are preliminary projections based on partial return information.

Appendix F2– Forecast performance for 9806 and Phase II Chinook model stocks, 1999–2021. (Page 1 of 3)
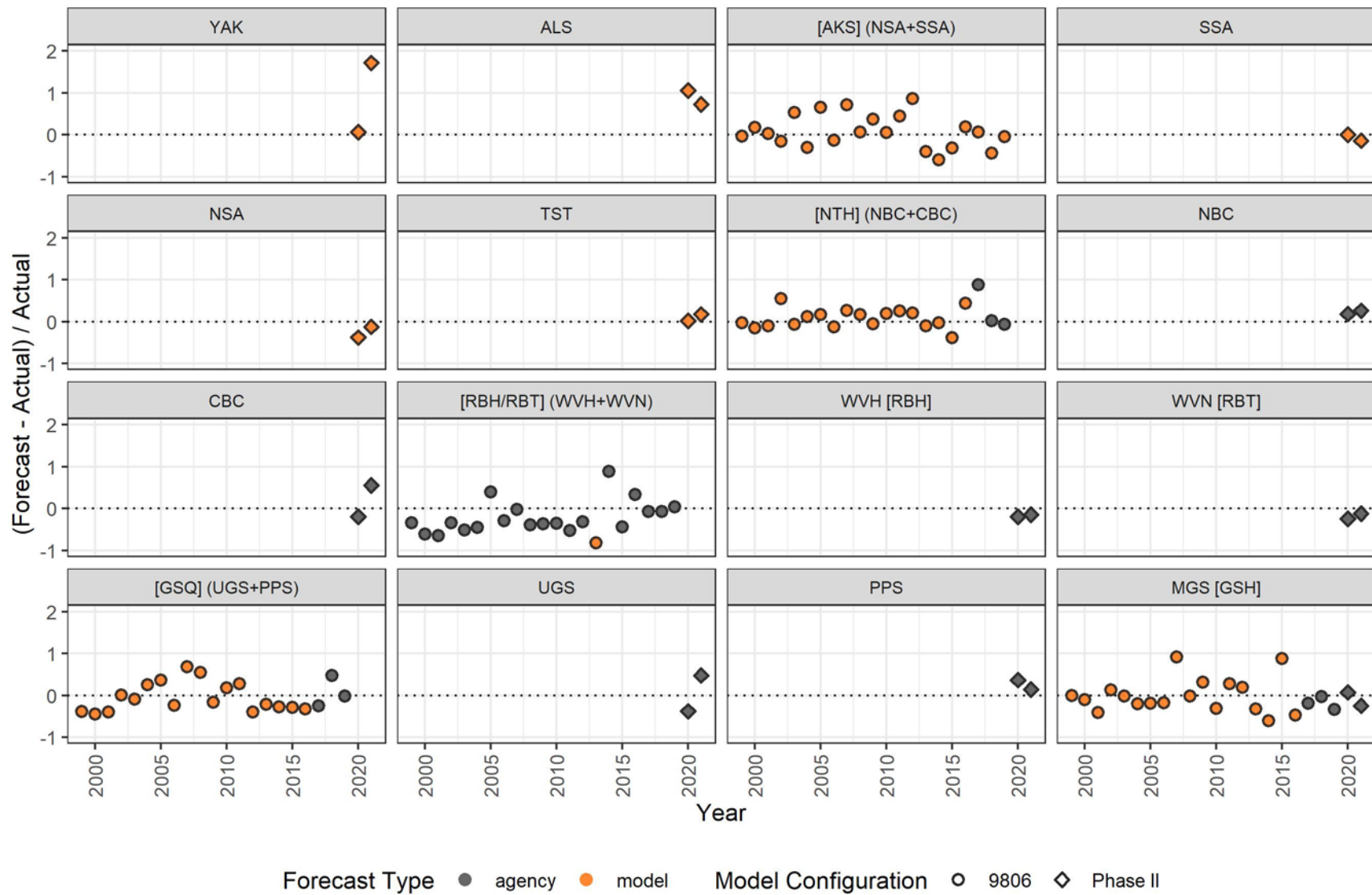
Appendix F2– Forecast performance for Chinook model stocks, 1999–2021. (Page 3 of 3)
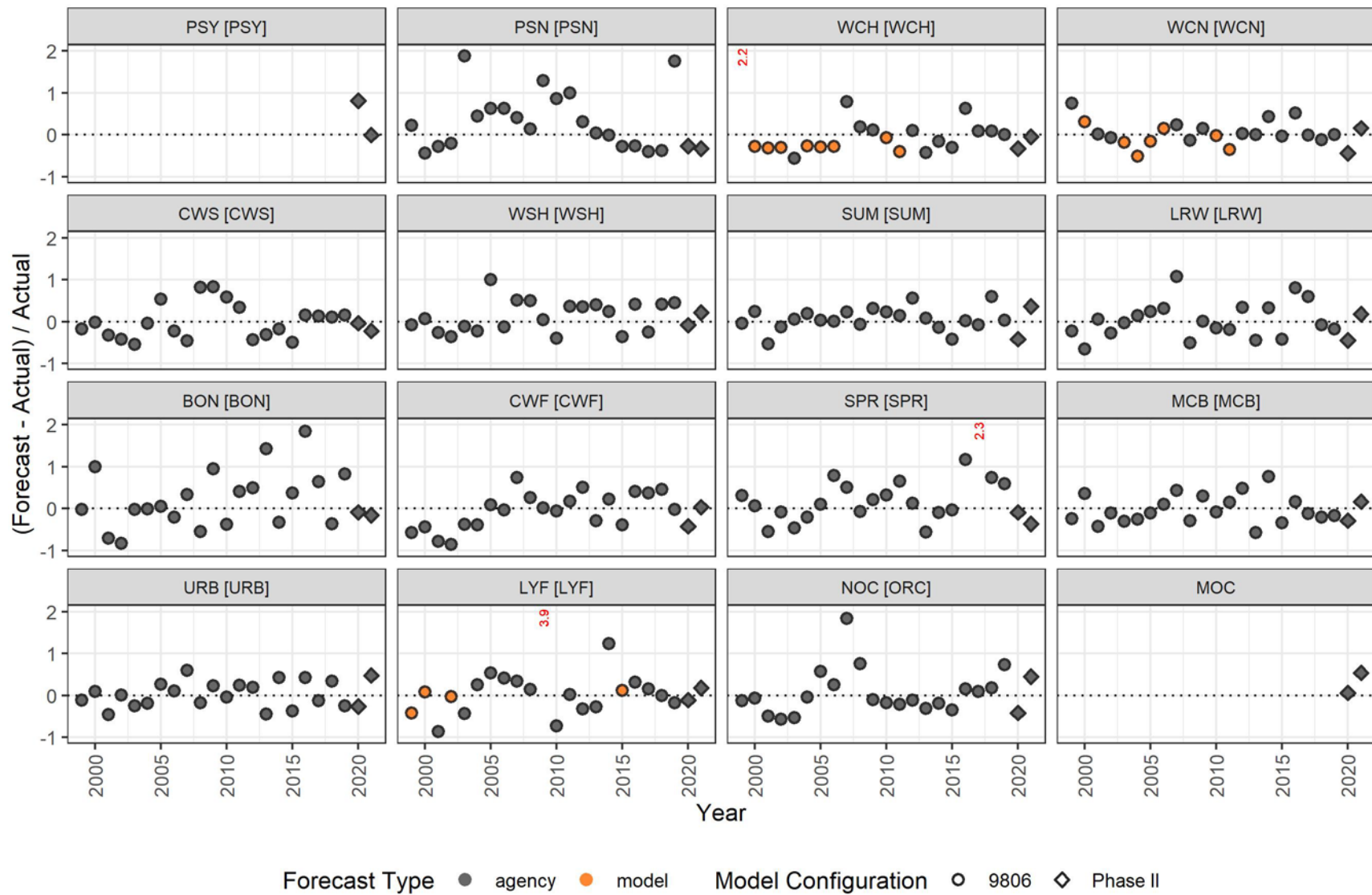
APPENDIX G: MODEL CALIBRATION METHODS

This section describes the calibration data and procedures used. For reference, a list of indicator stocks and fisheries in the model is provided in Appendix A. Estimation of the model base period parameters is described in CTC *In prep*. For 2021, the new "Phase II" model was used for estimating pre- and post-season AIs (see CTC 2021c and CTC 2021d for details on the Phase II transition).

Calibration Data

The first step in the annual calibration process is to gather new or revised data to update the model input files. For example, the file containing run size data is updated as pre-season forecasts and post-season run size estimates become available. Model predictions of the AIs are sensitive to pre-season forecasts and post-season estimates of terminal runs. Months in which forecasts are available for each stock, and the month the final return estimate becomes available, are presented in Appendix G1.

The model is recalibrated annually to incorporate observed data from the previous year (or years if post-season estimates are corrected) and available abundance forecasts for the current year (2022). In addition, recalibration may also occur when significant changes in one or more of the following model input files are made.

1. BSE (base): This file contains basic information describing the structure of the model (i.e., the number and names of stocks and fisheries, age classes, the base period identification of terminal fisheries, and stock production parameters). This file may be modified annually to incorporate productivity parameters that correspond to new CTC-agreed escapement goals.
2. CEI (ceiling): This file contains historical catch data for the 25 fisheries that are modeled as ceiling or catch quota fisheries (as opposed to fisheries modeled solely through control of exploitation rates) through the most recent fishing season.
3. CNR (Chinook salmon non-retention): Data used by the model to estimate mortalities during CNR periods are read from the CNR file. The data in the CNR file depends on which method is used to calculate CNR mortality. It may include direct estimates of encounters during the CNR period or indicators of fishing effort in the CNR period relative to the retention period.
4. ENH (enhancement file): For 13 hatchery stocks and one natural stock (Lower Strait of Georgia) with supplementation, this file contains productivity parameters as well as the differences (positive or negative) in annual smolt production relative to the base period. However, differences in smolt production relative to the base period have not been updated in over 10 years (other than a few stocks). The environmental variable (EV) scalars can instead provide the functionality of matching cohort numbers of the various stocks to observed terminal return and escapement. Additional discussion of the productivity parameters may be found in the draft model documentation (CTC 1991).
5. FCS (forecast): Agency supplied annual estimates of terminal run sizes or escapements as well as pre-season forecasts are contained in the FCS file. Age-specific information is used for those stocks and years with age data (Appendix G2). For those stocks with

forecasts of abundance provided externally by agencies in 2021, management agencies used three approaches to predict terminal returns or escapements:

    a. Sibling Regression Models: Empirical time-series relationships between abundance (commonly measured as terminal run or spawner escapement numbers) of age a fish in calendar year (CY) and the comparable abundance of age a+1 fish in year CY+1 are used to predict age-structured abundance from estimated age-structured terminal return or escapement (forecast type S in Appendix G2).

    b. Average Return Rate Models: Previous year age-specific return rates of adults per spawner or adults per smolt are applied to estimates of spawners or smolts from the brood years contributing to the coming year's return (forecast type R in Appendix G2).

    c. CTC program ForecastR: ForecastR relies on the open-source statistical software R to generate age-specific or total-abundance forecasts of escapement or terminal run using a variety of generic models including (i) simple and complex sibling regressions with the ability to include environmental covariates, (ii) time series models such as auto regressive integrated moving average (ARIMA), exponential smoothing, and naïve models (based on preceding one year, three years or five years in abundance time series), and (iii) mechanistic models such as average return rate models. ForecastR enables users to perform the following interactive tasks: (a) the selection of forecasting approaches from a wide set of statistical and/or mechanistic models for forecasting terminal run or escapement; (b) the selection of several measures of retrospective forecast performance (e.g., MRE, MAE, MAPE, MASE, RMSE); (c) the comparison of best forecasting models and model ranking based on the selected performance metrics; and, (d) the reporting of forecasting results (point forecasts and interval forecasts) and diagnostics. For both age-structured and non-age-structured data, AIC-based model selection takes place within model types prior to model ranking across model types based on the above-mentioned metrics of retrospective evaluation. ForecastR has been used to produce agency forecasts in 2016–2021 for Canada and Oregon model stocks (forecast type F in Appendix G2).

6. FP (fishery policy): This file contains scalars specific to year, fishery, stock, and age that are applied to base period fishery exploitation rates, primarily in terminal fisheries. The FPs are used to scale annual fishery exploitation rates relative to the model base period and can be used for a variety of purposes. For example, for the ocean areas of the Washington and Oregon North of Cape Falcon (WA/OR) troll fishery, the FPs are used to model differential impacts on Columbia River and Puget Sound stocks as the proportion of the catch occurring in the Strait of Juan de Fuca varies. The source of the FPs is generally the reported catch fishery index (Ratio of Means approach) computed from CWT data in the annual ERA, or the ratios of harvest rates computed from terminal area run reconstructions.

7. IDL (interdam loss): The IDL file contains stock-specific pre-spawning mortality between dams for the Columbia River Summer, Columbia Upriver Bright, Spring Creek Tule, and Snake River Fall stocks provided each year by Columbia River fishery managers. The

factors represent the fraction of the unharvested stock that can be accounted for after mainstem dam passage in the Columbia River. Losses can be attributed to direct mortality at the various dams, mortality in the reservoirs between dams, fall-backs, tailrace spawning, and other factors (as observed through window counts at the various dams upriver). The pre-spawning mortality factor between dams is equal to 1 minus the conversion factor and does not include pre-spawning mortality between the last dam count and the spawning grounds.

8. IM (changes in incidental mortality rates): The IM file contains the IM rates by fishery for legal and sublegal fish. These rates differ from those used in the base period due to alterations in gear, regulations, or fishery conduct.

9. MAT (maturity [MAT] and adult-equivalent [AEQ] factors): The MATAEQ file has annual estimates of maturation rates and AEQ factors for 27 stocks (BON, CBC, CWF, FCF, FHF, FS2, FSO, LGS, LRW, MCB, MGS, MOC, NBC, NOC, NSA, SKG, SPR, SSA, SUM, TST, UGS, URB, WCH, WCN, WSH, WVH, WVN). These annual estimates replace the single (not age-specific) maturation schedule rates in the stock (STK) file with age-specific rates. Exponentially smoothed (ETS) forecasts are used for years beyond the last year for which estimates are available (due to incomplete broods and the one-year lag for completion of the annual ERA). The AWG anticipates changes to the file and program to estimate maturation rates in future years.

10. PNV (proportion non-vulnerable): A PNV file is created for each fishery for which a size limit change has occurred since the model base period. Each file contains age-specific estimates of the proportion of fish not vulnerable to the fishing gear, or smaller in length than the minimum size limit. The PNVs were estimated from empirical size distribution data; in some instances, independent surveys of encounter rates were used to adjust the PNV for age-2 fish to account for the proportion of the cohort that was not vulnerable to the fishing gear. PNVs are not currently stock specific but that change is on the AWGs list of model improvements in the future.

11. STK (stock): This file contains the stock- and age-specific starting (base period) cohort sizes, the base period exploitation rates on the vulnerable cohort for each model fishery, and non-year specific maturation schedules and AEQ factors. This file is updated if new stocks or fisheries are added, new CWT codes are used to represent distribution patterns of existing model stocks, or a re-estimation of base period data occurs. Modification of this file will result in a model different from that used in the negotiations (CLB 9812).

The calibration is controlled through a file designated with an OP7 conversion extension.

Appendix G1— Month of the year when agencies can provide final estimates for the previous year and pre-season forecasts of abundance for the next fishing year.

Model Stock	Month Final Estimate Available	Month(s) Forecast Available
Southern SE Alaska	January	None[1]
Northern SE Alaska	January	None[1]
Alsek	January	None[1]
Taku and Stikine	January	None[1]
Northern British Columbia	November	February
Central British Columbia	November	February
Fraser Spring 1.2	February	February/March
Fraser Spring 1.3	February	February/March
Fraser Summer Ocean-type	February	February/March
Fraser Summer Stream-type	February	February/March
Fraser Harrison Fall	February	February/March
Fraser Chilliwack Fall Hatchery	February	February/March
WCVI Natural	January	February
WCVI Hatchery	January	February
Upper Strait of Georgia	January	February
Puntledge Summers	January	February
Lower Strait of Georgia	December	February
Middle Strait of Georgia	December	February
Nooksack Spring	June	February
Nooksack Fall (Samish)	June	February
Snohomish Wild	June	February
Skagit Wild	June	February
Puget Sound Natural Fingerling	June	February
Stillaguamish Wild	June	February
Puget Sound Hatchery Fingerling	June	February
Puget Sound Hatchery Yearling	June	February
Washington Coastal Wild	June	March[2]
Washington Coastal Hatchery	June	March[2]
Cowlitz Spring Hatchery	June	December
Willamette River Hatchery	June	December
Columbia River Summer	September	February
Fall Cowlitz Hatchery	February	February, April[3]
Spring Creek Hatchery	February	February, April[3]
Lower Bonneville Hatchery	February	February, April[3]
Upriver Brights	February	February, April[3]
Snake River Wild Fall	February	February
Mid-Columbia River Bright	February	February, April[3]
Lewis River Wild	February	February, April[3]
North Oregon Coast	February	March
Mid-Oregon Coast	February	March
Yakutat Forelands	January	None

[1] Forecast is internally estimated using the Pacific Salmon Commission Chinook Model so no agency forecast is provided.

[2] Normally forecasts are not available for the model calibration, but these were available in 2021.

[3] A preliminary ocean escapement forecast is released in February. An updated ocean escapement forecast reflecting the ocean fishery option adopted by the Pacific Fisheries Management Council is released in April.

Appendix G2— Characteristics used to forecast the abundance of stocks in the Pacific Salmon Commission Chinook Model.

Model Stock	Forecast Characteristics			Comments
	Forecast Type[1]	Pre-season age-specific	Post-season age-specific	
Yakutat Forelands	F	Yes	Yes	Calibrated to escapement
Southern SE Alaska	C	Yes	Yes	Calibrated to escapement
Northern SE Alaska	C	Yes	Yes	Calibrated to escapement
Alsek	C	Yes	Yes	Calibrated to escapement
Taku and Stikine	C	Yes	Yes	Calibrated to escapement
Northern British Columbia	F	No	No	Calibrated to escapement
Central British Columbia	F	No	No	Calibrated to escapement
Fraser Spring 1.2	F	No	No	Calibrated to terminal run
Fraser Spring 1.3	F	No	No	Calibrated to terminal run
Fraser Summer Ocean-type	F	Mixed	Yes	Calibrated to escapement
Fraser Summer Stream-type	F	No	No	Calibrated to terminal run
Fraser Harrison Fall	F	Yes	Yes	Calibrated to escapement
Fraser Chilliwack Fall Hatchery	F	Yes	Yes	Calibrated to escapement
WCVI Natural	F	Yes	Yes	Calibrated to terminal run
WCVI Hatchery	F	Yes	Yes	Calibrated to terminal run
Upper Strait of Georgia	F	No	No	Calibrated to escapement
Puntledge Summers	F	No	No	Calibrated to escapement
Lower Strait of Georgia Hatchery	F	Yes	Yes	Calibrated to terminal run
Middle Strait of Georgia	F	Yes	Yes	Calibrated to escapement
Nooksack Spring	R	No	No	Calibrated to escapement
Nooksack Fall (Samish)	R	No	No	Recent year average return rate
Snohomish Wild	R	No	No	Recruits per Spawner
Skagit Wild	R	Yes	Yes	Average cohort return rate
Puget Sound Natural Fingerling	R	No	No	Calibrated to terminal run
Stillaguamish Wild	R	No	No	Recruits per Spawner
Puget Sound Hatchery Fingerling	R	No	No	Age-specific forecasts not available for all components
Puget Sound Hatchery Yearling	R	No	No	Age-specific forecasts not available for all components
Washington Coastal Wild	R	No	No	Average return rate
Washington Coastal Hatchery	R	No	No	Average return rate
Cowlitz Spring Hatchery	S	Yes	Yes	Prediction is to mouth of tributary streams
Willamette River Hatchery	S	Yes	Yes	Prediction is to mouth of Willamette River
Columbia River Summer	S	No	No	Run reconstruction used to estimate Columbia River mouth return
Spring Creek Hatchery	S	Yes	Yes	Run reconstruction used to estimate Columbia River mouth return
Lower Bonneville Hatchery	S	Yes	Yes	Run reconstruction used to estimate Columbia River mouth return
Upriver Brights	S	Yes	Yes	Run reconstruction used to estimate Columbia River mouth return
Lyons Ferry (Snake River Wild	R	No	No	Run reconstruction used to estimate

Model Stock	Forecast Characteristics			Comments
	Forecast Type[1]	Pre-season age-specific	Post-season age-specific	
Fall)				Columbia River mouth return
Mid-Columbia River Bright	S	Yes	Yes	Run reconstruction used to estimate Columbia River mouth return
Lewis River Wild	S	Yes	Yes	Run reconstruction used to estimate Columbia River mouth return
North Oregon Coast	F	Yes	Yes	Individual river age structure from by-age/size recovery probability as well as age structure in nearby rivers
Mid-Oregon Coast	F	Yes	Yes	Individual river age structure from by-age/size recovery probability as well as age structure in nearby rivers

[1] Externally provided forecast type codes are S = sibling; R = return rate; F = ForecastR; C = PSC Chinook Model internally estimated projection.

Calibration Procedures

The calibration uses an iterative algorithm to estimate environmental variables (EV) scalars for each brood year and model stock to account for annual variability in natural mortality in the initial year of ocean residence. The EV scalars are used to adjust age-1 abundances estimated for each stock and BY to observed terminal return or escapement in combination with the base period spawner-recruit function. Fishing impacts and natural mortalities are then applied through model processes. The EVs also adjust for biases resulting from errors in the data or assumptions used to estimate the base period parameters for the spawner-recruit functions.

The EVs are estimated through the following steps for stocks calibrated to age-specific terminal run sizes. However, non-age specific data may also be used:

1. Predicted terminal runs/escapements are first computed for each year using the input files discussed above and the base period stock-recruitment function parameters (i.e., EV stock productivity scalars set equal to 1).
2. The stock scalar ratio (SC_{BY}) of the observed terminal run/escapement and the model predicted terminal run/escapement from the previous step is computed for each BY. For example, if the observed and model predicted terminal runs for the 1979 brood were 900 and 1,500 age-3 fish in 1982, 4,000 and 4,500 age-4 fish in 1983, and 1,000 and 1,500 age-5 fish in 1983, the ratio would be computed as:

$$SC_{BY} = \frac{\sum\limits_{a=Minage}^{Maxage}(ObservedTerminalRun)_a}{\sum\limits_{a=Minage}^{Maxage}(ModelPredictedTerminalRun)_a}$$

Equation H.1

$$SC_{BY} = \frac{900+4000+1000}{1500+4500+1500}$$

Equation H.2

In the absence of age-specific estimates of the terminal run, the components are computed by multiplying the total terminal run by the model predictions of age

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composition.

3. The EV for iteration *n* and brood year *BY* is computed as:

$$EV_{n,BY} = EV_{n-1,BY} * SC_{BY}$$

4. Steps 1–3 are repeated iteratively, across all stocks, until the absolute change in the EVs for each stock and brood is less than a predetermined tolerance level (0.05). The tolerance level can be changed if more precise agreement is desired:

$$\left| \frac{EV_{n,BY} - EV_{n-1,BY}}{EV_{n-1,BY}} \right| < 0.05$$

Several options for the calibration are provided in the OP7 control file. The options include the ability to control the BYs for which the EVs are estimated each iteration, and also the type of convergence criteria. For the 2021 pre-season calibration, EVs were estimated for all BYs each iteration. Convergence was defined at an EV change tolerance level of 0.05.

Stock-specific calibration options are specified in the FCS file:
- Minimum Number of Age Classes: Data for all age classes will not be available when the EVs are estimated for recent, incomplete broods. Since considerable uncertainty may exist in a single data point, application of the calibration algorithm can be restricted to cases in which a specific minimum number of age classes are present.
- Minimum Age: Considerable uncertainty often exists in the estimates of terminal runs or escapements for younger age classes, particularly age 2. The minimum age class to include in the calibration algorithm is specified in the FCS file.
- Estimation of Age Composition: Age-specific estimates of the terminal run or escapement may not be available. An option is provided to estimate the age composition using base period maturation and exploitation rates.

The 2021 calibration was completed in two stages (as it is normally conducted) to facilitate computation of the average exploitation rates and incorporation of the agency forecasts. The Stage 1 calibration provided initial estimates of exploitation rate scalars for fishing years 1979–2019 using updated catch and escapement data through 2020. Average exploitation rate scalars ($\overline{FP}$) were then computed and used as input values for the 2020 and 2021 fisheries in the Stage 2 calibration, except that the forecasts for the WCVI and Fraser Late (FRL) stocks already accounted for changes in the ocean fisheries.

The $\overline{FP}$ for each model fishery was obtained from the Stage 1 calibration using the following formula (subscripts follow those defined in Appendix G3):

$$\overline{FP}_{a,s,CY,f} = \frac{\sum_{CY=CY_{start}}^{CY_{end}} RT_{CY} * FP_{s,a,CY,f}}{(CY_{end} - CY_{start})}$$

The term RT_{CY} refers to the ratio of the catch quota in the current year to the catch that would be predicted given current abundance, current size limits, and base period exploitation rates.

The range of years used to compute the $\overline{FP}$ varied between stocks and was fishery- and age-specific. The input files used in the Stage 2 calibration were identical to those used in Stage 1 with two exceptions: the average exploitation rate scale factors for each fishery were inserted into the $\overline{FP}$ file for the penultimate year, and the Stage 1 EVs were used as starting values for the Stage 2 calibration.

To determine the acceptability of a calibration by the CTC (i.e., whether an annual calibration is deemed final by the CTC), several results are examined.
1. Accuracy of the reconstructed catches in the fisheries (these values will consistently differ from the actual catches if the calibration is not able to exactly recreate the actual catches in the years 1979 through 1984, the model years used prior to implementation of the ceiling algorithm);
2. Accuracy of model-predicted terminal runs or escapements relative to the data used for calibration of each stock;
3. Comparison of model-predicted age structure in terminal runs or escapements with the data used for calibration (consistent biases in age structure are addressed by changing maturation rates); and
4. Comparison of CWT-based and model estimates of fishery harvest rate indices.

Calibration usually involves an iterative process until a judgment is made by the CTC that an acceptable fit to all the data was achieved. This decision usually involves an inspection, discussion, and trial-and-error process. The determination of whether or not further calibrations are necessary is based principally on the significance of deviations from observed or estimated values for stocks and fisheries most relevant to the issues to be evaluated, and on the time constraints established for completion of the calibration.

Changes to model calibration procedures for 2021 are provided in Appendix H.

Key Calibration Outputs

The PSC Chinook Model was originally constructed as a tool to evaluate the effect of fishery management actions on the rebuilding of depressed Chinook salmon stocks. However, since the implementation of the 1999 PST Agreement (PST 2000), the primary purpose of the model has been to enable abundance-based management in the PST through the production of fishery abundance indices. The model generates pre-season projections of AIs for the SEAK, NBC, and WCVI AABM fisheries and post-season estimates of the AIs that enable evaluations of AABM performance (i.e., pre- versus post-season AI and annual catch comparisons). For each AABM fishery (f), an AI is computed for the upcoming fishing year (CY) as:

$$AI_{f,CY} = \frac{\sum_s \sum_a Cohort_{s,a,CY} ER_{s,a,f}(1-PNV_{a,f})}{\sum_s \sum_a Cohort_{s,a,BP} ER_{s,a,f}(1-PNV_{a,f})} \qquad \textit{Equation H.6}$$

where $Cohort_{s,a,CY}$ and $Cohort_{s,a,BP}$ are pre-season (projected) and base period (BP, fishing years 1979–1982) abundances of model stock (s) by age (a), respectively. Thus, the AI is the ratio between the expected catch in the year of interest under base period exploitation patterns and

the estimated average catch during the 1979–1982 base period. Given the pre-season AI projections, the ACLs are then set for the NBC and WCVI AABM fisheries according to the terms specified in Appendix C of Annex IV, Chapter 3 of the 2019 PST Agreement . Beginning in 2019, the ACL for the SEAK AABM fishery is based on the SEAK early winter District 113 Troll fishery CPUE metric and determined using Table 2 of Chapter 3 of the 2019 PST Agreement.

Fishery Indices

When the PST was originally signed in 1985, catch ceilings and increases in stock abundance were expected to reduce harvest rates in fisheries. The fishery index provided a means to assess performance against this expectation. Relative to the base period, an index less than 1.0 represents a decrease from base period harvest rates, whereas an index greater than 1.0 represents an increase. Although the determination of ACLs for AABM fisheries in the 2019 PST Agreement is different from the original PST catch ceilings, these fishery indices continue to provide a useful index of relative change in harvest rates in these fisheries. Fishery indices are used to measure relative changes in fishery harvest rates because it is not possible to directly estimate the fishery harvest rates.

Fishery indices are computed in adult equivalents (AEQs) for both reported catch and total mortality (reported catch plus IM). The total mortality AEQ exploitation rate is estimated as:

$$ER_{s,a,f,CY} = \frac{TotMorts_{s,a,f,CY} * AEQ_{s,BY=CY-a,a,f}}{Cohort_{s,BY=CY-a,a} * (1 - NM_a)}$$

Equation H.7

whereas the reported catch AEQ exploitation rate is estimated as

$$ER_{s,a,f,CY} = \frac{\mathrm{Re}\,pMorts_{s,a,f,CY} * AEQ_{s,BY=CY-a,a,f}}{Cohort_{s,BY=CY-a,a} * (1 - NM_a)}$$

Equation H.8

and a ROM estimator is used to calculate the FI

$$FI_{f,CY} = \frac{\sum_{s\in\{S\}}\sum_{a\in\{A\}} ER_{s,a,f,CY}}{\left(\dfrac{\sum_{BPYR=79}^{82}\sum_{s\in\{S\}}\sum_{a\in\{A\}} ER_{s,a,f,BPYR}}{4}\right)}$$

Equation H.9

For AABM fisheries, fishery indices are presented for troll gear only, although the ACLs also apply to sport and net fisheries in SEAK and sport fisheries in NBC and WCVI. As in past years, CWT recoveries from the troll fisheries are used because these fisheries represent the majority of the catch and have the most reliable CWT sampling. In addition, there are data limitations in the base period for the sport fisheries (e.g., few observed recoveries in NBC due to small fishery size). Because the allocation of the catch among gear types has changed in some fisheries (e.g., the proportion of the catch harvested by the sport fishery has increased in all AABM fisheries), the indices may not represent the harvest impact of all gear types.

The CTC uses fishery indices to reflect changes in fishery impacts relative to the base period (catch years 1979–1982). The ROM estimator of the fishery index confines inclusion of stocks to those with adequate tagging during the base period, but fishing patterns for some fisheries have changed substantially since the base period and some stocks included in the index are no longer tagged (e.g., University of Washington Accelerated). One example is the evolution of the seasonality of SEAK troll fishing. Because stock distributions are dynamic throughout the year, stock-specific impacts of the SEAK fishery have likely changed over time.

To account for changes in stock composition and to include stocks without base period data, the CTC has created alternative derivations of fishery indices (CTC 1996). The CTC determined that a useful FI should have these characteristics:

1. The index should measure changes in fishery harvest rates if the distribution of stocks is unchanged from the base period.
2. The index should have an expected value of 1.0 for random variation around the base period fishery harvest rate, cohort size, and stock distributions.
3. The index should weight changes in stock distribution by abundance.

After exploring several alternatives, the CTC concluded that the best estimate for a fishery index would consist of the product of a fishery harvest rate index and an index of stock abundance weighted by average distribution (i.e., the proportion of a cohort vulnerable to the fishery). To that effect, a report by the CTC (2009) stated that for all AABM fisheries, the stratified proportional fishery index (SPFI) was the most accurate and precise index for estimating the harvest rate occurring in a fishery. However, the SPFI was never fully implemented for the NBC and WCVI Troll fisheries for reasons described in Section 4.1.

For computation of the SPFI, the CWT harvest rate ($h_{t,CY}$) must initially be set to an arbitrary value between 0 and 1. Then, the stock-age distribution parameter ($d_{t,s,a}$) is calculated (Equation H.10), and the result is substituted into Equation H.11 to recursively recalculate $h_{t,CY}$ and subsequently $d_{t,s,a}$. The largest stock-age distribution parameter in a stratum is then set to 1 to create a unique solution. See Appendix G3 for notation description.

$$d_{t,s,a} = \sum_{CY} r_{t,CY,s,a} \bigg/ \sum_{CY} \left(h_{t,CY} * n_{CY,s,a} \right)$$

Equation H.10

$$h_{t,CY} = \sum_{s}\sum_{a} r_{t,CY,s,a} \bigg/ \sum_{s}\sum_{a} \left(d_{t,s,a} * n_{CY,s,a} \right)$$

Equation H.11

The resulting unique solution is inserted into the following equations to compute the yearly harvest rates for each stratum (Equation H.14) and the overall fishery (Equation H.15).

$$H_{t,CY} = \left[\left(\frac{\sum_{s}\sum_{a} c_{t,CY,s,a}}{\sum_{s}\sum_{a} r_{t,CY,s,a}} \right) * \left(C_{t,CY} - A_{t,CY} \right) \right] \bigg/ \left[\left(C_{t,CY} - A_{t,CY} \right) \big/ h_{t,CY} \right]$$

Equation H.12

$$H_{.CY} = \sum_{t}\left[\left(\frac{\sum_{s}\sum_{a}c_{t,CY,s,a}}{\sum_{s}\sum_{a}r_{t,CY,s,a}}\right)*\left(C_{t,CY}-A_{t,CY}\right)\right]\Bigg/\sum_{t}\left[\left(C_{t,CY}-A_{t,CY}\right)\Big/h_{t,CY}\right]$$

Equation H.13

$$S_{t,CY} = H_{t,CY}\Bigg/\sum_{CY=1979}^{1982}H_{t,CY}$$

Equation H.14

$$S_{.CY} = H_{.CY}\Bigg/\sum_{CY=1979}^{1982}H_{.CY}$$

Equation H.15

Appendix G3— Parameter descriptions for equations used for the stratified proportional fishery index (SPFI).

Parameter	Description
$A_{t,CY}$	Alaska hatchery origin catch by strata t, year CY
$c_{t,CY,s,a}$	adult equivalent CWT catch by strata t, year CY, stock s and age a
$C_{t,CY}$	catch by strata t, year CY
$d_{t,s,a}$	distribution parameter by strata t, stock s and age a
$h_{t,CY}$	CWT harvest rate by strata t, year CY
H_{CY}	harvest rate by year CY
$H_{t,CY}$	harvest rate by strata t, year CY
$n_{CY,s,a}$	CWT cohort size by year CY, stock s and age a
$r_{t,CY,s,a}$	CWT recoveries by strata t, year CY, stock s and age a
$S_{.CY}$	SPFI by year CY
$S_{t,CY}$	SPFI by strata t, year CY

APPENDIX H: ISSUES WITH AND CHANGES TO THE PACIFIC SALMON COMMISSION CHINOOK MODEL CALIBRATION

FPA Files

An error was found in the Fraser Freshwater Sport FPA file. Three of the six stock-specific FPs in this file are derived via the "Larrie Method" which determines the FP value to match the observed catch. The wrong observed catch has been supplied for the Fraser Summer stream-type (FSS) stock now for several years. Updated observed catches for this stock resulted in revised FPs.

FPs for the Alaska Troll FPA file are derived from the SPFI. These FPs changed slightly throughout the time series due to an error in one of the external input files for the SPFI to FPA program. The error was related to misalignment in the catch data by a single year. This has been an issue for, at a minimum, several years.

FCS File

In the comparisons folder of the calibration (comparisons to 2104), there is a *.pdf document ("1 fcs differences.pdf") that shows changes in the time series of terminal returns or escapement for model stocks. Commentary is provided below only for stocks with significant changes.

There were notable changes to the terminal run estimates for the Skagit Wild stock from 1994 to 2021 for all ages. Analysts could not resolve how estimates were previously calculated. New run-reconstruction techniques were developed. Forecast values for 2022 are from Washington Department of Fish and Wildlife (WDFW) and tribal co-managers and are consistent with terminal run estimate values.

Nooksack Spring escapement estimates since 2011 were updated. Previous estimates only included natural origin recruits. Hatchery returns to the spawning ground are now included. 2022 forecast values also include hatchery returns to the spawning grounds.

SACE R Program

Updates were made to the SACE R program to handle situations with sparse CWT data. The program was revised based on reformulated equations that no longer require CWT recoveries for the youngest age. Additional changes were also made to handle situations when a pre-terminal mortality rate could not be calculated due to no CWT recoveries. In this situation, the incalculable rate can be interpolated with a mean rate estimate from periods before and after 1999. Interpolation is also being used now in cases when the CWT pre-terminal total mortality exceeds the estimated cohort size resulting in a pre-terminal total mortality rate greater than one. When left uncorrected, the result of the latter two data anomalies resulted in SACE derived maturity rates of 1 for the next to oldest age. By imputing, SACE derived maturity rates can be used instead of CWT derived maturity rates. Using SACE derived maturity rates that relied on imputing generally resulted in better fits to the observed terminal run data by calendar year compared to using CWT derived maturity rates. With these updates to the

program, SACE derived maturity rates of 1 of the next to oldest age will only occur when the observed terminal run of the oldest age is 0.

The following broods now utilize SACE instead of CWT maturation rates:

- BON
  - 1986–1988,1990,1991,1993–1996, 2002–2008, 2010, 2013–2015
- CWF
  - 1997, 2004
- LGS
  - 1985,1987, 1990, 1993,1995–1997,2002–2007, 2009, 2012–2016
- MGS
  - 2007, 2014, 2015
- SKG
  - 1996, 2010
- SPR
  - 1983,1984, 1992,1994, 2002–2008, 2010, 2012–2015
- WSH
  - 1994, 2003

Maturation Rate Forecasting Procedure

Prior to this calibration, exponentially smoothed (ETS) forecasts were made four years prior to the current calendar year for all stocks in the MATAEQ file. Starting forecasts four years prior to the calendar year makes sense for Canadian and Alaskan stocks, but not for Southern U.S. (SUS) stocks that lack one additional year behind in the ERA (e.g., only CWT recoveries up until 2020 are used in the 2022 ERA). Because of this additional lag for SUS stocks, previous maturity rates for the SUS stocks part of the SACE procedure were a mixture of sources derived from the SACE procedure and CWTs. (i.e., the final maturity rate prior to forecasting was derived from CWTs and previous rates were derived from SACE). To avoid this, forecasting started one year earlier for SUS stocks so that there was not a mixture of CWT and SACE estimates.

OP7 File

Line 72 of the P.OP7 file changed value from 1 to 2 so that that the b.FP file, which includes FP x RT averages, are used in the projection run. This change reflects a decision of the AWG from several years ago. It is unclear how this value in the P.OP7 reverted back to 1.