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2019 Exploitation Rate Analysis and Model Calibration

Volume One

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Note: Product names used in this publication are included for completeness, but do not constitute product endorsement.

LIST OF ACRONYMS

AABM	Aggregate Abundance-Based Management
AC	Allowable Catch
ADF&G	Alaska Department of Fish and Game
AEQ	Adult Equivalent
AI	Abundance Index
AIC	Akaike Information Criterion
AMA	Additional Management Actions
ARIMA	Auto Regressive Integrated Moving Average
AWG	Analytical Working Group of the CTC
B.C.	British Columbia
BSE	Base Calibration File
BY	Brood Year
BYER	Brood Year Exploitation Rate
CBC	Central British Columbia
CDN	Canada
CEI	Ceiling file
CLB	Calibration
CNR	Chinook Non-retention
CPUE	Catch Per Unit Effort
CRITFC	Columbia River Intertribal Fish Commission
CTC	Chinook Technical Committee
CWTIP	Coded Wire Tag Improvement Program
CWT	Coded Wire Tag
CY	Calendar Year
DFO	Fisheries and Oceans Canada
DIT	Double Index Tag
ENH	Enhancement File
ERA	Exploitation Rate Analysis
EV	Environmental Variable
FI	Fishery Index
FNC	First Nations Caucus
FP	Fishery Policy
FSC	Forecast File
IDL	Interdam Loss
IM	Incidental Mortality
IDFG	Idaho Department of Fish and Game
iREC	Internet Recreational Effort and Catch
ISBM	Individual Stock-Based Management
JDF	Juan de Fuca
MAE	Mean Absolute Error
MAPE	Mean Absolute Percent Error
MASE	Mean Absolute Scaled Error
MAT	Maturity Factor
MDT	Mortality Distribution Table
MM	Mass Marked
MRE	Mean Relative Error

MSF	Mark-Selective Fishery
NA	No Data Available
NBC	Northern British Columbia (Dixon Entrance to Kitimat including Haida Gwaii)
NC	Not Calculated
NMFS	National Marine Fisheries Service
NSF	Non-Selective Fishery
NWIFC	Northwest Indian Fisheries Commission
ODFW	Oregon Department of Fish and Wildlife
PFMA	Pacific Fishery Management Area
PNV	Proportion Non-Vulnerable
PSC	Pacific Salmon Commission
PST	Pacific Salmon Treaty
QIN	Quinault Indian Nation
RM	Release Mortality
RMIS	Regional Mark Information System
RMSE	Root Mean Squared Error
ROM	Ratio of Means
SEAK	Southeast Alaska (Cape Suckling to Dixon Entrance)
SIT	Single Index Tag
SPFI	Stratified Proportional Fishery Index
SPS	South Puget Sound
STK	Stock File
SUS	Southern United States
TAC	Total Allowable Catch
TBR	Transboundary
UAF	University of Alaska Fairbanks
URB-MCB	Upriver and Mid-Columbia Bright
U.S.	United States
USFWS	United States Fish and Wildlife Service
WA/OR	Washington and Oregon
WCVI	West Coast Vancouver Island (excluding Area 20)
WDFW	Washington Department of Fish and Wildlife

Executive Summary

The 2019 Pacific Salmon Treaty (PST) Agreement requires the Chinook Technical Committee (CTC) to report annual catches, harvest rate indices, estimates of incidental mortality (IM) and exploitation rates for all Chinook salmon fisheries and stocks harvested within the Treaty area. The CTC provides an annual report to the Pacific Salmon Commission (PSC) to fulfill this obligation, as agreed by Canada and the United States (U.S.) under Chapter 3 of the Treaty. This report contains four sections: 1) an introduction and description of the Chinook model procedures, 2) a review of the results from the annual Exploitation Rate Analysis (ERA) based on coded wire tag (CWT) data, 3) a description of the calibration (CLB) procedure and results from the calibration of the PSC Chinook Model, and 4) CWT analyses for mark-selective fisheries (MSFs). This report includes the results of the 2019 annual exploitation rate assessment of CWT data through 2017 (Southern U.S. stocks) and 2018 (Alaskan and Canadian stocks), the pre-season PSC Chinook Model calibration results for 2019 (CLB 1905), and post-season PSC Chinook Model calibration results through 2018 (CLB 1905). Model calibrations are named using the last two digits of the year (19) followed by the iteration number of the calibration (05). Results include the abundance indices (AIs) for the aggregate abundance-based management (AABM) fisheries and individual stock-based management (ISBM) indices for each country. The 2019 PST Agreement applies to all analyses and model calibration results for 2019 fisheries. Assessment of 2018 fisheries, including post-season AIs, were conducted under the 2009 PST Agreement.

AABM Abundance Indices and Associated Catches

The pre- and post-season AIs for the three AABM fisheries—Southeast Alaska (SEAK), Northern British Columbia (NBC), and West Coast Vancouver Island (WCVI) are presented in Table 1. The 2019 PST Agreement also specifies an allowable catch associated with each AI for each AABM fishery. Each year, the final 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 estimate the total allowable catch (TAC) limits in the upcoming fishing season for the NBC and WCVI AABM fisheries. Beginning in 2019, the pre-season TAC limit for the SEAK AABM fishery is determined by the SEAK early winter District 113 troll fishery catch per unit effort (CPUE) metric. From 2009 to 2018, catch overages and underages were tracked relative to post-season AIs and their associated allowable catches, which are calculated by the first CTC-accepted post-season model calibration for a fishing year, per 2009 PST Agreement Chapter 3 subparagraph 11(a)(i). Beginning in 2019, catch overages and underages are tracked relative to pre-season and post-season AIs (or the CPUE metric) and their associated allowable catch limits. Any overages relative to the pre-season allowable catch limits must be paid back in the subsequent fishing year, per 2019 PST Chapter 3 subparagraph 6(h)(i). If overages are observed in two successive years relative to post-season allowable catch limits, then the affected AABM fishery must take steps to reduce the variance between the pre-season and post-season allowable catch limits per Chapter 3 subparagraph 7(b)(i) and the CTC must present a plan to the PSC to improve the pre-season, in-season and other management tools to reduce the discrepancies between the pre-season and post-season allowable catch limits to a maximum level of 10% per Chapter 3 subparagraph 7(b)(ii).

Table 1 Abundance Indices for 2009–2019 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.

	SEAK		NBC		WCVI	
Year	Pre-season	Post-season	Pre-season	Post-season	Pre-season	Post-season
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	3.38[3]		0.96		0.61	

[1] Due to changes in calibration procedures (reviewed in section 3.1.4), 2012 post-season (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 1602 to estimate the 2014 and 2015 post-season AIs and 2016 pre-season AI.
[3] Per paragraph 6(b) of the 2019 PST Agreement, this number represents a catch limit based on a CPUE statistic and corresponds to an AI of 1.07.

The maximum allowable pre-season and post-season Treaty catch by fishery for each year and the observed Treaty catches (total catch minus any hatchery add-on and exclusion catch) are shown for AABM fisheries for 2009–2019 in Table 2.

Table 2 Pacific Salmon Treaty (PST) pre-season allowable catches (2009–2019), and post-season allowable catches and observed catches (2009–2018) for Southeast Alaska (SEAK), Northern British Columbia (NBC), and West Coast Vancouver Island (WCVI) aggregate abundance-based management (AABM) fisheries. Post-season values for each year are from the first post-season calibration following the fishing year.

PST Allowable and Observed Catches									
	SEAK (Troll, Net, Sport)			NBC (Troll, Sport)			WCVI (Troll, Sport)		
Year	Pre-season Allowable Catch	Post-season Allowable Catch	Observed Catch	Pre-season Allowable Catch	Post-season Allowable Catch	Observed Catch	Pre-season Allowable Catch	Post-season Allowable Catch	Observed Catch
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	120,306	133,300	113,800	135,210[2]
2013	176,000	284,900	191,388	143,000	220,300	115,914	115,300	178,000	116,871[2]
2014[1]	439,400	378,600	435,195	290,300	262,600	216,901	205,400	191,700	192,705[2]
2015[1]	237,000	337,500	335,026	160,400	246,600	158,903	127,300	179,700	118,974[2]

2016	355,600	288,200	350,704	248,000	183,900	190,181	133,300	104,800	103,093[2]
2017	209,700	215,800	175,414	149,500	148,200	143,330	115,300	95,800	117,416[2]
2018	144,500	118,700	127,776	131,300	115,700	108,976	88,300	88,300	85,330
2019	140,323[3]			124,800			79,900		

[1] Due to a disagreement over Model calibration 1503, the Commission agreed to use output from CLB 1602 to estimate the catches associated with the 2014 and 2015 post-season AIs and 2016 pre-season AIs.
[2] WCVI observed catches have increased from previously reported values after a new electronic sport reporting system (internet recreational effort and catch; iREC) was implemented and approved for use.
[3] Per paragraph 6 (b) of the 2019 PST Agreement, this number represents a catch limit based on a CPUE statistic.

Overages and underages in AABM catches, relative to the first post-season calibration for a fishing year (Table 3), can arise due to the in-season management system, errors in the pre-season calibration process (e.g., forecast error), or a combination of the two. The relative influence of each was evaluated by inspecting differences in actual landed catch and allowable catches from both pre-season and post-season calibrations (Table 3). In 2018, actual landed catch was less than pre-season allowable catch by 16,724 (12%) in SEAK, 22,324 (17%) in NBC, and 2,970 (3%) in WCVI due to in-season management. In terms of the post-season allowable catches for evaluation of the provisions of the PST (subparagraph 11(a)(i)), 2018 actual catches were less than the post-season allowable catches by 6,724 (6%) in NBC and 2,970 (3%) in WCVI, and greater than the post-season allowable catch by 9,076 (8%) in SEAK.

From 2009–2018, the SEAK AABM observed catch was greater than post-season allowable catch in 7 of 10 years, whereas in NBC observed catch was greater than post-season allowable catch in 1 of 10 years and WCVI observed catch was greater than post-season allowable catch in 5 of 10 years (Table 3).

Table 3 Summary of aggreagate abundance-based management (AABM) fishery performance and deviations between pre- and post-season allowable catches and observed catches for Southern Alaska (SEAK), Northern British Columbia (NBC), and West Coast Vancouver Island (WCVI), 2009–2018.

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.

Year	Mgmt error Obs - Pre catches	Mgmt error Obs - Pre %	Model error Pre - Post catches	Model error Pre - Post %	Total error Obs - Post catches	Total error Obs - Post %
SEAK (Troll, Net, Sport)						
2009	9,154	4%	42,800	24%	51,954	30%
2010	8,811	4%	6,000	3%	14,811	7%
2011	-3,639	-1%	11,500	4%	7,861	3%
2012	-23,979	-9%	61,700	30%	37,721	18%
2013	15,388	9%	-108,900	-38%	-93,512	-33%
2014	-4,205	-1%	60,800	16%	56,595	15%
2015	98,026	41%	-100,500	-30%	-2,474	-1%
2016	-4,896	-1%	67,400	23%	62,504	22%
2017	-34,286	-16%	-6,100	-3%	-40,386	-19%
2018	-16,724	-12%	25,800	22%	9,076	8%
NBC (Troll, Sport)						
2009	-33,530	-23%	3,900	3%	-29,630	-21%
2010	-15,487	-10%	-8,300	-5%	-23,787	-15%
2011	-59,740	-33%	-4,400	-2%	-64,140	-34%
2012	-53,293	-31%	24,100	16%	-29,193	-20%
2013	-27,086	-19%	-77,300	-35%	-104,386	-47%
2014	-73,399	-25%	27,700	11%	-45,699	-17%
2015	-1,497	-1%	-86,200	-35%	-87,697	-36%
2016	-57,819	-23%	64,100	35%	6,281	3%
2017	-6,170	-4%	1,300	1%	-4,870	-3%
2018	-22,324	-17%	15,600	13%	-6,724	-6%
WCVI (Troll, Sport)						
2009	16,817	16%	16,500	18%	33,317	36%
2010	-4,653	-3%	1,400	1%	-3,253	-2%
2011	7,432	4%	62,000	46%	69,432	52%
2012	1,910	1%	19,500	17%	21,410	19%
2013	1,571	1%	-62,700	-35%	-61,129	-34%
2014	-12,695	-6%	13,700	7%	1,005	1%
2015	-8,326	-7%	-52,400	-29%	-60,726	-34%
2016	-30,207	-23%	28,500	27%	-1,707	-2%
2017	2,116	2%	19,500	20%	21,616	23%
2018	-2,970	-3%	0	0%	-2,970	-3%

Note: Due to a disagreement over Model calibration 1503, the Commission agreed to use output from CLB 1602 to estimate the catches associated with the 2014 and 2015 post-season AIs and 2016 pre-season AIs.

ISBM Indices

For ISBM fisheries, Paragraph 8 of the Chinook Chapter of the 2009 PST Agreement specifies that Canada and the U.S. will reduce base period exploitation rates on specified stocks by 36.5% (Canada) and 40% (U.S.), equivalent to ISBM indices of 63.5% (Canada) and 60% (U.S.). This requirement is referred to as the *general obligation* and does not apply to stocks that achieve their CTC-agreed escapement goal. The 2009 PST Agreement also specifies that for those stocks in which the general obligation is insufficient to meet the CTC-agreed escapement goal, the Party in whose waters the stock originates shall further constrain its fisheries to an extent that is not greater than the average ISBM exploitation rate which occurred in the years 1991 to 1996 (Paragraph 8(c)). This requirement is referred to as the *additional obligation*.

Post-season ISBM Indices

For 2017, five of the seven Canadian ISBM indices that could be calculated from CWT data were reduced more than required under the Agreement, WCVI Falls (0.629) exceeded the additional obligation rate (0.475), and Harrison (0.272) did not meet its escapement goal and exceeded its additional obligation rate (0.268, Table 4). For 2018, the computation of CWT-based ISBM indices was possible for four Canadian stocks, and all four were reduced more than required under the 2009 PST Agreement (Table 4).

Table 4 Review of performance in the Canadian individual stock-based management (ISBM) fisheries, 2009–2018.

Fisheries shaded in green or red indicate whether the Treaty obligation was met or not, respectively.

Stock (CTC agreed goal year)	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Yakoun, Nass, Skeena, Atnarko, Dean (no goal)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Artlish, Burman, Kauok, Tahsis, Tashish, Marble, Gold (no goal)	0.489	0.207	0.633	0.625	0.333	0.313	0.610	0.409	0.629	0.430
Cowichan (2005)	0.469	0.372	0.181	0.409	0.387	0.431	0.297	0.456	0.281	0.806
Nanaimo (no goal)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Klinaklini, Kawkweikan, Wakeman, Kingcome, Nimpkish (no goal)	0.200	0.365	0.091	0.143	0.086	0.079	0.211	0.207	0.235	0.197
Harrison (2001)	0.062	0.083	0.069	0.125	0.138	0.185	0.142	0.182	0.272	0.235
Upper Fraser, Mid-Fraser, Thompson (no goal)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Nooksack (no goal)	0.147	0.029	0.134	0.056	0.069	0.086	0.083	0.095	0.059	NA
Skagit Spring (no goal)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Skagit Fall (no goal)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Stillaguamish (no goal)	0.211	0.139	0.209	0.241	0.170	0.449	0.263	0.193	0.160	NA
Snohomish (no goal)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Lake Washington (no goal)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Green River (no goal)	0.275	0.135	0.275	0.310	0.301	0.412	1.023	0.730	0.441	NA

Notes: General obligation (0.635) or additional obligation (1991‑1996 ISBM rate average for the Party in whose waters the stock not meeting escapement goal originates), whichever is lower, for stocks listed in Annex 4, Chapter 3, Attachment V.

NA = no data available. NC = not calculated.

In 2017, 13 of the 15 U.S. stocks for which CWT-based ISBM indices could be calculated in the U.S. ISBM fishery either met their escapement goals (12 stocks) or had an ISBM index below 0.600 (three stocks; Table 5). Only the Nehalem (2.134) and Siuslaw (2.559) exceeded the general obligation of 0.600; these stocks have a PSC-agreed escapement goal that was not met so the general obligation applies. Additionally, the US ISBM index for the Harrison stock (Fraser Late) was well below the general obligation (0.285).

Table 5 Review of performance in the U.S. individual stock-based management (ISBM) fisheries, 2009–2018.

Fisheries shaded in green or red indicate whether the Treaty obligation was met or not, respectively.

Stock Group	Stock (CTC agreed goal year)	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Fraser Late	Harrison (2001)	0.136	0.295	0.285	0.351	0.442	0.38	0.283	0.173	0.285	NC
Puget Sound Spring	Nooksack (no goal)	0.585	0.757	0.89	1.859	0.871	1.283	0.551	0.269	0.422	NC
	Skagit (no goal)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Puget Sound Fall	Skagit (no goal)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Stillaguamish (no goal)	0.212	0.196	0.199	0.164	0.236	0.749	0.28	0.169	0.144	NC
	Snohomish (no goal)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Lake Washington (no goal)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Green River (no goal)	0.486	0.289	0.417	0.521	0.301	0.408	0.62	0.312	0.352	NC
WA Coast Falls	Hoko (no goal)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Grays (2014)	0.689	0.624	0.741	0.943	0.781	0.75	0.984	0.643	0.556	NC
	Queets (2004)	0.662	0.482	0.701	1.03	0.926	0.518	0.278	0.419	0.758	NC
	Hoh (2004)	1.003	0.839	1.753	1.59	2.642	1.257	1.213	0.259	1.164	NC
	Quillayute (2004)	1.821	1.377	1.693	1.961	1.782	2.58	2.037	1.097	2.268	NC
Columbia Fall	Brights (2002)	2.67	1.678	2.706	2.711	2.223	1.938	1.604	1.632	1.819	NC
	Deschutes (2010)	0.82	0.696	0.771	0.774	0.794	0.758	0.698	0.782	1.021	NC
	Lewis (1999)	0.217	0.554	1.37	0.866	1.111	0.815	0.546	0.479	0.622	NC
Columbia Summers	Summers (1999)	4.947	6.898	10.978	6.13	7.774	8.152	7.504	8.972	8.253	NC
N. Oregon Coast	Nehalem (1999)	0.339	1.03	2.077	1.776	2.301	2.909	3.455	1.782	2.134	NC
	Siletz (1999)	1.344	0.636	3.061	1.682	1.783	1.807	3.557	1.797	2.656	NC
	Siuslaw (1999)	1.381	1.386	2.24	1.517	2.39	1.882	2.396	2.556	2.559	NC

Notes: General obligation (0.600) or additional obligation (1991-1996 ISBM rate average for the Party in whose waters the stock not meeting escapement goal originates), whichever is lower, for stocks listed in Annex 4, Chapter 3, Attachment V.

NA = no data available; NC = not calculated.

Mark-Selective Fisheries

Section 4 of this report contains harvest information by region from MSFs. In 2018, MSFs occurred in terminal areas along the Oregon and Washington coasts, and in the Columbia River, Puget Sound, and Canadian Strait of Juan de Fuca. The magnitude of impact of a MSF relative to the total exploitation of a stock can be measured using the percentage of the total landed catch in net, sport, and troll fisheries of tagged and marked PSC indicator stocks that occurs in MSFs. Traditionally, the CTC has used PSC indicator stocks that have been double index tagged (DIT) to evaluate the impact of MSFs on the unmarked stocks represented by the unmarked tag group in a DIT pair,[1] however many CWT indicator stocks do not have a DIT pair (e.g., Canada and Alaska origin stocks). Accordingly, an approach was applied in 2018 to estimate mortality distributions for natural stocks that have single index tag (SIT) indicator stocks under conditions where the MSF impacts mainly occur on mature SIT fish proximal to their terminal area.

[1] A DIT group consists of at least two tag groups, one with the mass mark (or adipose fin clip) and one without the mark. These two tag groups are treated identically except for the mark, and differences in mortality should be due to the MSFs—assuming there is no mark mortality occurring prior to recruitment to the fisheries.

1. INTRODUCTION

The Pacific Salmon Treaty (PST) requires the Chinook Technical Committee (CTC) to report annually on catches, harvest rate indices, estimates of incidental mortality (IM) and exploitation rates for all Chinook salmon fisheries and stocks harvested within the Treaty area. To fulfill this obligation, the CTC uses a Pacific Salmon Commission (PSC) Chinook Model to generate key outputs of relevance to the PSC's annual fishery management cycle. The model is calibrated each year, incorporating pre-season stock-specific abundance forecasts with the latest information on catches, exploitation rates generated through cohort analysis, terminal runs, and escapements. The Parties rely upon the model to generate annual estimates of abundance for aggregate abundance-based management (AABM) fisheries and indices for individual stock-based management (ISBM) fisheries (Figure 1.1).

Abundance index (AI) prediction is the primary goal of the PST Chinook salmon management process, as pre-season AIs determine the total allowable catches (TAC) for each of the three AABM fisheries: Southeast Alaska (SEAK), Northern British Columbia (NBC), and West Coast Vancouver Island (WCVI). These pre-season estimates of the TAC drive the in-season management of AABM fisheries, because no reliable mechanism exists to update the AIs in season. In addition to generating pre-season AIs, the 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 the final TAC to which the AABM fisheries are held accountable. Post-season ISBM indices are computed through a separate process using the coded wire tag (CWT) data that comes from the exploitation rate analysis (ERA), to which ISBM fisheries are held accountable. In this report, the 2019 Agreement applies to the pre-season analyses and the 2009 Agreement applies to the post-season analyses.

This report describes the methods and annual results of the ERA used to estimate exploitation rates from CWT data (Section 2) and the PSC Chinook Model calibration (CLB) (Section 3). The results of the pre-season model calibration for 2019 are based on the ERA using CWT data through catch year 2017 (2018 for Canadian stocks); coastwide data on catch, spawning escapements, and age structure through 2018; and forecasts of Chinook salmon returns expected in 2019. Additionally, this report includes reviews of recent Chinook salmon mark-selective fisheries (MSFs; Section 4).

Of particular interest to PST implementation, this report includes: (1) estimated post-season AIs for 1979 through 2018 and the pre-season AIs for 2019 for the AABM fisheries; (2) estimated ISBM indices, previously referred to as nonceiling indices, for 1999–2018; (3) estimated stock composition for 1979–2018 and a projection for 2019 for the AABM and other fisheries; and (4) estimated fishery indices (harvest rates) for the AABM fisheries.

Appendix A shows the relationship between the exploitation rate indicator stocks, escapement indicator stocks, model stocks, and PST Annex stocks. Appendices B to I present additional output from the ERA and model calibration beyond the summaries presented in the main body of the report. Appendix B provides the time series of ISBM CWT indices from the final ERA. Appendix C shows the percent distribution of total mortality by catch year for exploitation rate indicator stocks. Appendices D (AABM only, Tables) and E (all fisheries, Figures) show the model estimates of stock composition in AABM and other sport and troll fisheries. Appendix F lists the

IM rates used in the PSC Chinook Model. Appendix G gives the time series of total AIs for the AABM fisheries, and Appendix H provides the AIs for each Model stock for each AABM fishery. Appendix I presents the time series of CWT-based fishery exploitation rate indices by stock, age, and fishery. Appendix J provides a tabular summary of forecast error for PSC Chinook Model stocks. CWT data quality and Model calibration issues, as well as their resolution, are detailed in Appendix K and L.

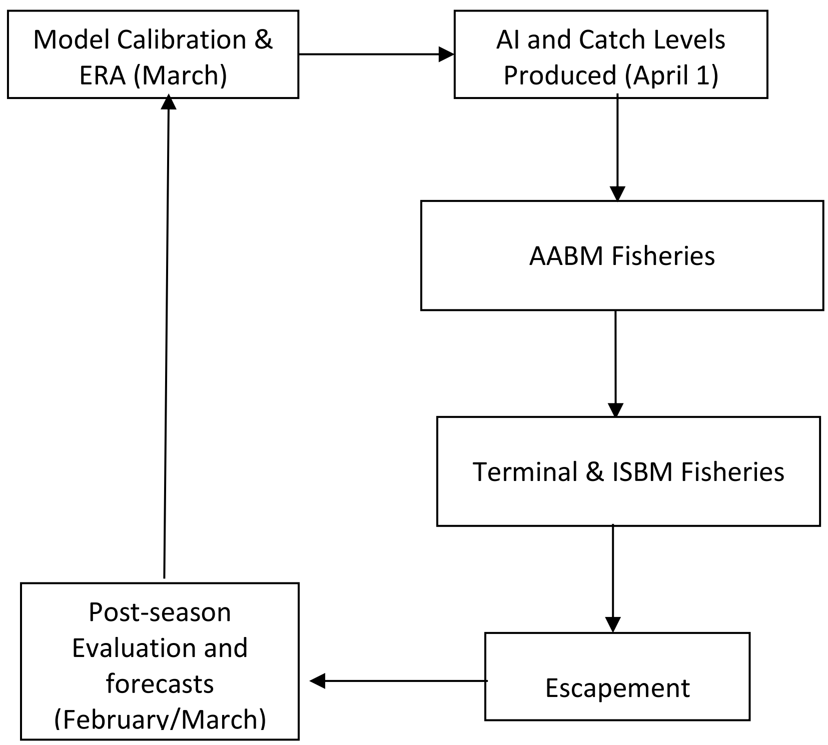

Figure 1.1 Pacific Salmon Treaty (PST) Chinook management and fisheries process.

2. Exploitation Rate Analysis

The CTC currently monitors 45 CWT exploitation rate indicator stocks (Figure 2.1; Table 2.1). The ERA relies on cohort analysis, a procedure that reconstructs the cohort size and exploitation history of a given stock and brood year (BY) using CWT release and recovery data (CTC 1988). The ERA provides stock-specific estimates of BY total, age- and fishery-specific exploitation rates, maturation rates, survival rates to age-2 or age-3, annual distributions of fishery mortalities, fishery indices for AABM fisheries, and ISBM indices for ISBM fisheries (Table 2.2). Estimates of age- and fishery-specific exploitation and maturation rates from the cohort analysis are combined with data on catches, escapements, incidental mortalities, and stock enhancement to complete the annual calibration of the PSC Chinook Model.

Indicator stocks used for ERA and the estimates derived from the analysis for each stock are shown in Table 2.2. Relationships between the exploitation rate indicator stocks, model stocks, and PST Annex stocks are provided in Appendix A.

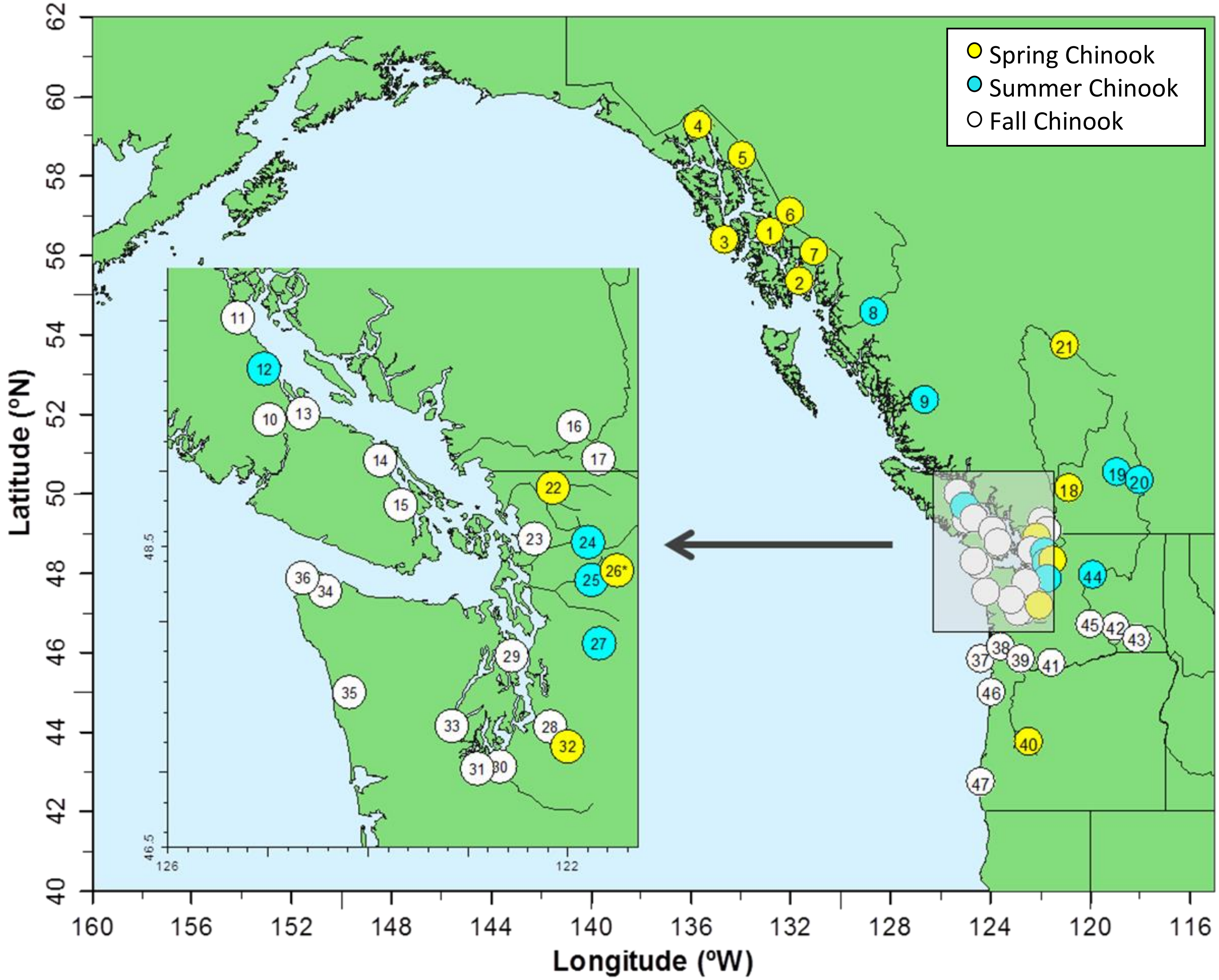

Figure 2.1 Geographical locations of all past and present Chinook salmon coded wire tag (CWT) indicator stocks.

Note: See Table 2.1 for the full stock names associated with each abbreviation. Not all stock indicators presented in the figure are current. Current indicator stocks are listed in Table 2.1.

Note: The southern British Columbia (B.C.) and Puget Sound area, where the concentration of the CWT indicators is greatest, is shown in the expanded view. Numbered circles indicate the CWT indicators as follows:

1 - AKS(ACI)
2 - AKS(ADM)
3 - AKS(ALP)
4 - CHK
5 - TAK
6 - STI
7 - UNU
8 - KLM/KLY
9 - ATN/ATS
10 - RBT
11 - QUI
12 - PPS
13 - BQR
14 - NAN
15 - COW
16 - HAR
17 - CHI
18 - NIC
19 - SHU
20 - MSH
21 - DOM
22 - NSF
23 - SAM
24 - SSF
25 - STL
26 - SKF (SKS/SKF)
27 - SKY
28 - SPS(GRN)
29 - SPS(GRO)
30 - NIS
31 - SPY
32 - WRY
33 - GAD
34 - HOK
35 - QUE
36 - SOO
37 - LRH
38 - CWF
39 - LRW
40 - WSH
41 - SPR
42 - HAN
43 - LYF
44 - SUM
45 - URB
46 - SRH
47 - ELK

Table 2.1 CWT exploitation rate indicator stocks, location, run type, and smolt age.

Stock/Area	Exploitation Rate Indicator Stocks	Hatchery	Run Type	Smolt Age
Southeast Alaska	Alaska Spring (AKS)	Crystal Lake, Whitman Lake, Little Port Walter, Deer Mountain, Neets Bay	Spring	Age 1
	Chilkat (CHK)	Wild	Spring	Age 1
	Taku (TAK)	Wild	Spring	Age 1
	Unuk (UNU)	Wild	Spring	Age 1
North/Central B.C.	Atnarko (ATN)	Snootli	Summer	Age 0
	Kitsumkalum (KLM)	Deep Creek	Summer	Age 1
WCVI	Robertson Creek (RBT)	Robertson Creek	Fall	Age 0
Strait of Georgia	Phillips (PHI)	Gillard Pass	Fall	Age 0
	Big Qualicum (BQR)	Big Qualicum	Fall	Age 0
	Cowichan (COW)	Cowichan	Fall	Age 0
	Nanaimo (NAN)	Nanaimo	Fall	Age 0
	Puntledge (PPS)	Puntledge	Summer	Age 0
	Quinsam (QUI)	Quinsam	Fall	Age 0
Fraser River	Chilliwack (Harrison Stock)[1] (CHI)	Chilliwack	Fall	Age 0
	Dome (DOM)	Penny Creek	Spring	Age 1
	Harrison (HAR)	Chehalis	Fall	Age 0
	Lower Shuswap (SHU)	Shuswap Falls	Summer	Age 0
	Middle Shuswap (MSH)	Shuswap Falls	Summer	Age 0
	Nicola (NIC)	Spius Creek	Spring	Age 1
North Puget Sound	Nooksack Spring Fingerling (NKF)	Kendall Creek	Spring	Age 0
	Nooksack Spring Yearling (NKS)	Kendall Creek	Spring	Age 1
	Samish Fall Fingerling[1] (SAM)	Samish	Summer/Fall	Age 0
	Skagit Spring Fingerling (SKF)	Marblemount	Spring	Age 0
	Skagit Spring Yearling[1] (SKS)	Marblemount	Spring	Age 1
	Skagit Summer Fingerling (SSF)	Marblemount	Summer	Age 0
Central Puget Sound	Skykomish Sum. Fingerling[1] (SKY)	Wallace	Summer/Fall	Age 0
	Stillaguamish Fall Fingerling (STL)	Stillaquamish Tribal	Summer/Fall	Age 0
South Puget Sound	Nisqually Fall Fingerling[1] (NIS)	Clear Creek	Summer/Fall	Age 0
	S. Puget Sound Fall Fingerling[1] (SPS)	Soos /Grovers/Issaquah creeks	Summer/Fall	Age 0
	South Puget Sound Fall Yearling (SPY)	Tumwater Falls	Summer/Fall	Age 1
	White River Spring Yearling[2] (WRY)	White River	Spring	Age 1
Hood Canal	George Adams Fall Fingerling[1] (GAD)	George Adams	Summer/Fall	Age 0
Juan de Fuca	Elwha Fall Fingerling (ELW)	Lower Elwha	Summer/Fall	Age 0
North Washington Coast	Hoko Fall Fingerling (HOK)	Hoko Makah National Fish Hatchery	Fall	Age 0
	Queets Fall Fingerling (QUE)	Wild broodstock, Salmon River (WA)	Fall	Age 0
	Tsoo-Yess[7] Fall Fingerling (SOO)	Makah National Fish Hatchery	Fall	Age 0
Lower Columbia River	Columbia Lower River Hatchery[1] (LRH)	Big Creek	Fall Tule	Age 0
	Cowlitz Tule (WA) (CWF)	Cowlitz	Fall Tule	Age 0
	Lewis River Wild (LRW)	Wild	Fall Bright	Age 0
	Spring Creek Tule (WA)[1] (SPR)	Spring Creek National Fish Hatchery	Fall Tule	Age 0
	Willamette Spring[1] (WSH)	Willamette Hatchery	Spring	Age 1
Upper Columbia River	Columbia Summers[3] (WA) (SUM)	Wells	Summer	Age 0/1
	Columbia Upriver Bright (URB)	Priest Rapids	Fall Bright	Age 0
	Hanford Wild (HAN)	Wild	Fall Bright	Age 0
Snake River	Lyons Ferry[1,4] (LYY/LYF)	Lyons Ferry	Fall Bright	Age 0
North Oregon Coast	Salmon (SRH)	Salmon	Fall	Age 0
Mid Oregon Coast	Elk River (ELK)	Elk River	Fall	Age 0

[1] Double index tags (DIT) associated with this stock.
[2] No longer adipose fin clipped.
[3] Model base period tag groups are fingerlings, exploitation rate analsysi (ERA) tag groups are a combination of fingerlings and yearlings.
[4] Subyearlings have been coded wire tag (CWT)-tagged since brood year (BY) 1986, except for BYs 1993–1997.
[5] Tagged releases for the Nanaimo Fall stock were discontinued after the 2004 brood.
[6] Hatchery production of the Dome Creek stock was discontinued after the 2002 brood.
[7] The name for the Sooes River and hatchery was changed to Tsoo-Yess in 2015. This will replace all occurrences of *Sooes* in future reports.

Table 2.2 Coded wire tag (CWT) exploitation rate indicator stocks used in the exploitation rate analysis (ERA) and data derived from them: fishery, individual stock-based management (ISBM) and survival indices, brood year exploitation rates (BYER), and stock catch distribution (Dist) with escapement estimates (Esc) and base period (1979–1982) tag recoveries.

Exploitation Rate Indicator Stock	Fishery Index	ISBM Index	BYER[1]	Survival Index	Dist	Esc	Base Recoveries
Alaska Spring (AKS)	Yes	—	Ocean	Yes	Yes	Yes	Yes
Chilkat (CHK)	—	—	Total	Yes	Yes	Yes	—
Taku (TAK)	—	—	Total	Yes	Yes	Yes	Yes
Stikine (STI)	—	—	Total	Yes	Yes	Yes	—
Unuk (UNU)	—	—	Total	Yes	Yes	Yes	—
Atnarko (ATN/ATS)	Yes	No	Total	Yes	Yes	Yes	Yes
Kitsumkalum (KLM/KLY)	—	—	Total	Yes	Yes	Yes	—
Robertson Creek (RBT)	Yes	Yes	Ocean	Yes	Yes	Yes	Yes
Big Qualicum (BQR)	Yes	Yes	Total	Yes	Yes	Yes	Yes
Cowichan (COW)	Yes	Yes	Total	Yes	Yes	Yes	—
Nanaimo (NAN)	—	Yes	Total	Yes	Yes	Yes	Yes
Phillips River Fall (PHI)	—	—	—	—	Yes	—	—
Puntledge (PPS)	Yes	—	Total	Yes	Yes	Yes	Yes
Quinsam (QUI)	Yes	Yes	Total	Yes	Yes	Yes	Yes
Chilliwack (Harrison Fall Stock) (CHI)	—	Yes	Total	Yes	Yes	Yes	—
Dome (DOM)	—	—	Total	Yes	Yes	Yes	—
Harrison (HAR)	—	—	Total	Yes	Yes	Yes	—
Lower Shuswap (SHU)	—	—	Total	Yes	Yes	Yes	Yes
Middle Shuswap (MSH)	—	—	Total	Yes	Yes	Yes	—
Nicola (NIC)	—	—	Total	Yes	Yes	Yes	—
Nooksack Spring Fingerling (NSF)	—	—	Ocean	Yes	Yes	Yes	Yes
Nooksack Spring Yearling (NKS)	—	Yes	Ocean	Yes	Yes	Yes[2]	—
Samish Fall Fingerling (SAM)[3]	Yes	—	Ocean	Yes	Yes	Yes[2]	Yes
Skagit Spring Fingerling (SKF)	—	—	Ocean	Yes	Yes	Yes	—
Skagit Spring Yearling (SKS)	—	—	Ocean	Yes	Yes	Yes[2]	—
Skagit Summer Fingerling (SSF)	—	—	Ocean	Yes	Yes	Yes	—
Skykomish Summer Fingerling (SKY)	—	—	Ocean	Yes	Yes	Yes	—
Stillaguamish Summer Fingerling (STL)	—	Yes	Ocean	Yes	Yes	Yes	—
Nisqually Fall Fingerling (NIS)	—	—	Ocean	Yes	Yes	Yes	Yes
South Puget Sound Fall Fing. (SPS)	Yes	Yes	Ocean	Yes	Yes	Yes[2]	Yes
South Puget Sound Fall Yearling (SPY)[3]	Yes	—	Ocean	Yes	Yes	Yes[2]	Yes
Squaxin Pens Fall Yearling (SQP)	—	—	—	—	Yes	—	—
University of WA Accelerated (UWA)	—	—	—	—	Yes	—	Yes
White River Spring Yearling (WRY)	—	—	Ocean	Yes	Yes	Yes[2]	Yes
George Adams Fall Fingerling (GAD)	Yes	—[3]	Ocean	Yes	Yes	Yes[2]	Yes
Elwha Fall Fingerling (ELW)	—	—	Ocean	Yes	Yes	—	—
Hoko Fall Fingerling (HOK)	—	—	Total	Yes	Yes	Yes	—
Queets Fall Fingerling (QUE)	—	Yes	Total	Yes	Yes	—	Yes
Tsoo-Yess Fall Fingerling (SOO)	—	—	Total	Yes	Yes	Yes	—
Columbia Lower River Hatchery (LRH)[3]	Yes	—	Total	Yes	Yes	Yes	Yes
Cowlitz Tule (CWF)	Yes	—	Ocean	Yes	Yes	Yes	Yes
Lewis River Wild (LRW)	Yes	Yes	Total	Yes	Yes	Yes	Yes
Spring Creek Tule (SPR)[3]	Yes	—	Total	Yes	Yes	Yes	Yes
Willamette Spring (WSH)	Yes	—	Ocean	Yes	Yes	Yes	Yes
Columbia Summers (SUM)	Yes	Yes	Total	Yes	Yes	Yes	Yes

-continued-

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Exploitation Rate Indicator Stock	Fishery Index	ISBM Index	BYER[1]	Survival Index	Dist	Esc	Base Recoveries
Columbia Upriver Bright (URB)	Yes	Yes	Total	Yes	Yes	Yes	Yes
Hanford Wild (HAN)	—	—	Total	Yes	Yes	Yes	—
Lyons Ferry (LYF)	—	—	Total	Yes	Yes	Yes	—
Salmon River (SRH)	Yes	Yes	Ocean	Yes	Yes	Yes	Yes
Elk River (ELK)	Yes	Yes	Ocean	Yes	Yes	Yes	Yes

[1] For stocks of hatchery origin and subject to terminal fisheries directed at harvesting surplus hatchery production, ocean fisheries do not include terminal net fisheries. Otherwise, total fishery includes terminal net fisheries.
[2] Only hatchery rack recoveries are included in escapement.
[3] Stock of hatchery origin not used to represent naturally spawning stock.

2.1 ERA Methods

2.1.1 Description of Incidental Mortality

For AABM fisheries, fishery indices are presented for both reported catch and total mortality; for ISBM fisheries, only total mortality fishery indices are presented. The difference between reported catch and total mortality is that IM is included in the latter. IM includes mortality of legal-size fish in Chinook non-retention (CNR) fisheries and mortality of sublegal-size fish in both retention and CNR fisheries. Management strategies have changed considerably for fisheries of interest to the PSC since 1985. Regulatory changes have included size limit changes, extended periods of CNR in troll fisheries, and mandatory release of Chinook salmon caught in some net fisheries. Estimates of IM are crucial for assessment of total fishery impacts, yet they cannot be determined directly from CWT recovery data. There are four categories of IM that are estimated in the ERA and PSC Chinook Model:

1. Shakers: Chinook salmon below the legal size limit that are encountered, brought to the boat, and released during a Chinook salmon retention fishery.
2. Sublegal CNR: Chinook salmon below the legal size limit that are encountered, brought to the boat, and released during a CNR fishery. The mortality rate per encounter applied to sublegal CNR is the same as applied to shakers.
3. Legal CNR: Chinook salmon above the legal size limit that are encountered, brought to the boat, and released during a CNR fishery.
4. Drop-off: Chinook salmon above or below the legal size limit that are encountered during either retention or non-retention fisheries, but lost from the gear before they reach the boat. Drop-off mortality is assumed the same for legal and sublegal fish, but can vary by gear type.

Additional details about the methods used to estimate IM have been described by the CTC Analytical Working Group (AWG)[2] and CTC (2004).

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[2] Chinook Technical Committee Analytical Work Group. Unpublished. Draft 1991 PSC Chinook Model Documentation.

2.1.2 Brood Year Exploitation Rates

A brood year exploitation rate (BYER) provides a measure of the cumulative impact of fisheries upon all age classes of a stock and brood. The BYER is computed for each stock as the ratio of adult equivalent (AEQ) total fishing mortality to AEQ total fishing mortality plus escapement.

$$BYER_{BY,F} = \frac{\sum_{a=Minage}^{Maxage}\left(\sum_{f\in\{F\}} TotMorts_{BY,a,f} * AEQ_{BY,a,f}\right)}{\sum_{a=Minage}^{Maxage}\left(\sum_{f=1}^{Numfisheries} TotMorts_{BY,a,f} * AEQ_{BY,a,f} + Esc_{BY,a}\right)}$$ *Equation 2.1*

All terms are defined in Table 2.3. The AEQ factor represents the proportion of fish of a given age that would, in the absence of fishing, leave the ocean to return to the terminal area.

The AEQ factor is calculated as

$$AEQ_{BY,a-1,f} = MatRte_{a-1,BY} + (1 - MatRte_{a-1,BY}) * Surv_a * AEQ_{BY,a,f}$$
$$AEQ_{BY,Maxage,f} \equiv 1.0$$ *Equation 2.2*

The AEQ factor is equal to 1 for the oldest age of maturation and for all ages in terminal fisheries.

The BYER can be partitioned into AEQ reported catch and AEQ IM. BYERs are not computed for incomplete BYs.

If a hatchery indicator stock is subject to directed terminal fisheries, its BYER will differ from the corresponding wild stock. In these circumstances, this issue is addressed by reporting the BYER in the ocean fisheries (i.e., excludes the terminal fishery impacts). The BYER statistic reported for each exploitation rate indicator stock is given in Table 2.2.

Table 2.3 Parameter definitions for all equations except those used for the Stratified Proportional Fishery Index (SPFI).

Parameter	**Description**
a	age class
A	set of all ages that meet selection criteria
$AEQ_{BY,a,f}$	adult equivalent factor in brood year *BY*, age *a*, and fishery *f* (for terminal fisheries, AEQ = 1.0 for all ages)
$CohSurv_{BY,a=2or3}$	cohort survival of CWT fish to age 2 or 3 for brood year *BY*
$AvgMatRte_{a}$	average maturation rate for age *a*
BPYR	base period year
$BYER_{BY,f}$	brood year exploitation rate in adult equivalents for brood year *BY* and fishery *f*
$BPISBMER_{f,a}$	average base period ISBM exploitation rate for fishery *f* and age *a*
BY	brood year
$Cohort_{BY,a}$	cohort by brood year *BY* and age *a* (*where stock is implied from context*)
$Cohort_{s,BY,a}$	cohort by stock *s*, brood year *BY* and age *a* (*where stocks are defined explicitly in a summation*)
CY	calendar year
$CYDist_{CY,F}$	proportion of total stock mortality (or escapement) in a calendar year *CY* attributable to a fishery or a set of fisheries *F*
CY_{end}	end calendar year for average
CY_{start}	start calendar year for average
$d_{t,s,a}$	distribution parameter for time step *t*, stock *s*, and age *a*
$Esc_{Y,a}$	escapement past all fisheries for either brood year *BY* or calendar year *CY* and age a
$ER_{s,a,f,CY}$	exploitation rate at age *a* divided by cohort size at age *a* for stock *s* in fishery *f* in year *CY*
$EV_{n,BY}$	the stock productivity scalar for iteration *n* and brood year *BY*
f	a single fishery
$f \in \{F\}$	a fishery *f* within the set of fisheries of interest
F	ocean, terminal or other sets of fisheries or spawning escapements
$FI_{f,CY}$	fishery exploitation rate index for fishery *f* in year *CY*
$FP_{a.s.CY,f}$	ratio of $ER_{s,a,f,CY}$ to *BPISBMER*
ISBMIdxCY	ISBM index for calendar year *CY*
$MatRte_{a-1,BY}$	maturity rate at next younger age by brood year
Maxage	maximum age of stock (generally age 6 for stream type stocks, age 5 for ocean type stocks)
Minage	minimum age of stock (generally age 3 for stream type stocks, age 2 for ocean type stocks)
$Morts_{CY,a,f}$	landed or total fishing mortality in year *CY* and age *a* in fishery *f*
NM_{a}	annual natural mortality prior to fishing on age *a* cohort
Numfisheries	total number of fisheries
RT_{CY}	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
s	a particular stock
S	set of all stocks that meet selection criteria
SC_{BY}	ratio of the estimated and model predicted terminal run for brood year *BY*
$Surv_{a}$	survival rate (1-NM_{a}) by age
$TotMorts_{BY,a,f}$	total fishing related mortality for brood year *BY* or calendar year *CY* or during the base period BPER and age *a* in fishery *f*
$RepMorts_{BY,a,f}$	Reported fishing-related mortality for brood year *BY* or calendar year *CY* or during the base period BPER and age *a* in fishery *f*
$TotCWTRelease_{BY}$	number of CWT fish released in the indicator group in brood year *BY*

2.1.3 Brood Year Survival Rates

The BY survival of CWT-tagged juveniles after release is calculated for most exploitation rate indicator stocks (Table 2.2). This survival rate is frequently referred to as the marine survival of the tag group but also includes any mortality occurring in fresh water following release; it is calculated up to age 2 for subyearling stocks and up to age 3 for yearling stocks based on CWT recoveries. The CWT-based estimate is our most direct measure of a brood's survival, but this measure is not final until the brood is complete (i.e., all ages have returned to spawn). Preliminary estimates are generated, but not reported, for incomplete broods using available CWT data and average maturation rates.

The BY survival rate for a fingerling stock is the estimated age-2 cohort (from the cohort analysis) divided by the number of CWT fish released, whereas for yearling stocks, the survival rate is calculated using the estimated age-3 cohort.

$$CohSurv_{BY,a=2or3} = \frac{Cohort_{BY,a=2or3}}{TotCWTRelease_{BY}}$$

Equation 2.3

where $Cohort_{BY,a}$ is calculated recursively from the oldest age down to the youngest age using:

$$Cohort_{BY,a} = \frac{\sum_{f=1}^{Numfisheries} TotMorts_{BY,a,f} + Esc_{BY,a} + Cohort_{BY,a+1}}{1 - NM_a}$$

Equation 2.4

If there are no CWT recoveries for the oldest ocean age of a stock, the next youngest cohort size is estimated using:

$$Cohort_{BY,\max age-1} = \frac{\sum_{f \in Preterminal} TotMorts_{BY,\max age-1,f} + \dfrac{Esc_{BY,\max age-1} + \sum_{f \in Terminal} TotMorts_{BY,\max age-1,f}}{AvgMatRte_{\max age-1}}}{1 - NM_{\max age-1}}$$

Equation 2.5

2.1.4 Mortality Distribution Patterns

The distributions of mortalities (reported catch and total) among fisheries and escapement in a catch year were calculated for each stock to determine the exploitation patterns. The distributions were computed if at least two BYs contributed to the CWT recoveries for a catch year. Distributions were computed for each fishery across all ages present in the catch year as

$$CYDist_{CY,F} = \frac{\sum_{a=Minage}^{Maxage} \sum_{f \in \{F\}} Morts_{CY,a,f} * AEQ_{BY=CY-a,a,f}}{\sum_{a=Minage}^{Maxage} \left(\sum_{f=1}^{Numfisheries} Morts_{CY,a,f} * AEQ_{BY=CY-a,a,f} + Esc_{CY,a} \right)}$$

Equation 2.6

Calculated mortality distributions may not indicate the true distribution of an indicator stock.

For example, no CWTs will be recovered if a fishery area is closed but this would not necessarily indicate zero abundance of a given stock in that fishing area.

2.1.5 Fishery Indices

When the PST was originated in 1985, catch ceilings and increases in stock abundance were expected to reduce harvest rates in fisheries. The fishery index (FI) 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 allowable catch (AC) for AABM fisheries in the 2009 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 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 2.7

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 2.8

and a ratio of means (ROM) estimator is used to calculate the FI

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

Equation 2.9

For AABM fisheries, indices are presented for troll gear only, although the catch limitations also apply to sport and net fisheries in SEAK and sport fisheries in NBC and WCVI. As in past years, recoveries from the troll fisheries are used because the majority of the catch and the most reliable CWT sampling occur in these fisheries. 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 limits 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 of a change in the fishing pattern is the SEAK troll fishery, where the catch during the winter season has increased, the spring fishery has been largely curtailed, and the summer season has become markedly shorter. 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 (2009a) 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.

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 distribution parameter ($d_{t,s,a}$) is calculated (Eq. 2.10), and the result is substituted into Eq .2.11 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 Table 2.4 for notation description.

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

Equation 2.10

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

Equation 2.11

The resulting unique solution is inserted into the following equations to compute the yearly harvest rates for each stratum (Equation 2.14) and the overall fishery (Equation 2.15).

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

Equation 2.12

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

Equation 2.13

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

Equation 2.14

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

Equation 2.15

Table 2.4 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*

2.1.6 ISBM Indices

The CTC (1996) proposed a nonceiling fishery index as a measure of the pass-through provision specified in the 1985 PST. This index compares an *expected* AEQ mortality (assuming base period exploitation rates and current stock abundance) with the observed AEQ mortality on a stock within a calendar year (CY), over all non-AABM fisheries of a Party (Table 2.5). Index values less than 1.0 indicate that the exploitation rates have decreased relative to the base period. Paragraph 8(d), Chapter 3 of the 2009 PST Agreement directs the CTC to use these ISBM indices to measure the performance of ISBM fisheries:

"(d) unless otherwise recommended by the CTC and approved by the Commission, the nonceiling index defined in CTC (2005) where data are available for the required time periods, the average total annual AEQ mortality rate that occurred in 1991 to 1996, or an alternative metric recommended by the CTC and approved by the Commission will be used to monitor performance of ISBM fisheries relative to the obligations set forth in this paragraph;"

Table 2.5 Fisheries included in the individual stock-based management (ISBM) index by nation.

Fisheries Included in ISBM Index	
United States	**Canada**
Washington/Oregon Ocean Troll	Central B.C. Troll
Puget Sound Northern Net	Strait of Georgia Troll
Puget Sound Southern Net	Northern B.C. Net
Washington Coastal Net	Central B.C. Net
Freshwater Terminal Net	West Coast Vancouver Island Net
Washington/Oregon Ocean Sport	Strait of Juan de Fuca Net
Puget Sound Northern Sport	Johnstone Strait Net
Puget Sound Southern Sport	Fraser Net
Freshwater Terminal Sport	Freshwater B.C. Net
	Strait of Georgia Sport
	Strait of Juan de Fuca Sport
	Freshwater B.C. Sport

The ISBM index is computed as:

$$ISBMIdx_{CY} = \frac{\sum_{f \in \{F\}} \sum_{a=Minage}^{Maxage} \left(TotMorts_{CY,f,a} * AEQ_{BY=CY-a,a,f}\right)}{\sum_{f \in \{F\}} \sum_{a=Minage}^{Maxage} \left(BPISBMER_{f,a} * Cohort_{BY=CY-a,a}\right)}$$

Equation 2.16

where

$$BPISBMER_{f,a} = \frac{\sum_{BPER=79}^{82} \frac{\left(TotMorts_{BPER,f,a} * AEQ_{BY=BPER-a,a,f}\right)}{Cohort_{BY=BPER-a,a}}}{4}$$

Equation 2.17

However, these equations assume (1) the available cohort size is the same for all fisheries, and (2) no external information is required (i.e., complete base period data and no external harvest rate adjustments). Thus Eq. 2.16 and Eq. 2.17 represent an idealized, simplified form of the post-season ISBM index; in practice, none of the ISBM stocks use Eq. 2.16 or Eq. 2.17 as reported. In 2017, a CTC ISBM subgroup was formed to address issues with the algorithms and computer program used to calculate CWT-based ISBM indices. Details of the revision of the ISBM algorithms and the program improvements that took place can be found in the CTC ISBM Special Report (CTC 2019).

Direct application of the PSC Chinook Model alone or CWT data alone is not possible in the computation of all ISBM indices; some fisheries require a finer resolution than the Chinook model currently provides, and some terminal fisheries target only marked hatchery fish, which makes the estimated CWT-based exploitation rate non-representative of the untagged stocks. In those instances, the following methods have been used.

For terminal fisheries with marked harvest rates that are not representative of the untagged stocks of interest, external estimates are used instead of model estimates. For pre-season estimates, the Fisheries Regulation Assessment Model is used to generate external estimates for Puget Sound net and sport fisheries, and the Columbia River Harvest Model is used to generate external estimates for Columbia River net and sport fisheries. For post-season CWT-based estimates, base period exploitation rates for the model stock associated with the wild stock are used if the indicator stock did not have base period recoveries.

Many ISBM fisheries or stock/fishery combinations have no pre-season predictions of harvest rates and some have no abundance forecasts. In those cases, the previous year's harvest rates are assumed. Given the above issues and the large discrepancies between pre-season Chinook Model ISBM indices and post-season CWT-based indices, the CTC decided to stop reporting Chinook Model-based pre-season ISBM indices as of April 2017 and focus resources on post-seasons ISBM improvements.

2.1.7 Assumptions of the CWT Exploitation Rate Analyses

Assumptions for the procedures used in the ERA are summarized below and are discussed in more detail in a previous publication (CTC 1988):

1. CWT recovery data are obtained in a consistent manner from year to year or can be adjusted to make them comparable.
2. Use of ratios may reduce or eliminate the effect of data biases that are consistent from year to year. Many of the analyses rely upon indices that are computed as the ratio of a statistic in a particular year to the value associated with a base period.
3. For ocean age-2 and older fish, natural mortality varies by age but is constant across years. Natural mortality rates applied by age are: age 2, 40%; age 3, 30%; age 4, 20%; and age 5 and older 10% (i.e., after fishing mortality and maturation of the age 4 cohort, 10% of the remaining immature fish die due to natural causes before moving to the next age class and before the commencement of fishing the next year).
4. All stocks within a fishery have the same size distribution at age and the distribution is constant across years.
5. The spatial and temporal catch distribution of sublegal-size fish of a given stock and age is the same as that for legal-size fish of that stock and age.
6. IM rates per encounter are constant between years. The rates vary by fish size (legal or sublegal) and fishery, and rates for troll and sport fisheries were published by the CTC (1997).
7. The procedures for estimating the mortality of CWT fish of legal size during periods of CNR assume that for any year the stock distribution during CNR periods is the same as during legal catch retention periods. To account for this in Canadian fisheries, the number of legal encounters during the CNR fishery was adjusted by a selectivity factor. A factor of 0.34 was used for the WCVI and Strait of Georgia troll fisheries. This value

was the average selectivity factor calculated from three years of observer data in the Alaska troll fishery. A factor of 0.20 was used in the North Central British Columbia (B.C.) troll fishery. This factor corresponds to the proportion of fishing areas that remain open during CNR periods. A selectivity factor is not required for the SEAK troll fishery since an independent estimate of legal and sublegal encounters is provided annually.

8. Maturation rates for BYs in which all ages have not matured (incomplete broods) are equal to the most recent nine-year average of completed BYs. Maturation rates are stock- and age-specific.
9. Age-4 (age-5 for spring stocks) and older Chinook salmon recovered in ocean net fisheries are assumed to be mature fish.
10. When using the fishery indices as a measure of change in fishery harvest rates between years, the temporal and spatial distribution of stocks in and among fisheries and years is assumed to be stable.
11. CWT recoveries used in the ERA are from adipose-clipped fish. There is no adjustment to the estimate of mortality in the ERA on adipose-intact fish that must be released in fisheries under adipose-clipped mark-selective regulations.

An exploitation rate indicator stock is not used in the ERA in the following instances:

1. The number of CWT recoveries is limited (i.e., fewer than 10 estimated recoveries for a given brood stock–age combination).
2. There are no CWT recoveries in the spawning escapement.
3. There are fewer than four BYs with CWT recoveries.

Indicator stocks used for ERA and the estimates derived from the analysis for each stock are shown in Table 2.2. Relationships between the exploitation rate indicator stocks, model stocks, and PST Annex stocks are provided in Appendix A.

2.2 Results

In this section, key ERA results are reviewed on a region-by-region basis and discussed briefly in terms of general patterns and trends at the stock and stock group level. Results are presented for the following ERA metrics: BY exploitation rate (total or ocean, depending on stock), early marine survival rate, and mortality distribution. Although some of this content is germane to assessments on the effectiveness of the PST, such evaluations necessitate that other information also be considered (e.g., performance of escapement indicator stocks, AABM and ISBM fisheries, etc.). Thus, the emphasis of this section is on pattern description only, not on drawing inferences about cause-effect relationships due to changing management regimes.

2.2.1 Southeast Alaska Stocks

There are four wild, one wild aggregate, and three hatchery aggregate CWT indicator stocks in SEAK used in CTC analyses. The four wild stocks are the Chilkat River (CHK), Stikine River (STI), Taku River (TAK), and Unuk River (UNU). The one wild aggregate stock is the Taku and Stikine Rivers (TST). The wild CWT indicator stocks are not currently used to represent SEAK stocks in the PSC Chinook Model; however, these data are used to ground truth the PSC Chinook Model and the one wild aggregate stock (TST) is being incorporated into the new version of the PSC

Chinook Model. The three SEAK hatchery indicator stocks are comprised of CWT data from multiple hatcheries. Alaska Spring (AKS) is composed of CWT data from five SEAK hatcheries (Little Port Walter, Crystal Lake, Neets Bay, Deer Mountain, and Whitman Lake), and collectively represents the Alaska Southern Southeast model stock in the PSC Chinook Model. Southern Southeast Alaska Spring (SSA) is composed of CWT data from four SEAK hatcheries (Little Port Walter, Neets Bay, Deer Mountain, and Whitman Lake) and Northern Southeast Alaska Spring (NSA) is composed of CWT data from one SEAK hatchery (Crystal Lake). The SSA and NSA CWT indicator stocks will be used by the new version of the PSC Chinook Model. SEAK wild and hatchery stocks enter the ocean as yearlings, and age 3 is the youngest age at which CWTs are recovered.

2.2.1.1 Brood Year Exploitation Rates

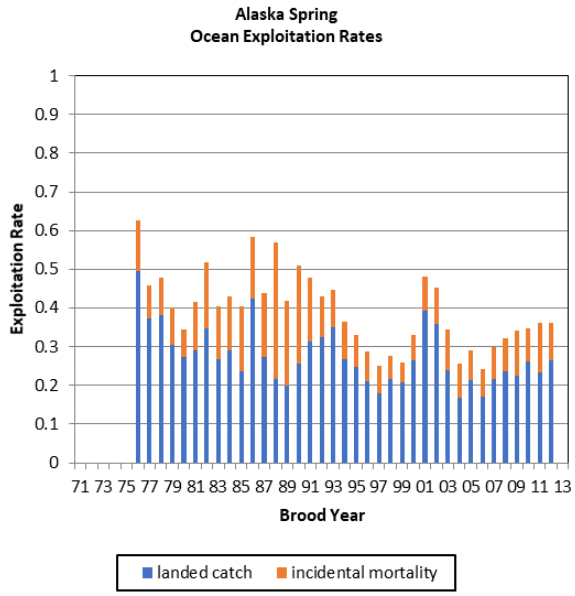
The BYERs computed for CHK, STI, TAK, TST, and UNU include recoveries from ocean and terminal fisheries. The BYERs computed for AKS, NSA, and SSA do not include terminal recoveries because the exploitation rate on hatchery fish in the terminal areas is not representative of the exploitation rate on SEAK wild stocks in these terminal areas. The AKS and SSA BYER usually exceed 30%; since 1976, only BYs 1996-1999 and 2004-2007 were less than 30% (Table 2.6; Figure 2.2). The BYERs for SEAK wild stocks CHK and TAK are usually less than 20% which includes recent BYs. BYERs are usually less than 30% for STI and UNU but have exceeded 40% in four of the last five complete BYs for the UNU stock (Table 2.6; Figure 2.3).

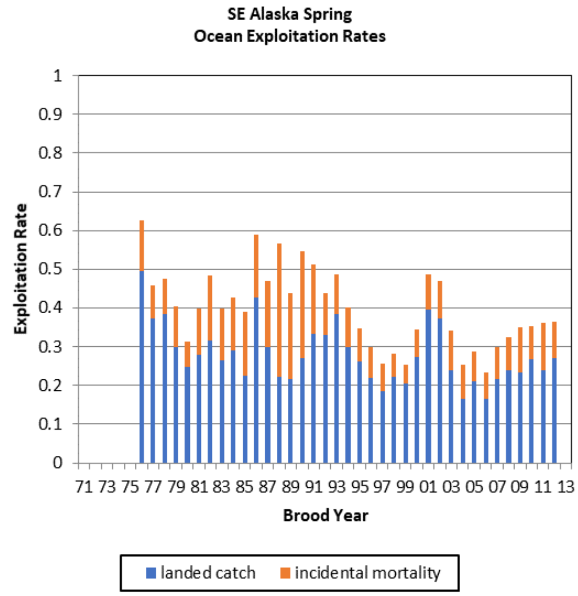
Table 2.6 Summary of statistics generated by the 2019 coded wire tag (CWT) cohort analysis for Southeast Alaska (SEAK) and transboundary (TBR) indicator stocks. Statistics include total mortality (catch plus incidental mortality) brood year exploitation rate (BYER), cohort survival rate to age 3, and calendar year (CY) percent distribution of the total mortality in the escapement for 1999 (1999–2008) and 2009 (2009–2018) Treaty Agreement periods.

						CY % Escapement[1]		
		BYER (total mortality)		Survival rate		1999–2008	2009–current	
Stock	**Indicator Stock Name**	**Mean (range)**	**Last complete BY**	**Mean (range)**	**Last complete BY**	**Mean (range)**	**Mean (range)**	**Last CY**
AKS	Alaska Spring[2]	39% (24%-63%)	36% (2012)	7.97% (2.37-25.29%)	3.19% (2012)	47% (31-58%)	51% (36-66%)	66% (2018)
SSA	Southern Southeast Alaska Spring[2]	40% (23%-63%)	36% (2012)	8.33% (2.37-26.00%)	3.45% (2012)	46% (29-58%)	51% (35-66%)	66% (2018)
NSA	Northern Southeast Alaska Spring[2]	40% (24%-65%)	24% (2012)	5.91% (1.02-23.98%)	1.82% (2012)	48% (40-59%)	52% (31-78%)	78% (2018)
CHK	Chilkat River	19% (11%-31%)	11% (2012)	3.45% (1.45-8.04%)	1.95% (2012)	78% (69-88%)	85% (72-95%)	88% (2018)
STI	Stikine River	39% (23%-81%)	23% (2012)	4.09% (1.44-7.09%)	2.40% (2012)	51% (29-80%)	74% (57-96%)	96% (2018)
TAK	Taku River	18% (5%-37%)	11% (2012)	7.61% (1.73-26.45%)	3.20% (2012)	78% (54-90%)	82% (61-96%)	96% (2018)
TST	Taku and Stikine Rivers	21% (5%-50%)	18% (2012)	7.07% (1.73-26.45%)	2.69% (2012)	73% (49-90%)	77% (59-96%)	96% (2018)
UNU	Unuk River	30% (15%-53%)	32% (2012)	4.6% (1.04-13.24%)	1.04% (2012)	73% (60-80%)	66% (42-86%)	72% (2018)

[1] % Escapement is not a measure of performance for the escapement indicator stock(s) associated with a given CWT indicator stock. See CTC (2013) for these details.

[2] BYER is ocean exploitation rate only.





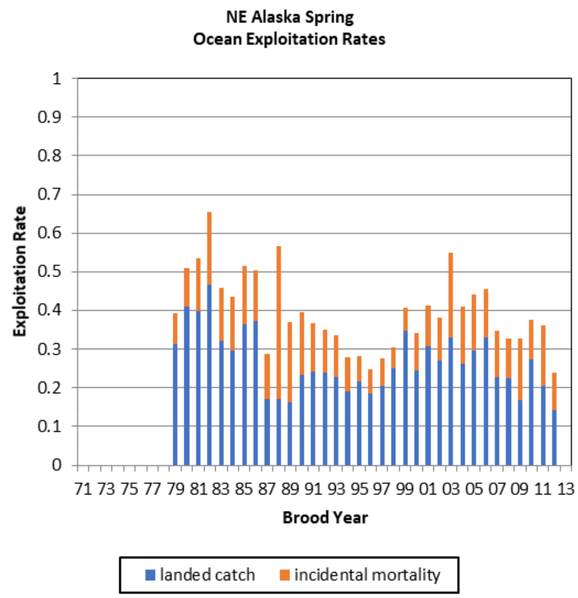


Figure 2.2 Brood year exploitation rate for Southeast Alaska (SEAK) hatchery indicator stocks. Catch and incidental mortality are shown. Only completed brood years are included.

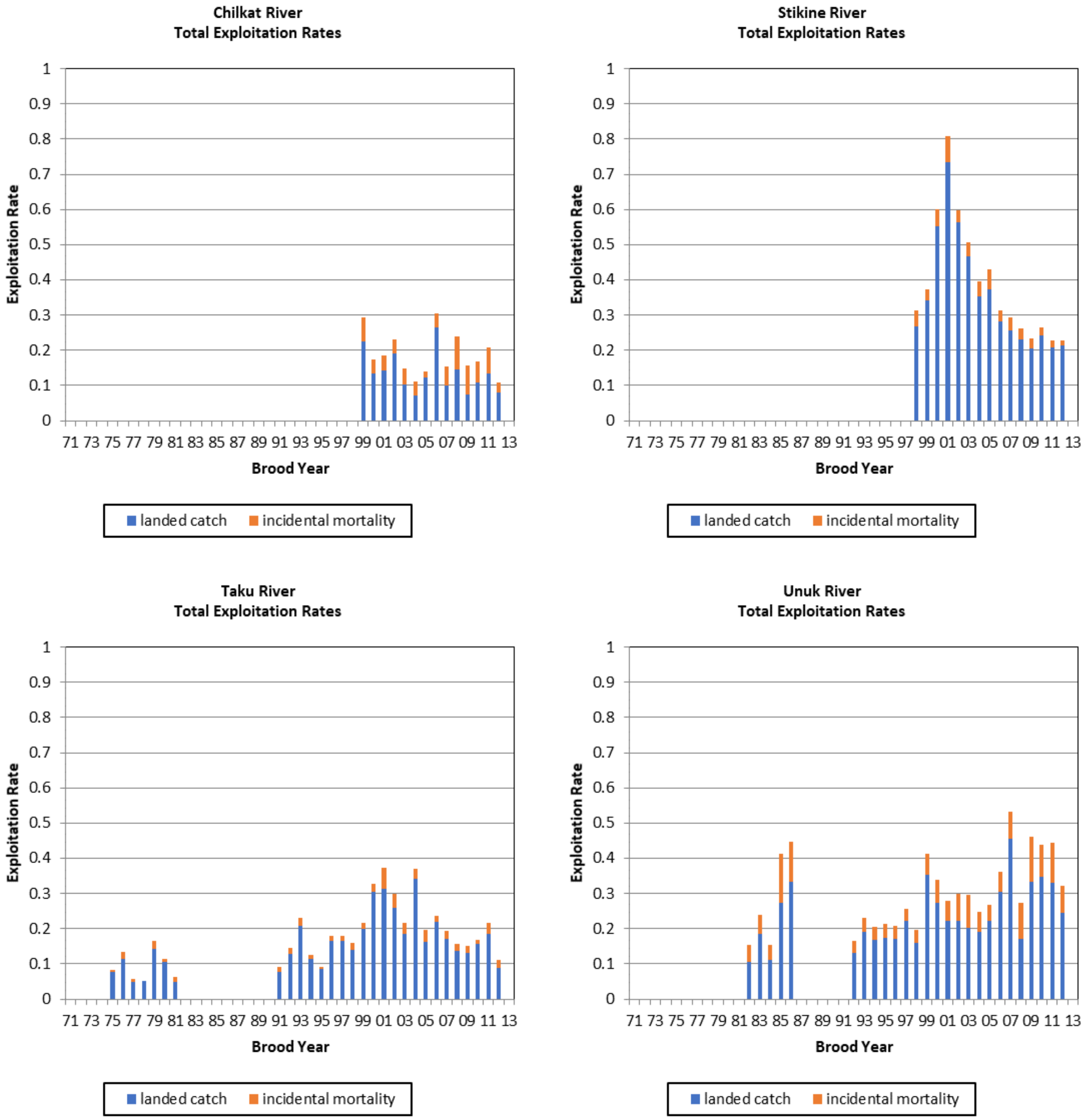


Figure 2.3 Brood year exploitation rate for Southeast Alaska (SEAK) wild indicator stocks. Catch and incidental mortality are shown. Only completed brood years are included.

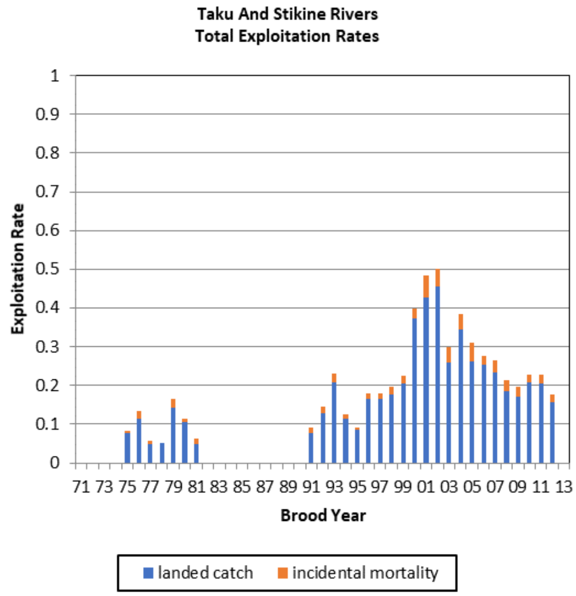


Figure 2.3 Page 2 of 2.

2.2.1.2 Survival Rates

Survival rates for SEAK and transboundary (TBR) stocks (Table 2.6; Figure 2.4) were computed as the survival to age 3 because the fish enter the ocean as yearlings. The CHK survival rates ranged from 1% to 8%, including 2% for the last complete BY (2012). The STI survival rates ranged from 1% to 7%, including 2% for the last complete BY (2012). The TAK can have extremely high survival rates (BY 1991-2000 average 13%) but has been less than its long-term average (8.2%) for the last 12 complete BYs (average 4.5% for BYs 2001-2012). The UNU survival rates have been as high as 13% (BY 1982), but the last 12 complete BYs have been below the long-term average (4.6%). The survival rates for the AKS stock have ranged from 25% for BY 1976 to 2% for BY 1977, and the last nine complete BYs for AKS have been less than the long-term average (8.0%), including the last complete BY (2012) survival rate of 3% (Figure 2.5).

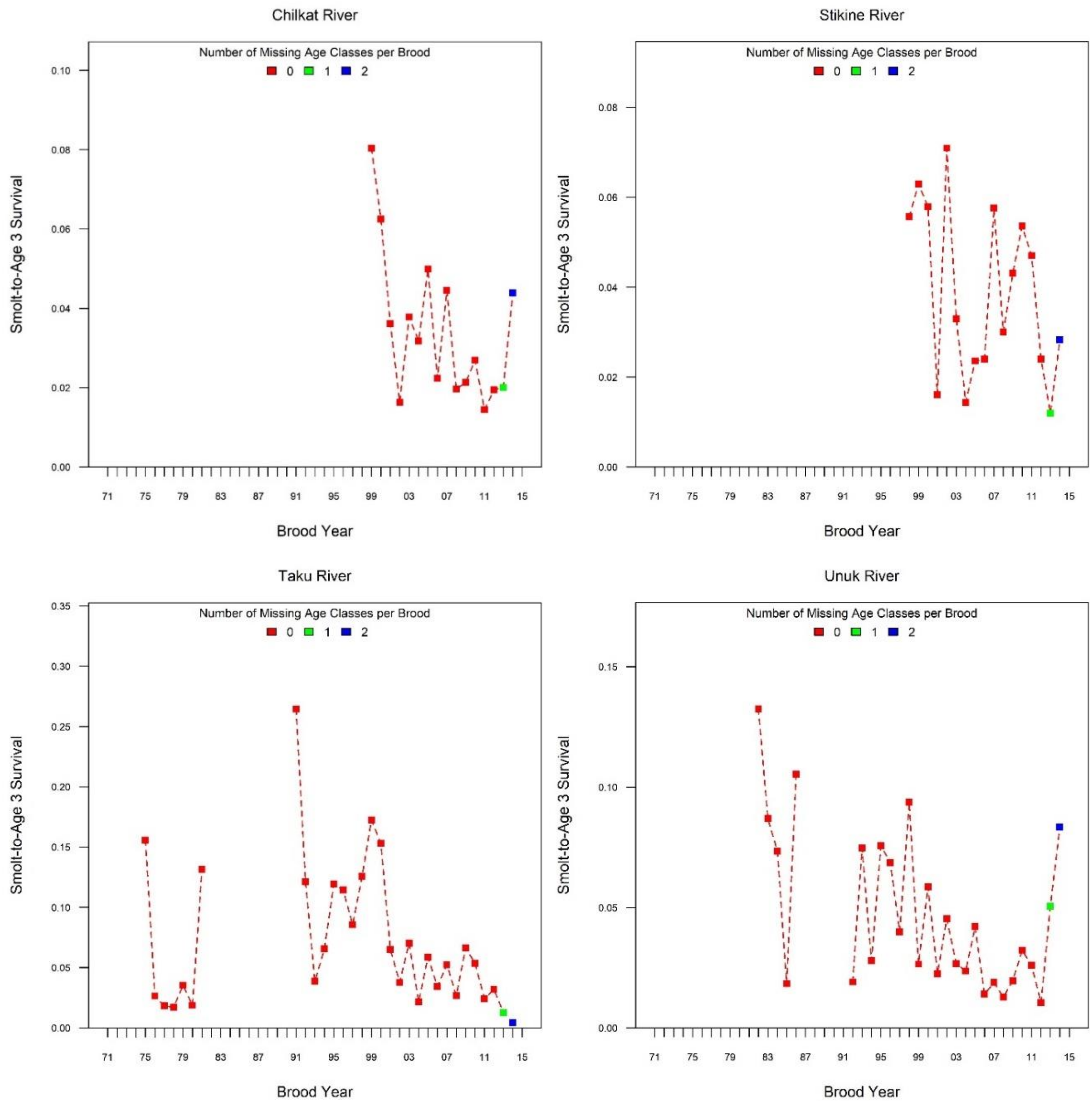


Figure 2.4 *Survival rate for* Southeast Alaska (*SEAK) wild indicator stocks*.

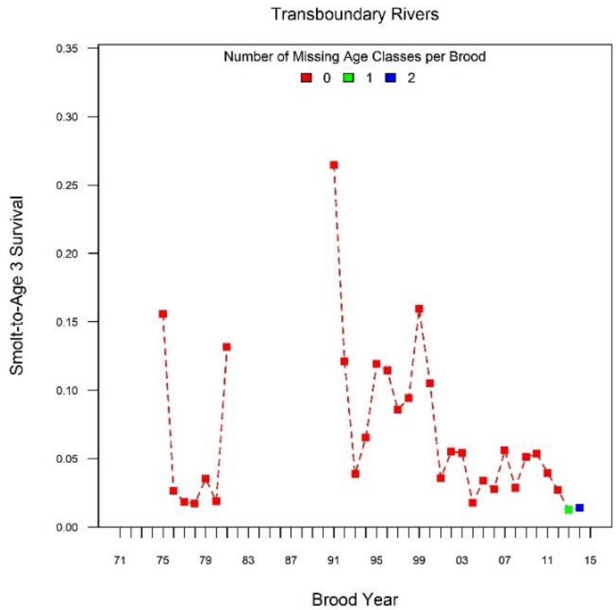


Figure 2.4 Page 2 of 2.

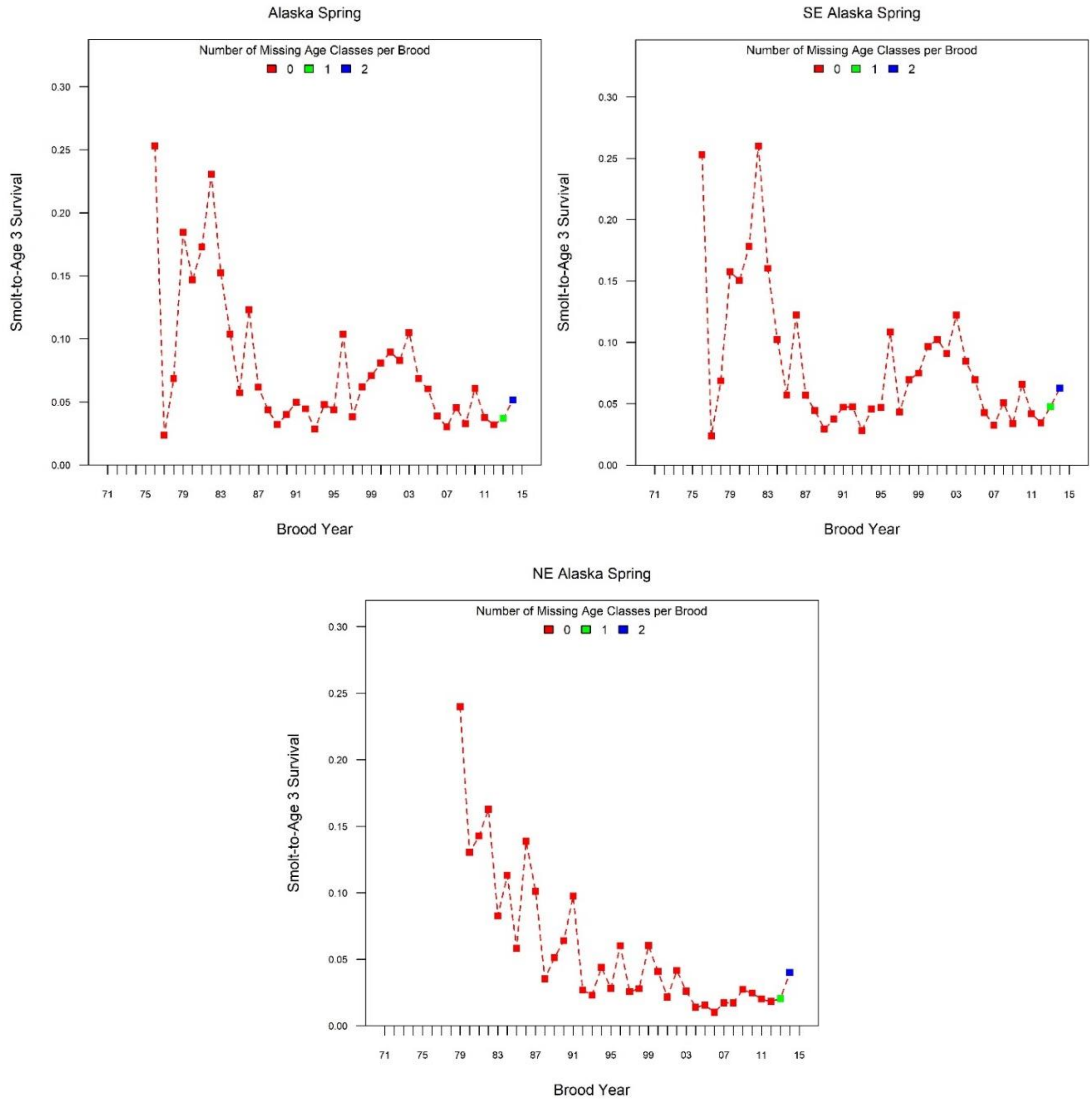


Figure 2.5 Survival rate for the Southeast Alaska (SEAK) hatchery indicator stocks (Alaska Spring, Southern Southeast Alaska Spring, Northern Southeast Alaska Spring).

2.2.1.3 Mortality Distributions

Mortalities for SEAK wild and SEAK hatchery stock groups are illustrated in Table 2.6 and Figure 2.6. A high percentage of the mortality distributions for CHK (2004–2018 average of 82% (Appendix C5), STI (2003–2018 average of 64%; Appendix C46), TAK (1999–2018 average of 80%; Appendix C49), and UNU (1999–2018 average of 69%; Appendix C52) were within the escapement, with most of the remaining mortality distribution in the SEAK AABM sport, troll, and net fisheries. Within the SEAK AABM fisheries in the 1999–2018 time period, the SEAK troll fishery caught a higher percentage of STI fish (average of 7%), TAK fish (average of 4%), and UNU fish (average of 16%), whereas the SEAK net fishery caught a higher percentage of CHK fish (average of 7%). Outside of SEAK AABM fisheries, a few STI and UNU mortalities have occurred in the Canadian net and NBC troll and sport fisheries in some years. Approximately 49% of AKS mortalities occurred at hatcheries in the 1999–2018 time period, with the remaining mortalities occurring in the SEAK AABM and terminal fisheries. The SEAK AABM troll fishery accounted for an average of 21% of the AKS total mortalities for the 1999–2018 time period, whereas the SEAK AABM terminal troll averaged 10%, and the SEAK AABM net and sport averaged 2% and 4% respectively (Appendix C1).

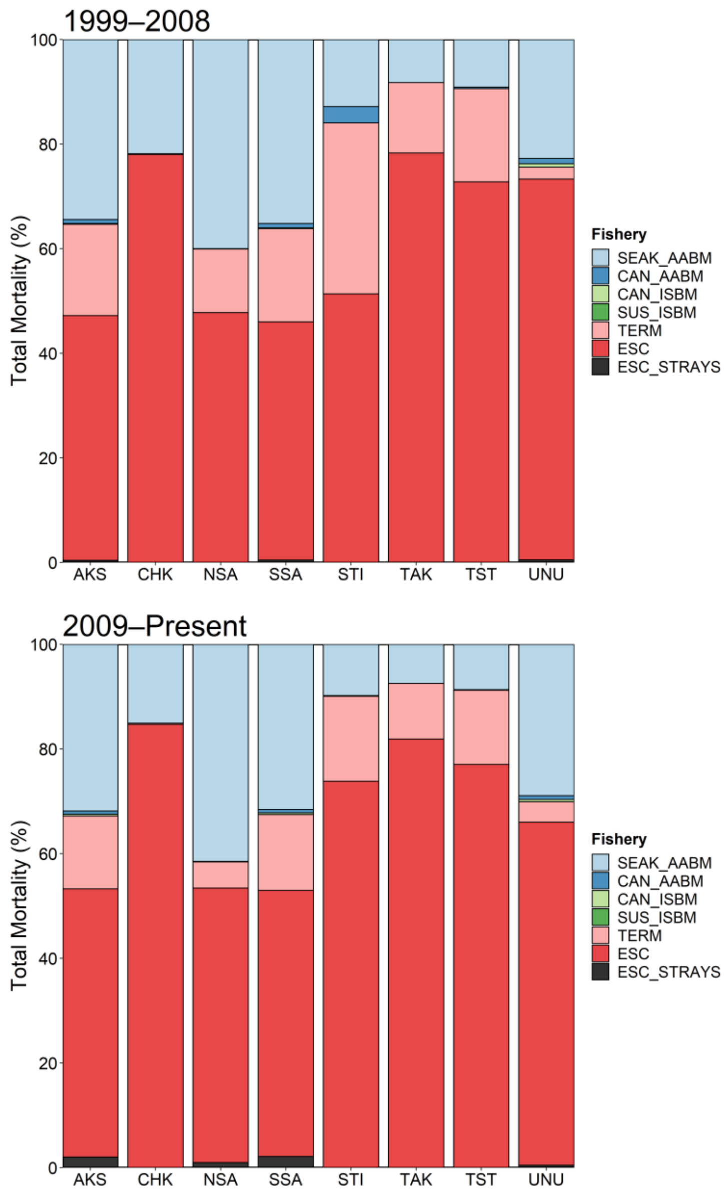


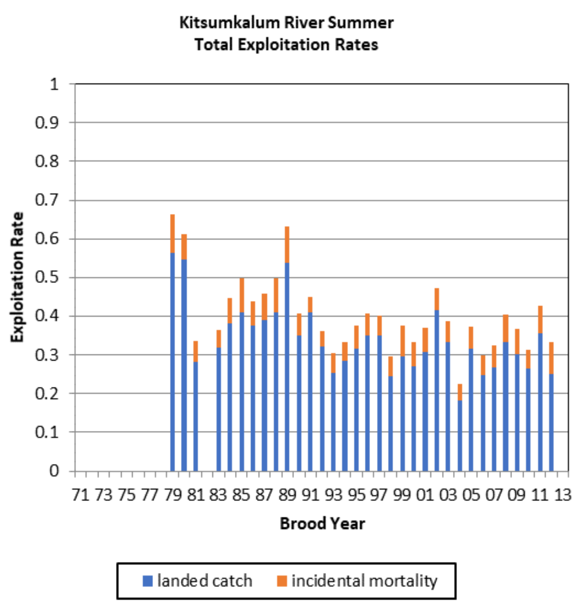
Figure 2.6 Distribution of total mortality for Southeast Alaska (SEAK) indicator stocks 1999-2008 and the 2009-2018 Agreement periodsthe 1999 (1999–2008) and 2009 (2009-2018) Treaty Agreement periods.

2.2.2 Northern and Central British Columbia Stocks

There are two hatchery CWT indicator stocks for Northern/Central B.C.: Atnarko and Kitsumkalum. Atnarko (ATN) is composed of tag recoveries from the Snootli Hatchery and is not currently used to represent a PSC Chinook Model stock. The Kitsumkalum hatchery indicator stock (KLM) is composed of tag releases from the Deep Creek Hatchery, and it is used to represent the Northern/Central B.C. model stock NTH. Kitsumkalum Chinook enter the ocean as yearlings, and age 3 is the youngest age at which CWTs are recovered, whereas Atnarko Chinook enter the ocean as subyearlings, and age 2 is the youngest age recovered. The KLM time series begins in BY 1979, and the ATN time series begins in BY 1986. There were no KLM CWT releases in 1982, and no ATN CWT releases in 2003 and 2004.

2.2.2.1 Brood Year Exploitation Rates

The BYERs computed for KLM and ATN include recoveries from both ocean and terminal fisheries. Although the BYER for KLM has been generally decreasing from levels greater than 60% for BYs 1979–1980 to approximately 33% for BY 2012, the BYER for ATN increased from approximately 34% for BY 1986 to approximately 61% for BY 2006 and then declined to approximately 22% for BY 2013 (Figure 2.7). KLM BYER averaged 40% and ranged from 22% for BY 2004 to 66% for BY 1979, whereas ATN BYER averaged 40% and ranged from 22% for BY 2013 to 61% for BY 2006. Incidental mortalities within the total KLM BYER range from 4 to 10% and show an increase for BY 2012 to 8%. In the case of ATN, the IM portion of BYER tended to decrease over time, averaging 3.2% with values near 2% from BY 2011–2013.



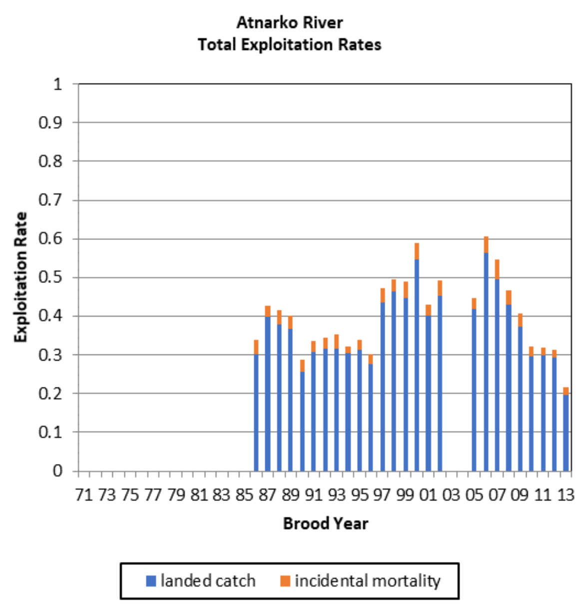


Figure 2.7 Total brood year exploitation rate for Northern and Central B.C. stocks. Catch and incidental mortality are shown. Only completed brood years are included.

2.2.2.2 Survival Rates

The survival rate of KLM is survival to age 3 because the fish enter the ocean as yearlings, whereas the survival rate of ATN is survival to age 2 because the fish enter the ocean as subyearlings. The KLM survival rates have averaged about 0.9% and ranged from around 0.2–2.5% with a rate of 0.5% for the last complete BY, 2012. In ATN, survival rates have averaged 2.4% and ranged from around 0.5–6.2% with a survival rate of 2.0% for the last complete BY, 2013 (Figure 2.8).

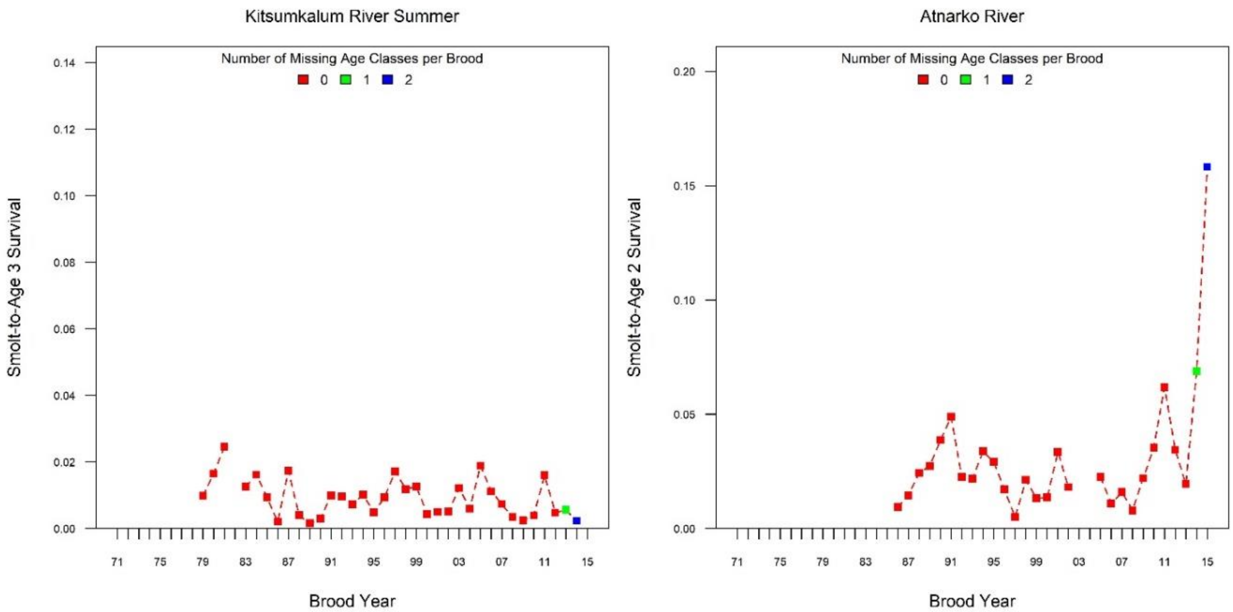


Figure 2.8 Smolt-to-age 3 survival rates for Northern and Central B.C. stocks.

2.2.2.3 Mortality Distributions

Escapement accounted for an average of 60% of the KLM total mortality (Figure 2.9; Appendix C17) and 59% of the ATN total mortality (Figure 2.9; Appendix C2) across the entire mortality distribution time series which began in 1985 for KLM and 1990 for ATN (catch years). Average mortality in the escapement was 61% for KLM and 55% for ATN during 2009–2018. Most of the remaining mortalities for KLM were associated with catch and IM in the SEAK AABM troll (2009–2018 average: 10%) and the NBC AABM sport (2009–2018 average: 4%) fisheries. NBC AABM troll and ISBM Canada net fisheries were important mortality components for KLM during 1985–1995 with 9% (AABM troll) and 14% (ISBM terminal net) of the total mortality, but their relevance diminished to approximately 3% (AABM troll) and 2% (ISBM terminal net) during 1999–2018. In the case of ATN, most of the fishing mortality was associated with catch and IM in the SEAK AABM troll (2009–2018 average: 7%), the NBC AABM sport (2009–2018 average: 2%), the NBC AABM troll (2009–2018 average: 2%), and the ISBM terminal fisheries (2009–2018 average: 15%). There are essentially no strays for KLM and ATN.

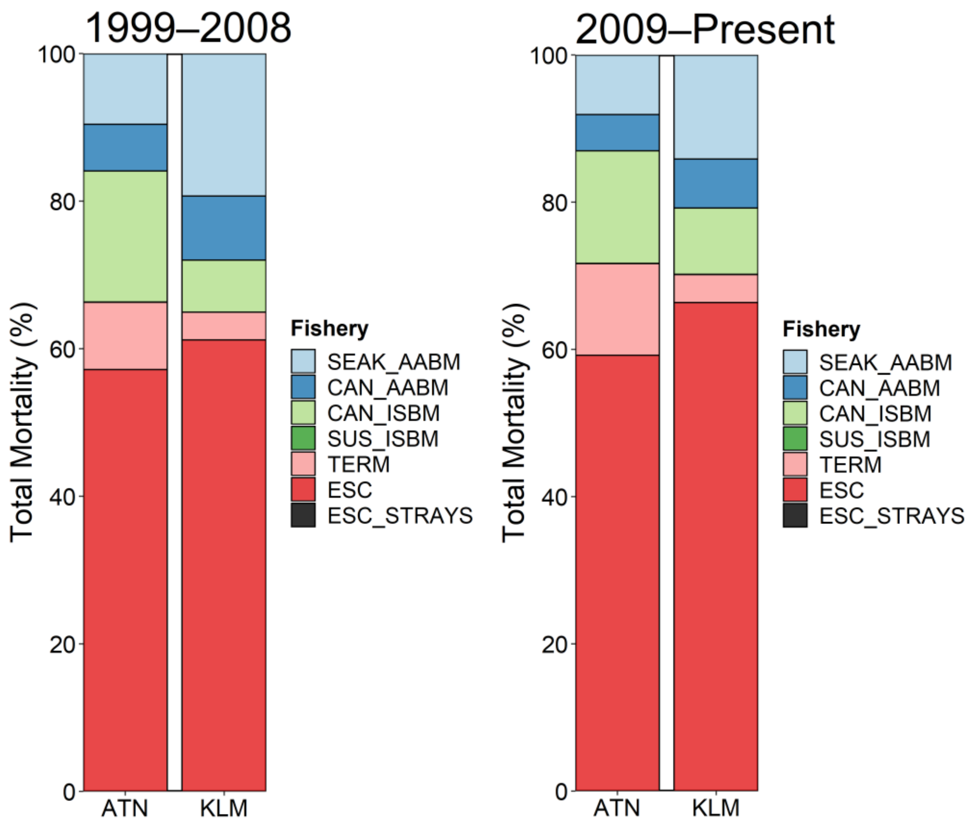


Figure 2.9 Distribution of total mortality for Northern and Central B.C. indicator stocks for the 1999–2008 and 2009–2018 agreement periods.

2.2.3 West Coast Vancouver Island Stocks

There is one hatchery CWT indicator stock to represent wild and hatchery WCVI Chinook: Robertson Creek Fall. The Robertson Creek Fall indicator stock (RBT) is composed of tag recoveries from the Robertson Creek hatchery, and it is used to represent the WCVI model stocks RBH (Hatchery) and RBT (Natural). WCVI Chinook enter the ocean as subyearlings, and age 2 is the youngest age recovered. The RBT time series begins in BY 1973 and the latest complete BY is 2013.

2.2.3.1 Brood Year Exploitation Rates

The BYER computed for RBT includes only recoveries from ocean fisheries. The BYER for RBT has been decreasing from approximately 67% for BY 1973 to approximately 37% for BY 2013 (Figure 2.10). Not including BY 1992, which was characterized by zero recoveries in the catch as a result of the poorest survival to age 2 observed for this stock (see next section), BYER for RBT averaged is entirely attributed to CWT recoveries of sublegal fish. The percentage of the RBT BYER that is IM increased during the first 10 years of the time series from approximately 10% for BY 1973 to 20% for BY 1983. It then decreased substantially to approximately 6% for BY 1985, 43% and ranged from 23% for BY 1998 to 67% for BY 1973. The 18% IM experienced by BY 1992 then increased exponentially again for the following six BYs to approximately 30% for

BY 1991. The variation in the percentage of the RBT BYER that is IM subsided after BY 1992. The percentage of the RBT BYER that is attributed to IM averages approximately 10% for the entire time series.

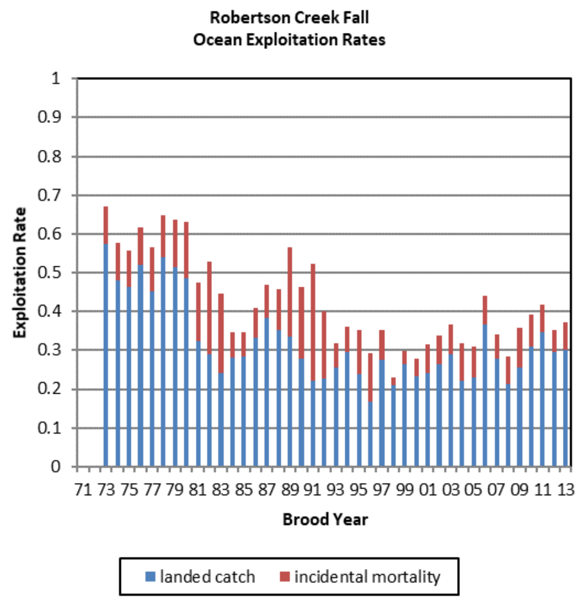


Figure 2.10 Brood year ocean exploitation rates for Robertson Creek Fall. Catch and incidental mortality are shown. Only completed brood years are included.

2.2.3.2 Survival Rates

The survival rate of RBT is survival to age 2 because the fish enter the ocean as subyearlings. The RBT survival rates show a general declining trend, averaging 4.6% and ranging from around 0.03% for BY 1992 to 20.1% for BY 1974, with a survival rate of 3.0% for the last complete BY (Figure 2.11). In addition to BY 1992, BYs 1983, 1995, 1996, 1997, 2009, and 2011 have also experienced extremely low survival rates.

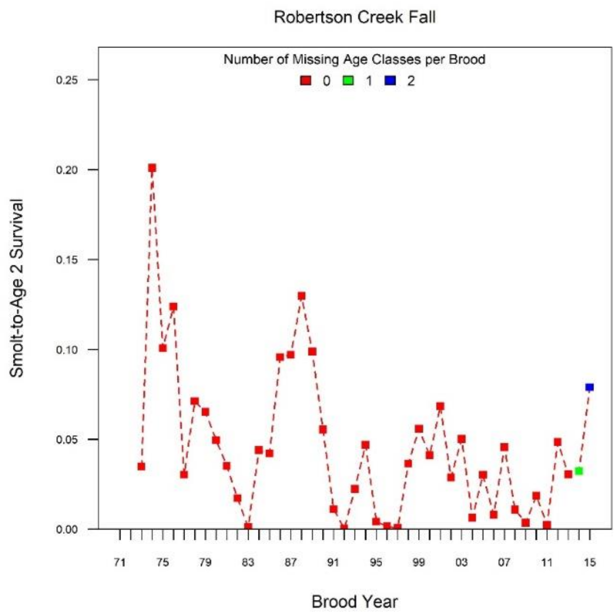


Figure 2.11 Smolt-to-age 2 survival rates for Robertson Creek Fall.

2.2.3.3 Mortality Distributions

An average of 38% of the RBT total mortality (Figure 2.12; Appendix C33) occurred in the escapement during 1979–2018. The RBT average mortality in the escapement increased to 45% during 2009–2018. Most of the remaining mortalities in this stock are associated with the SEAK AABM troll (2009–2018 average: 11%), Canada terminal net (2009–2018 average: 10%) and sport (2009–2018 average: 9%) fisheries. The NBC AABM troll fishery used to be an important mortality component for RBT during 1979–1995, with 9–12% of the total mortality, but it diminished to approximately 2% during 2009–2018 due to domestic management measures. The ISBM Canada net fisheries were an important component during 1979–1984 with around 6% of the total mortality, but the contribution effectively became 0% during 2009–2018.

Strays make only a small percentage (0.1% during 1979–2018) of the total mortality in RBT. The largest percentage of the total mortality represented by strays in RBT was 1.3% in 2018.

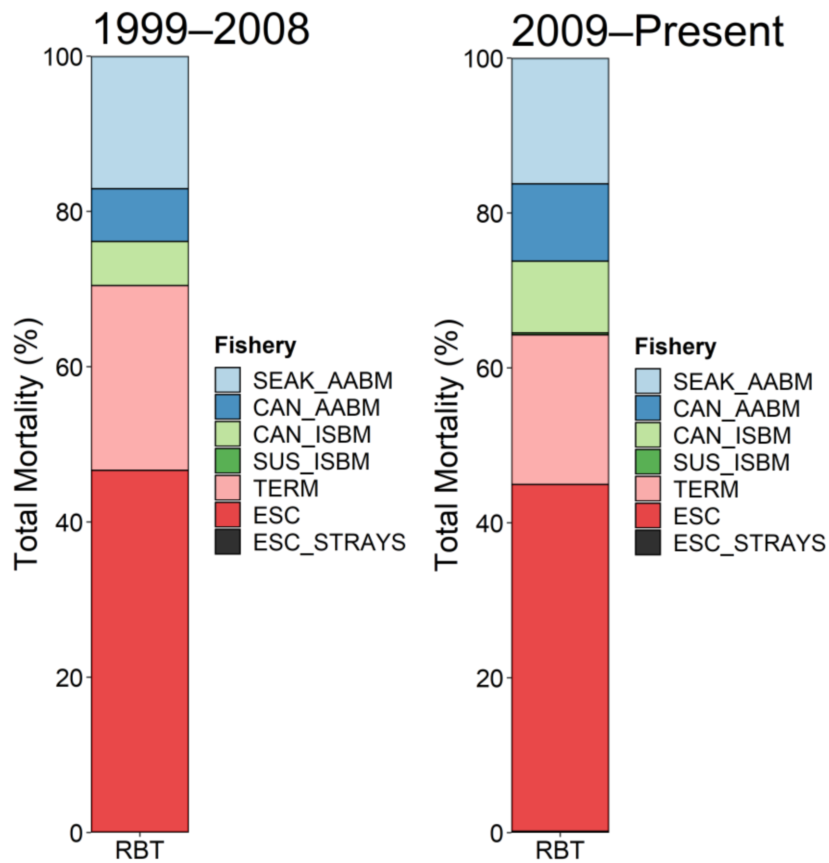


Figure 2.12 Distribution of total mortality for the West Coast Vancouver Island (WCVI) indicator stock (Robertson Creek) for the 1999-2008 and 2009-2018 Agreement periods.

2.2.4 Strait of Georgia Stocks

Strait of Georgia model stocks are segregated into Upper Strait of Georgia (GST) and Lower Strait of Georgia (GST for wild Chinook and GSH for hatchery Chinook). There is one hatchery CWT indicator stock for Upper GST (Quinsam [QUI]), two for Lower GST Natural (Cowichan [COW] and Nanaimo [NAN]), and two for Lower GST Hatchery (Puntledge [PPS] and Big Qualicum [BQR]). QUI is composed of tag recoveries from the Quinsam Hatchery. COW and NAN are composed of tag recoveries from the Cowichan and Nanaimo hatcheries, whereas PPS and BQR are composed of tag recoveries from the Puntledge and Big Qualicum hatcheries. GST Chinook enter the ocean as subyearlings and age 2 is the youngest age at which CWTs are recovered. The QUI time series begins in brood year 1974, COW in 1985, NAN in 1979, PPS in 1975, and BQR in 1973. The NAN stock was terminated after BY 2004.

2.2.4.1 Brood Year Exploitation Rates

The BYERs computed for GST stocks include recoveries from ocean fisheries and terminal fisheries. There is a general declining trend for BYERs of the indicator stock for Upper GST (Figure 2.13) as well as for most of the indicator stocks for Lower Strait of Georgia (Figure 2.14). The BYER for QUI has been generally decreasing from about 71% in 1974 to approximately 44%

in 2013, averaging 55% and ranging from 29% for brood year 1997 to 85% for brood year 1977 (Figure 2.13). The percentage of the QUI BYER that is incidental mortality increased consistently during the first 17 years of the time series reaching 43% for brood year 1991, and then decreased substantially to average levels for subsequent brood years averaging 11% for the entire time series. Similar exploitation rate patterns occurred for all Lower GST indicator stocks, except for COW (Figure 2.14) for which BYERs generally decreased from brood year 1985 to brood year 1995, and then increased for subsequent brood years. COW BYER averaged about 67% and ranged from 36% for brood year 1995 to 89% for brood year 1985. The percentage of the COW BYER that is incidental mortality increased during the first five years of the time series reaching 33% for brood year 1990 and averaged about 19% for the entire time series. BYERs in Lower GST also include indicator stocks BQR, NAN, and PPS. BQR decreased from exploitation rate levels of 88% in 1973 to exploitation rate levels of 29–57% since 1994. The lowest BYERs for these stocks were experienced by brood year 2007 and 2013 in BQR (33%), by brood year 2001 and 2004 in NAN (35%), and by brood years 1998 and 2004 in PPS (13%). The exploitation rates due to incidental mortality in these three stocks increased consistently during the first 15-20 years of the time series but recently decreased to approximately 10% in BQR, 12% in NAN (during last year of 2004), and 16% in PPS.

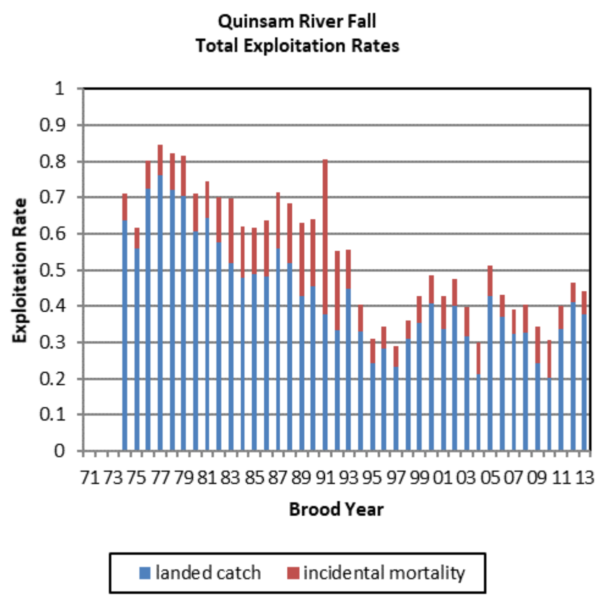


Figure 2.13 Total brood year exploitation rate for the Upper Strait of Georgia indicator stock (Quinsam River Fall). Catch and incidental mortality are shown. Only completed brood years are included.

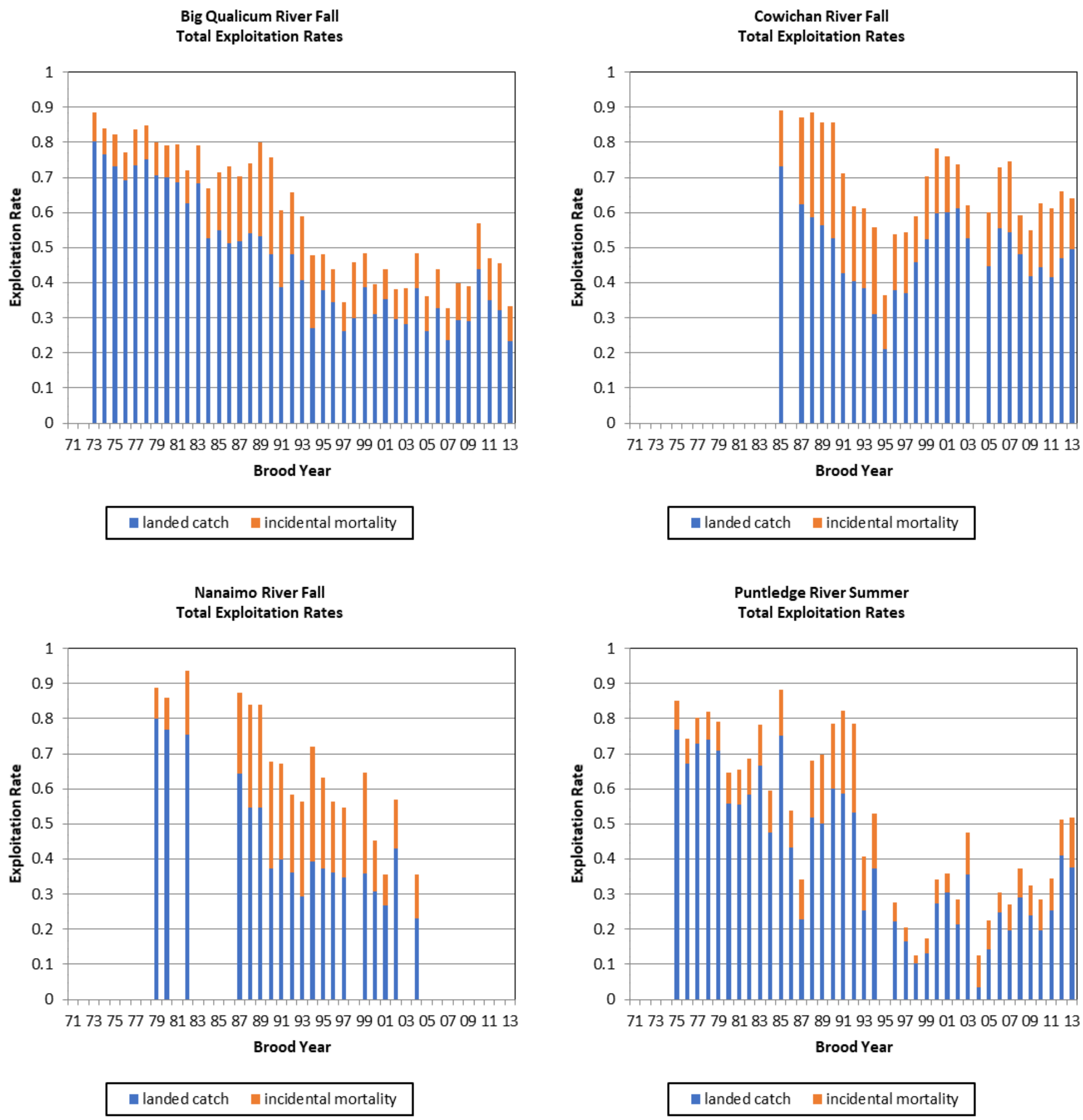


Figure 2.14 Total brood year exploitation rates for Lower Strait of Georgia indicator stocks. Catch and incidental mortality are shown. Only completed brood years are included.

2.2.4.2 Survival Rates

The survival rates of GST CWT indicator stocks represent survival to age 2 because fish enter the ocean as subyearlings. All of these stocks show a clear declining trend in survival rates (Figures 2.15 & 2.16). The QUI survival rates have averaged 2.0% and ranged from around 0.2% for brood years 1989 and 2006 to 9.1% for brood years 1974 and 1976 (Figure 2.15). In the case of Lower GST CWT indicator stocks, BQR survival rates have averaged 2.4% and ranged from around 0.1% to 25.4% (the highest observed for GST stocks), COW survival rates have averaged 1.8% and ranged from around 0.3% to 6.8%, NAN survival rates have averaged 3.0% and ranged from around 0.5% to 13.6%, and PPS survival rates have averaged 1.2% and ranged from around 0.1% to 12.8% (Figure 2.16). The survival rate for the last completed brood of the time series (2013 for QUI, BQR, COW and 2004 for NAN) was 1.6% for QUI, 0.7% for BQR, 0.6% for COW, 3.1% for NAN, and 1.2% for PPS.

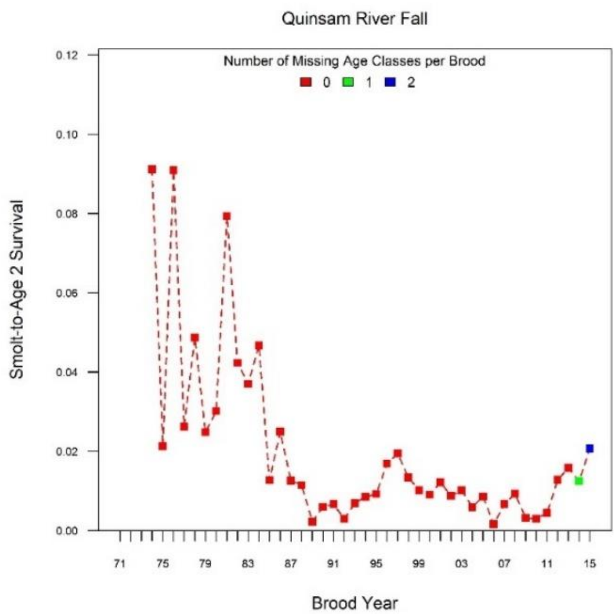


Figure 2.15 Smolt-to-age 2 survival rates for Quinsam River Fall.

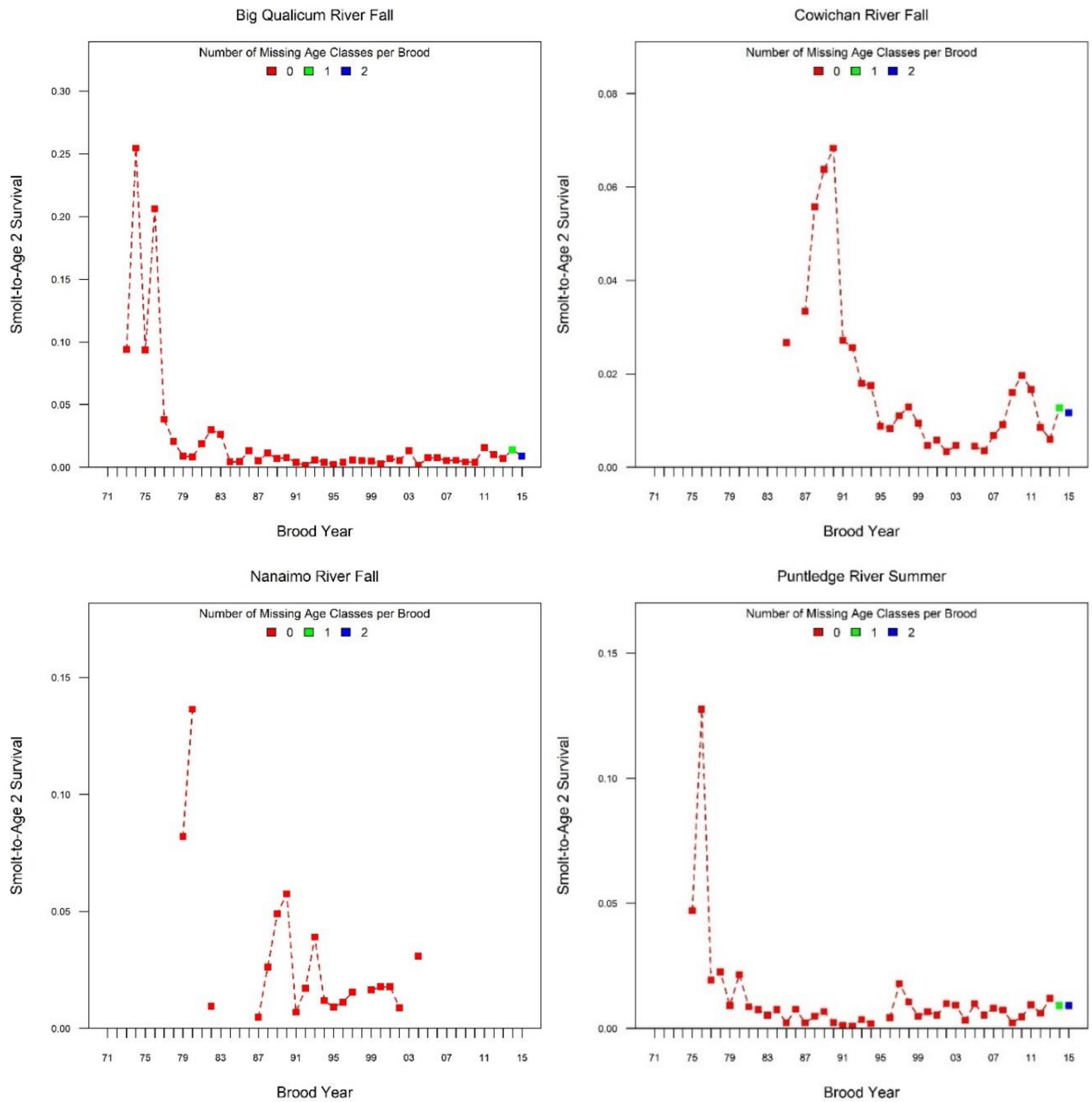


Figure 2.16 Smolt-to-age 2 survival rates for Lower Strait of Georgia stocks.

2.2.4.3 Mortality Distributions

An average of 47% of the total mortality in the Upper GST indicator stock QUI (Figure 2.17; Appendix C32) occurred in the escapement during 1979–2018 and remained relatively similar in the 1999–2008 period (61%) and the 2009–2018 period (59%). Most of the fishing mortalities on this stock are from catch and IM occurring in the SEAK AABM troll (1999–2008 average: 15%, 2009–2018 average: 11%), NBC and Central British Columbia (CBC) ISBM sport (1999–2008 average: 8%, 2009–2018 average: 9%) and Southern B.C. sport (1999–2008 average: 6%, 2009–2018 average: 11%) fisheries. The NBC AABM troll and ISBM NBC, CBC and Southern B.C. troll and net fisheries used to be important mortality components for QUI from 1979–1995 with 7–

10% of the total mortality in NBC AABM troll, 5–12% in ISBM Canada troll, and 16–22% in ISBM Canada net. Average mortality in these fisheries diminishes during 1999–2018 to about 1% (NBC AABM troll), 0% (ISBM NBC, CBC and Southern B.C. troll), and 0.1% (ISBM NBC, CBC and Southern B.C. net).

Strays make only a small percentage (average approximately 0.1% during 1979–2018) of the total mortality in QUI. The largest percentage of the total mortality represented by strays in QUI was 0.8% in 2014. In BQR, strays averaged 0.6% of the total mortality between 1979–2018. The largest percentage of the total mortality represented by strays in BQR was 2.4% in 1998. COW had the largest percentage of the total mortality represented by strays (average 2.8% during 1990–2018). The highest observed contribution of strays to the COW total mortality was 11.3% in 2009. Strays also represented a significant percentage of the total mortality in NAN (1.3% during 1991–2007). The largest percentage of the total mortality represented by strays in NAN was 4.6% in 2004. In PPS, strays comprise only a small percentage (average 0.3% during 1979–2018) of the total mortality. The greatest percentage of the total mortality represented by strays at PPS was 6.5% in 2003.

Among the Lower GST indicator stocks, an average of 45% of the BQR total mortality (Figure 2.17; Appendix C4), 33% of the COW total mortality (Figure 2.17; Appendix C7), 34% of the NAN total mortality (Figure 2.17; Appendix C23), and 53% of the PPS total mortality (Figure 2.17; Appendix C30) occurred in the escapement during 1979–2018 (note that COW mortality distribution time series begins in 1990 and that of NAN is truncated to 1984–2006). The average percent of total mortality represented by escapement increased to 61% BQR (2009–2018), to 37% in 2009–2018 in COW, and declined in PPS to 62% in 2009–2018. Most of the remaining mortalities in BQR are associated with catch and IM in the ISBM Southern B.C. sport (1999–2008 average: 16%, 2009–2018 average:24%) and the SEAK AABM troll (1999–2008 average: 9%, 2009–2018 average: 5%) fisheries. The ISBM Southern B.C. troll and net fisheries used to be important mortality components for BQR during 1979–1995 with an average of 10% and 8% of the total mortality but their relevance diminishes to less than 1% during 1999–2018. In the case of COW, total fishing mortality is dominated by the ISBM Southern B.C. sport fishery (1999–2018 average: 33%), but the WCVI AABM troll (1999–2008 average: 10%, 2009–2018 average: 4%), the ISBM Puget Sound sport (1999–2008 average: 2%, 2009–2018 average: 5%), the Canada terminal net (1999–2008 average: 5%, 2009–2018 average: 5%) and Southern U.S. net (1999–2008 average: 7%, 2009–2018 average: 3%) fisheries are also important COW mortality components. The ISBM Southern B.C. troll fishery used to be an important mortality component for COW during 1985–1995, averaging 9% of the total mortality but its contribution becomes effectively 0% during 1999–2018. Similar to COW, most of NAN fishing mortality has been dominated by the ISBM Southern B.C. sport fishery (1984–2006 average: 41%). ISBM Canada troll and net fisheries were important mortality components for NAN in the past with 14% and 19% of the total mortality in 1984 but their relevance diminished to mortality levels of 0% during 1999–2007. Lastly, most of PPS fishing mortality is associated to catch and IM in the ISBM Southern B.C. sport (1999–2008 average: 12%, 2009–2018 average: 24%), the SEAK AABM troll (1999–2018 average: 5%), and the ISBM NBC & CBC sport (1999–2018 average: 2%) fisheries. ISBM Canada troll and net fisheries used to be important mortality components for PPS during 1979–1984 with 23% of the total mortality associated to ISBM NBC, CBC and

Southern B.C. troll and 12% to ISBM NBC, CBC and Southern B.C. net but their relevance diminishes to mortality levels of less than 1% during 1999–2018.

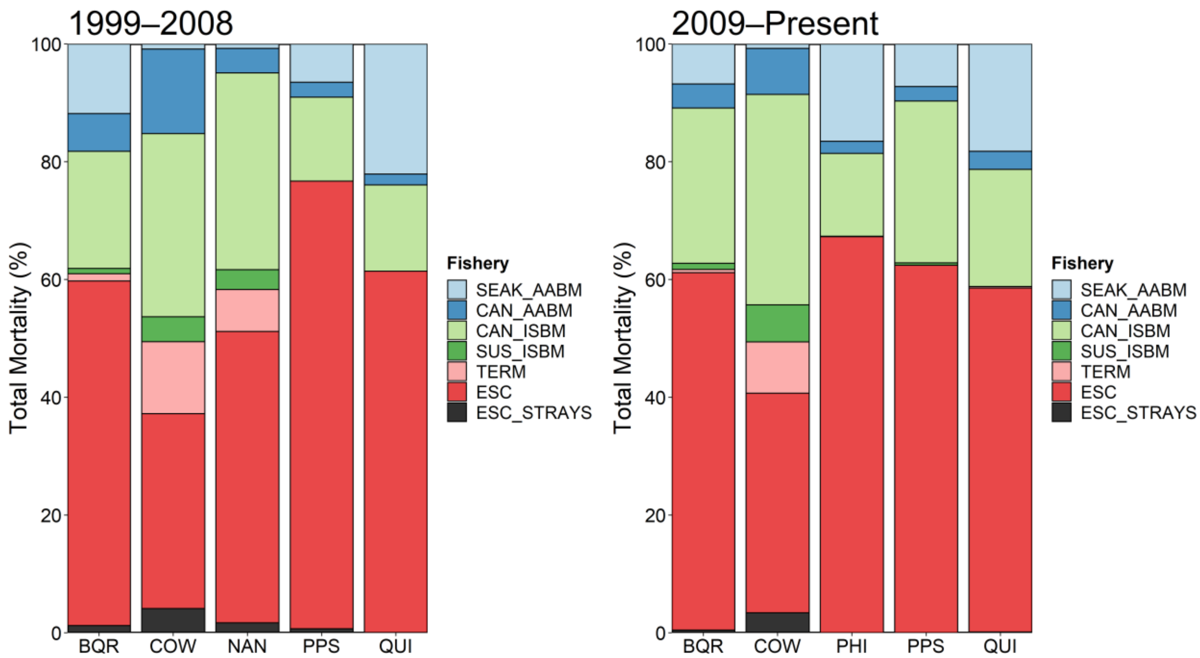


Figure 2.17 Distribution of total mortality for upper and Lower Strait of Georgia indicator stocks for the 1999-2008 and the 2009-2018 Agreement periods.

2.2.5 Fraser Stocks

Fraser River Chinook have been represented by two model stocks, Fraser Early (FRE), and Fraser Late (FRL). The CWT indicator stocks for Fraser Early represent different combinations of run type and life history. There are two hatchery CWT indicator stocks for Fraser Late (Chilliwack [CHI] and Harrison [HAR]), two for Fraser Early Spring-run type (Nicola [NIC; age 1.2] and Dome [DOM; age 1.3]), and two for Fraser Early subyearling Summer-run type (Lower Shuswap [SHU; age 0.3]; Middle Shuswap [MSH; age 0.3]). Currently, there is no CWT indicator for Fraser Early Yearling Summer-run type [age 1.3 and DOM was discontinued after the 2002 BY. CHI is composed of tag recoveries of the Chilliwack River fall stock released from the Chilliwack Hatchery whereas HAR is composed of tag recoveries of the Harrison River stock released from the Chehalis Hatchery. NIC is composed of tag recoveries of the Nicola River stock released from the Spius Creek hatchery and DOM was composed of releases of Dome Creek stock reared at the Penny Hatchery. SHU is composed of tag recoveries of Lower Shuswap River Chinook and MSH is composed of tag recoveries of Middle Shuswap River Chinook, both of which are produced at the Shuswap Falls Hatchery. Fraser Late (Fall) enter the ocean as subyearlings and age 2 is the youngest age at which CWTs are recovered. Fraser Early includes stocks that enter the ocean as subyearlings and stocks that enter the ocean as yearlings. The SHU stock is a summer-run, entering the ocean as subyearlings, whereas the NIC and DOM stocks are spring-runs, entering the ocean as yearlings with age 3 as the youngest age at which CWTs are recovered. The time series of recoveries for Fraser Late stocks CHI and HAR starts with BY 1981, the time series of DOM begins with BY 1986, NIC with BY 1985, SHU with BY 1984 and MSH with BY 2008. Unlike the other Fraser River stocks with time series ending with BY 2013, the last completed BY for DOM is 2002.

2.2.5.1 Brood Year Exploitation Rates

The BYERs computed for Fraser River stocks include recoveries from ocean fisheries and terminal fisheries within the Fraser River and tributaries. BYERs for the Fraser Late indicator stocks have a declining tendency over their time series (Figure 2.18). In the Fraser Early indicator stocks, BYER was increasing for DOM when that program was discontinued (last completed BY 2002); however, no clear trend is apparent for NIC (Figure 2.19). Since BY 2001, BYER was decreasing for SHU, and since BY 2008 there is no trend apparent for MSH. From BY 1981 to BY 2014, the BYERs decreased from approximately 66% to 30% for CHI and from approximately 70% to 34% for HAR. CHI BYER averaged 41% and ranged from 22% for BY 1995 to 83% for BY 1982, whereas HAR BYERs averaged 46% and ranged from 19% for BY 1995 to 86% for BY 1982.

Within BYERs, the percentage of the BYER represented by IM for CHI averaged 20% over the entire time series, and increased during the first 15 years, reaching 31% for BY 1995, and then decreased substantially to average levels for subsequent BYs. Similarly, the percentage of the HAR BYER that results from IM averaged 21% and also increased during the first 15 years of the time series, reaching 37% for BY 1994, followed by fluctuations around the average level from 12% in 2001 and 31% in 1999.

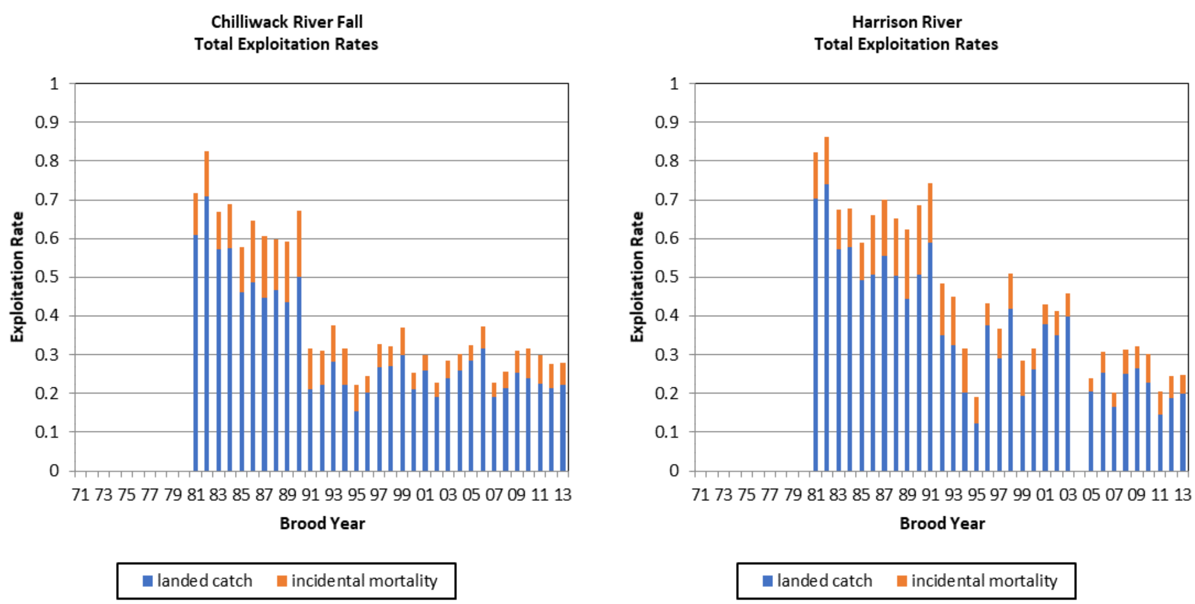


Figure 2.18 Total brood year exploitation rate for Fraser Late stocks. Catch and incidental mortality are shown. Only completed brood years are included.

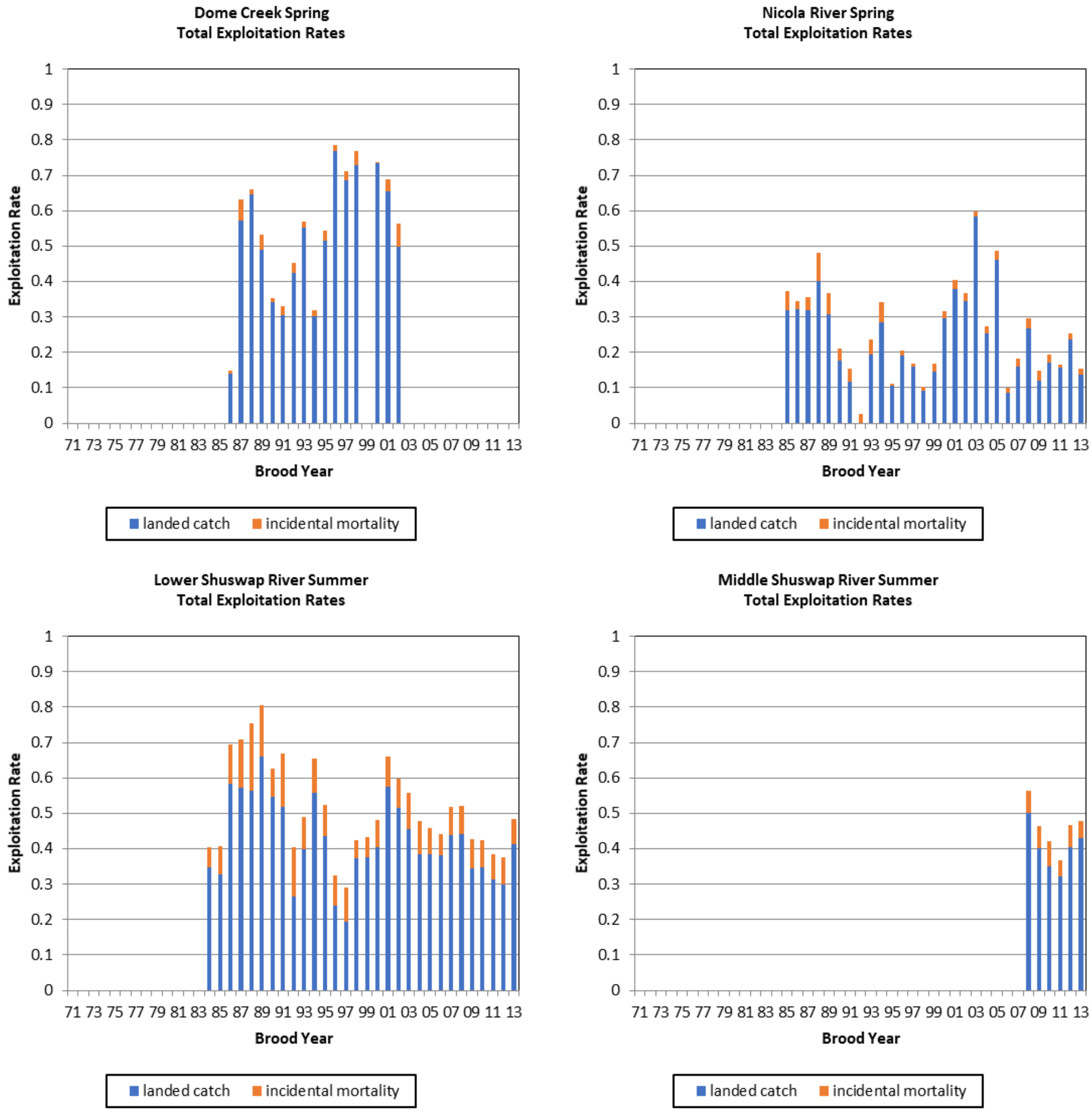


Figure 2.19 Total brood year exploitation rate for Fraser Early stocks. Catch and incidental mortality are shown. Only completed brood years are included.

Exploitation rate patterns differed for the three indicator stocks representing Fraser Early. DOM BYER averaged approximately 55% and ranged from 15% for BY 1986 to 78% for BY 1996. The percentage of the DOM BYER that is attributed to IM remained relatively stable, averaging approximately 5% for the entire time series, and reached its lowest values for BYs in 2000 at (<0.01%). Excluding BY 1992, for which there were no recoveries in the catch, likely as a result of the poorest survival observed for this stock (see next Section), NIC BYERs are the lowest among Fraser River and all other Canadian CWT indicator stocks. Estimated BYERs for NIC averaged approximately 26% and ranged from approximately 10% for BY 2006 to approximately 60% for BY 2003. The estimates of IM remained relatively stable, averaging approximately 14%

for the entire time series, and ranging from 3% for BY 2003 to 24% for BY 1991. Estimated BYERs for MSH averaged approximately 45%, and ranged from 36% to 56%. The percentage of MSH BYER attributed to IM averaged 13% and ranged from 10% to 17%. Lastly, BYER for SHU averaged approximately 51%, and ranged from 29% for BY 1997 to 80% for BY 1989. SHU BYER IM percentages have remained relatively stable, averaging approximately 18% for the entire time series and ranging from 12% for BY 1998 to 34% for BY 1992.

2.2.5.2 Survival Rates

Estimated survival rates for CHI, HAR, MSH and SHU represent survival to age 2 because juveniles from those stocks enter the ocean as subyearlings. Estimated survival rates for DOM and NIC represent survival to age 3 because smolts from those stocks enter the ocean as yearlings and age 3 is the youngest age recovered. If the first BY of the time series for CHI and HAR is removed, there is no apparent trend for the survival rates of Fraser River indicator stocks.

For CHI, survival averaged 11.6%, with a range of 1.7% for BY 1991 to 30.6% for BY 1981 (the highest observed for any Fraser River stock). Estimated survival rates for HAR averaged 3.6% and ranged from 24.0% in BY 1981 to a low of 0.4% for BY 1991 (Figure 2.20). For the Fraser Early indicator stocks, DOM survival rates averaged 1.1% and ranged from a low of 0.1% for BY 1994 to 2.5% for BY 1993. NIC survival rates averaged 2.6% with a range of 0.1–15.5%, and the SHU survival rates averaged 3.0% with a range of 0.5–8.1% (Figure 2.21). The survival rate for the last completed brood of the time series was 8.8% for CHI, 3.6% for HAR, 0.6% for NIC, 1.0% for MSH and 0.5% for SHU. DOM has been discontinued, and survival for the last completed BY (2002) was 0.4%.

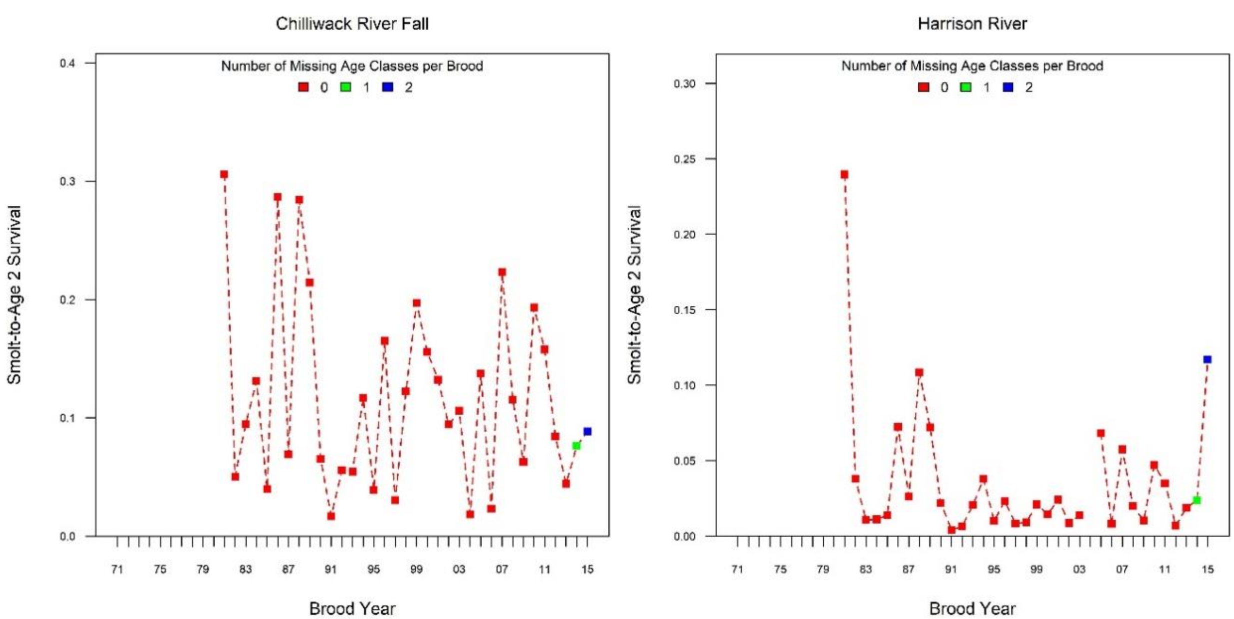


Figure 2.20 Survival rate for Fraser Late stocks.

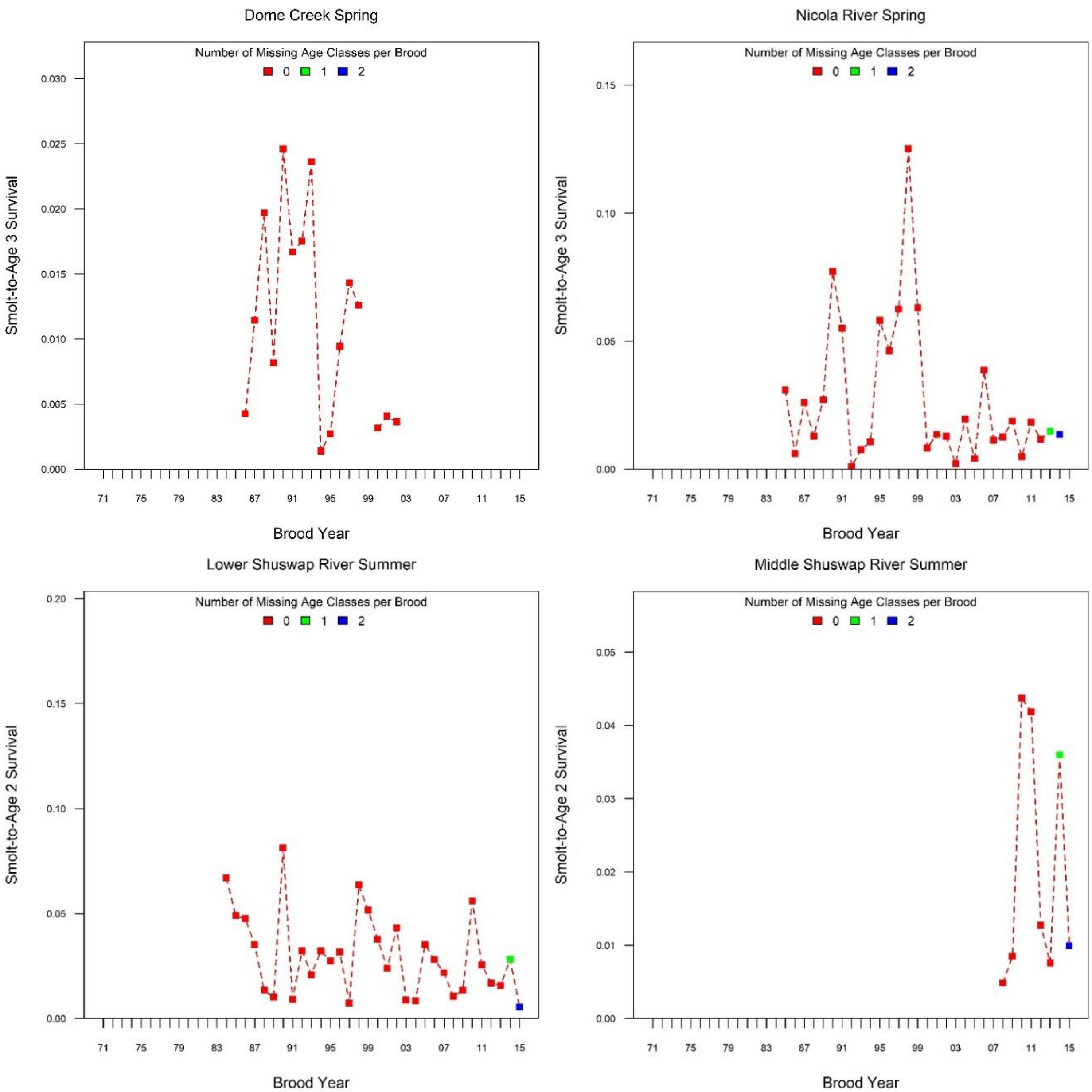


Figure 2.21 Survival rate for Fraser Early stocks.

2.2.5.3 Mortality Distributions

For the Fraser Late indicator stocks, escapement represented an average of 58% of the CHI total mortality (Figure 2.22; Appendix C6) and 54% of the HAR mortality (Figure 2.22; Appendix C14) between 1985 and 2018 (mortality distribution time series for both stocks began in 1985). The CHI average mortality in the escapement remained approximately the same from the 1999–2008 period (70%) to the 2009–2018 period (69%). The HAR average mortality in the escapement increased from the 1999–2008 period (60%) to the 2009–2018 period (73%). For CHI, fishing mortality mainly occurred in the Canadian terminal sport (1999–2008 and 2009–2018 averages: 6% and 6% respectively), the ISBM Southern B.C. sport (1999–2008 average:

5%; 2009–2018 average: 11%) the ISBM North of Falcon troll (1999–2008 average: 6%; 2009–2018 average: 4%), and the WCVI AABM troll (1999–2008 average: 6%; 2009–2018: 2%) fisheries. Between 1985 and 1995, the ISBM Southern B.C. (Strait of Georgia) troll fishery was an important component of the total mortality for CHI (average 6%); however, that fishery for Chinook salmon ceased from 1996 onward. For HAR, most of the fishing mortality from 1999–2008 was associated with catch and IM in the WCVI AABM troll fishery (average: 13%), which declined to 2% during 2009–2018; other important components of the total mortality were the North of Falcon troll ISBM fishery (1999–2008 average: 9%; 2009–2018 average: 4%) and the Southern B.C. sport ISBM fishery (1999–2008 average: 6%; 2009–2018 average: 11%). The ISBM Southern B.C. sport fishery was a larger mortality component for HAR during 1985–1998 ranging from 3% to 32%. There is only limited terminal recreational fishing opportunity on HAR.

Among the Fraser Early indicator stocks, escapement represented a larger amount of the total mortality distribution during the 2009-2018 period than the 1999-2008 period for NIC (77% vs 73%, respectively; Figure 2.22; Appendix C24), 53% of the MSH total mortality (Figure 2.22; Appendix C22), and SHU (56% and 54% respectively; Figure 2.22; Appendix C36). During 2009–2018, the largest components of the total fishing mortality for SHU occurred in the SEAK AABM troll fishery (average: 9%), followed by the ISBM Southern B.C. sport (average: 9%), NBC AABM troll fishery (average: 7%) and the terminal net fishery (average: 6%). MSH is part of the same stock group as SHU, however for MSH the largest component of the total fishing mortality during 2009–2018 occurred in the ISBM Southern B.C. sport fishery (average: 14%), followed by the NBC AABM troll fishery (average: 6%), SEAK troll fishery (average: 5%) and the Terminal net fishery (average: 6%; Figure 2.22; Appendix C24). During 2009–2018, the largest components of the total fishing mortality for NIC occurred in the terminal net fishery (average: 10%), followed by the ISBM Southern B.C. sport fishery (average: 5%).

Strays make an average 1.0% of the total mortality in CHI during 1985–2018. The largest percentage of the total mortality represented by strays in CHI was 5.6% in 2003. In HAR, strays make 0.3% of the total mortality during 1985–2018. The largest percentage of the total mortality represented by strays in HAR was 4.6% in 1995. In DOM, strays make only a small percentage (0.2% during 1991–2006), but strays were only reported in one year, (2.6% of the total mortality that year). Strays also represented a very small percentage of the total mortality in NIC (~0% during 1989–2018). The largest percentage of the total mortality represented by strays in NIC was 1.7% in 1990. Similarly, strays make up only a small percentage of the total mortality in SHU (1988–2018 average: 0.4%) and MSH (2012–2018 average: 2.1%). The largest percentage of the total mortality represented by strays in SHU was 1.4% in 2015 and it was 4.8% and 4.9% for MSH in 2015 and 2016 respectively.

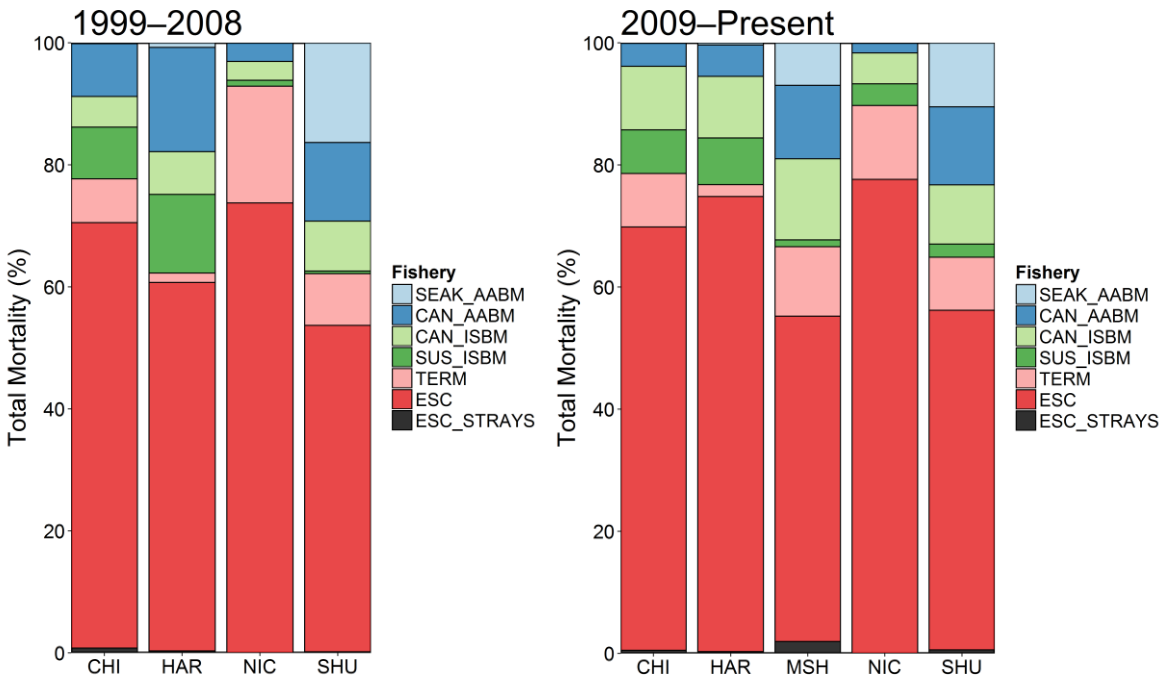


Figure 2.22 Distribution of total mortality for the Fraser River indicator stocks for the 1999-2008 and the 2009-2018 Agreement periods.

2.2.6 Regional Summary for Canadian Stocks

With exception of the RBT indicator stock, for which BYER represents ocean fishing mortality, BYERs in Canadian indicator stocks represent fishing mortality in both ocean and terminal fisheries. BYERs of most Canadian indicator stocks have been generally declining. Notwithstanding, Strait of Georgia stocks have experienced the largest BYERs among Canadian indicator stocks with Lower Strait of Georgia Natural stocks COW and NAN experiencing average BYERs greater than 60%. Except for DOM (for which 2002 was the last complete BY reported) and PPS, BYERs for the last complete BY of all Canadian stocks were lower than their long-term averages (Table 2.7). Fraser Early indicator stock NIC has experienced the lowest BYERs among Canadian indicator stocks with an average of 27% across all complete BYs and 15% for its last complete BY.

Average survival rates to age 2 (to age 3 for KLM and DOM) are lower than 5% for all Canadian indicator stocks, except for CHI, which has the largest average survival rate at 11.8% (Table 2.7). CHI also experienced the largest estimated survival rate (30.6% in 1981) for any given BY among all Canadian stocks. Other stocks that have experienced BY survival rates greater than 20% are RBT, BQR, and HAR. These high survival rates occurred in all cases in the first few years of the time series. Survival rates for these stocks have clearly subsided relative to those high values. The lowest survival rate for the last complete BY (2012 or 2013) among all Canadian indicator stocks was 0.47% for KLM.

In terms of calendar year statistics for 1999–2008 and 2009–2018, the average percentage of total mortality occurring in the escapement was greater than 50% for most Canadian indicator stocks. RBT and COW experienced average escapement percentages of the total mortality below 50% in both time periods: 47–45% (RBT) and 33–37% (COW). The percentage of total mortality occurring through escapement during the 1999–2008 time period for DOM was 26%. Escapement percentages by calendar year lower than 20% have occurred only in COW, and DOM. These low escapement percentages of the total mortality took place in 2009 for COW and 2003 for DOM. The largest escapement percentages of the total mortality in 2018 occurred in KLM (89%) and ATN (91%). Differences in average escapement percentages of the total mortality between Agreement periods 1999–2008 and 2009–2018 were small in most cases (Table 2.7). Important differences occurred only for PPS and HAR, where average escapement percentages decreased from 76% in 1999–2008 to 62% in 2009–2018 for PPS, whereas it increased from 60% to 73% for HAR.

Table 2.7 Summary of statistics generated by the 2019 coded wire tag (CWT) cohort analysis for Canadian indicator stocks by region. Statistics include total mortality (catch plus incidental mortality) brood year exploitation rate (BYER), cohort survival rate to age 2 (age 3 for KLM and DOM), and calendar year (CY) percent distribution of the total mortality and the escapement for 1999 (1999–2008) and 2009 (2009–2018) Treaty Agreement periods.

						CY % Escapement[1]		
		BYER (total mortality)		**Survival rate**		**1999–2008**	**2009–current**	
Region	**Indicator Stock**	Mean (range)	Last complete BY	Mean (range)	Last complete BY	Mean (range)	Mean (range)	Last calendar year
North/ Central B.C.	Kitsumkalum (KLM)	40% (22%-66%)	33% (2012)	0.94% (0.16-2.46%)	0.47% (2012)	61% (47-70%)	66% (54-89%)	89% (2018)
	Atnarko (ATN)	40% (22%-61%)	22% (2013)	2.4% (0.50-6.18%)	1.96% (2013)	55% (41-72%)	59% (37-91%)	91% (2018)
WCVI	RobertsonCreek (RBT)	42%[2,3] (23–67%)	37% (2013))	4.55% (0.03-20.1%)	3.05% (2013)	47% (20-87%)	45% (28-64%)	28% (2018)
Georgia Strait	Quinsam (QUI)	55% (29%-85%)	44% (2013)	2.04% (0.16-9.11%)	1.58% (2013)	61% (50-78%)	58% (51-69%)	51% (2018)
	BigQualicum (BQR)	59% (33%-88%)	33% (2013)	2.40% (0.12-25.44%)	0.70% (2013)	59% (49-74%)	61% (44-78%)	78% (2018)
	Cowichan (COW)	68% (36%-89%)	64% (2013)	1.84% (0.33-6.83%)	0.60% (2013)	33% (21-59%)	37% (18-52%)	24% (2018)
	Nanaimo (NAN)	66% (35%-94%)	35% (2004)	2.99% (0.48-13.63%)	3.09% (2004)	50% (34-76%)	NA[4]	NA
	Puntledge (PPS)	51% (13%-88%)	52% (2013)	1.17% (0.09-12.76%)	1.20% (2013)	76% (68-90%)	62% (40-77%)	63% (2018)
Fraser River	Chilliwack (CHI)	41% (22%-83%)	28% (2013)	11.77.% (1.68-30.55%)	4.42% (2013)	70% (51-83%)	69% (58-80%)	66% (2018)
	Harrison (HAR)	46% (19%-86%)	25% (2013)	3.40% (0.40-23.97%)	1.86% (2013)	60% (47-84%)	73% (51-84%)	68% (2018)
	Dome (DOM)	55% (15%-79%)	56% (2002)	1.11% (0.14-2.46%)	0.36% (2002)	26% (15-50%)	NA	25% (2005)
	Nicola (NIC)	27%[2] (10–60%)	15% (2013)	2.81% (0.10-12.51%)	1.16% (2012)	74% (40-89%)	77% (45-90%)	74% (2018)
	Lower Shuswap (SHU)	51% (29%-80%)	48% (2013)	3.08% (0.73-8.13%)	1.57% (2013)	54% (35-75%)	56% (50-65%)	65% (2018)

[1] % Escapement is not a measure of performance for the escapement indicator stock(s) associated with a given CWT indicator stock. See CTC (2013) for these details.

[2] Does not include BY 1992 from which there were no CWT recoveries in the catch due to extremely low survival rates.

[3] BYER based on ocean exploitation rate; terminal exploitation rate is not included because fishing mortality on hatchery fish does not represent fishing mortality on wild fish.

[4] NA = No data available

2.2.7 Washington Coast Stocks

Three facilities on the Washington Coast currently release coded wire tagged Chinook salmon which are used by the CTC to represent natural fall Chinook salmon production in the rivers between the Columbia River in the south to the Strait of Juan de Fuca in the north. Indicator stocks include the Queets River (QUE, released from Quinault Division of Natural Resources Salmon River Hatchery) and Tsoo-Yess River (SOO, released from the U.S. Fish and Wildlife Service Makah National Fish Hatchery) on the coast, and the Hoko River at the western end of the Strait of Juan de Fuca (HOK, released from Makah's Hoko Falls Hatchery). Queets, Tsoo-Yess, and Hoko indicator stocks share a common life history: they are ocean type (fingerling releases), fall-timed fish with a maximum age at maturity of 6. These three stocks also have extensive historical tagging and recovery coverage (20+ completed BYs), with Hoko and Tsoo-Yess records starting in 1985 and Queets records starting in 1977.

2.2.7.1 Brood Year Exploitation Rates

BYER patterns for Hoko, Queets, and Tsoo-Yess are presented in terms of total exploitation, including both ocean and terminal fisheries (Table 2.8; Figure 2.23). The BYERs for Hoko and Tsoo-Yess indicator stocks have tracked closely for the entirety of their time series, averaging 34% and 36%, respectively. Both stocks exhibited higher BYERs for the first two years on record (1985–1986, approximately 60%) than those observed in recent years. The BYERs for the most recent complete BY (2012) are 36% for Hoko and 19% for Tsoo-Yess. Approximately one quarter of all fishery-related mortality for HOK and SOO is in the form of non-landed, incidental impacts. Across its 34 complete BYs, the total BYER for the Queets indicator stock has averaged 58%, ranging between 37% and 82%, and displaying no discernible temporal trend. The BYER for the last complete Queets BY (2012) is 57%.

Table 2.8 Summary of statistics generated by the 2019 CWT cohort analysis for Washington Coast indicator stocks. Statistics include total mortality (catch plus incidental mortality) brood year exploitation rate (BYER), cohort survival rate to age 2, and calendar year (CY) percent distribution of the total mortality in the escapement for 1999 (1999–2008) and 2009 (2009–2018) Treaty Agreement periods.

		BYER (total mortality)		Survival rate		CY % Escapement[1]		
						1999–2008	2009–current	
Stock Abbrev.	Indicator Stock Name	Mean (range)	Last complete BY	Mean (range)	Last complete BY	Mean (range)	Mean (range)	Last CY (if ≠ current)
HOK	Hoko Fall Fingerling	34% (16-64%)	36% (2012)	1.37% (0.11-3.14%)	0.87% (2012)	66% (30-89%)	71% (58-85%)	73% (2017)
QUE	Queets Fall Fingerling	58% (37-82%)	57% (2012)	2.61% (0.59-5.65%)	2.87% (2012)	54% (24-75%)	39% (20-51%)	45% (2017)
SOO	Tsoo-Yess Fall Fingerling	36% (12-61%)	19% (2012)	0.61% (0.01-2.11%)	2.11% (2012)	56% (29-84%)	75% (61-84%)	79% (2017)

[1] % Escapement is not a measure of performance for the escapement indicator stock(s) associated with a given CWT indicator stock. See CTC (2013) for these details.

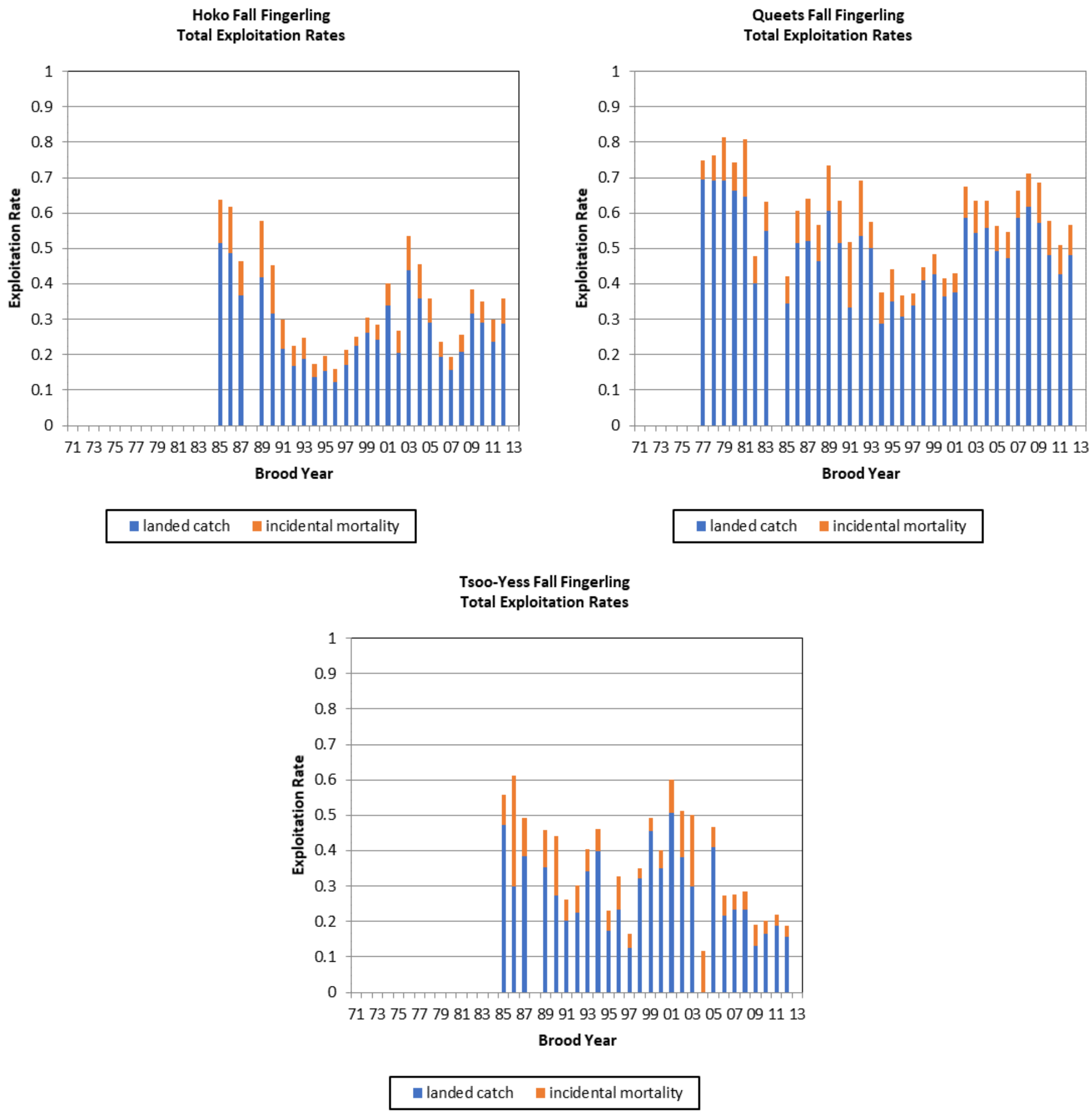


Figure 2.23 Brood year exploitation rate in terms of landed catch and incidental mortality for Washington Coast indicator stocks.

2.2.7.2 Survival Rates

CWT data indicate that release-to-age-2 survival for Chinook salmon on the Washington Coast indicator stocks is highly variable across stocks and years (Figure 2.24; Table 2.8). Tsoo-Yess Chinook salmon, for instance, consistently experience some of the lowest survivals of any CWT indicator stock evaluated by the CTC. The series-wide mean survival from release-to-age-2 for this stock is 0.61%, but it has ranged more than two orders of magnitude (0.01–2.11%). The Queets Chinook indicator stock exhibits the highest survival rates among the three indicator stocks, with a range of 0.59–5.65%, and a mean of 2.61%. Hoko Chinook survival rates lie between these extremes with a mean of 1.37% and a range of 0.11–3.14%. Across their time series, there is little evidence of a long-term trend in early marine survival. In terms of more recent performance, the survival rates of the Hoko and Queets stocks have declined considerably from the highs observed for the 1999 BY with some rebounding in the past couple of years. In contrast, the highest observed survival for the Tsoo-Yess was in BY 2011.

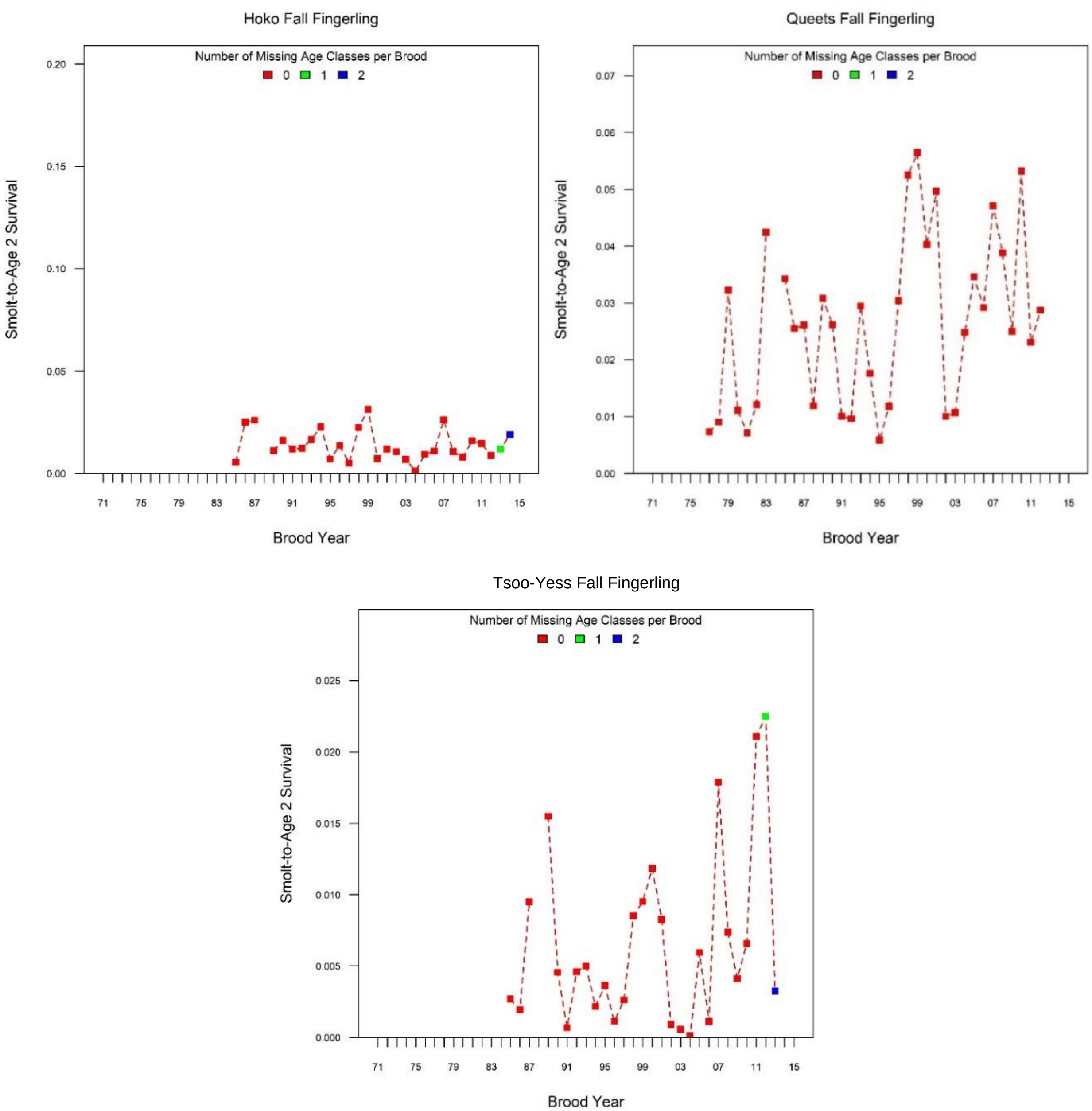


Figure 2.24 Survival rate for Hoko, Queets, and Tsoo-Yess Fall Fingerling stocks.

2.2.7.3 Mortality Distributions

Washington coastal indicator stocks exhibit a mortality distribution consistent with a far north migration pattern. On average, since 1999, 83% of all fishery-related mortality and approximately a third of total mortality, results from fisheries occurring north of the southern border between U.S. and Canada. The majority of these fishery-related mortalities occur in the SEAK and NBC AABM troll fisheries (Figure 2.25; Appendix C15,C31, and C51). In the 2017 calendar year (CY2017), Southern U.S. fisheries accounted for 1.2% of total mortalities for the Hoko indicator stock and 2.4% for the Tsoo-Yess indicator. Terminal net fisheries targeting Queets River Fall-run Chinook account for 24.8% of the annual mortality distribution in CY2017. Escapement for the three stocks has ranged from 20% (Queets) to 86% (Hoko) of the total distribution in recent years (Table 2.8). Lastly, aside from increases in escapement (all three stocks, Appendix C), there is limited evidence of a systematic shift in mortality distributions for these stocks between the 1999 and 2009 Agreement periods (Figure 2.25).

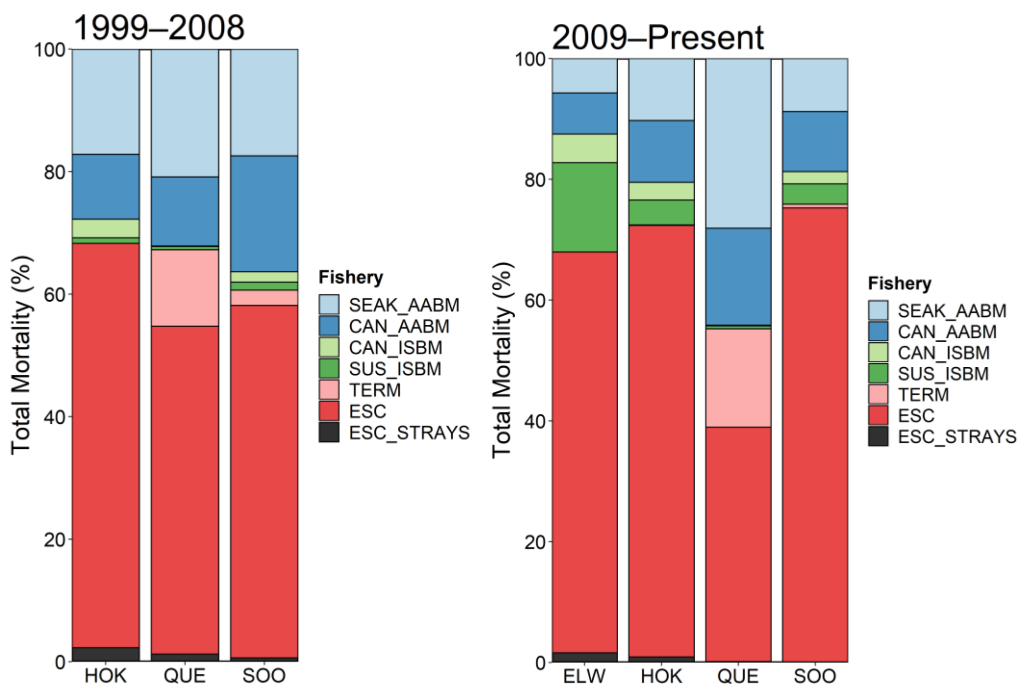


Figure 2.25 Distribution of total mortality for Washington Coast indicator stocks for the 1999-2008 and 2009-2018 Agreement periods.

Note: ELW is discussed in Section 2.2.8.4.

2.2.8 Washington Salish Sea Stocks

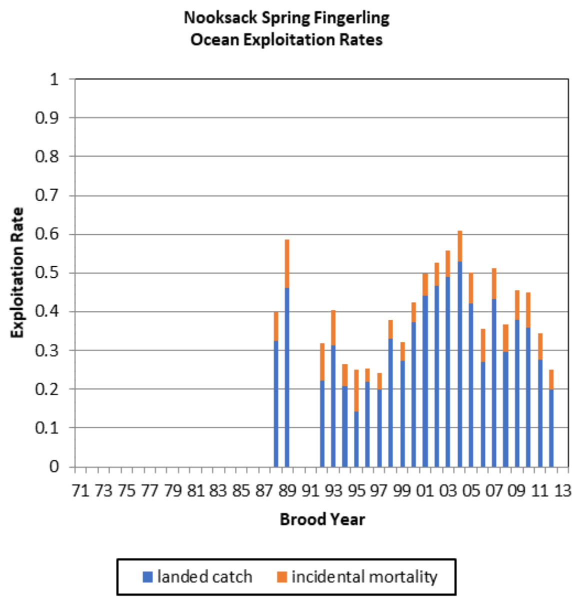
There are 14 CWT indicator stocks analyzed within the Washington Salish Sea. The indicator stocks are a mixture of traditional hatchery production for harvest purposes, and natural stock supplementation programs from brood stock collected on the spawning grounds. Current non-tribal sport fisheries for Chinook within Puget Sound are almost exclusively under MSF regulations. Except for one stock, White River Spring Yearlings, these CWT indicator groups are adipose-clipped (marked), and therefore available for retention in MSFs. Consequently, estimates of fishing mortality from these adipose-clipped CWT recoveries will likely overestimate the fishing mortality and, in turn, the BYER estimates of unmarked natural-origin fish that must be released. MSFs or directed fisheries on hatchery surplus create a differential terminal fishery structure for these indicator groups; hence, BYERs are expressed in terms of ocean fisheries for all of these indicators. Details on the CWT indicator stock groups and influence of mark-selective and terminal fisheries on the estimates are presented in the regional subsections below.

2.2.8.1 Northern Puget Sound

Indicator stocks in Northern Puget Sound include Fingerling and Yearling Spring tag groups from Nooksack River (NSF, NKS) and Skagit River (SKF, SKS) and Summer/Fall Fingerling groups from Samish (SAM) and Skagit (SSF) Rivers. Nooksack and Skagit Spring stocks are listed in the Northern Puget Sound Natural Spring stock group in Attachments IV and V. Releases of Yearling Spring Chinook salmon into the Nooksack River were discontinued following the 1996 BY. The Nooksack Spring hatchery program's primary purpose is natural supplementation, and supporting a small tribal subsistence fishery in the river. The SAM indicator does not represent an associated natural production, but is important for evaluating the large hatchery production program from the Samish Hatchery. The Skagit Spring program's primary purpose is harvest augmentation; the returning fish are subjected to an MSF in the area near the hatchery. The Skagit Summer Fingerling (SSF) group's purpose is evaluation of fishery impacts to the natural stock in the system. Spawning ground recoveries are the source of brood stock for the SSF program. The yearling program in the Skagit River was discontinued with the 2010 BY, released in spring of 2012.

2.2.8.1.1 Brood Year Exploitation Rates

The time series of BYER for the NSF group spans BYs 1988 to 2012, missing only 1990 and 1991 (Figure 2.26). The average BYER for the period is 40%, ranging from a low of 24% to a high of 61%. The most recent BYER, for the 2012 brood, was 25%. BYERs for NKS are available for broods from 1981 to 1996, minus BYs 1983, 1985 and 1991 (Figure 2.26). Exploitation rates for the years of available NKS data ranged from 34% to 76%, with an average of 51%. Data to estimate BYERs for the SAM group were available for the 1974, 1975, 1979, and 1985 to 2012 broods (Figure 2.27). The average BYER across the time series was 43%%, ranging between 27% and 68%. The most recent BYER, for the 2012 brood, was 35%. BYERs are available for SKF for 1985 and 1993 through 2012 (Figure 2.27). The average BYER for these years was 29% with a range from 13% in 2006 to 49% in 1985. The BYER in the most recent brood year, 2012, was 23%. Tagging information is available for SKS to estimate ERs for BYs 1981 to 1987, 1990, and 1993 to 2010 (Figure 2.28). The average ER across all BYs is 42%, with a low of 18% (BY 2007) and a high of 78% for BY 1982. The last year of tagging data for SKS is BY 2010, which had an ER of 29%. Consistent BY tagging of Skagit Summer Fingerlings (SSF) has been conducted from BY 1994 to 2012 (Figure 2.28). Exploitation rates for these broods has averaged 32% and ranged between 21% and 54%. The most recent BYER (2012) was 54%.



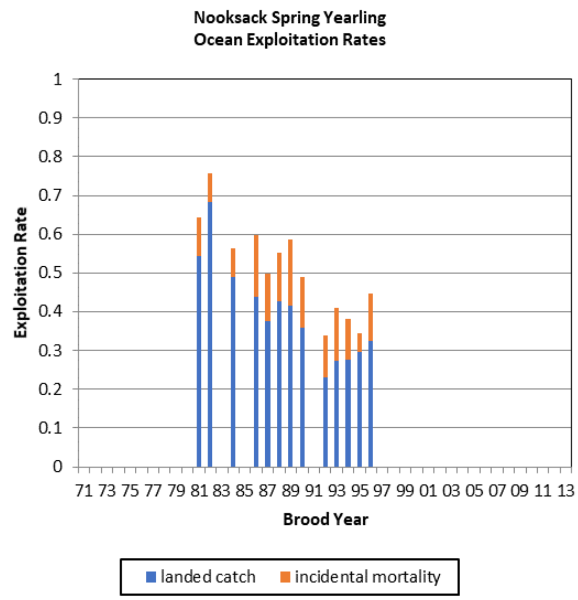
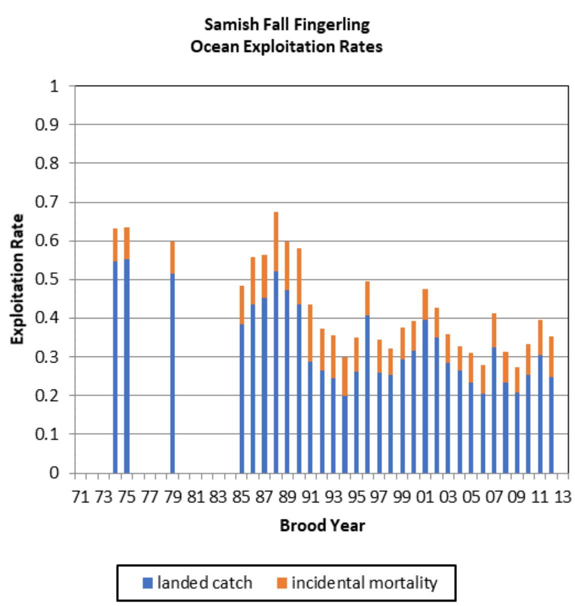


Figure 2.26 Brood year exploitation rate in terms of landed catch and incidental mortality for Nooksack Spring Fingerling and Nooksack Spring Yearling coded wire tag (CWT) indicator stocks.



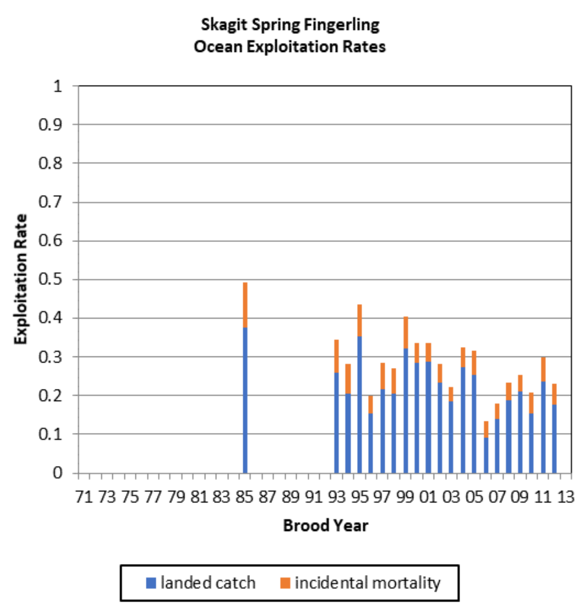


Figure 2.27 Brood year exploitation rate in terms of landed catch and incidental mortality for Samish Fall Fingerling and Skagit Spring Fingerling coded wire tag (CWT) indicator stocks.

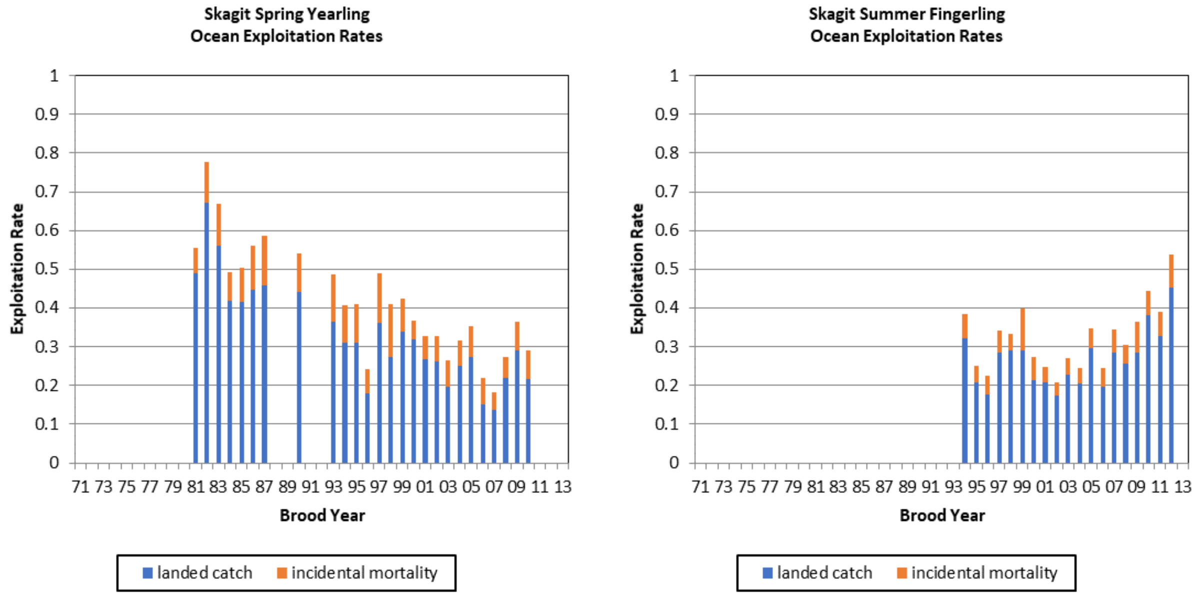


Figure 2.28 Brood year exploitation rate in terms of landed catch and incidental mortality for Skagit Spring Yearling and Skagit Summer Fingerling coded wire tag (CWT) indicator stocks.

2.2.8.1.2 Survival Rates

Since the mid-1990s, survival rates from release to age 2 (fingerlings) or age 3 (yearlings) for Northern Puget Sound indictor stocks have no obvious trends (Figure 2.29–Figure 2.32). More recently (during the last five BYs), survival rates have generally been ≤ 1%, with a few examples in the range of 1–2%.

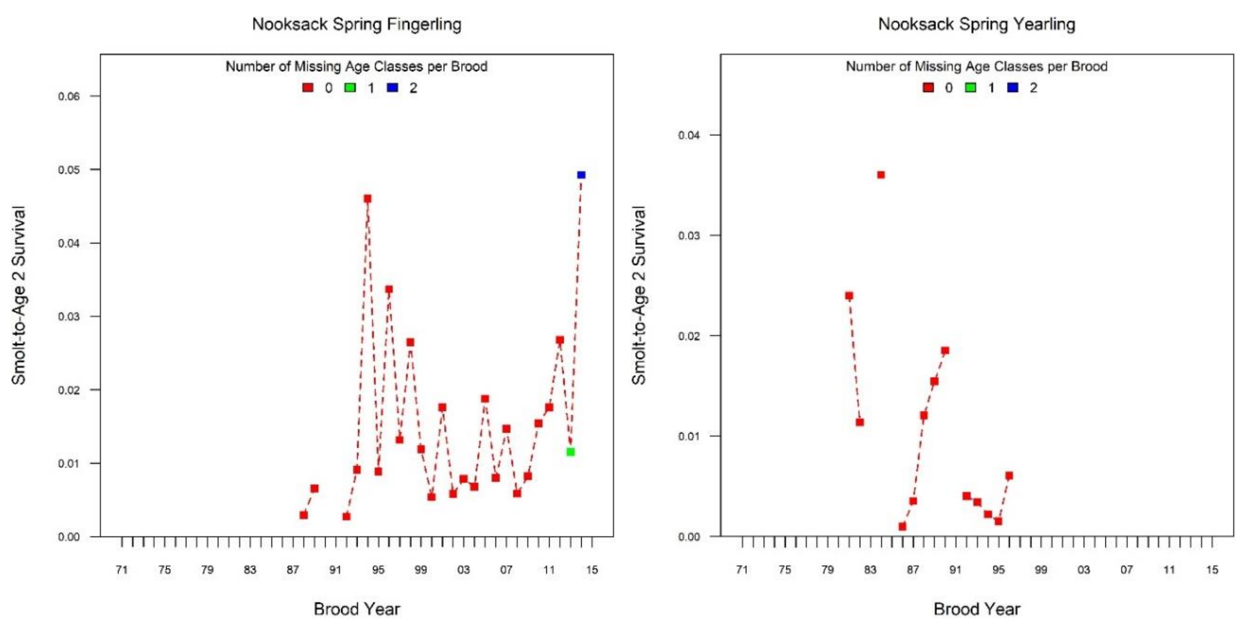


Figure 2.29 Survival rate for Nooksack Spring Fingerling and Nooksack Spring Yearling stocks.

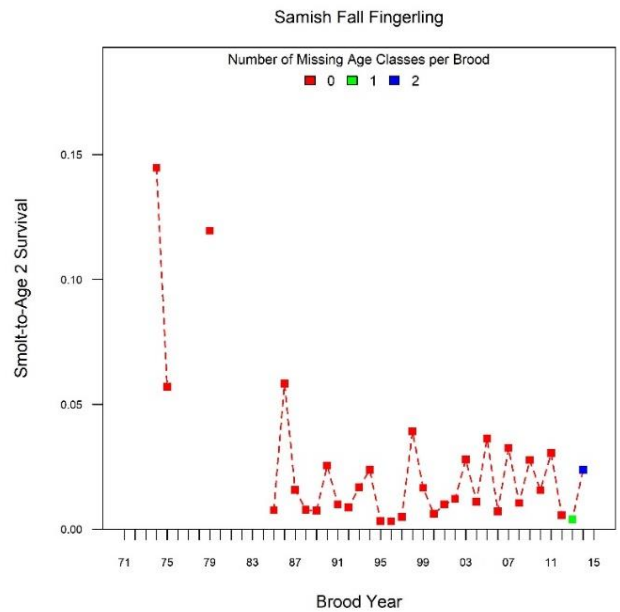


Figure 2.30 Survival rate for Samish Fall Fingerling stock.

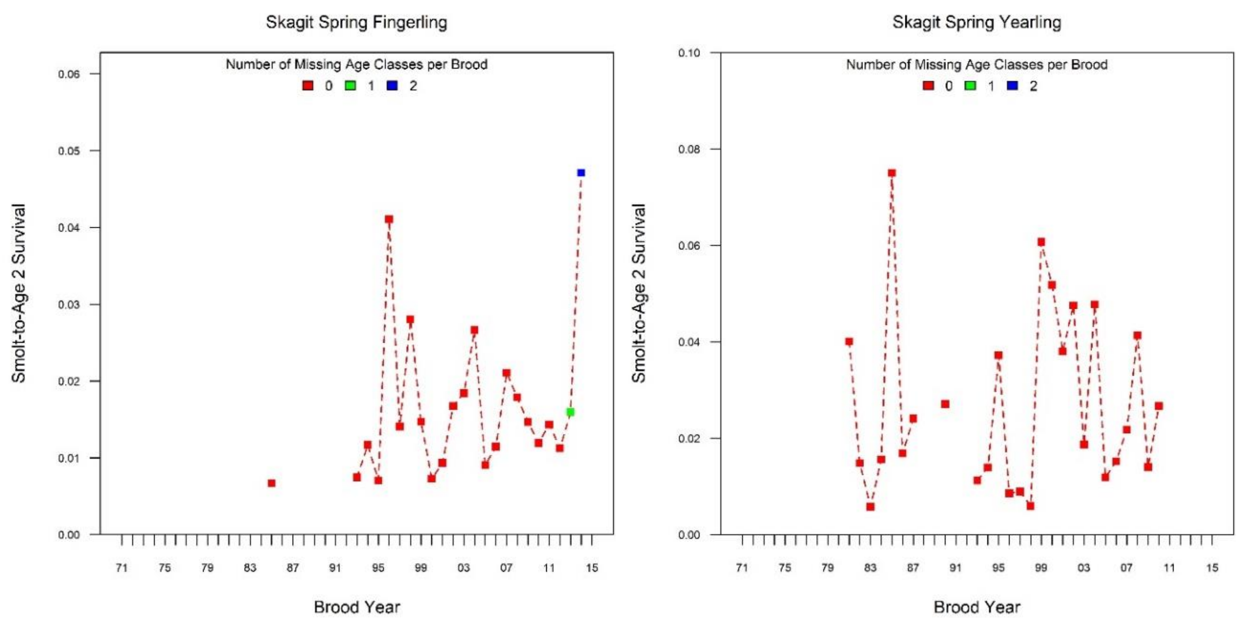


Figure 2.31 Survival rate for Skagit Spring Fingerling and Skagit Spring Yearling stocks.

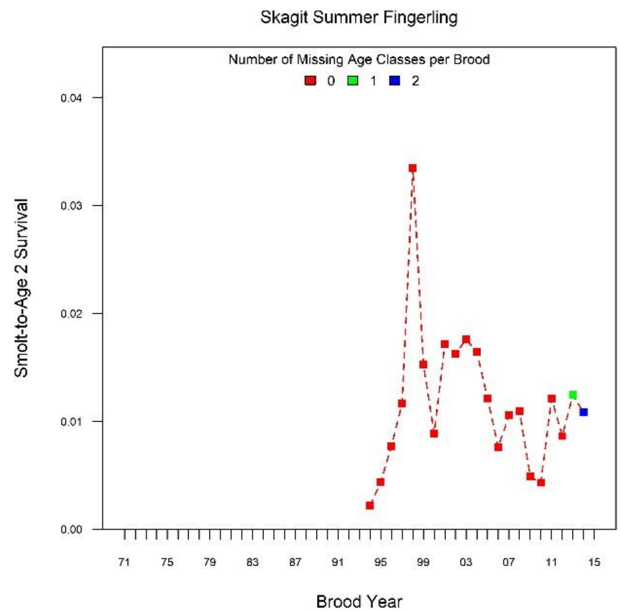


Figure 2.32 Survival rate for Skagit Summer Fingerling stock.

2.2.8.1.3 Mortality Distributions

As a percentage of total AEQ mortality for the North Puget Sound stocks during 1999–present, fishery related mortality averaged 46% for NKS (Appendix C27; one year only, 1999), 43% for NSF (Appendix C26), 73% for SAM (Appendix C35), 36% for SKF (Appendix C37), 41% for SKS (Appendix C38) and 42% for SSF (Appendix C39; Figure 2.33).

Because of their location and northerly ocean migration, the majority of fishing mortality on Northern Puget Sound stocks is in Canadian and Puget Sound fisheries. Mortality in Canadian fisheries has averaged 23% since 1999 and occurs primarily in WCVI and in Southern B.C. sport fisheries. In Puget Sound, mortality has averaged 19% since 1999 and occurs mostly in terminal net fisheries and in marine sport fisheries (which are now almost exclusively under mark-selective regulations). A sizeable state and tribal net fishery within Bellingham Bay targets SAM, contributing the majority of the percentage value shown under Southern U.S. net in Appendix C35. The remaining portion of mortality associated with Puget Sound net for SAM results from the San Juan Islands net fishery, which is under Fraser Panel control in the late summer and fall. With the exception of SAM, mortality in Puget Sound marine and freshwater net fisheries was low through 2007. Since then, mortalities in freshwater net fisheries have been higher, primarily due to higher abundances of Skagit Summer/Fall Chinook and a corresponding directed river net fishery. Although SSF experienced the highest fishery mortality in SEAK among all Salish Sea stocks (9%) during 1999–present, for the combined Northern Puget Sound stock group, the percent mortality in fisheries in SEAK and along the Washington and Oregon Coast is low, averaging approximately 3% (SEAK) and 2% (WA/OR) for these years.

For the aggregate group, the distribution of fishing mortality between fisheries north or south of the U.S. and Canada border has shifted slightly during 1999–present, with a greater proportion of impacts occurring in U.S waters in more recent years. The increase for southern U.S. fisheries is primarily due to the implementation of MSFs beginning in 2003 and a terminal net fishery in the Skagit River starting in the late 2000's.

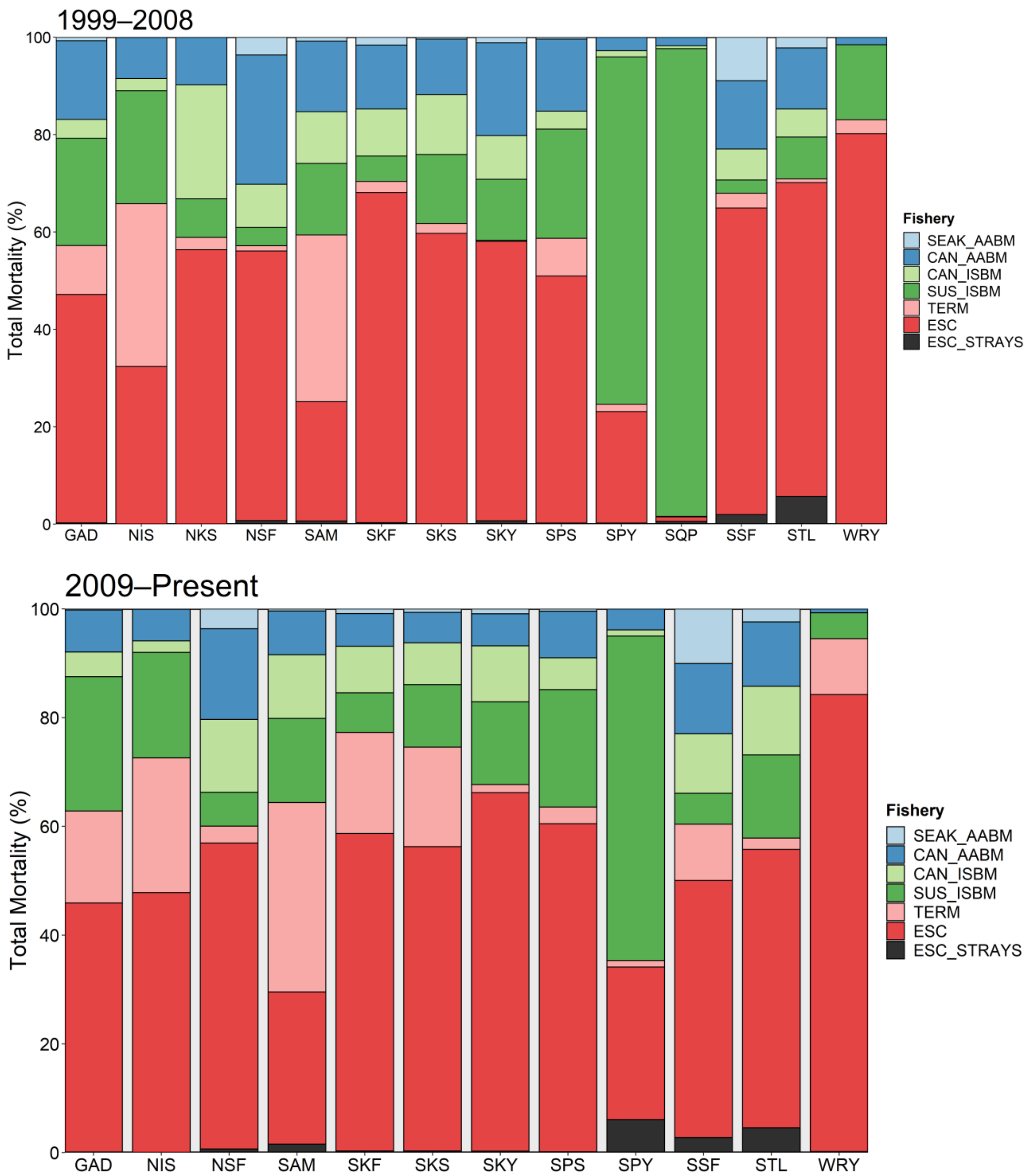


Figure 2.33 Distribution of total mortality for Washington Salish Sea indicator stocks for the 1999-2008 and 2009-2018 Agreement periods.

2.2.8.2 Central Puget Sound

Indicator stocks in Central Puget Sound, from north to south, include fingerling tag groups from the Stillaguamish River (STL) and the Skykomish River (SKY), a tributary in the Snohomish Basin. The Stillaguamish and Snohomish stocks are listed as part of the Puget Sound Natural Summer/Fall stock group in Attachment IV and V in the 2009 PST Agreement and Attachment I in the 2019 PST Agreement. The Stillaguamish Fall CWT program's primary purpose is for the evaluation of fishery impacts, and some natural supplementation. Brood stock for this program is captured on the spawning grounds. The Skykomish program's primary purpose, which uses returns of summer-run fish to the Wallace Salmon Hatchery for brood stock, is for fishery evaluation, providing some limited harvest in the inriver mark-selective sport fishery when abundance is favorable.

2.2.8.2.1 Brood Year Exploitation Rates

Between BY 1980 at BY 2009, ocean fishery BYERs declined dramatically for STL—from 91% for BY 1980 to 31% in 2009. Estimates of BYERs increased for the last three complete BYs with the most recent BYER for 2012 being 54% (Figure 2.34). The increase in BYERs for 2010-2012 could be attributable to low escapement and few CWT recoveries in recent years. The average BYER for STL across the time series was 48%. The rates for SKY have only been available starting with the 2000 BY and have ranged from a high of 43% (2001) to a low of 21% (2006) with a recent 3-year average of 38%, and an average of 35% across all years (Figure 2.34).

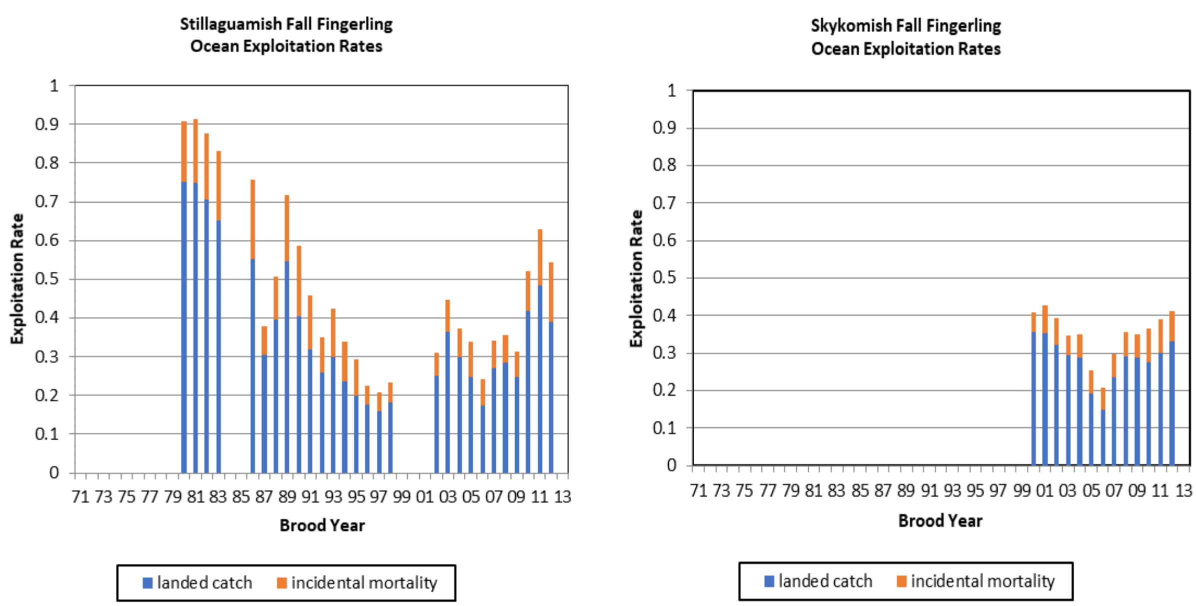


Figure 2.34 Brood year exploitation rate in terms of landed catch and incidental mortality for Stillaguamish Fall and Skykomish Summer Fingerling coded wire tag (CWT) indicator stocks.

2.2.8.2.2 Survival Rates

Survival rates to age 2 for STL ranged from a high of 7.0% in 1990 to a low of 0.3% in BY 1980 (Figure 2.35). Cohort survival to age 2 for SKY ranged from 0.4% in BY 2005 to 1.9% in BY 2004 (Figure 2.35).

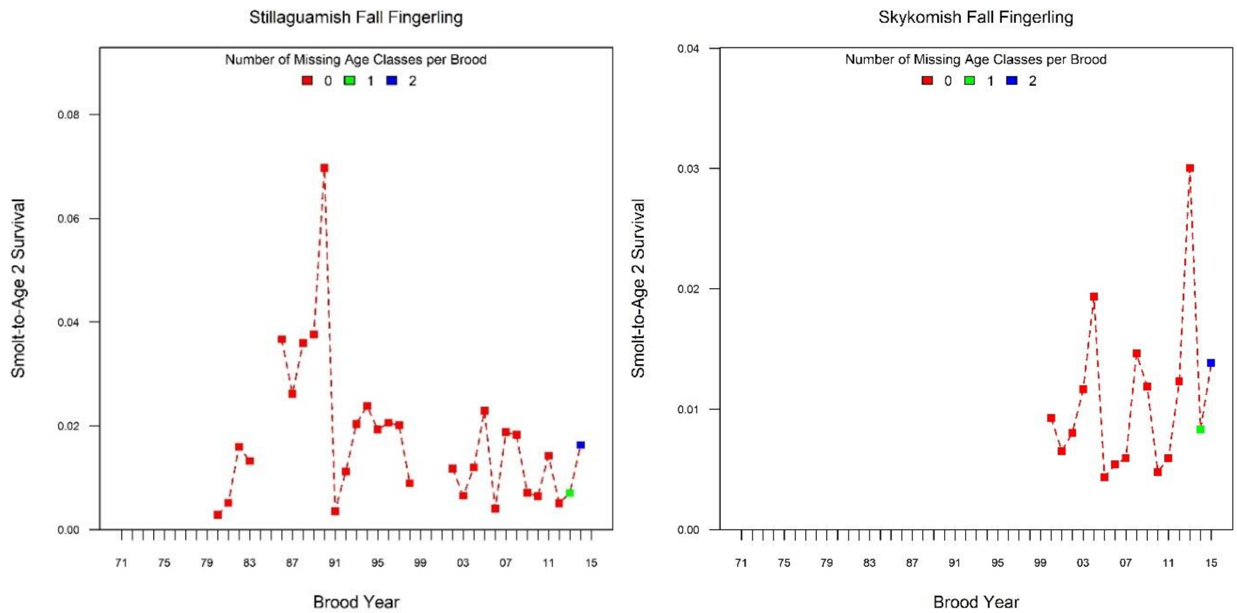


Figure 2.35 Survival rates for Stillaguamish Fall Fingerling and Skykomish Fall Fingerling stocks.

2.2.8.2.3 Mortality Distributions

Fishery mortality, as a percentage of total AEQ mortality, for the Central Puget Sound stocks during 1999–present averaged 35% for SKY (2004–present; Figure 2.33; Appendix C40), and 39% for STL (1999–2001 and 2006–present; Figure 2.33; Appendix C47). Similar to Northern Puget Sound stocks, the percentage of fishing mortality is very low in SEAK (1% and 2% for SKY and STL, respectively) and highest in Canadian fisheries, averaging 20% for SKY and 22% for STL. The average percent mortality in Puget Sound fisheries of 13% for SKY and 13% for STL is lower than that for the Northern Puget Sound group because of the limited terminal fisheries for these stocks. In recent years, the bulk of the fishery mortalities in Puget Sound have occurred in marine area mark-selective sport fisheries.

Since 1999, the two combined stocks experienced an increase in the percentage of mortality in fisheries south of the U.S. and Canada border. The increase in the southern U.S. fisheries since 2007 is primarily due to mark-selective sport fisheries and may not correctly represent impacts on natural stocks. The percentage of mortality in fisheries in SEAK and Canada has also increased for STL in recent years.

2.2.8.3 Southern Puget Sound

Indicator stocks in Southern Puget Sound include South Puget Sound Fall Fingerling (SPS), South Puget Sound Fall Yearling (SPY), Nisqually Fall Fingerling (NIS), and White River Spring Yearling (WRY). The SPS indicator group is an aggregate of several CWT indicator programs, which is now composed of tag releases from Soos Creek Hatchery in the Green River Basin and Grovers Creek Hatchery on the western shore of Puget Sound across from Seattle. Of the stocks included in the Puget Sound Natural Summer/Fall stock group in Attachments IV and V, the SPS indicator is the best representative of mixed stock fishery impacts that occur on the Green River and Lake Washington stocks. However, it should not be used to represent terminal fisheries due to the varying intensity with which they occur on stocks within the SPS aggregate and on those the aggregate is intended to represent. In addition, because stocks originating in South Puget Sound are exposed to a number of MSFs, exploitation rates measured from marked tag recoveries may overestimate the impacts on unmarked natural stocks. The NIS and SPY stocks are the southernmost indicator tag groups in Puget Sound. The SPY indicator represents hatchery production where the intent of the program is to release yearling Chinook salmon that have a higher tendency to remain within Puget Sound and benefit the Puget Sound sport fishery. This hatchery program has been reduced substantially since Chinook salmon were listed in 1999 as threatened status under the U.S. Endangered Species Act. The WRY indicator has not been adipose-clipped since the 2002 BY and all tag recoveries result from electronic tag detection sampling. The migration range of WRY is almost exclusively within the Salish Sea where all fisheries are sampled with electronic tag detectors.

2.2.8.3.1 Brood Year Exploitation Rates

The ocean fishery BYER for SPS has ranged between a high of 75% for the 1975 BY to a low of 23% for the 1996 BY, with a mean of 47% across all BYs (Figure 2.36). The average BYER for SPY was 68% and ranged from 16% (BY 2000) to 90% (BY 1978). For BY 2000, the 16% ER is estimated entirely as IMs as there were no CWT recoveries in ocean fisheries for this brood. The relatively high BYER for SPY reflects the intent of full harvest on this hatchery stock with achievement of egg-take goals as the only escapement objective. The BYERs in the 1980s for NIS ranged between about 50–70%. Since BY 2000, ocean BYERs averaged 28% for NIS and 10% for WRY (Figure 2.37). A total fishery BYER for SPS and NIS would include additional mortalities from freshwater fisheries, which can be significant for these indicators.

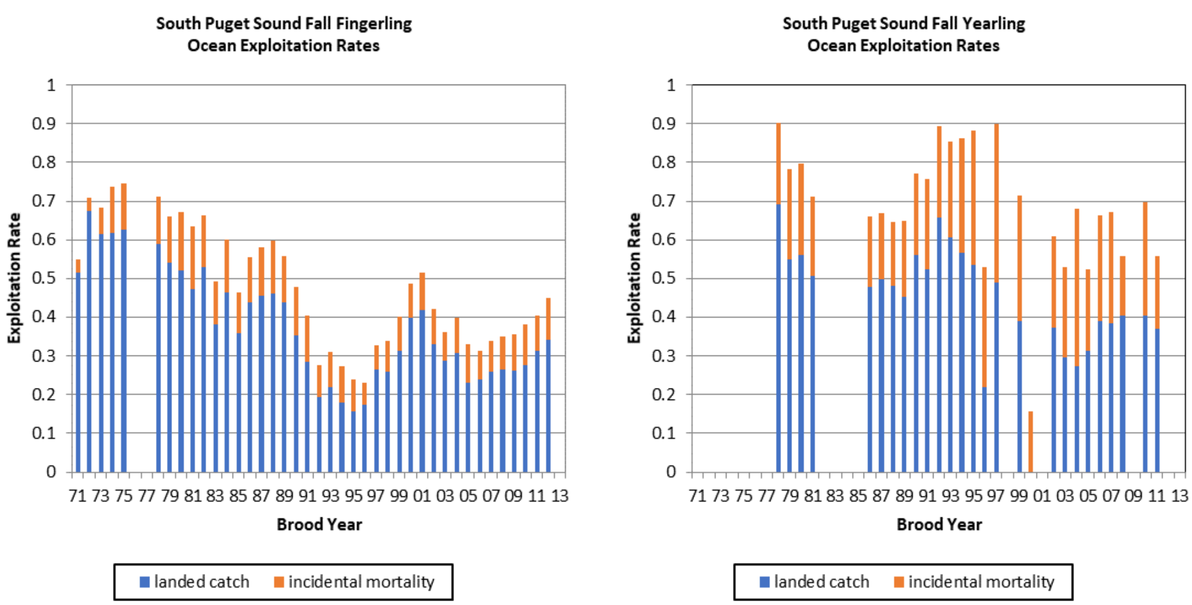


Figure 2.36 Brood year exploitation rate in terms of landed catch and incidental mortality for South Puget Sound Fall Fingerling and Yearling indicator stocks.

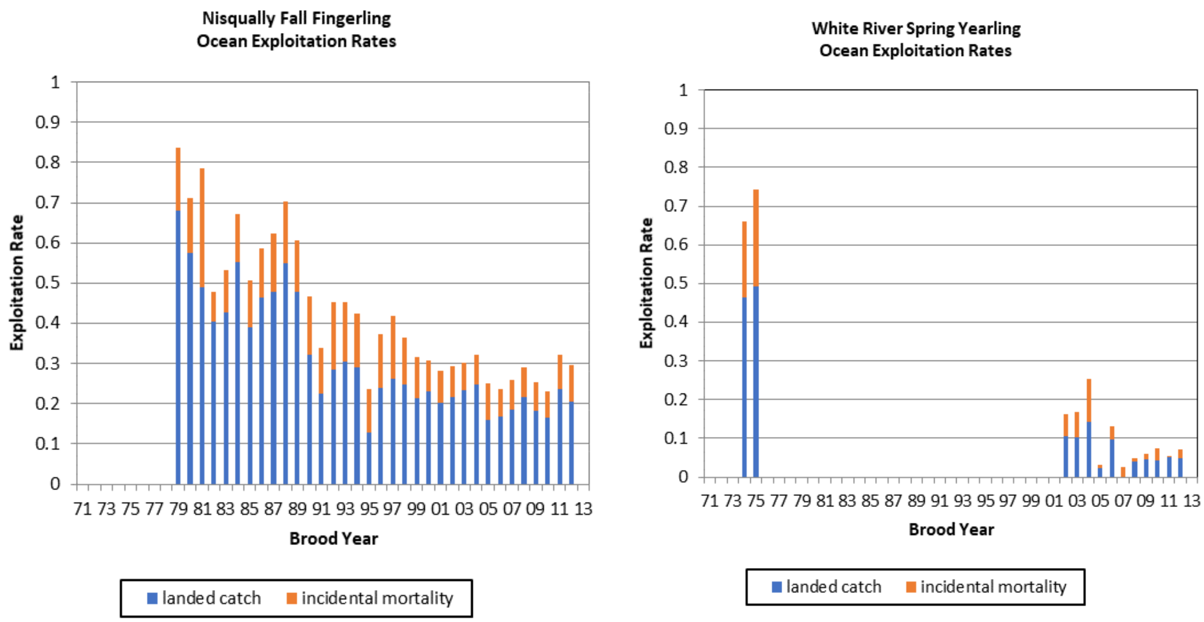


Figure 2.37 Brood year exploitation rate in terms of landed catch and incidental mortality for Nisqually Fall Fingerling and White River Spring Yearling coded wire tag (CWT) indicator stocks.

2.2.8.3.2 Survival Rates

Survival rates from release-to-age-2 for SPS ranged from a low of 0.4% for 1989 BY to a high of 9.5% for 1975 BY (Figure 2.38). With the exception of the 1987 BY where the survival rate was 14.4%, the rates for SPY have been low and often less than 1% (Figure 2.38). Survival for NIS ranged from a low of 0.1% for 1987 BY to a high of 4.3% for 2003 BY (Figure 2.39). Survival for WRY ranged from a low of 0.1% for 1975 BY to a high of 5.7% for the 2002 BY (Figure 2.39).

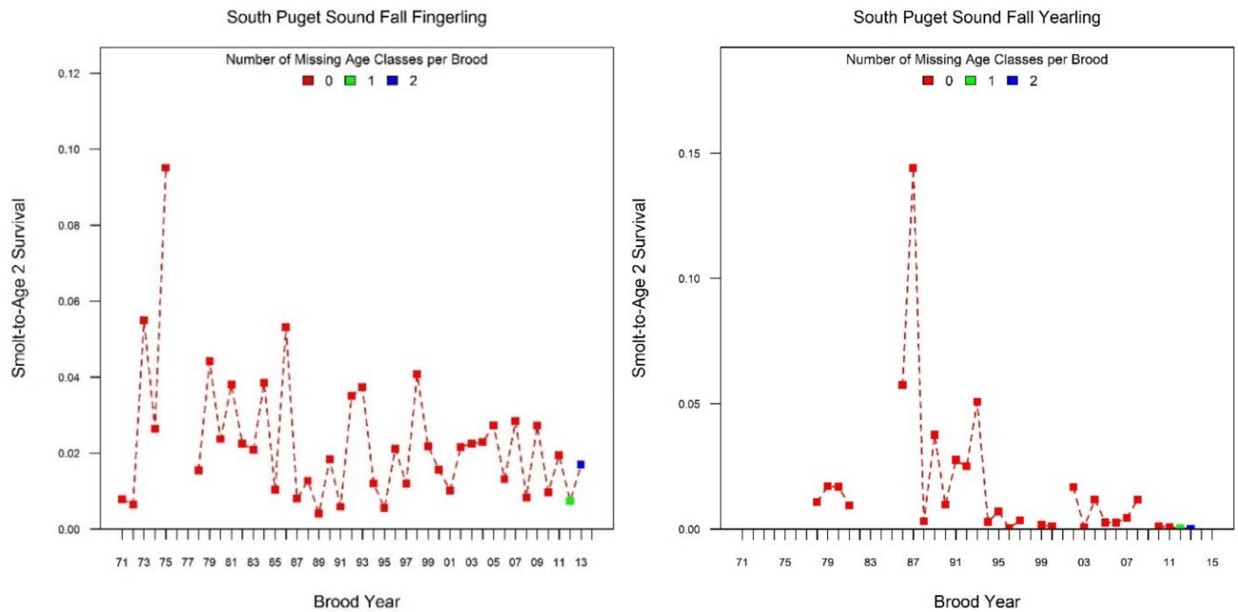


Figure 2.38 Survival rate for South Puget Sound Fall Fingerling and South Puget Sound Fall Yearling stocks.

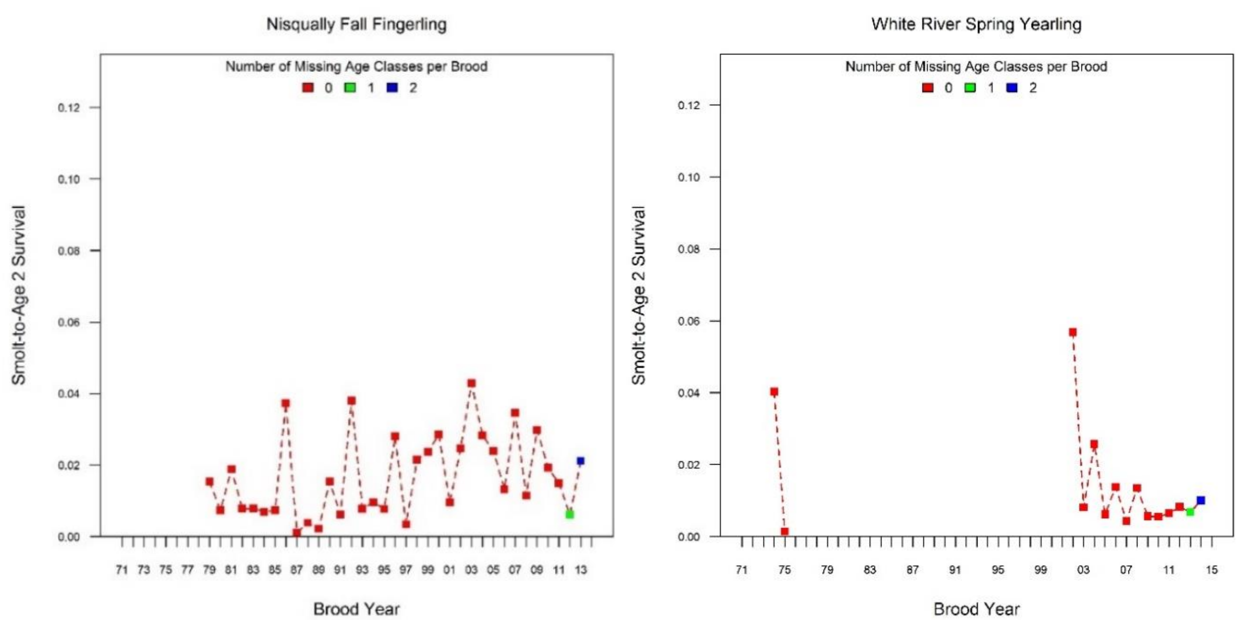


Figure 2.39 Survival rate for Nisqually Fall Fingerling and White River Spring Yearling stocks.

2.2.8.3.3 Mortality Distributions

Fishery mortality as a percentage of total AEQ mortality for the Southern Puget Sound stocks during 1999–present averaged 45% for SPS (Figure 2.33; Appendix C41), 73% for SPY (Figure 2.33; Appendix C42), 60% for NIS (Figure 2.33; Appendix C25) and 18% for WRY (Figure 2.33; Appendix C55). The fishery mortality distribution for SPS and NIS north of the U.S. and Canada border is similar to the other Puget Sound Fall Fingerling stocks, with a very low percentage (<0.5%) in SEAK and much higher rates (approximately 13%), in Canadian fisheries (primarily

WCVI). The fall fingerling stocks (SPS and NIS) have a higher mortality in Puget Sound fisheries than the Northern and Central Puget Sound indicators. The higher rates are the result of exposure to mark-selective sport fisheries throughout Puget Sound and to significant terminal net fisheries in most years that can target large-scale hatchery production. Fishing mortality for WRY is predominantly within Puget Sound. Since 1999, the distribution of fishing mortality for SPS and NIS has remained stable.

2.2.8.4 Juan De Fuca and Hood Canal

Tagging of Elwha River (ELW) Fall Fingerling stock in Juan de Fuca was discontinued with the 1994 BY. A hatchery program continues using brood stock collected from the spawning grounds and to the hatchery rack. The Elwha Hatchery program has now shifted to a stock restoration and recovery program with the removal of the Elwha River dams that began in September 2011. Marking and tagging of this stock resumed with the 2012 BY as part of monitoring and evaluation of the restoration project. The George Adams (GAD) stock indicator is used to represent fishery and escapement distribution of natural fall fingerlings in Hood Canal tributaries, primarily the Skokomish River at the southern end of the Hood Canal.

2.2.8.4.1 Brood Year Exploitation Rates

For the BYs available for ELW, the ocean fishery BYER ranged from a high of 78% for BY 1982 to a low of 34% for the 2012 BY (Figure 2.40). The ocean fishery BYER for GAD ranged from a high of 83% in 1989 to a low of 22% in 1994 (Figure 2.40). A total fishery BYER for GAD would include additional mortality associated with the significant freshwater fisheries that occur in most years.

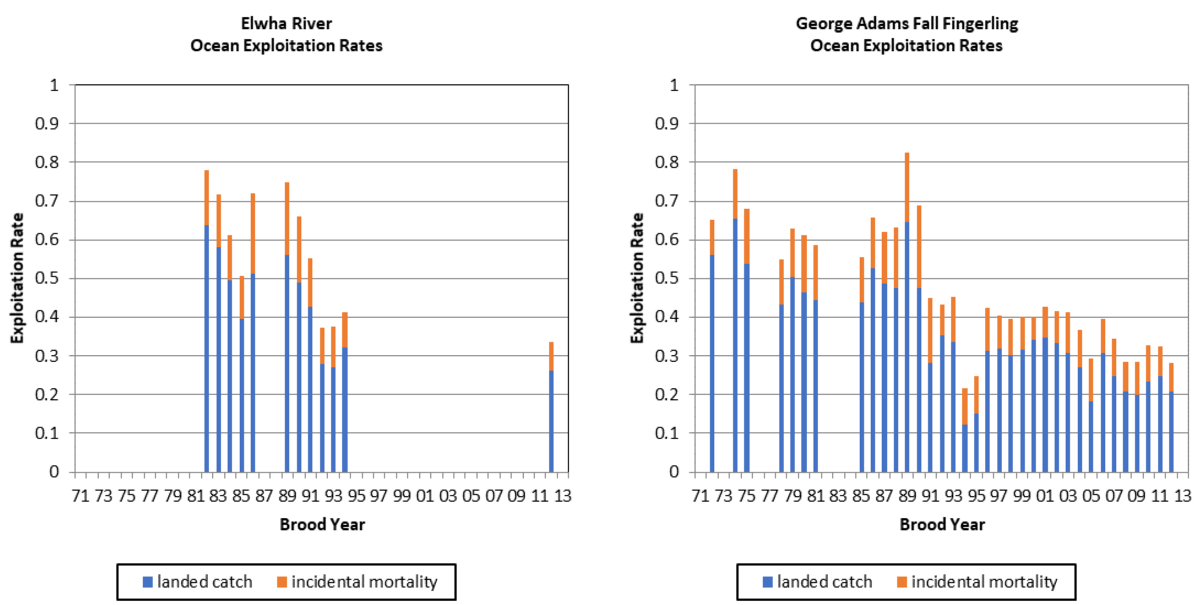


Figure 2.40 Brood year exploitation rate in terms of landed catch and incidental mortality for Elwha and George Adams (Skokomish River) Fall Fingerling coded wire tag (CWT) indicator stocks.

2.2.8.4.2 Survival Rates

Survival rates of ELW were initially approximately 2% in the first three years of tagging (1982–1984), then decreased in 1985 to less than 1% and remained there until the program was discontinued (Figure 2.41). Since the reinstatement of the Elwha program survival rates have been similar to the later years of the initial program, with the exception of the most recent year where survival appears to have been quite high (9% in 2014). Survival rates for GAD averaged 1.4% during 1985–2012 and ranged from a low of 0.04% for BY 1990 to a high of 5.9% for BY 1978 (Figure 2.41).

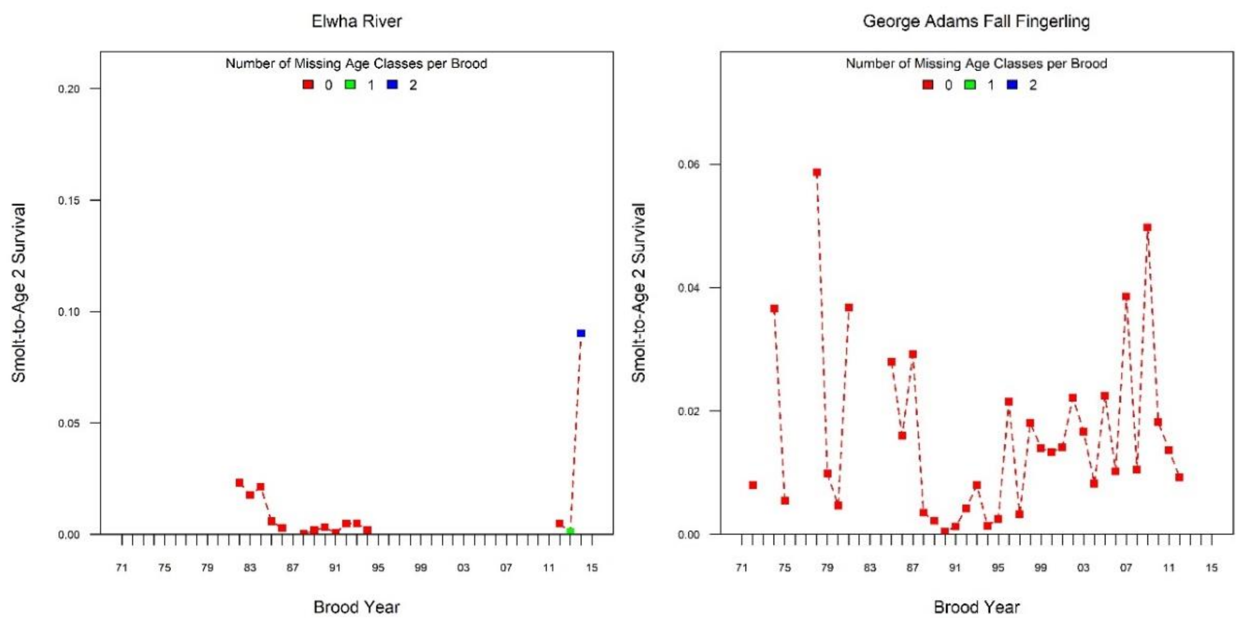


Figure 2.41 Survival rate for Elwha River and George Adams (Skokomish River) Fall Fingerling stocks.

2.2.8.4.3 Mortality Distributions

For GAD during 1999–present, fisheries in Alaska made up less than 1% of the fishery and escapement mortality distribution, Canada 16%, Washington and Oregon coast 5% and Puget Sound 31% (Figure 2.33; Appendix C12). Escapement of GAD during 1999–present averaged 47%.

Distribution of fishing mortality for GAD during 1999–present between Alaska, Canada and the southern U.S. was shifted slightly south by a reduction in impacts in fisheries north of the U.S. and Canada border, but proportion of escapement of GAD has remained relatively unchanged.

In recent years, fishing morality on ELW has been about 5% in Alaska, 10% in Canada, and less than 5% in the Southern United States (SUS) (Appendix C11; Figure 2.25).

2.2.8.5 Regional Summary for Washington Salish Sea Stocks

For Washington Salish Sea stocks, BYER is measured in terms of ocean mortality only because terminal fisheries may not properly reflect the impacts on the natural stock represented by the CWT indicator. Some terminal fisheries are designed as hatchery fish target zones which would exceed the impacts on any natural stocks in the basin. Additionally, some river sport fisheries are now managed under MSF regulations that likely overestimate impacts on natural stocks. The ocean fishery BYERs contain estimates of exploitation in the Puget Sound marine area mark-selective sport fisheries which have grown significantly since 2003. Consequently, these BYERs for Puget Sound stocks, especially those from Central and Southern Puget Sound, will tend to overestimate the exploitation relative to that of the natural stocks they are intended to represent. Therefore, because of the exclusion of terminal fisheries and the inclusion of Puget Sound marine area MSFs, the ocean fishery BYERs for Washington Salish Sea stocks will not reflect total fishery impacts on natural stocks.

The BYERs for Washington Salish Sea Stocks averaged 44% (per stock average range of 32–57%) for the fall fingerling stocks (SAM, SSF, STL, SKY, SPS, NIS, ELW, and GAD) and 36% (range 20–51%) for the spring fingerling and yearling stocks (NSF, NKS, SKF, SKS, and WRY; Table 2.9). Comparing the mean BYER to the rate in the last complete BY, the BYER was higher in the last complete BY for only two of the fall fingerling stocks (SSF, STL).

Survival rates to age 2 for Washington Salish Sea stocks averaged between 0.7–2.6% , which is similar to the rates commonly observed for fall-run fingerling type stocks (Table 2.9). Survival rates to age 3 for spring-run yearling stocks were 1.1-2.7%, and were at the lower end of rates usually observed for yearling type releases that should accrue some survival benefit from an extra year of rearing in the hatchery. The trend in survival rates for those stocks with a long continuous time series of analysis (e.g., SAM, SPS, GAD) shows the lowest survival rates occurring for the late 1980s to early 1990s broods, with somewhat improved survivals beginning in the early 2000s.

CY escapement for fall fingerling stocks varies between the stocks with significant terminal fisheries that have 2009–present average escapements of 28–60% (SAM, SPS, NIS, and GAD) and stocks that do not have significant terminal fisheries where escapement is 47-69% (SSF, STL, and SKY; Table 2.9). The mean escapement for spring stocks has ranged from 56-84%.

Table 2.9 Summary of statistics generated by the 2019 CWT cohort analysis for Washington Salish Sea indicator stocks by region. Statistics include total ocean fishery mortality (adult equivalent catch plus incidental mortality) brood year exploitation rate (BYER), cohort survival rate to age 2, and calendar year (CY) percent distribution in the escapement.

Subregion	Stock Abbrev	Indicator Stock Name	BYER (total mortality) Mean (range)	BYER (total mortality) Last complete BY	Survival rate Mean (range)	Survival rate Last complete BY	CY % Escapement[1] 1999–2008 Mean (range)	CY % Escapement[1] 2009–current Mean (range)	CY % Escapement[1] 2009–current Last CY (if ≠ current)
North Puget Sound	NSF	Nooksack Spring Fingerling[2]	40% (24-61%)	25% (2012)	1.39% (0.27-4.60%)	2.68% (2012)	55% (38-82%)	56% (37-76%)	58% (2017)
	NKS	Nooksack Spring Yearling[2]	51% (34-76%)	45% (1996)	1.07% (0.10-3.60%)	0.61% (1996)	54% (NA; n = 1)	NA[3]	NA
	SAM	Samish Fall Fingerling[2]	43% (27-68%)	35% (2012)	2.59% (0.31-14.47%)	0.56% (2012)	24% (14-32%)	28% (18-39%)	19% (2017)
	SKF	Skagit Spring Fingerling[2]	29% (13-49%)	23% (2012)	1.53% (0.67-4.11%)	1.12% (2012)	68% (58-78%)	58% (46-70%)	57% (2017)
	SKS	Skagit Spring Yearling[2]	42% (18-78%)	29% (2010)	2.69% (0.58-7.5%)	2.66% (2010)	60% (48-68%)	58% (54-65%)	57% (2013)
	SSF	Skagit Summer Fingerling[2]	32% (21-54%)	54% (2012)	1.17% (0.22-3.35%)	0.86% (2012)	63% (55-76%)	47% (29-72%)	29% (2017)
Central Puget Sound	STL	Stillaguamish Fall Fingerling[2]	48% (21-91%)	54% (2012)	1.78% (0.28-6.97%)	0.51% (2012)	64% (42-82%)	51% (29-68%)	47% (2017)
	SKY	Skykomish Fall Fingerling[2]	35% (21%-43%)	41% (2012)	0.92% (0.44-1.94%)	1.23% (2012)	62% (57-72%)	66% (56-77%)	71% (2017)
South Puget Sound	SPS	South Puget Sound Fall Fingerling[2]	47% (23%-75%)	45% (2012)	2.31% (0.41-9.51%)	0.74% (2012)	51% (34-71%)	60% (48-70%)	67% (2017)
	SPY	South Puget Sound Fall Yearling[2]	67% (16%-90%)	56% (2011)	1.77% (0.04-14.41%)	0.08% (2011)	29% (19-53%)	18% (1-52%)	4% (2012)
	NIS	Nisqually Fall Fingerling[2]	43% (23%-84%)	30% (2012)	1.66% (0.11-4.29%)	0.60% (2012)	32% (11-59%)	48% (38-72%)	42% (2017)
	WRY	White Spring Yearling[2]	19% (3%-74%)	7% (2012)	1.51% (0.14-5.68%)	0.82% (2012)	78% (73-85%)	84% (68-95%)	95% (2017)
Juan de Fuca/Hood Canal	ELW	Elwha[2]	57% (34%-78%)	34% (2012)	0.72% (0.02–2.32%)	0.48% (2012)	ND[4]	79% (73-84%)	84% (2017)
	GAD	George Adams Fall Fingerling[2]	47% (22%-83%)	28% (2012)	1.60% (0.04-5.87%)	0.92% (2012)	47% (39-64%)	46% (24-55%)	53% (2017)

[1] % Escapement is not a measure of performance for the escapement indicator stock(s) associated with a given CWT indicator stock. See CTC (2013) for these details.

[2] BYER is ocean exploitation rate only.

[3] NA = Not available.

[4] ND = No data available.

2.2.9 Columbia River Stocks

The Columbia River stocks are split into those from the Lower Columbia, the Upper Columbia, the Snake River tributary, and the Willamette River tributary. There are three tule fall Chinook CWT indicator stocks from Lower Columbia River hatcheries, and one wild stock tagging program on the only bright Chinook stock below Bonneville Dam: Lower River Hatchery (LRH, now released from Big Creek/Bonneville Hatchery), Cowlitz Hatchery (CWF), Spring Creek Hatchery (SPR), and Lewis River Wild (LRW). There are two bright fall and one summer Chinook CWT indicator stocks for the Upper Columbia River: Columbia Upriver Brights (URB, from Priest Rapids Hatchery), Hanford Wild (HAN, from Hanford Reach), and Mid-Columbia Summers (SUM, from Wells Hatchery, including subyearling and yearling releases). Lyons Ferry Hatchery is currently the only CWT indicator stock for the Snake River tributary. Lyons Ferry Hatchery releases both subyearlings (LYF) and yearlings (LYY), but only the subyearlings are representative of the natural production. The Willamette River spring Chinook CWT indicator (WSH) is a conglomeration of yearling releases from several Willamette basin hatcheries.

2.2.9.1 Brood Year Exploitation Rates

The three hatchery stocks in the lower Columbia River (CWF, LRH, and SPR) showed a decline in BYERs from high levels during the late 1970s (over 65%) to lower levels during the early to mid–1990s (Figure 2.42). Since 2000, BYERs have returned to higher levels for LRH and SPR (averaging 58% and 72%).The BYERs for CWF showed greater variability and averaged 25%. Incidental mortality rates for CWF (5%), LRH (7%) and SPR (5%) have averaged 4-7%.

The LRW and SUM stock BYERs reached highs in the early 1980s (70%, 81%), lows in the 1990s (17–18%), and then have recently returned to higher rates; 50-70% for SUM (averaging 63%) and 30-65% for LRW (averaging 44%). Incidental mortality for both averaged 6% since 2000. URB BYERs also reached a high in the 1980s (80%), hit a low in 1978 (24%), and since 2000 have ranged from 46-67% (averaging 56%). Coded wire tagging of the wild component of upriver brights in the Hanford Reach (HAN) and of LYF both began in 1984. BYERs for HAN were between 41-68% through 2000, and 51-78% since, averaging 64% over the time series and averaging 65% since 2000, 8 percentage points higher than for URB. BYERs for LYF averaged 23% for the 1998 through 2007 broods. The next three broods averaged 54%, similar to URB. The 2011 brood year exploitation rate appears to have increased to 72%, but this recent increase is likely due to passing tagged hatchery fish over Lower Granite Dam, where they cannot be recovered in escapement, thus inflating BYERs. This practice has increased with run size, due to hatchery brood stock needs being met and more frequent crowding at the fish trap. In following years, escapement recoveries will be adjusted to account for this practice. IM rates for HAN, LYF, and URB have averaged 3-7% since 2000.

BYERs for WSH appear much lower than for summer and fall run stocks (Figure 2.43), but due to fairly high exploitation in mark-selective terminal fisheries, only ocean exploitation is presented. Ocean BYERs ranged from 10% to 29% prior to 1990 (averaging 17%), and have remained under 13% (averaging 7%) since. IM rates for WSH in the ocean have averaged 1.6% since 1990.

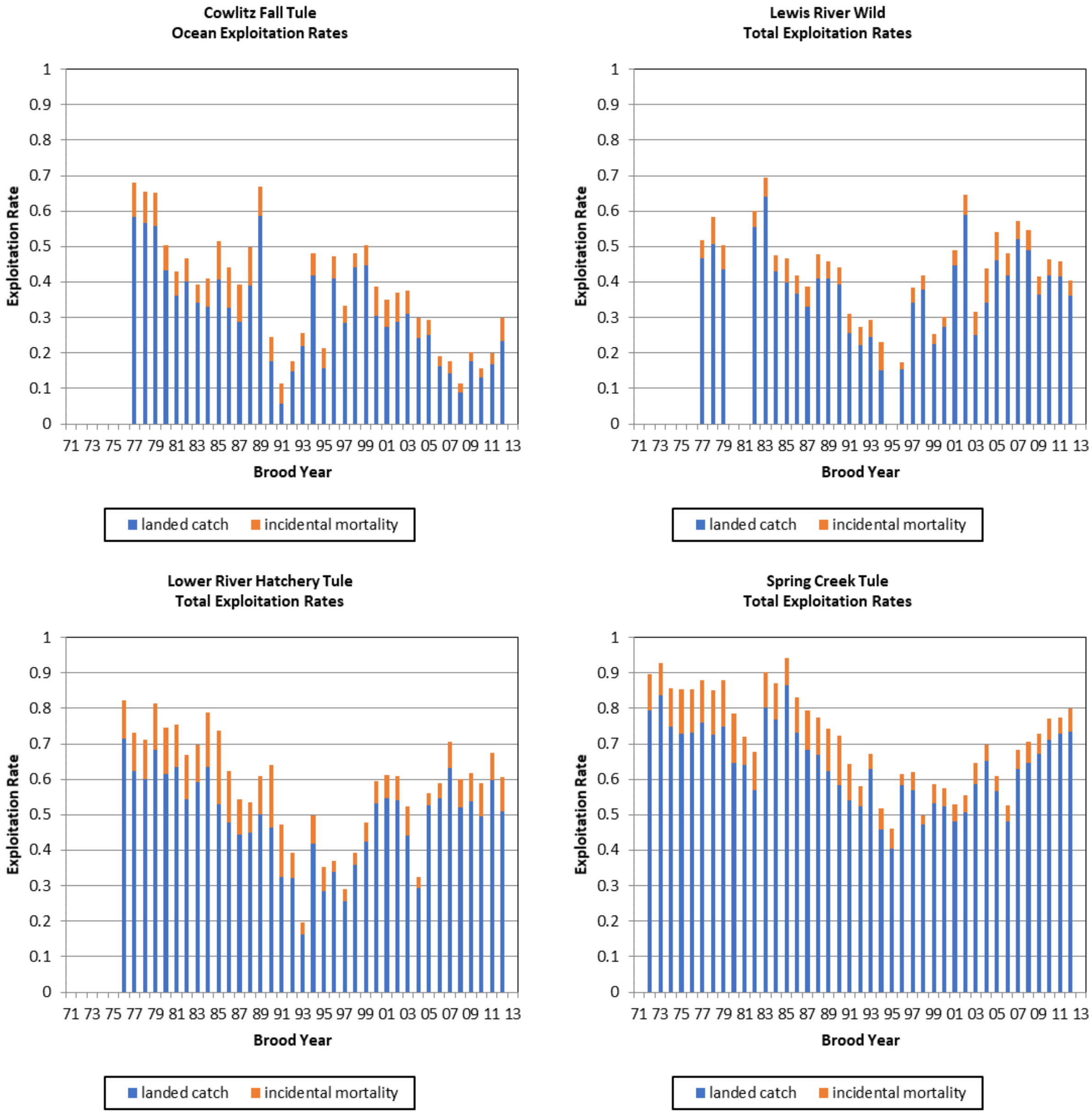
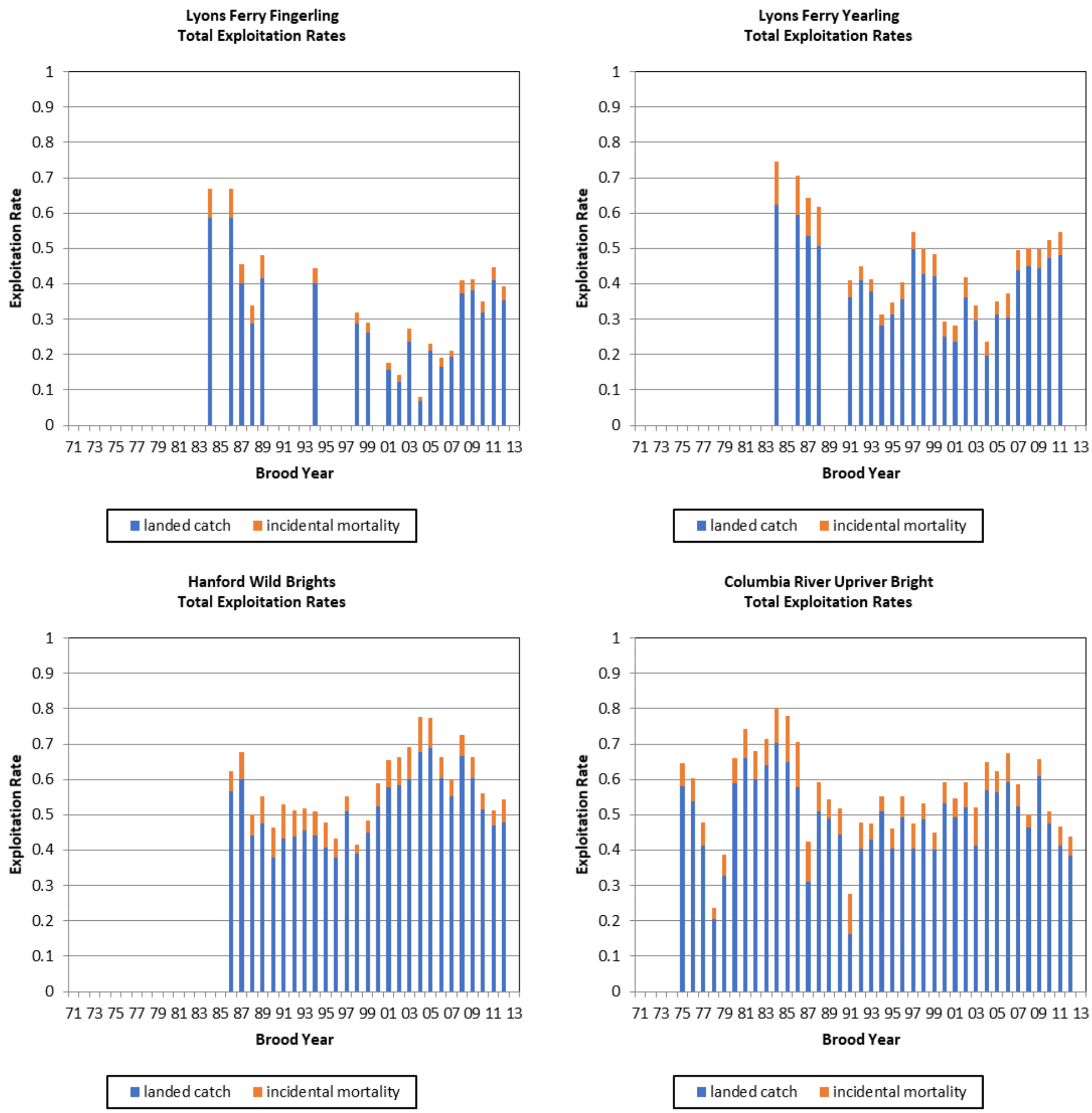


Figure 2.42 Brood year exploitation rate for summer and fall Columbia River stocks. Catch and incidental mortality are shown. Only completed brood years are included.



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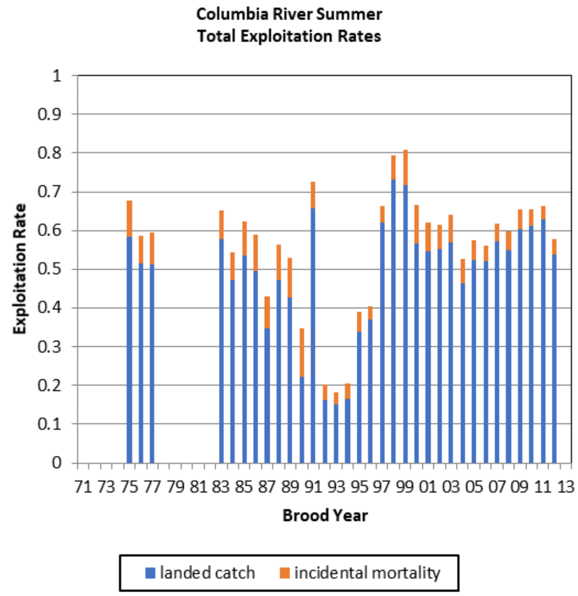

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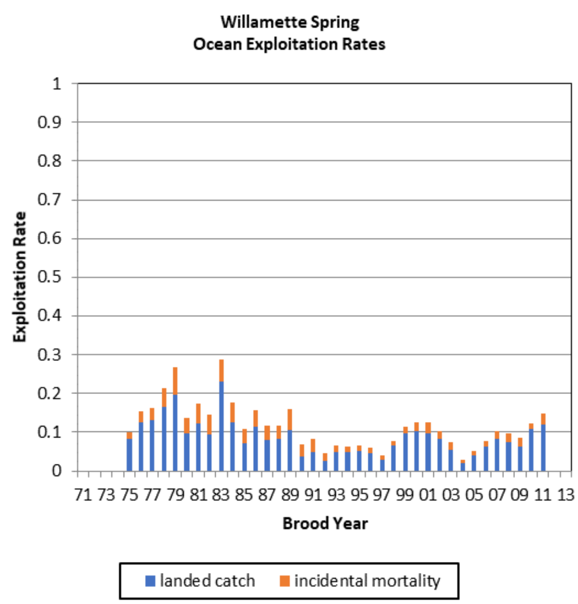


Figure 2.43 Brood year exploitation rate for Willamette Spring Chinook. Catch and incidental mortality are shown. Only completed brood years are included.

Table 2.10 Summary of statistics generated by the 2019 CWT cohort analysis for Columbia River indicator stocks. Statistics include total mortality (catch plus incidental mortality) brood year exploitation rate (BYER), cohort survival rate to age 2, and calendar year (CY) percent distribution of the total mortality in the escapement for 1999 (1999–2008) and 2009 (2009–2018) Treaty Agreement periods.

		BYER (total mortality)		Survival rate		CY % Escapement[1]		
						1999–2008	2009–current	
Stock Abbrev	Indicator Stock Name	Mean (range)	Last complete BY	Mean (range)	Last complete BY	Mean (range)	Mean (range)	Last CY (if ≠ current)
CWF	Cowlitz Fall Tule[2]	37% (11%-68%)	30% (2012)	0.7% (0.06-3.54%)	0.59% (2012)	51% (26-68%)	67% (47-90%)	58% (2017)
HAN	Hanford Wild Brights	58% (41%-78%)	54% (2012)	1.5% (0.19-5.82%)	3.74% (2012)	44% (28-56%)	36% (11-47%)	38% (2017)
LRH	Lower River Hatchery Tule	58% (20%-82%)	61% (2012)	1.12% (0.02-9.59%)	1.3% (2012)	53% (38-70%)	36% (28-44%)	28% (2017)
LRW	Lewis River Wild	44% (17%-70%)	40% (2012)	2.05% (0.23-6.9%)	1.0% (2012)	57% (37-81%)	53% (31-73%)	73% (2017)
LYF	Lyons Ferry Fingerling	35% (8%-67%)	39% (2012)	2.33% (0.08-8.%)	3.75% (2012)	75% (53-92%)	62% (40-88%)	40% (2017)
SPR	Spring Creek Tule	72% (46%-94%)	80% (2012)	2.0% (0.12-8.26%)	4.34% (2012)	40% (30-54%)	27% (21-46%)	23% (2017)
LYY	Lyons Ferry Yearling	46% (24%-75%)	55% (2011)	4.58% (0.96-14.79%)	5.9% (2011)	60% (40-76%)	48% (32-71%)	32% (2017)
SUM	Columbia Summer	56% (18%-81%)	58% (2012)	1.69% (0.01-5.57%)	3.7% (2012)	38% (20-61%)	40% (33-48%)	48% (2017)
URB	Columbia River Upriver Bright	56% (24%-80%)	44% (2012)	2.22% (0.08-7.97%)	4.21% (2012)	48% (40-62%)	49% (33-60%)	52% (2017)
WSH	Willamette Spring Hatchery[2]	11% (2%-29%)	10% (2010)	2.9% (0.73-7.15%)	2.93% (2011)	65% (54-75%)	57% (43-72%)	72% (2017)

[1] % Escapement is not a measure of performance for the escapement indicator stock(s) associated with a given CWT indicator stock. See CTC (2013) for these details.

[2] BYER is ocean exploitation rate only.

2.2.9.2 Survival Rates

Columbia River stocks typically have survival rates from 0–3%, with the most successful broods surviving at 6–8% (Figure 2.44). Average survival rates since BY 2000 have been 0.6-1.6% for all the Lower Columbia River stocks (CWF, LRH, LRW, SPR) and HAN, listed from low to high, 2.1-2.2% for LYF, URB, WSH, and SUM, and 5.3% for LYY.

Lower Columbia River stocks, specifically both CWF and LRH have suffered from persistently low survival throughout the time series available for CWT survival analysis (1977-1978 through 2018). In the Lower Columbia River, CWF has had an average survival rate of 0.5% since 1984, with rates of less than 1% for all but 3 broods at 1-2%. Survival rates for CWF and LRH have averaged only 0.6 and 0.7% since 2000. LRH has had brood year survival rates under 2% since 1984, except for 1999 and 2000 (3%). Survival rates for SPR were 0-1% for 17 of 18 broods before 1998, but nine of the 14 broods since have had improved survivals including six broods (1998-2001, 2007 and 2011) with rates of 3-4%. Survival rates for LRW have declined from an average of 2.8% for the 1982-1992 broods. Since then, 15 of 17 broods have had survivals of 0-2%, averaging 1.5%.

Survival rates for WSH have been somewhat cyclical, with 13 of 15 broods from 1975-1989 above 3% (averaging 4%), 1-2% for the next seven, 3-7% (averaging 4%) for the next four, and back down to 1-2 % for eight of 10 of the 2000-2010 broods (Figure 2.45).

In the Upper Columbia River, SUM had survival rates less than 1.3% until 1997, except for 1985 (2.2%), averaging only 0.7%. Since then, survival rates have improved to 1.0-5.4%, averaging 2.6%. The 5.4% survival for 2011 is the highest value for SUM, while it was the 2010 brood that excelled for URB (7.9%), HAN (5.8%) and LYY (5.9%). From 1975-1985, URB survival rates were 2–7% for 1975-1985 broods (averaging 4%), below 3% from 1986–2008 (averaging 1%), and then returning to higher survival rates of 3-8% (averaging 5%) for 2009-2011 broods. HAN survival rates were 0-2% for 20 of 21 broods from 1986-2006, (averaging 1%), and then three of the last five broods were 3%-6% (averaging 3%). LYF has data gaps through the 2000 brood, and highly variable survival rates since, with 11 broods under 2% and seven broods at 2-6% (averaging 2.2%). Since 1995, LYY, which are yearlings, have had 4-5% survival rates for 12 of 16 broods (averaging 5%).

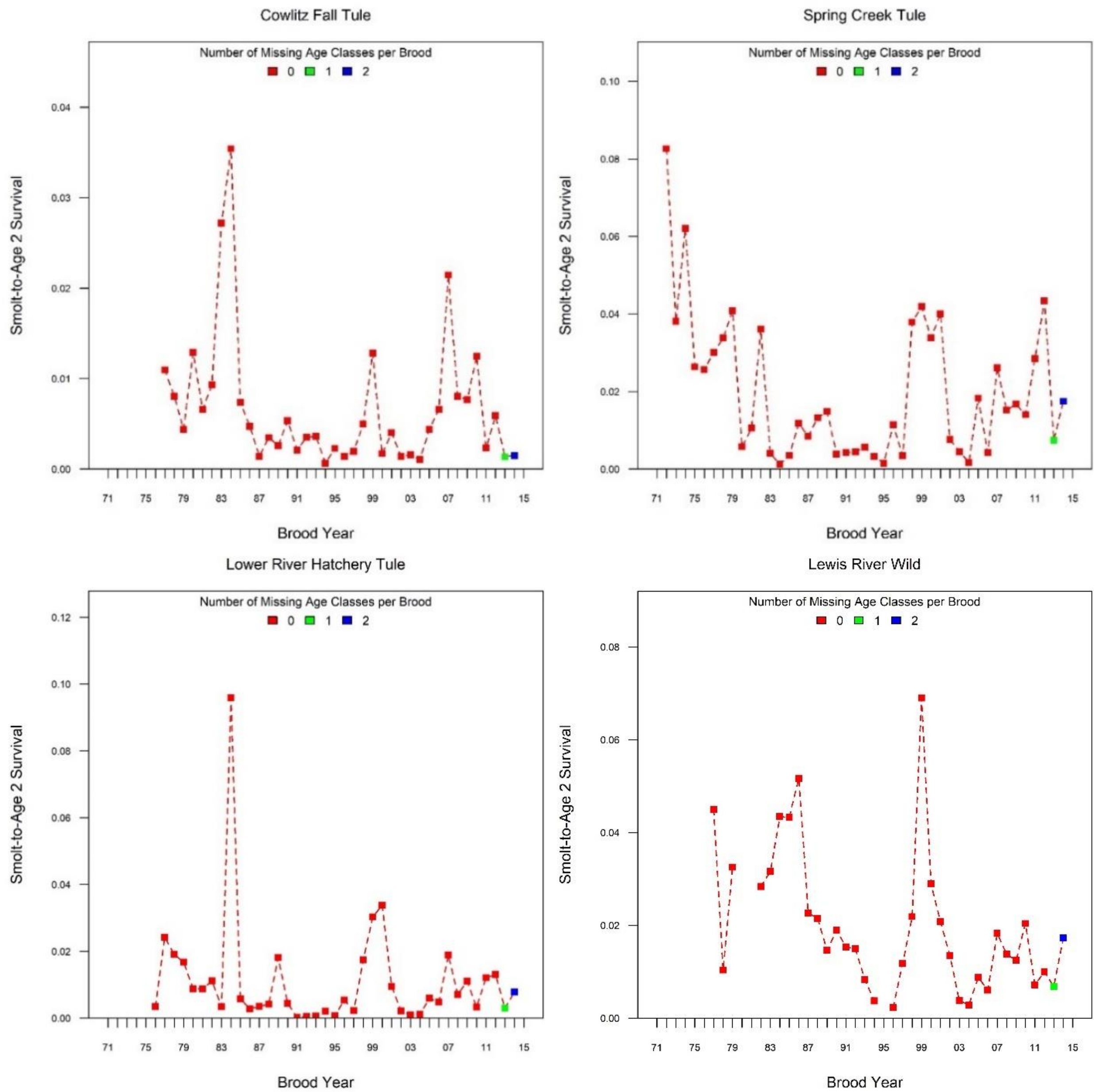
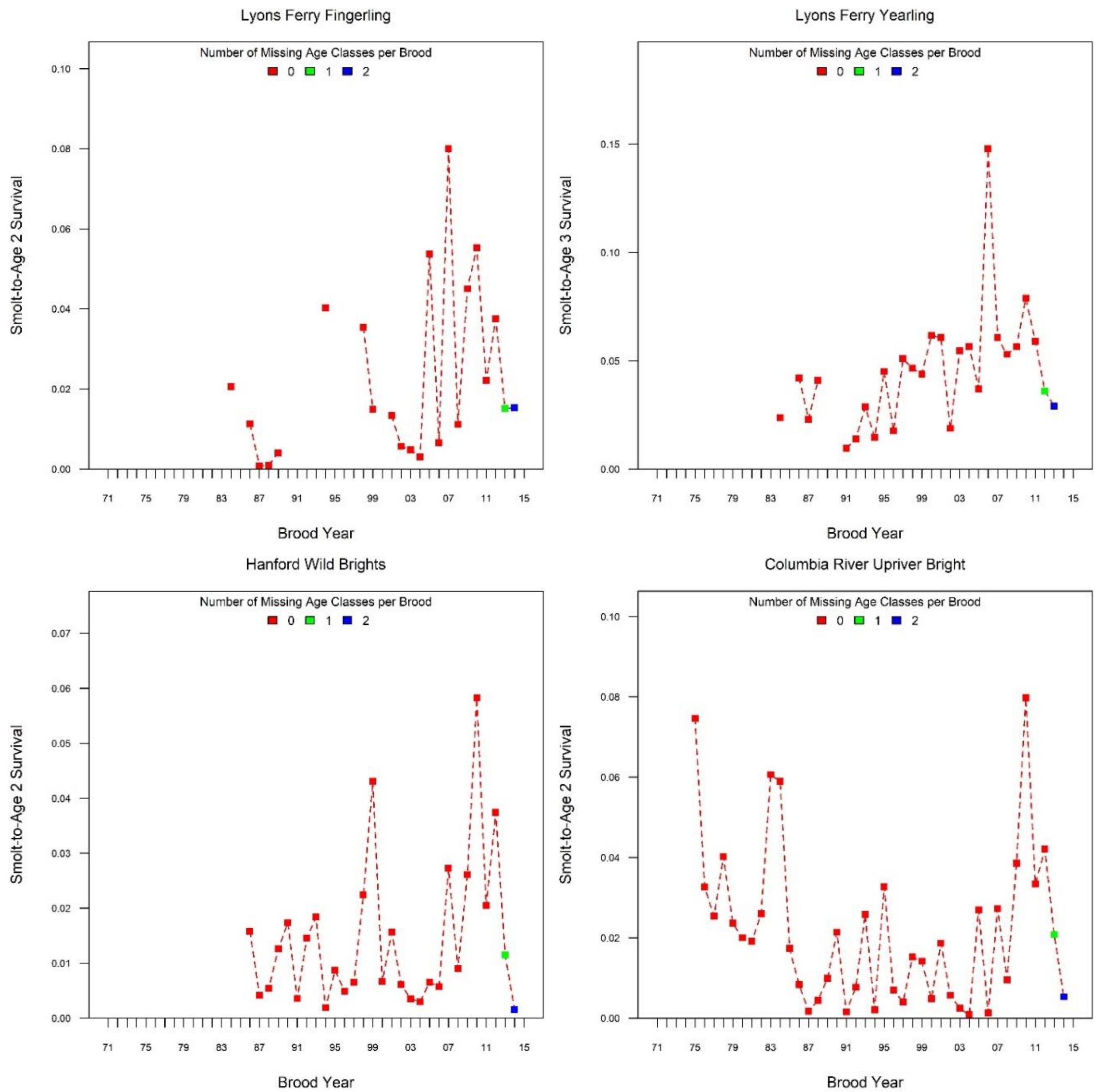


Figure 2.44 Survival rate for summer and fall Columbia River Chinook stocks.



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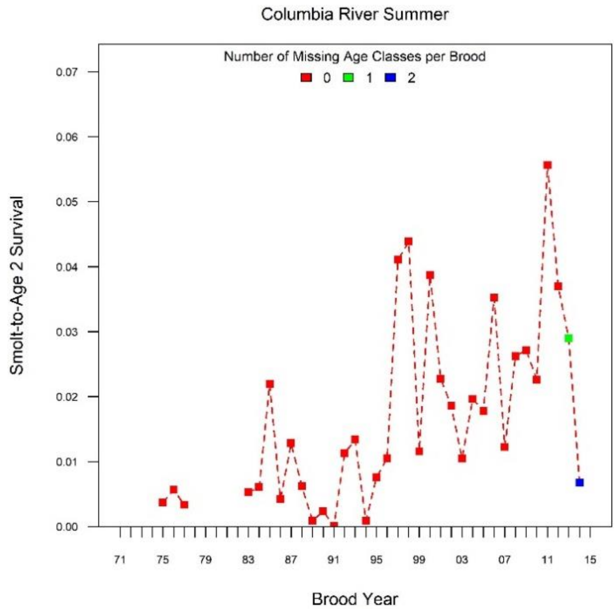

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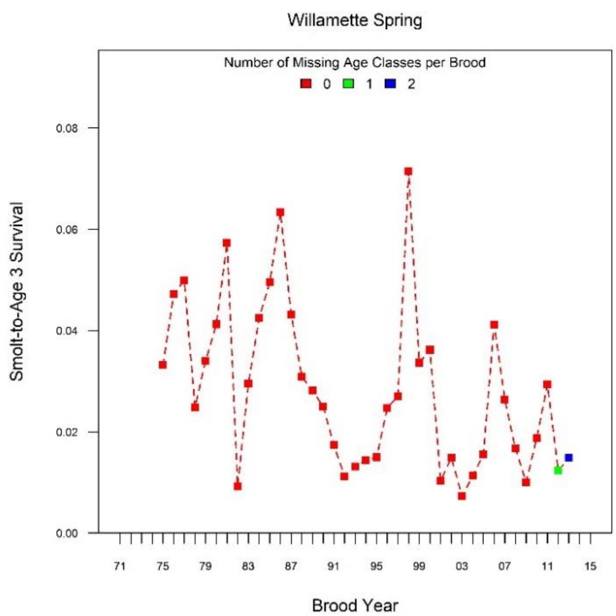


Figure 2.45 Survival rate for the Willamette River Spring Chinook indicator stock.

2.2.9.3 Mortality Distributions

The distribution of mortality for each stock can be found in Appendix C. For Columbia River stocks, sport data take two years to complete, so the most recent numbers are for 2017. For most stocks, about 20–30% of mortality attributable to fisheries occurs in AABM fisheries; primarily in SEAK for WSH, LRW, URB, HAN, and SUM, and in WCVI for SPR and LRH tules. It is lower for CWF (14%), which is widely distributed, and SPR (8%) which was only in fisheries from WCVI south. WSH mortality in SEAK during 2016 was much higher than average (5%) at 18%.

Impacts in SUS fisheries were low (14%) for LRW, about 30–60% for other Lower Columbia River and Snake River stocks, and 2030% for Upper Columbia River stocks.

Figure 2.46 demonstrates changes in the proportion of CY total mortality in fisheries and escapement. The proportion of escapement for most Lower Columbia River stocks declined except CWF, where escapement proportion increased due to reductions in SUS and Canadian (CDN) AABM fisheries. The other Lower Columbia tule stocks, LRH and SPR, both showed reductions in escapement and CDN AABM, and increases in SUS fisheries. For LRW, there were smaller reductions in escapement and SEAK, and increases in CDN AABM and terminal fisheries. Above Bonneville, URB proportions changed little, while for HAN, terminal impacts increased (6 points) and escapement dropped (8 points). SUM impacts declined in SEAK and CDN AABM fisheries, while terminal impacts increased. LYF and LYY showed similar increases in terminal areas and SUS fisheries, but showed declines in escapement. In the Willamette Basin, terminal impacts increased, while escapement declined.

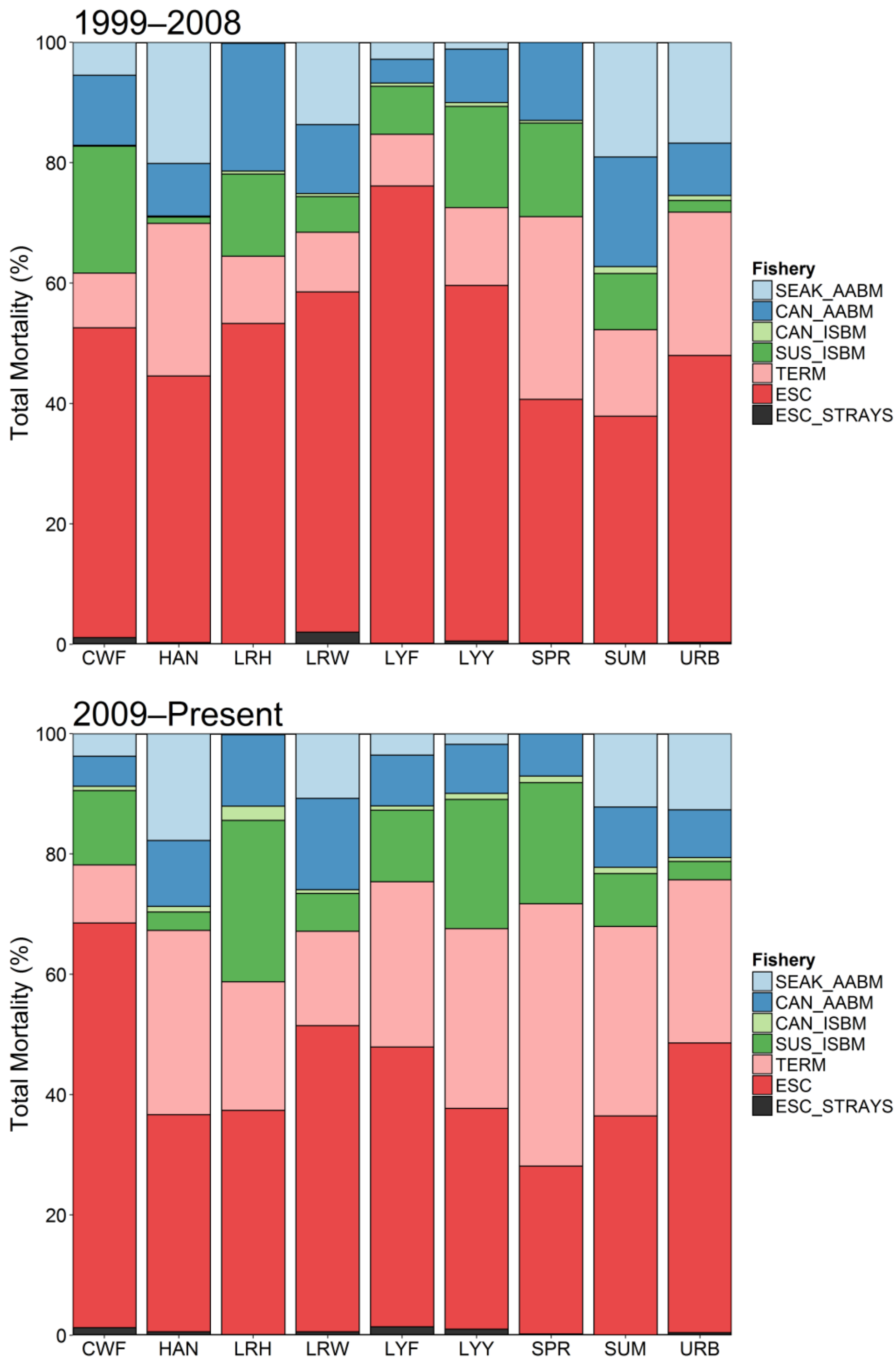


Figure 2.46 Distribution of total mortality for Columbia River indicator stocks for the 1999-2008 and the 2009-2018 Agreement periods.

2.2.9.4 Regional Summary for Columbia River Stocks

LRW seems to have much in common with URB, HAN, and SUM stocks, whereas LYF and LYY share several attributes with LRH and SPR tule stocks. CWF and WSH are also similar in many ways.

In general, most Lower Columbia River and Snake River stocks showed increases in BYERs, while upper Columbia River stocks had lower BYERs. Except for WSH and CWF, Columbia River stocks have had BYERs of about 50–70% since 2000. BYER for WSH and CWF are lower, but those are ocean exploitation rates that do not include terminal harvest impacts (Table 2.10). Therefore, WSH and CWF also show a higher percentage of escapement, compared to escapement proportions of about 50% for URB and LRW, and 30–40% for other stocks.

Except for SPR, Lower Columbia River stocks generally have lower survival rates recently than Upper Columbia and Snake River stocks, especially CWF and LRH. In general, Upper Columbia River stocks experienced higher than average survival rates in recent years.

Most Columbia River stocks have recently experienced an increased proportion of mortality in terminal fisheries and a decreased proportion of mortality in AABM fisheries.

2.2.10 North Oregon Coast Stocks

There are two hatchery-origin CWT indicator stocks representing the production of Chinook salmon on the Oregon coast, the Salmon River Hatchery (SRH) release group and the Elk River Hatchery (ELK) release group. Both groups are fall ocean type subyearling stocks which are recovered earliest at the total age of 2. The SRH release group represents the Northern Oregon Coast aggregate, whereas the ELK release group represents the Mid-Oregon Coast aggregate. There have been consistent releases of CWT groups of Chinook salmon from the SRH every year since 1976, with the exception of 1981. There have been consistent, if sometimes small (prior to 1989) releases from the ELK since 1977. Release group size for the ELK was somewhat normalized to higher levels after 1990. Average CWT release group size between 1977 and 1989 was approximately 37,000, and between 1990 and 2007 this increased to an average of approximately 184,000. Since 2007, after a two-year decline of coded wire tagged ELK releases in 2008-2009 (average 40,000), the release size increased to an average of 284,000 in 2010–2016. The recent Elk CWT release totals benefitted from the Coded Wire Tag Improvement Program's (CWTIP) implementation initiatives between 2010 through 2015. Since the sunset of this bilateral program, additional implementation funding has been sought and secured to support adequate CWT release group sizes. Consistent support into the future is needed to maintain this CWT group and model stock representation.

2.2.10.1 Brood Year Exploitation Rates

BYERs for both the SRH and ELK exploitation rate indicator stocks include only those mortalities attributable to ocean fisheries (Figure 2.47; Table 2.11). The BYER has averaged 35% (range 23–63%) for the SRH releases. BYER for the ELK has averaged 21% (range 10–32%) for the time series, excluding BY 1977 and 1978. There is no discernible trend through time regarding the percentage of IM occurring in ocean fisheries for either SRH or ELK River hatchery releases.

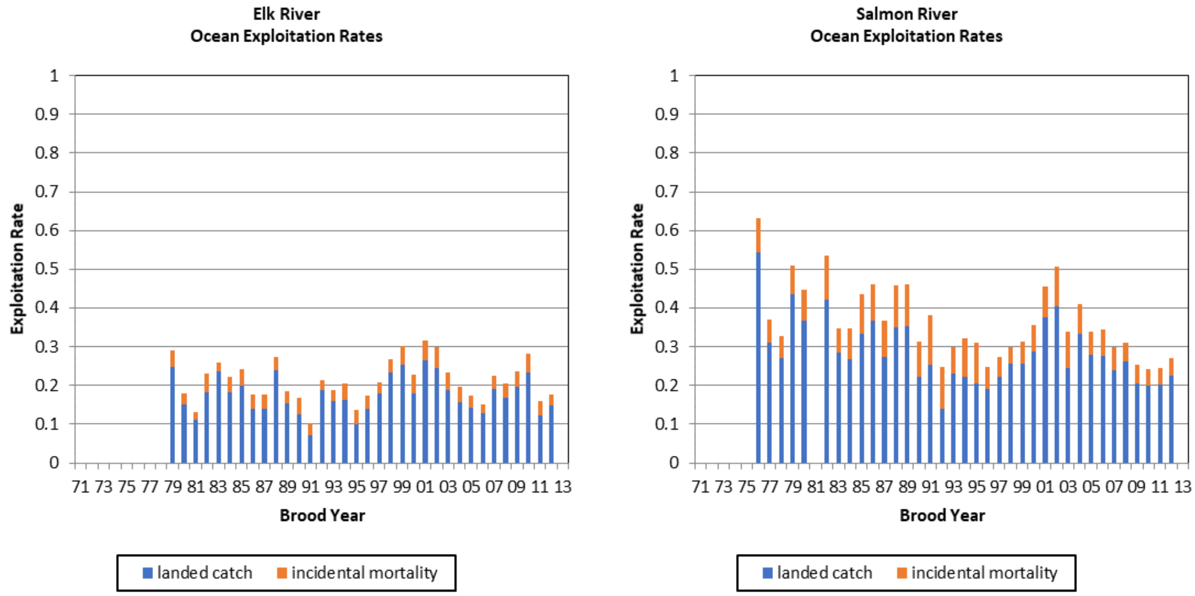


Figure 2.47 Brood year exploitation rate (ocean only) for Oregon Coast coded wire tag (CWT) indicator stocks. Catch and incidental mortality are shown. Only completed brood years are included.

Table 2.11 Summary of statistics generated by the 2019 CWT cohort analysis for Oregon Coast indicator stocks. Statistics include total mortality (catch plus incidental mortality) brood year exploitation rate (BYER), cohort survival rate to age 2, and calendar year (CY) percent distribution of the total mortality for 1999 (1999–2008) and 2009 (2009–2018) Treaty Agreement periods.

		BYER (total mortality)		Survival rate		CY % Escapement[1]		
						1999–2008	2009–current	
Stock Abbrev.	Indicator Stock Name	Mean (range)	Last complete BY	Mean (range)	Last complete BY	Mean (range)	Mean (range)	Last CY (if ≠ current)
ELK	Elk River[2]	21% (10%-32%)	18% (2012)	8.31% (1.04-32.9%)	8.71% (2012)	46% (34-63%)	54% (42-68%)	52% (2017)
SRH	Salmon River[2]	36% (23%-63%)	27% (2012)	6.27% (0.63-16.37%)	18.64% (2012)	40% (18-58%)	47% (33-57%)	54% (2017)

[1] % Escapement is not a measure of performance for the escapement indicator stock(s) associated with a given CWT indicator stock. See CTC (2013) for these details.

[2] BYER is ocean exploitation rate only.

2.2.10.2 Survival Rates

Survival rates for both SRH and ELK Hatchery stocks are to age 2. Generally, survival rates for ELK have been variable, yet robust, and averaged 8% (range of 1–33%; Figure 2.48; Table 2.11), among the highest average survival tracked coastwide by the CTC, exceeded only by the average survival displayed by CHI (12%). Since 2012, the last year with complete broods to calculate survival from, the survival rates for the ELK stock have been in decline. Survival rates for SRH had been generally increasing through 2012 with a long-term average of 6%, with survival from the first three BYs averaging 7%, and the last three complete BY survivals averaged 13%. Recently, there has been rapidly declining survival with the SRH stock demonstrating a range of 19 to 1% from the last three analyzed brood years.

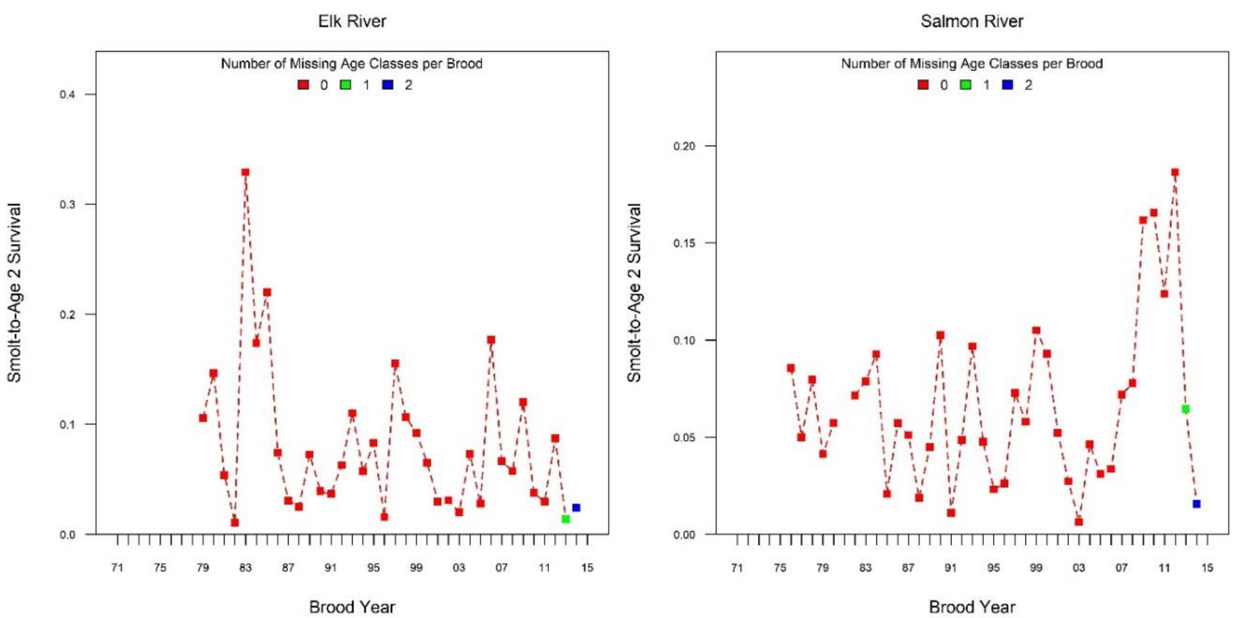


Figure 2.48 Survival rate for Oregon Coast indicator stocks.

2.2.10.3 Mortality Distributions

An average of 41% of SRH (Appendix C46) mortality, and 48% of the ELK (Appendix C12) mortality, is attributed to escapement for the 1985–present time series (Table 2.11). *Mortality to escapement* is the proportion of AEQ mortalities in a CY attributable to spawning escapement. Both stocks exhibit slight variation in the proportion which escapes to spawn through the time series, but there is no visible trend. According to the 1999–2008 CY data, the largest impacts on the SRH stock occur in terminal sport (25%), SEAK troll fisheries (19%), NBC troll (7%), and NBC sport (4%). During the same time period, the largest impacts on the ELK stock occur in terminal troll (15%), terminal sport fisheries (15%), SEAK troll (8%), and NBC troll (4%). WCVI troll used to be a larger component of the impacts on the ELK stock (6%: 1979–1984), but has impacted this stock less in more recent years (2%: 2009-2018). These impact distributions are displayed graphically in Figure 2.49.

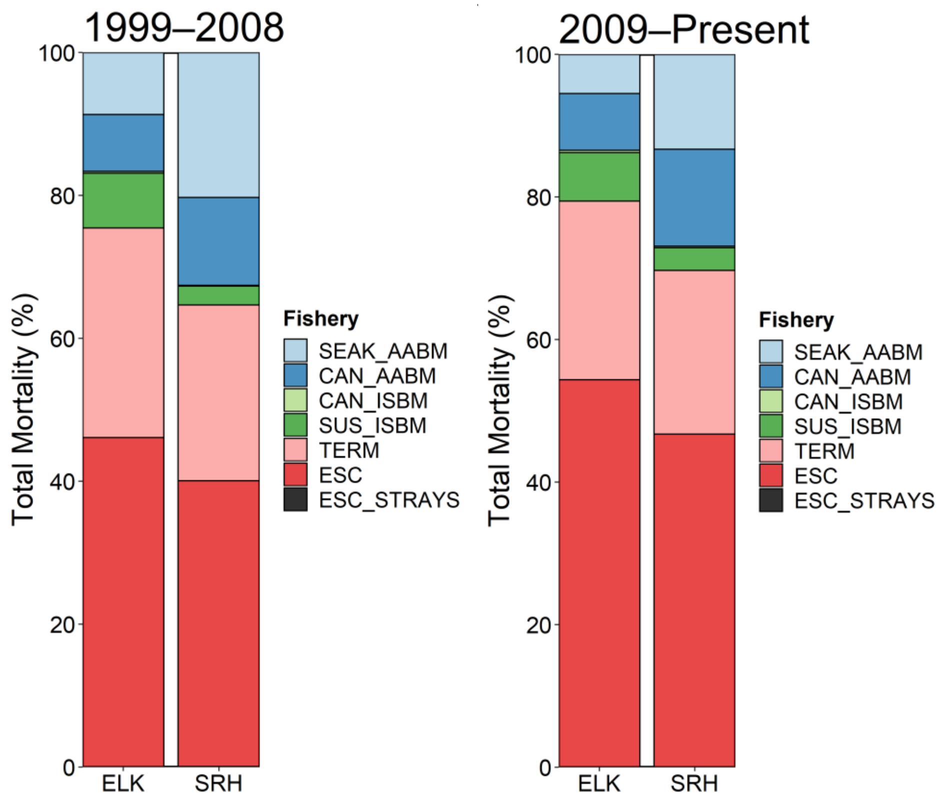


Figure 2.49 Distribution of total mortality for Oregon Coast indicator stocks for the 1999-2008 and 2009-2018 Agreement periods.

3. PSC CHINOOK MODEL CALIBRATION AND OUTPUT

The annual calibration of the PSC Chinook Model provides pre-season AIs for the three AABM fisheries, post-season AIs for the previous year, and pre-season ISBM indices. The 2019 pre-season AIs are used to estimate the allowable catch of Treaty Chinook salmon in the NBC and WCVI AABM fisheries for 2019. Post-season AIs are used to determine the previous (2018) season's allowable catches and to evaluate compliance in AABM fisheries. The 2009 PST Agreement specifies that total AEQ mortality in ISBM fisheries will be limited to no greater than 63.5% for Canada and 60% for the U.S. relative to that observed in the base period (1979–1982) for the indicator stocks identified in Attachments IV and V that have CTC-agreed management objectives but are not achieving them. The ISBM indices estimate annual exploitation rates relative to the base period for those fisheries. Post-season ISBM indices for 2017 (all ISBM stocks) and 2018 (Canadian ISBM stocks) are computed using results of the ERA. The Agreement specifies that the post-season ISBM indices estimated through ERA of CWT recoveries will be used to assess whether ISBM obligations were met in stocks that did not meet or have escapement goals; however, post-season indices are computed on a two-year lag because some CWT data are not reported until two years later. Additionally, post-season CWT-based ISBM indices provide insight on the performance of the (pre-season) model-generated index.

3.1 MODEL CALIBRATION

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 the draft model documentation (CTC AWG 1991). For 2019, the model used was the same as used during the PST negotiations (CLB 9812), with the actual catches, escapements, and other data through 2018 added, along with forecasts for 2019. In addition, CTC-agreed escapement goals were used where available and the form of the Ricker production function was adjusted for new stocks with CTC-agreed goals.

3.1.1 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 AI 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 Table 3.1.

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 (2019). 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 19 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 Naturals) 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 (Table 3.2). For those stocks with externally-provided forecasts of abundance in 2019, 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 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 Table 3.2).
    b. Average Return Rate Models: Return rates of adults by age from smolts or parents are averaged over past BYs, then these averages are used to discount abundance of smolts or parents for BYs that will be exploited (forecast type R in Table 3.2).
    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., 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 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, Akaike information criterion (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 2016-2019 for Canada and Oregon Model stocks (forecast type F in Table 3.2).

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 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 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 is equal to 1 minus the conversion factor.

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 and AEQ factors): The MATAEQ file has annual estimates of maturation rates and AEQ factors for 12 stocks (AKS, BON, CWF, FRL, GSH, LRW, ORC, RBH, RBT, SPR, URB, and WSH). These annual estimates replace the single (non-year specific) maturation schedule rates in the STK file with years specific rates. Average values 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).

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. Note, PNVs are not stock specific and is on the AWGs work schedule to change in future years.

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.

Table 3.1 Month of the year when agencies are able to provide final return estimates for the previous year and pre-season forecasts of abundance for the next fishing year.

Model Stock	Month Final Return Estimate Available	Month(s) Forecast Available
Alaska South SE	January	None
Northern/Central B.C.	November	February
WCVI Natural	January	February
WCVI Hatchery	January	February
Upper Strait of Georgia	January	February
Lower Strait of Georgia Hatchery	December	February
Lower Strait of Georgia Natural	December	February
Fraser Early	January	February
Fraser Late	February	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[1]
Washington Coastal Hatchery	June	March[1]
Cowlitz Spring Hatchery	June	December
Willamette River Hatchery	June	December
Columbia River Summer	September	February
Fall Cowlitz Hatchery	April	February, April[2]
Spring Creek Hatchery	April	February, April
Lower Bonneville Hatchery	April	February, April
Upriver Brights	April	February, April
Snake River Wild Fall	April	April
Mid-Columbia River Bright	April	February, April
Lewis River Wild	April	February, April
Oregon Coast	February	March

[1] Normally forecasts are not available for the model calibration, but these were available in 2019.

[2] 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.

Table 3.2 Methods used to forecast the abundance of stocks in the PSC Chinook Model.

Model Stock	Forecast Characteristics			Comments
	Forecast Type[1]	Pre-season age-specific	Post-season age-specific	
Alaska South SE	C	-	Yes	Calibrated to escapement
Northern/Central B.C.	F	No	No	Calibrated to terminal run
WCVI Hatchery + Natural (RBH and RBT model stocks)	F	Yes	Yes	Robertson Creek Hatchery forecasts plus expansion for other WCVI stocks based on ratio of terminal run sizes
Upper Strait of Georgia	F	No	No	Calibrated to escapement
Lower Strait of Georgia Hatchery	F	Yes	Yes	Calibrated to escapement to GSH hatchery systems and Squamish River
Lower Strait of Georgia Natural	F	Yes	Yes	Calibrated to escapement to Cowichan and Nanaimo Rivers
Fraser Early	F	No	No	Calibrated to terminal run
Fraser Late	F	Yes	Yes	Combined forecasts of escapements for Harrison River and Chilliwack Hatchery
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 + 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 Fall)	R	No	No	Calibrated to escapement to Lower Granite.
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
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 = model internally estimated projection.

3.1.2 Calibration Procedures

The calibration uses an iterative algorithm to estimate EV scalars for each BY 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, bench-marking 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:

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 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 estimated 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:

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

Equation 3.1

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

Equation 3.2

   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 composition.

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

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

Equation 3.3

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

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

Equation 3.4

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 2018 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 and discussed below.

- 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 2019 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 1979–2018 using updated catch and escapement data through 2018. Average exploitation rate scalars ($\overline{FP}$) were then computed and used as input values for the 2018 and 2019 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 Table 2.3):

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

Equation 3.5

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 next to last 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 previous model calibration procedures for 2019 are provided in Appendix L.

3.1.3 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, 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 allowable catch comparisons). For each AABM fishery (*f*), an AI is computed for the upcoming fishing year (*CY*) as:

$$AI_{f,CY} = \frac{\sum_s \sum_a Cohort_{s,a,CY} ER_{s,a,f}(1-PNV_{a,f})}{\sum_s \sum_a Cohort_{s,a,BP} ER_{s,a,f}(1-PNV_{a,f})} \quad \textit{Equation 3.6}$$

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 stocks (*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 TACs 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 pre-season TAC for the SEAK AABM fishery is based on the SEAK early winter District 113

Troll fishery CPUE metric and determined using Table 2 of Annex IV, Chapter 3 of the 2019 PST Agreement.

3.2 Model Calibration Results

3.2.1 Overview of 2019 Calibration Process

The CTC AWG met in March 2019, to perform the PSC Chinook Model calibration for use in the upcoming fishing year. Several preliminary calibrations were produced during that week and the following week where up-to-date escapement and terminal runs, catches, and Fishery Policy (exploitation rate) scalar were discussed and the AWG agreed to endorse a subsequent calibration (Clb1905). In late March, the CTC produced its annual memo to the PSC detailing the 2019 pre-season and 2018 post-season AIs and allowable catches for the AABM fisheries based on CLB1905 and the SEAK early-winter troll fishery CPUE index (per the 2019 PST Agreement).

3.2.2 AABM Fishery Calibration Results

3.2.2.1 AABM Abundance Indices

The AABM fishery management regime relies on relationships that are based on data for catches and IM, 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 through the use of pre-season AIs, where a specific estimate of allowable harvest level corresponds to a given AI for each fishery. The revised 2019 PST Agreement continues the use of pre-season AIs for NBC and WCVI AABM fisheries, and establishes a CPUE metric to set management targets for the SEAK AABM fisheries. Pre-season AIs that were used to establish harvest management targets are listed in Table 3.3 along with the CPUE metric used to set the pre-season SEAK limit for 2019. The 2019 pre-season AI was 0.96 for the NBC AABM fishery and 0.61 for the WCVI AABM fishery; the CPUE metric is 3.38 for the SEAK AABM fishery.

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 include the negotiated reductions of 15% in SEAK and 30% in WCVI, but the NBC AABM fishery retained the same allowable catch 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 have a diet reliant on Chinook salmon, 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 the negotiated reductions of up to 7.5% in SEAK and 12.5%% in WCVI, but the NBC AABM fishery retained the same allowable catch and harvest rates specified in the 1999 PST Agreement.

Post-season AIs are more accurate estimates of the abundance indices for the AABM fisheries than are the pre-season AIs. Thus, overage or underage of AABM landed catches is assessed relative to the final allowable catches based on post-season AIs. Post-season AIs for 1999–2018 are listed Table 3.3.

Table 3.3 Abundance Indices for 1999–2019for the SEAK, NBC, and WCVI AABM fisheries. Post-season values for each year are from the first post-season calibration following the fishing year.

	SEAK		NBC		WCVI	
Year	**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	3.38[3]		0.96		0.61	

[1] Due to changes in calibration procedures (reviewed in section 3.1.4), 2012 post-season (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 1602 to estimate the 2014 and 2015 post-season AIs and 2016 pre-season AI.

[3] Per paragraph 6 (b) of the 2019 PST Agreement, this number represents a catch limit based on a CPUE statistic and corresponds to an AI of 1.07.

3.2.2.2 AABM Fishery Performance

The 2009 PST Agreement specifies the allowable catch for various values of the AI for each fishery. Allowable catches for 1999–2008 were from Table 1 in the Chinook Annex to the 1999 PST Agreement. In the 2009 PST Agreement, the relationship between the AI and the allowable catch changed for SEAK and WCVI; thus the allowable catches since 2009 were derived from Table 1 of the Chinook Annex to the 2009 PST Agreement. The performance of the AABM fishery management regimes was evaluated based on a comparison of actual catches to allowable post-season catch levels derived from Table 1 of Chapter 3 based upon the first post-season AIs estimated by the PSC Chinook Model (Paragraph 11(a)(i)).

Per 2009 Treaty Agreement subparagraph 11(a)(i), AIs and associated allowable catches from the first post-season Model calibration for a given fishing year are used to track catch overages and underages (Table 3.4).

Overages and underages in AABM catches, relative to the first post-season calibration for a fishing year can arise due to imprecision in the in-season management system, errors in the pre-season AIs (e.g., forecast error), or a combination of the two. The relative influence of each was evaluated by inspecting differences in actual landed catch and allowable catches from both the pre-season and post-season calibrations (Table 3.4, Table 3.5, Table 3.6, Table 3.7). Regarding the in-season management system in 2018, actual landed catch was less than pre-season allowable catch by 16,724 (12%) in SEAK, 22,324 (17%) in NBC, and 2,970 (3%) in WCVI. In terms of the post-season allowable catches for evaluation of the provisions of the PST (subparagraph 11(a)(i)), 2018 actual catches were less than the post-season allowable catches by 6,724 (6%) in NBC and 2,970 (3%) in WCVI, and greater than the post-season allowable catch by 9,076 (8%) in SEAK.

3.2.2.2.1 Actual Catches Versus Pre-season and Post-season Allowable Catches

The differences between observed catches and the catches prescribed by the AIs from the first post-season Chinook model calibration are the result of two processes: 1) management error, defined here as the difference between the actual catch and the catch target set using the pre-season AI; and 2) model error which is the difference between catches prescribed by the pre-season AIs and those prescribed by the first post-season AIs. We use the term *management error* but recognize it a misnomer in many situations as the deviations of observed catch from the pre-season allowable catch may have been the result of deliberated actions. Pre-season allowable catches are included with the post-season allowable catches and observed catches in Table 3.4.

Management errors and model errors are linked but the relationships have not been constant so their respective contributions to the final assessments have been considered independently (Table 3.5, Table 3.6, and Table 3.7). Overall, the performance of AABM fisheries, as measured by the deviation of observed catches from the post-season allowable catches, had deviations ranging from -74% to 52%. Poor performance was greatest when management error and model error were in the same direction, as was the case in NBC in 2000, when the maximum negative error was observed (Table 3.6), and in WCVI during 2011, when the maximum positive error was observed (Table 3.7). Improved performances, with deviations near zero, were the result of pre-season AIs close to the post-season value and relatively small management errors such as was observed in SEAK in 2006, NBC in 2005 and WCVI in 2010. Improved performances were also the result of management errors in the opposite direction of model errors, thereby cancelling out portions of these different deviations. The most extreme example of management and model errors cancelling each other out occurred in SEAK in 2015. In the last 10 years, the SEAK, NBC, and WCVI AABM fisheries have exceeded the post-season allowable catch on 13 occasions, including seven in SEAK, one in NBC, and five in WCVI.

Model error was largely responsible for catch reductions not being met in six of 10 years in SEAK, one of 10 years in NBC and in four of 10 years in WCVI. The reductions realized by the AABM fisheries were assessed against the post-season TACs that would have been allowed without the negotiated reductions. To generate the TACs without the reductions, the WCVI post-season TACs were adjusted upward by 30% (WCVI post-season AC / 0.70) and the SEAK post-season TACs were adjusted upward by 15% (SEAK post-season AC / 0.85). No adjustment was required for NBC. Actual catches were then subtracted from the adjusted TACs to provide a measure of the reductions realized by the management changes. Actual reductions realized from the negotiated reductions in AABM catches averaged 11% in SEAK and 26% in WCVI from the 2009–2018 limitations. In addition, NBC realized an average reduction of 20% over the current annex period. Total catch reductions associated with the 2009 annex adjustments for AABM fisheries from 2009–2018 were 886,648 fish; including 337,714 fish from SEAK and 548,934 fish from WCVI. There was an additional foregone catch of 389,846 from NBC for a total reduction of 1,276,494 fish over the course of the 2009 PST Agreement.

Table 3.4 Pre-season allowable catches for 1999–2019, and post-season allowable catches and observed catches for 1999–2018, for AABM fisheries. Post-season values for each year are from the first post-season calibration following the fishing year.

	SEAK (Troll, Net, Sport)			NBC (Troll, Sport)			WCVI (Troll, Sport)		
Year	Pre-season Allowable Catch	Post-season Allowable Catch	Observed Catch	Pre-season Allowable Catch	Post-season Allowable Catch	Observed Catch	Pre-season Allowable Catch	Post-season Allowable Catch	Observed 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	350,704	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	140,323[2]			124,800			79,900		

[1] Due to a disagreement over Model calibration 1503, the Commission agreed to use output from CLB 1602 to estimate the catches associated with the 2014 and 2015 post-season AIs and 2016 pre-season AIs.

[2] Per paragraph 6 (b) of the 2019 PST Agreement, this number represents a catch limit based on a CPUE statistic and corresponds to an AI of 1.07.

3.2.2.2.2 SEAK AABM Fishery

Average management error was 1% for SEAK across the 1999–2018 time series and ranged between –16% and 41%. Average management error was 2% across the 2009–2018 time period and 1% in the 1999–2008 time period (Table 3.5). The difference in the average management error in the recent 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 allowable catch was largely driven by Model error. SEAK management error was relatively small in all years other than 2015 and was in the opposite direction of the model error in seven of the 10 years 2009–2018 (Figure 3.1).

Table 3.5 Summary of Southeast Alaska (SEAK) aggregate abundance-based management (AABM) fishery performance and deviations from post-season allowable catch, 1999–2018. The summaries present cumulative numbers of fish and average percent error for the period. *Fisheries shaded in green or red indicates whether the Treaty obligation was met or not, respectively. T = Troll, N = Net, S = Sport.*

SEAK (T, N, S)						
Year	Mgmt error Obs - Pre #	Mgmt error Obs - Pre %	Model error Pre - Post #	Model error Pre - Post %	Total error Obs - Post #	Total error Obs - Post %
1999	6,042	3%	8,600	5%	14,642	8%
2000	-3,407	-2%	11,400	6%	7,993	4%
2001	-2,981	-2%	-60,400	-24%	-63,381	-25%
2002	633	0%	-15,400	-4%	-14,767	-4%
2003	14,052	4%	-73,500	-17%	-59,448	-14%
2004	33,519	9%	-34,800	-8%	-1,281	0%
2005	-27,760	-7%	29,000	7%	1240	0%
2006	13,294	4%	-7,700	-2%	5,594	2%
2007	-1,132	0%	70,200	27%	69,068	27%
2008	2,905	2%	17,100	11%	20,005	13%
2009	9,154	4%	42,800	24%	51,954	30%
2010	8,811	4%	6,000	3%	14,811	7%
2011	-3,639	-1%	11,500	4%	7,861	3%
2012	-23,979	-9%	61,700	30%	37,721	18%
2013	15,388	9%	-108,900	-38%	-93,512	-33%
2014	-4,205	-1%	60,800	16%	56,595	15%
2015	98,026	41%	-100,500	-30%	-2,474	-1%
2016	-4,896	-1%	67,400	23%	62,504	22%
2017	-34,286	-16%	-6,100	-3%	-40,386	-19%
2018	-16,724	-12%	25,800	22%	9,076	8%
1999-2018 Avg	3,941	1%	250	3%	4,191	3%
1999-2008 Avg	3,516	1%	-5,550	0%	-2,034	1%
2009-2018 Avg	4,365	2%	6,050	5%	10,415	5%

Note: Due to a disagreement over Model calibration 1503, the Commission agreed to use output from CLB 1602 to estimate the catches associated with the 2014 and 2015 post-season AIs and 2016 pre-season AIs.

Figure 3.1 Performance of Southeast Alaska (SEAK) aggregate abundance-based management (AABM) fishery, 1999–2018.

Note: AC = allowable catch.

3.2.2.2.3 NBC AABM Fishery

NBC catch was consistently below the pre-season allowable catch with an average of -22% from 1999–2018 (range -1% to -75%; Table 3.6). The average NBC catch was –26% below the pre-season allowable catch from 1999–2008 and -19% from 2009–2018. Management errors in NBC were the result of Canada's domestic efforts to reduce impacts on WCVI-origin Chinook. Management error in the NBC fishery was near zero from 2003 to 2006 and in 2015 and 2017, but catches were significantly below the allowable catch in all other years except 2016 (Figure 3.2). Management actions in NBC outweigh model errors in most years with a -23% average error between the observed catch and the post-season allowance.

Table 3.6 Summary of Northern British Columbia (NBC) aggregate abundance-based management (AABM) fishery performance and deviations from post-season allowable catch, 1999–2018. The summaries present cumulative numbers of fish and average percent error for the period.

Fisheries shaded in green or red indicates whether the Treaty obligation was met or not, respectively. T = Troll, S = Sport.

NBC (T, S)						
Year	Mgmt error Obs - Pre #	Mgmt error Obs - Pre %	Model error Pre - Post #	Model error Pre - Post %	Total error Obs - Post #	Total error Obs - Post %
1999	-61,276	-42%	19,500	15%	-41,776	-33%
2000	-97,952	-75%	6,500	5%	-91,452	-74%
2001	-89,266	-67%	-26,300	-17%	-115,566	-73%
2002	-42,869	-22%	-45,100	-19%	-87,969	-37%
2003	-2,303	-1%	-80,100	-29%	-82,403	-30%
2004	-2,092	-1%	-23,400	-9%	-25,492	-10%
2005	-2,994	-1%	5,900	2%	2,906	1%
2006	-7,215	-3%	23,200	12%	15,985	8%
2007	-33,765	-19%	35,000	24%	1,235	1%
2008	-29,153	-23%	3,900	3%	-25,253	-21%
2009	-33,530	-23%	3,900	3%	-29,630	-21%
2010	-15,487	-10%	-8,300	-5%	-23,787	-15%
2011	-59,740	-33%	-4,400	-2%	-64,140	-34%
2012	-53,293	-31%	24,100	16%	-29,193	-20%
2013	-27,086	-19%	-77,300	-35%	-104,386	-47%
2014	-73,399	-25%	27,700	11%	-45,699	-17%
2015	-1,497	-1%	-86,200	-35%	-87,697	-36%
2016	-57,819	-23%	64,100	35%	6,281	3%
2017	-6,170	-4%	1,300	1%	-4,870	-3%
2018	-22,324	-17%	15,600	13%	-6,724	-6%
1999-2018 Avg	-35,962	-22%	-6,020	0%	-41,982	-23%
1999-2008 Avg	-36,889	-26%	-8,090	-1%	-44,979	-27%
2009-2018 Avg	-35,035	-19%	-3,950	0%	-38,985	-20%

Note: Due to a disagreement over Model calibration 1503, the Commission agreed to use output from CLB 1602 to estimate the catches associated with the 2014 and 2015 post-season AIs and 2016 pre-season AIs.

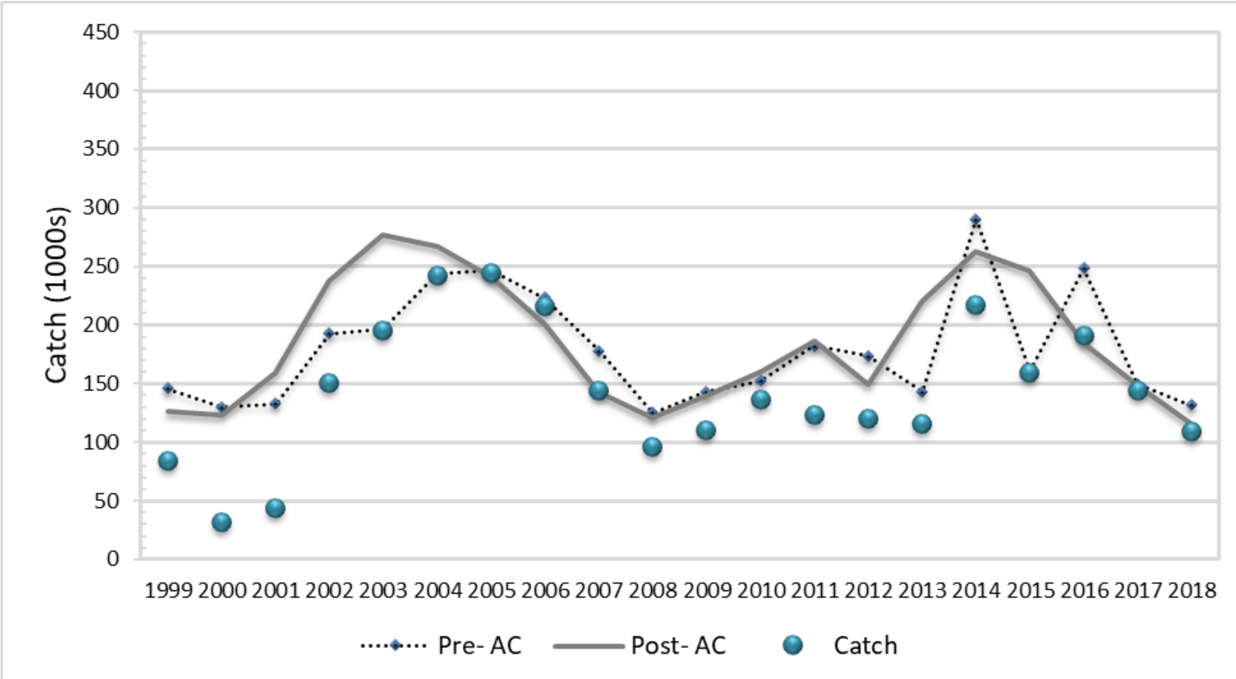


Figure 3.2 Performance of Northern British Columbia (NBC) aggregate abundance-based management (AABM) fishery, 1999–2018.
Note: AC = allowable catch.

3.2.2.2.4 WCVI AABM 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 (Table 3.7). The deviations of observed catch from the post-season allowable catch in WCVI ranged from -64% to 52%. Although management error in WCVI played a larger role in the deviation from the post-season allowable catch, Model errors made up the largest component of the deviations. In five of 10 years during the 2009–2018 time series, the WCVI management and model errors occurred in a common direction. In 2010, 2014, and 2018 both model and management errors were small (Figure 3.3).

Table 3.7   Summary of West Coast Vancouver Island (WCVI) aggregate abundance-based management (AABM) fishery performance and deviations from post-season allowable catch, 1999–2018. The summaries present cumulative numbers of fish and average percent error for the period.

Fisheries shaded in green or red indicates whether the Treaty obligation was met or not, respectively. T = Troll, S = Sport.

	WCVI (T, S)					
Year	Mgmt error Obs - Pre #	Mgmt error Obs - Pre %	Model error Pre - Post #	Model error Pre - Post %	Total error Obs - Post #	Total error Obs - Post %
1999	-89,760	-70%	21,300	20%	-68,460	-64%
2000	-26,883	-23%	29,300	34%	2,417	3%
2001	-20,896	-15%	-4,300	-3%	-25,196	-17%
2002	-45,280	-22%	6,400	3%	-38,880	-20%
2003	-8,239	-5%	-87,100	-32%	-95,339	-35%
2004	22,752	12%	-17,100	-8%	5,652	3%
2005	11,279	6%	8,500	5%	19,779	11%
2006	-14,889	-9%	14,900	10%	11	0%
2007	-2,686	-2%	21,400	18%	18,714	15%
2008	-16,874	-10%	25,700	19%	8,826	6%
2009	16,817	16%	16,500	18%	33,317	36%
2010	-4,653	-3%	1,400	1%	-3,253	-2%
2011	7,432	4%	62,000	46%	69,432	52%
2012	1,910	1%	19,500	17%	21,410	19%
2013	1,571	1%	-62,700	-35%	-61,129	-34%
2014	-12,695	-6%	13,700	7%	1,005	1%
2015	-8,326	-7%	-52,400	-29%	-60,726	-34%
2016	-30,207	-23%	28,500	27%	-1,707	-2%
2017	2,116	2%	19,500	20%	21,616	23%
2018	-2,970	-3%	0	0%	-2,970	-3%
1999-2018 Avg	-11,024	-8%	3,250	7%	-7,774	-2%
1999-2008 Avg	-19,148	-14%	1,900	6%	-17,248	-10%
2009-2018 Avg	-2,901	-2%	4,600	7%	1,700	5%

Note: Due to a disagreement over Model calibration 1503, the Commission agreed to use output from CLB 1602 to estimate the catches associated with the 2014 and 2015 post-season AIs and 2016 pre-season AIs.

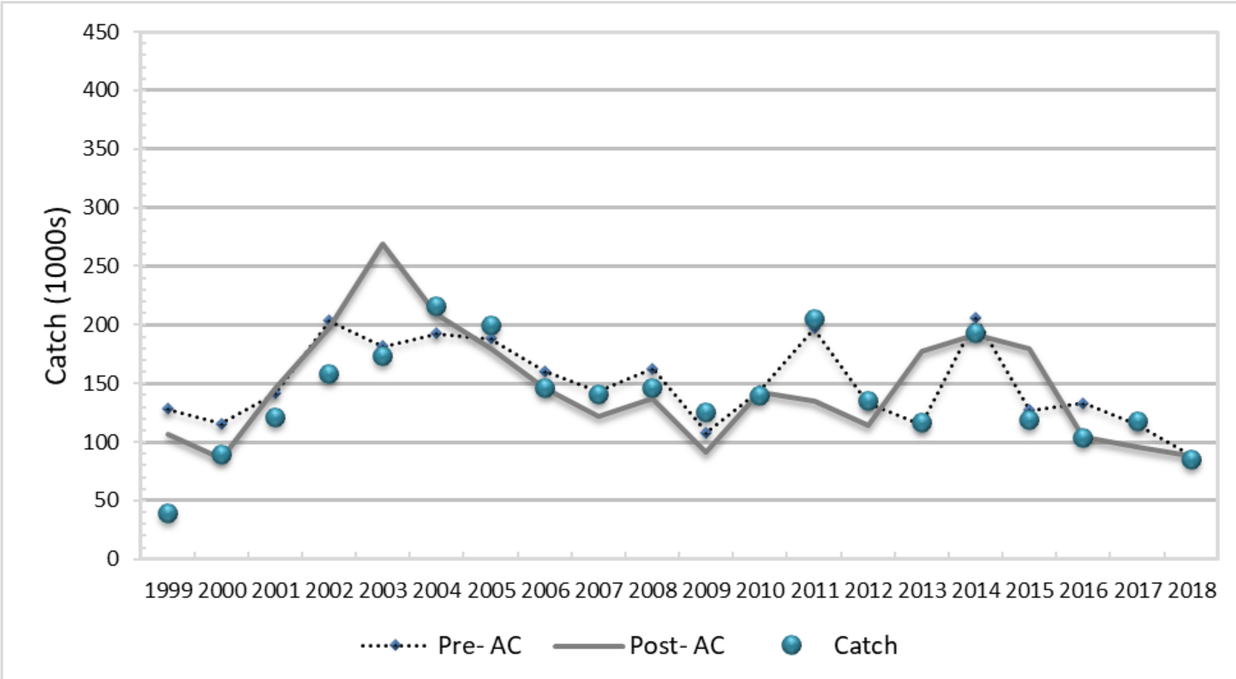


Figure 3.3 Performance of West Coast Vancouver Island (WCVI) aggregate abundance-based management (AABM) fishery, 1999–2018.
Note: AC = allowable catch.

3.2.2.3 Model Error

For the purposes of this section of the report, model error will refer to differences between model-generated pre-season AIs for the AABM fisheries and the first post-season estimate of AIs for the AABM fisheries as generated by the annual calibration in the following year. The yearly percent deviations between pre-season and post-season AIs for the three AABM fisheries are illustrated in Figure 3.4. For each AABM fishery, the deviations between the pre-season and post-season AIs have varied considerably since 1999. Large deviations can compromise the utility of pre-season AIs for setting objectives for each of the fisheries, which provisions in the 2009 Agreement were intended to address.

AIs are generated without any measures of their uncertainty and although corrective techniques have been explored, none have been applied. The regimes for the three AABM fisheries relate fishery-specific catch and fishery indices to AIs using a proportionality constant that varies annually but is currently based on the 1979 to 1997 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. As part of its model improvement initiative, the CTC is developing a model evaluation tool that will facilitate the ability to compare different types of abundance estimation models (e.g., statistical catch-at-age model) using a common data set of simulated abundance values.

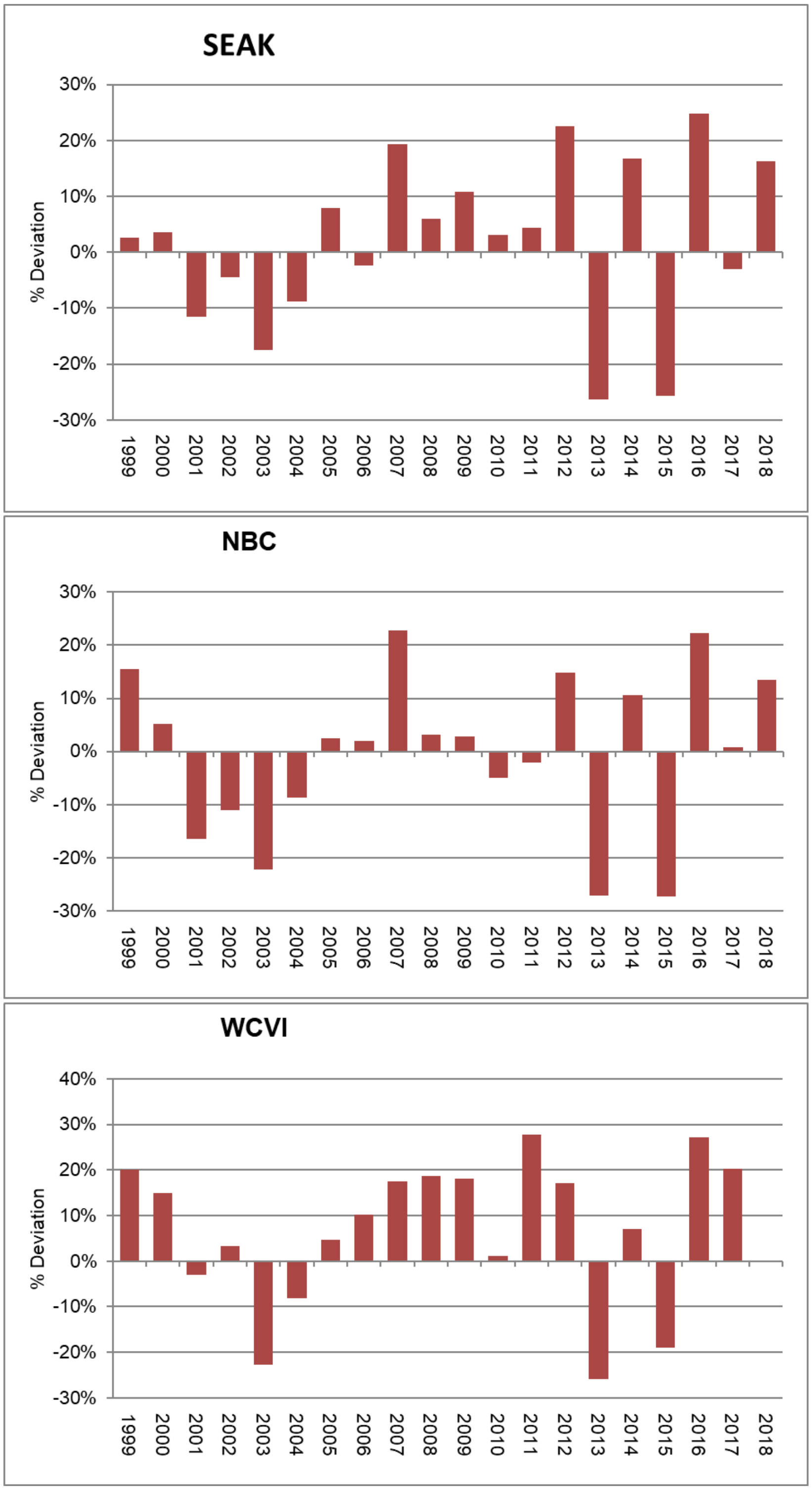


Figure 3.4 Difference between pre- and post-season abundance indices (AIs) for the three aggregate abundance-based management (AABM) fisheries, 1999–2018.

Note: There was no CTC consensus on the 2015 and 2016 Model calibrations (CLB 1503 and 1601). Outputs from CLB 1503 was used by the Commission to configure AABM fisheries in 2015. Abundances indices for AABM fisheries generated from CLB 1601 were accepted by the Commission. Values for the 2014 and 2015 post-season AIs are from CLB 1601 and values for the 2015 pre-season AI is from CLB 1503.

3.2.2.4 Stock Composition of Abundances Available in AABM fisheries, 1979–2018

The majority of catches in each AABM fishery are often composed of only a small subset of the 30 model stocks listed in Appendix A. Figure 3.5–Figure 3.7 show the relative abundance for each major stock (resulting from CLB 1905) in AABM troll fisheries only. In general, post-season AIs had a peak during the late 1980s (1987–1989), another in 2003 and 2004, and another in 2014 and 2015.

The major model stocks contributing to the SEAK AIs are Columbia River Upriver and Mid-Columbia Bright (URB-MCB), WCVI Natural and Hatchery, Oregon Coastal, Northern/Central B.C., and Fraser Early (Figure 3.5). The “other” category is mainly Washington Coast Hatchery and Natural, Columbia River Summers, and Upper Strait of Georgia.

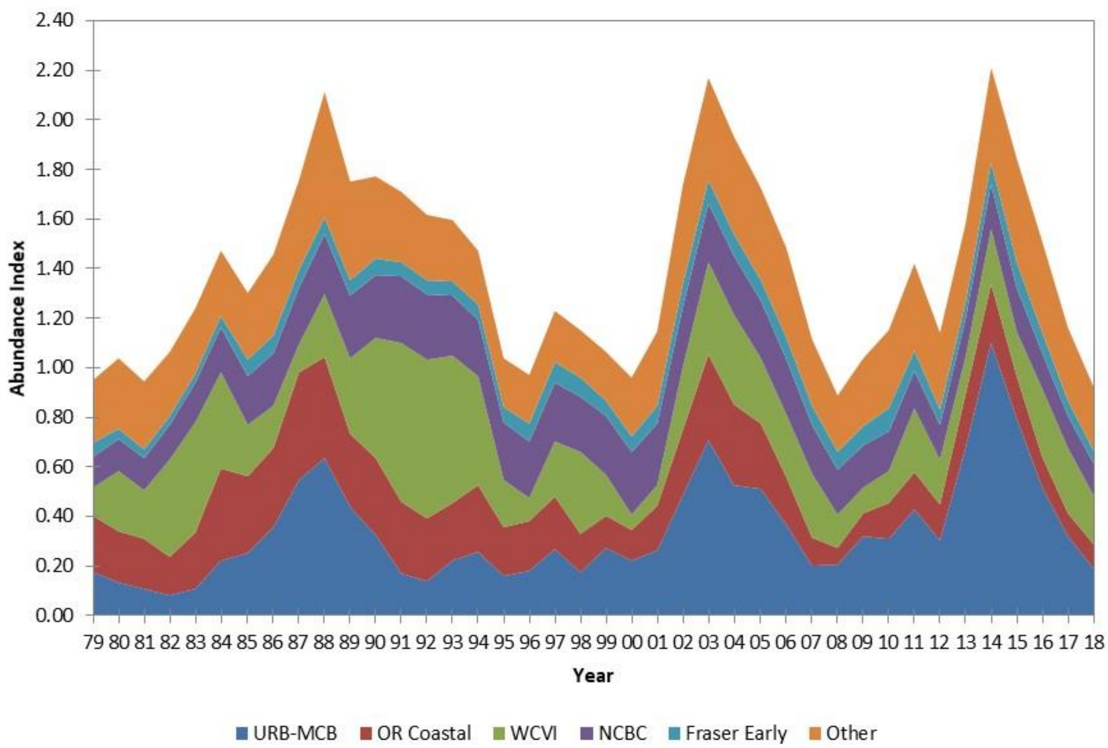


Figure 3.5 Stock composition of the annual abundance indices for the Southeast Alaska (SEAK) troll fishery from CLB 1905.

The major model stock groups contributing to the NBC AABM troll fishery AIs are Oregon Coastal, URB-MCB, WCVI Natural and Hatchery, Northern/Central B.C., and Fraser Early (Figure 3.6). The “other” category consists primarily of Washington Coast Hatchery and Natural, Willamette Springs, and Upper Strait of Georgia stocks.

The major Model stock groups in the AI for the WCVI AABM troll fishery are Columbia River Tules, Puget Sound, Fraser Lates, URB-MCB, and WCVI Natural and Hatchery (Figure 3.7). The “other” category is composed primarily of Oregon Coast, Columbia Summers, and Washington Coastal. See Appendix E for Model-generated stock composition estimates for all fisheries (AABM + ISBM).

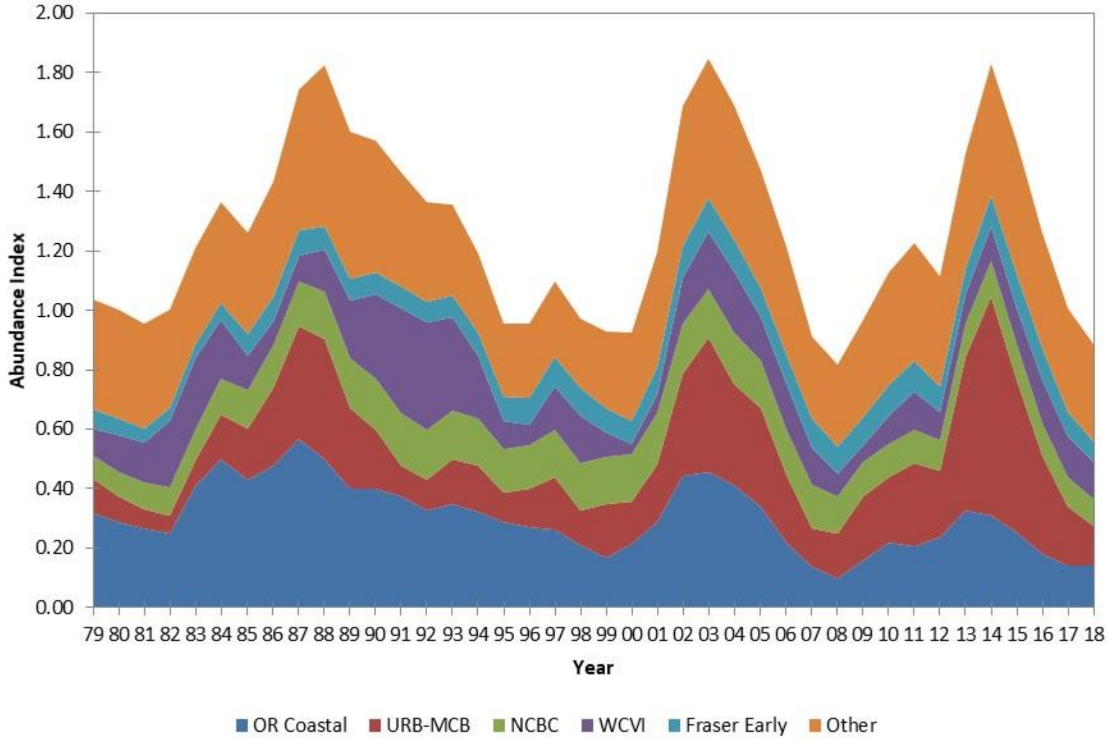


Figure 3.6 Stock composition of the abundance indices for the Northern B.C. troll fishery from CLB 1905.

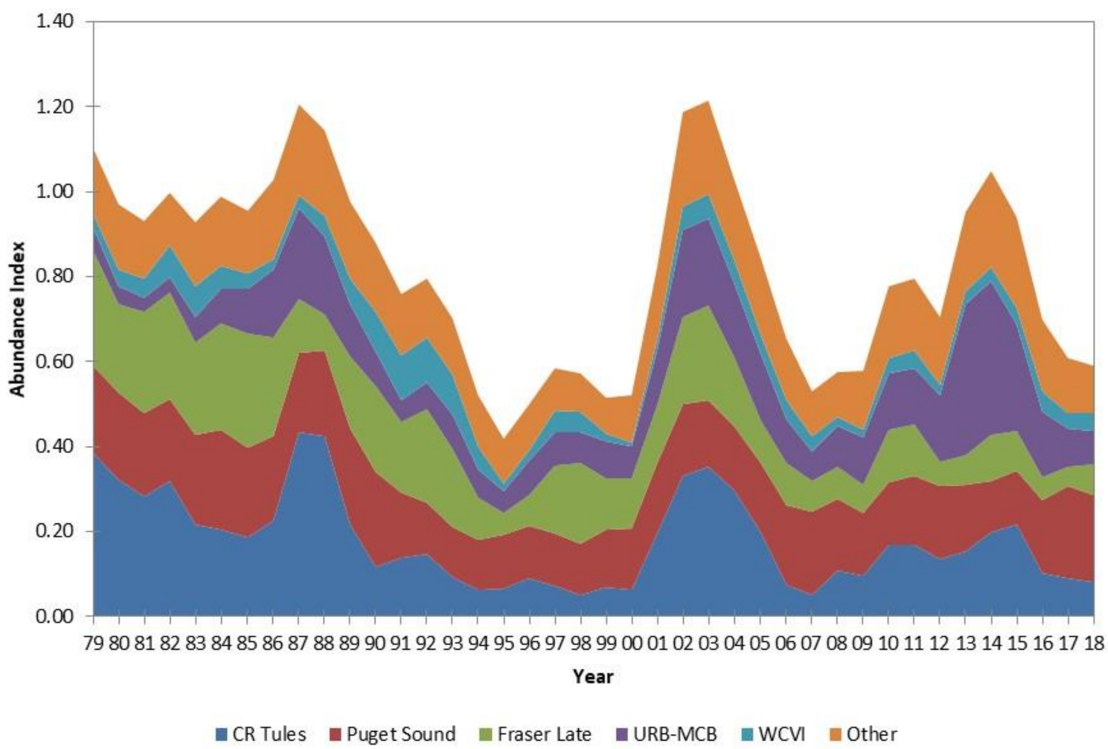


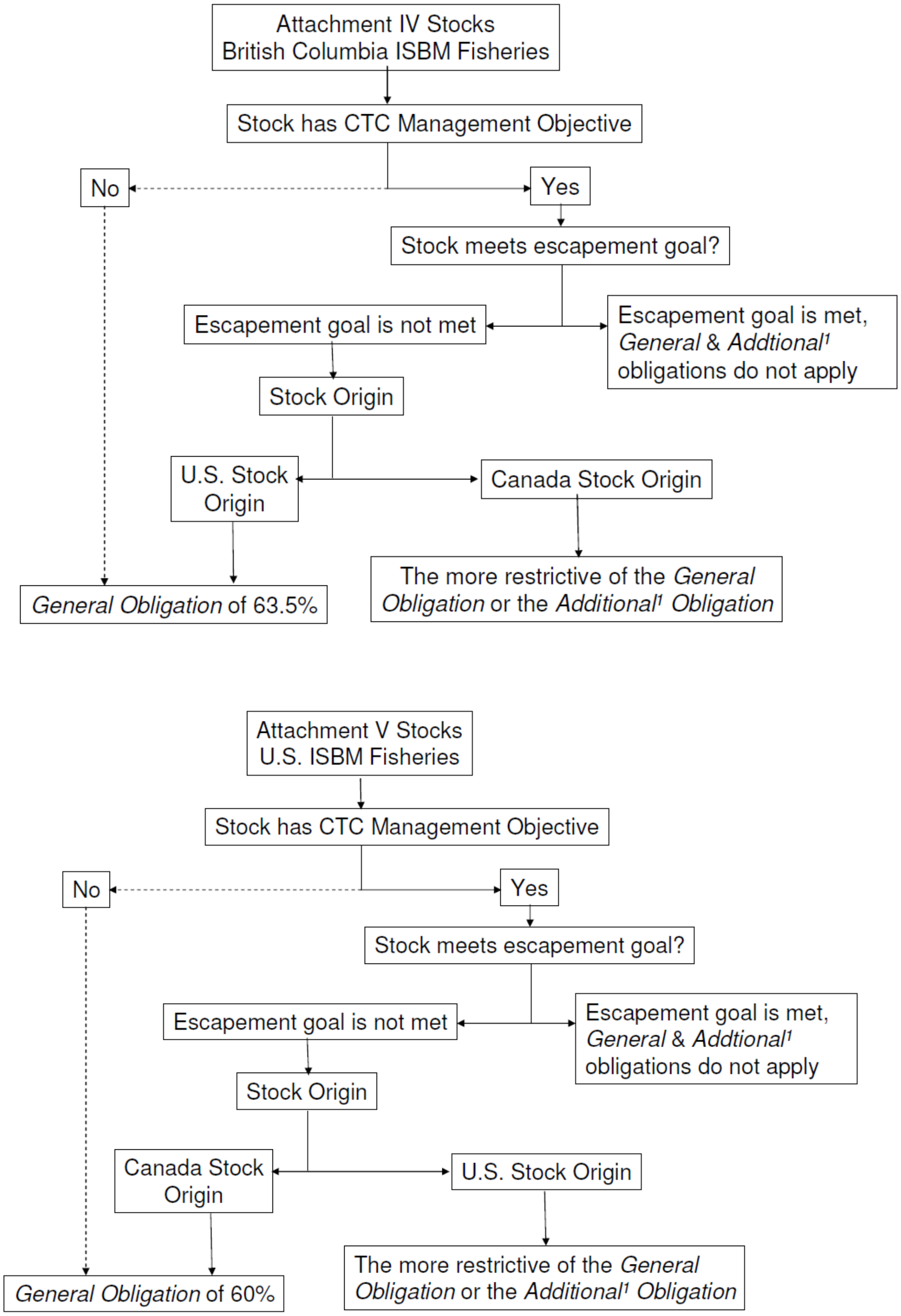
Figure 3.7 Stock composition of the abundance indices for the West Coast Vancouver Island (WCVI) troll fishery from CLB 1905.

3.2.3 ISBM Fishery Calibration Results

The 2009 PST Agreement specifies that Canada and the U.S. will reduce base period exploitation rates on specified stocks harvested in ISBM fisheries by 36.5% (Canada) and 40% (U.S.), equivalent to ISBM indices of 63.5% (Canada) and 60% (U.S.). This requirement is referred to as the *general obligation* and does not apply to stocks that achieve their PSC-agreed escapement goal. The Treaty also specifies that for those stocks in which the general obligation is insufficient to meet the escapement goal, the Party in whose waters the stock originates shall further constrain its fisheries to an extent that is not greater than the average ISBM exploitation rate that occurred in the years 1991 to 1996. This requirement is referred to as the *additional obligation*. Figure 3.8 shows how the lesser of the of the two rates (general obligation or additional obligation), would be used as reference to evaluate performance of ISBM fisheries for the Party in which a stock with an accepted escapement goal originates, whereas only the general obligation would be used as reference for stocks not meeting their accepted escapement goals or not having escapement goals.

The 2009 Agreement specifies that post-season assessment of ISBM fisheries use CWT-based indices; 2017 is the most recent analysis available for all stocks, and the computation of ISBM indices for 2018 was possible for four Canadian stocks. Estimated ISBM fishery indices are shown in Table 3.8 (2017), Table 3.9 (2018) for Canadian fisheries and in Table 3.10 (2017) and for U.S. fisheries. CWT-based ISBM indices for 1999–2017 are presented in Appendix B of this report. Several inconsistencies in the way these indices were computed in the past were recently corrected. Details regarding corrections and improvements to the ISBM program and calculations can be found in ISBM Subgroup (CTC 2019).

One of the limitations of the post-season CWT-based ISBM indices is that the catch and CWT expansion data needed to calculate the indices for several stocks caught in U.S. ISBM fisheries are not available at the time the index must be computed for use (CTC 2011). For example, sport harvest estimates are based on punch cards filled in by the fishers and returned by mail once the fishing year has ended, delaying estimates by more than a year from when catch occurred. Sport catch estimates are needed to estimate cohort sizes; thus, ISBM indices for both countries may not be computed within a timeframe for ISBM evaluations to inform fishing plans for the upcoming season. Each agency’s procedures for sampling fisheries for CWTs, decoding CWTs, and data management, generally meet the timelines necessary for the CTC to develop the ISBM indices on time. However, the catch estimates that are necessary to expand the CWT sample data as well as some of the escapement CWT samples are less timely for some Washington and Oregon sport and net fisheries.



[1] The additional obligation is the average ISBM exploitation rate during 1991-1996

Figure 3.8 Flow diagrams depicting the sequence of decisions leading to the implementation of individual stock-based management (ISBM) general and additional obligations for stocks in Attachments IV and V of Chapter 3 of the 2009 Agreement according to Paragraph 8 of the Chinook Chapter.

3.2.3.1 Canadian ISBM Indices

Of the seven Canadian ISBM indices that could be calculated for 2017 from the CWT data, all seven were below the general obligation rate of 0.635 (Table 3.8). WCVI Falls (0.629) does not have a CTC-agreed escapement goal and exceeded the additional obligation rate (0.475). Harrison (0.272) did not meet its escapement goal and exceeded its additional obligation rate (0.268). In the case of Lower Strait of Georgia, Nanaimo was dropped from the CWT-based index because of concern about the method of estimating the terminal fishery rates. Nanaimo and Cowichan stocks are no longer reported separately in the model-based index because a way to split the two stocks in the base period has not yet been developed.

Table 3.8 Review of performance in the Canadian individual stock-based management (ISBM) fisheries, 2017.

Stock Group	Escapement Indicator Stock	CTC Esc. Goal	2017 Escapement	Goal met?	Obligation[1]	2017 CWT Index	Treaty Obligations Met? [2]
Northern/ Central B.C.	Yakoun, Nass, Skeena, Area 8		NA[3]	NA	0.635	NA	NA
WCVI Falls	Artlish, Burman, Kauok, Tahsis, Tashish, Marble		NA	NA	0.475	0.629	No
Upper Strait of Georgia	Klinaklini, Kakweikan, Wakeman, Kingcome, Nimpkish		NA	NA	0.635	0.235	Yes
Lower Strait of Georgia	Cowichan	6,500	10,590	Yes	0.635	0.281	Yes
	Nanaimo		NA	NA	0.635	NA	NA
Fraser Late	Harrison	75,100	29,799	No	0.268	0.272	No
Fraser Early (Spring & Summers)	Upper Fraser, Mid Fraser, Thompson		NA	NA	0.635	NA	NA
Puget Sound Spring	Nooksack		NA	NA	0.635	0.059	Yes
	Skagit		NA	NA	0.635	NA	NA
Puget Sound Fall	Skagit		NA	NA	0.635	NA	NA
	Stillaguamish		NA	NA	0.635	0.160	Yes
	Snohomish		NA	NA	0.635	NA	NA
	Lake Washington		NA	NA	0.635	NA	NA
	Green		NA	NA	0.635	0.441	Yes

[1] General obligation (0.635) or additional obligation (1991‑1996 ISBM rate average for the Party in whose waters the stock not meeting escapement goal originates), whichever is lower, for stocks listed in Annex 4, Chapter 3, Attachment IV.

[2] Annex 4, Chapter 3, Paragraph 8.

[3] NA = No data available.

For 2018, computation of CWT-based ISBM indices was possible for four Canadian stocks (Lower Strait of Georgia, Fraser Late, Upper Strait of Georgia, and WCVI Falls). All four met Treaty obligations either by being below the general or additional obligation of 0.635 or additional obligation or meeting a CTC-agreed escapement Goal (Cowichan).

Table 3.9 Review of performance in the Canadian individual stock-based management (ISBM) fisheries, 2018.

Stock Group	Escapement Indicator Stock	CTC Esc. Goal	2018 Escapement	Goal met?	Obligation[1]	2018 CWT Index	Treaty Obligation Met? [2]
Northern/ Central B.C.	Yakoun, Nass, Skeena, Area 8		NA[3]	NA	0.635	NA	NA
WCVI Falls	Artlish, Burman, Kauok, Tahsis, Tashish, Marble		NA	NA	0.475	0.430	Yes
Upper Strait of Georgia	Klinaklini, Kakweikan, Wakeman, Kingcome, Nimpkish		NA	NA	0.635	0.235	Yes
Lower Strait of Georgia	Cowichan	6,500	14,353	Yes	0.635	0.806	Yes
	Nanaimo		NA	NA	0.635	NA	NA
Fraser Late	Harrison	75,100	46,094	No	0.258	0.235	Yes
Fraser Early (Spring & Summers)	Upper Fraser, Mid Fraser, Thompson		NA	NA	0.635	NA	NA

[1] General obligation (0.635) or additional obligation (1991‑1996 ISBM rate average for the Party in whose waters the stock not meeting escapement goal originates), whichever is lower, for stocks listed in Annex 4, Chapter 3, Attachment IV.

[2] Annex 4, Chapter 3, Paragraph 8.

[3] NA = No data available.

3.2.3.2 U.S. ISBM Indices

Of the 15 U.S. ISBM indices that could be calculated from CWT data for 2017, 13 met the Treaty obligation (Table 3.10). Of the 15 stocks with ISBM indices, nine have PSC-agreed escapement goals that were met or exceeded, thus the general obligation did not apply under the Treaty. Three stocks have PSC-agreed escapement goals that were not met, Harrison, Nehalem and Siuslaw; thus, the general obligation of 0.600 applies and the Treaty obligation was not met for these 2 stocks. The Canadian Harrison River stock has a PSC-agreed escapement goal which was not met in 2017, but the ISBM index (0.285) was below the general obligation for this stock.

A considerable proportion of the recoveries in the U.S. fisheries for Puget Sound stocks as well as the Fraser Late stock, the only Canadian stock included in Attachment V corresponding to U.S. ISBM fisheries, have occurred in mark-selective fisheries in which only clipped hatchery-origin fish are retained. Hence, CWT-based ISBM indices for these stocks should be viewed as maximum estimates because unmarked (wild) fish cannot be legally retained.

One of the recommendations of the CTC's ISBM workgroup was that if late CWT data reporting issues are irresolvable for some U.S. ISBM fisheries, then estimation models should be developed and reviewed to enable the CTC to report the ISBM indices on time to use in the pre-season management process for the next season (CTC 2011). Reducing the 2-year time lag for CWT-based indices is highly desirable.

Table 3.10 Review of performance in the U.S. ISBM fisheries, 2017.

Stock Group	Escapement Indicator Stock	CTC Esc. Goal	2017 Escapement	Goal met?	Obligation[1]	2017 CWT Index	Treaty Obligation Met? [2]
Fraser Late	Harrison	75,100	29,799	No	0.600	0.285	Yes
Puget Sound Spring	Nooksack	NA[3]	NA	NA	0.600	0.422	Yes
	Skagit	NA	NA	NA	0.600	NA	NA
Puget Sound Natural Summer/ Falls	Skagit	NA	NA	NA	0.600	NA	NA
	Stillaguamish	NA	NA	NA	0.482	0.144	Yes
	Snohomish	NA	NA	NA	0.600	NA	NA
	Lake Washington	NA	NA	NA	0.600	NA	NA
	Green	NA	NA	NA	0.600	0.352	Yes
Washington Coastal Fall Naturals	Hoko	NA	NA	NA	0.600	NA	NA
	Grays Harbor	13,326	17,145	Yes	0.600	0.556	Yes
	Queets	2,500	2,721	Yes	0.412	0.758	Yes
	Hoh	1,200	1,405	Yes	0.600	1.164	Yes
	Quillayute	3,000	3,604	Yes	0.600	2.268	Yes
Columbia River Falls	Brights	40,000	120,582	Yes	0.600	1.819	Yes
	Deschutes	4,532	4,943	Yes	0.433	1.021	Yes
	Lewis	5,700	6,058	Yes	0.583	0.622	Yes
Columbia River Summers	Col. R. Summers	12,143	56,265	Yes	0.600	8.253	Yes
Far North Migrating Oregon Coastal Falls	Nehalem	6,989	6,473	No	0.600	2.134	No
	Siletz	2,944	7,364	Yes	0.600	2.656	Yes
	Siuslaw	12,925	10,957	No	0.600	2.559	No

[1] General obligation (0.600) or additional obligation (1991‑1996 ISBM rate average for the Party in whose waters the stock not meeting escapement goal originates), whichever is lower, for stocks listed in Annex 4, Chapter 3, Attachment V.
[2] Annex 4, Chapter 3, Paragraph 8.
[3] NA = No data available.

3.3 PARAGRAPH 13

Paragraph 13 of the 2009 Agreement describes a set of rules involving interactions between data, stocks, and fisheries, which must be met in order to require additional reductions to be taken in SEAK and NBC AABM fisheries, as well as in ISBM fisheries to contribute to the attainment of maximum sustainable yield or other agreed biologically based management objectives.

3.3.1 Paragraph 13(c) Analysis

The CTC provides an evaluation of the stocks listed in Attachments I–II (Table 3.11) for Paragraph 13(c), comparing agreed management objectives to observed values for 2017 and 2018. For SEAK and NBC, the stock groups in Attachment I and II are identical, and thus are combined in the AABM fishery column. Stocks with agreed management objectives listed in those attachments all have escapement-based management objectives. The CTC did not include an evaluation of the stock groups in Attachment III because of paragraph 13(g). Note that ISBM obligations for 2018 cannot be calculated for Oregon and Washington stocks due to the two-year delay in availability of required CWT data from most southern U.S. monitoring programs.

Table 3.11 Evaluation of criteria for consideration of additional management action in Southeast Alaska (SEAK) and Northern B.C. (NBC) aggregate abundance-based management (AABM) fisheries in regard to Paragraph 13(c) of Chapter 3 of the 2009 PST Agreement.

Stock Group	Stocks	Stocks with agreed objective	No. below threshold (2017 and 2018)	Stocks with a 2019 forecast	No. of 2019 forecasts below threshold	Paragraph 13(c)(ii) qualified
Northern/Central British Columbia	3	0	NA[1]	0	NA	No
Upper Strait of Georgia	5	0	NA	0	NA	No
West Coast Vancouver Island Falls	7	0	NA	0	NA	No
Far North Migrating Oregon Coastal Falls	3	3	1	3	1	No
Columbia River Falls	3	3	0	2	0	No
Columbia River Summers	1	1	0	1	0	No
Washington Coastal Fall Naturals	5	4	0	4	0	No
Fraser Early (Spring and Summers)	3	0	NA	0	NA	No

[1] Not available due to an insufficient number of stocks with agreed escapement objectives, or forecasts were not provided.

The management objectives for stock groups in Attachments I–II were within 85% of the escapement goals in 2017 and in 2018, with the exception of Siuslaw River in the Oregon Coastal Falls which was 35% of its escapement goal in 2018. In January 2013, the CTC advised the Chinook Interface Group that annual escapement forecasts are not practical for use in implementing Paragraph 13(c) because reliable escapement forecasts were not available for 21 out of 30 stocks at that time. Currently, forecasts are not available for 19 of the 30 stocks. Of the forecasts that were available, only one (Siuslaw) was below its threshold escapement level.

3.3.2 Paragraph 13 (d) and (e) Evaluation

An evaluation of ISBM performance under paragraphs 13(d) and 13(e) was first conducted by the CTC and reported in TCCHINOOK (11)–4 (CTC 2011). Paragraph 13(d) describes a situation when a stock can be identified as meeting the criteria to trigger additional management action, even if escapement exceeded the threshold, whereas Paragraph 13(e) describes a situation when a stock can be excluded from triggering additional management action, even when escapement is below the threshold (Figure 3.9). Paragraph 13(d) is evaluated only for the jurisdiction in which the stock originates. Paragraph 13(e) prevents a stock from being incorrectly identified as having not achieved its escapement-based management objective because a jurisdiction's ISBM fisheries exceeded the general obligation. The evaluation demonstrated that paragraphs 13(d) and 13(e) can be quantitatively evaluated using a common method since both require estimation of the spawning escapement that would have occurred if a jurisdiction's ISBM fishery impact was the same as the general obligation level.

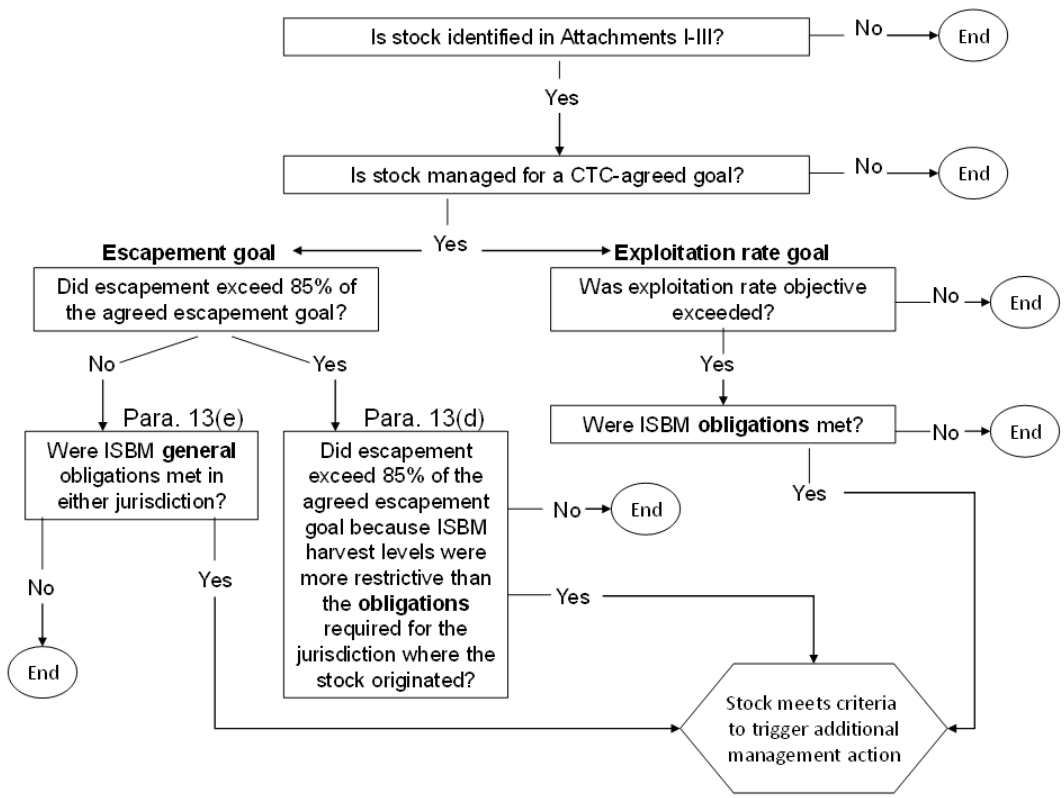


Figure 3.9 Diagram outlining the steps involved in a single-year evaluation of Paragraph 13(d) and 13(e) provisions in the 2009 Agreement pertaining to criteria for adjustment of individual stock-based management (ISBM) fisheries.

Accordingly, in 2012 the CTC developed a computer program (Paragraph13Evaluation.exe) to evaluate these provisions. The program uses CWT-based AEQ total mortality, external terminal harvest rates, CTC-agreed escapement goals, and age-specific escapement if available (if not, it derives average age-specific escapement from CWT recoveries). After computing average exploitation rates for the two base periods, 1979–1982 (i.e., general obligation, required for either jurisdiction) and 1991–1996 (i.e., additional obligation, required for the jurisdiction where the stock originated if it is more restrictive than the general obligation), the program estimates escapement that may have occurred if fishing were at the applicable obligation level. It provides detailed quantitative output for each stock and year and a summary for all stocks with CTC-agreed goals showing whether stocks were flagged under 13(d) or 13(e) and whether additional management action was needed. Equations and methods are described in detail in TCCHINOOK (11)–4 (CTC 2011). This program will enable the CTC to fulfill, if needed, Paragraph 13(f). However, the availability of the data needed for this analysis in February for the current management year remains an issue. The data needed for the program has three main limitations. First, the program can only perform post-season evaluations since it requires CWT data. Second, only six of the 12 stock groups can be evaluated on the basis of CTC-agreed escapement goals. Third, even when escapement data are available, the necessary AEQ total mortality data can be more than two years out of date, which prevents implementing Paragraph 13. For example, the evaluation for Paragraph 13(d) and (e) in this report will cover four of the eight stock groups in Attachments I–II (North Oregon Coastal Falls, Washington Coastal Fall Naturals, Columbia River Summers, and Columbia River Falls) through 2017 or 2018. Management entities have not presented escapement goals meeting CTC-agreed data standards for the other stock groups (Upper Strait of Georgia, WCVI, NBC, and Fraser Early).

The evaluations of Paragraph 13(d) and (e) are shown in Table 3.12. This evaluation found that none of the indicator stocks or stock groups met the conditions requiring additional management actions. The evaluation for all four stock groups (North Oregon Coastal Falls, Columbia River Summers, Columbia River Falls, and Washington Coastal Falls) showed that annual evaluations were based on 13(d) because escapements all exceeded 85% of the corresponding escapement goals except Siuslaw River in 2018. Since paragraph 13(c) only applies when the majority of indicator stocks withing a stock group do not achieve their management objectives, none of the stock groups were flagged.

3.3.3 Other Considerations

The 2009 Agreement directed the CTC to provide a review of Attachments I–V by 2014 or earlier, to determine if the current lists of stock groups continue to be appropriate, if there are new criteria that could be employed to revise stock group listings for each Attachment, and whether any changes to the Attachments proposed by a Party may be appropriate. This task never occured due to competing priorities, plus budget and personnel limitations.

Table 3.12 Evaluation of paragraphs 13(d) and 13(e) provisions for stock groups and indicator stocks listed in Attachments I and II of the 2009 Agreement. The last column shows if criteria were met for additional management actions (AMA) based on the evaluation for the last two years with data.

Stock Group	Indicator Stock	CTC Goal	13(d) or 13(e)	2016	2017	2018	AMA (last 2 years)
North Oregon Coastal Falls							No
	Nehalem	Yes	>85% Goal & 13(d)	No	No	No	
			<85% Goal & 13(e)	NA	NA	NA	
	Siletz	Yes	>85% Goal & 13(d)	No	No	No	
			<85% Goal & 13(e)	NA	NA	NA	
	Siuslaw	Yes	>85% Goal & 13(d)	No	No	No	
			<85% Goal & 13(e)	NA	NA	NA	
Columbia River Summers							No
	Mid-Col	Yes	>85% Goal & 13(d)	No	No	No	
			<85% Goal & 13(e)	NA	NA	NA	
Columbia River Falls							No
	Up River Brights	Yes	>85% Goal & 13(d	No	No	No	
			<85% Goal & 13(e)	NA	NA	NA	
	Deschutes	Yes	>85% Goal & 13(d	No	No	No	
			<85% Goal & 13(e)	NA	NA	NA	
	Lewis	Yes	>85% Goal & 13(d	No	No	ND	
			<85% Goal & 13(e)	NA	NA	ND	
Washington Coastal Falls [2,3]							No
	Hoko	No		ND	ND	ND	
	Grays Harbor	Yes	>85% Goal & 13(d	No	No	ND	
			<85% Goal & 13(e)	NA	NA	NA	
	Queets	Yes	>85% Goal & 13(d	No	No	ND	
			<85% Goal & 13(e)	NA	NA	NA	
	Quillayute	Yes	>85% Goal & 13(d	No	No	ND	
			<85% Goal & 13(e)	NA	NA	NA	
	Hoh	Yes	>85% Goal & 13(d	No	No	ND	
			<85% Goal & 13(e)	NA	NA	NA	

NA = Not available. ND = No data available.

3.4 Model Validation and Improvement

The changes in AIs between pre- and post-season calibrations from 2012 to 2016 that are noted in Section 3.2.2 are among the largest observed, equating to a large change (greater than 20% difference) in allowable catch across the three AABM fisheries (Table 3.4; Figure 3.4). 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. The reliability of model outputs, including AI predictions, is dependent on a number of factors including model parameters (e.g., base period exploitation rates); model structure (e.g., spatio-temporal fishery strata); and/or the annual CWT, catch, and run-size inputs (forecast or post-season estimates) used for calibration. In the following section, we report on annual comparisons of fishery indices based on model-generated data and CWT estimates and pre-season (forecast) versus post-season run sizes. Lastly, we briefly review ongoing, related model improvement activities.

3.4.1 Evaluation of Fishery Indices

Fishery mortality indices (FI) calculated from model-generated data for all model stocks can be compared to values generated from the estimates of catches or total mortality of CWT exploitation rate indicator stocks. Model and CWT-based FIs use the same equation however CWT empirical estimates are considered more accurate. Fishery indices can be constructed as a ROM or as a SPFI (CTC 2009). Results from the Harvest Rate Index Analysis in 2009 (CTC 2009) indicated that the SPFI was unbiased and the most accurate estimator for most fisheries, 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. Consequently, a SPFI was developed for the WCVI and NBC 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 make implementation of these FIs in the Model problematic. Therefore, in 2019, the CTC decided that ROMs were more appropriate FIs for the WCVI and NBC troll fisheries. Comparisons among the SPFI, the currently implemented CWT-based ROM FI, and the model data-based FI are provided in this section.

The SEAK troll FI based on model data closely follows the trend of the CWT-derived estimate from 1979 through 1989 for both landed catch and total mortality (Figure 3.10 and Figure 3.11). Between 1990 and 2000, the model estimates of both the landed catch and total FIs were less than the CWT-derived estimate for most years. However, since 2001, the model estimates have typically been higher. Since 1990, the model estimates also show less year-to-year variability than the CWT-derived indices.

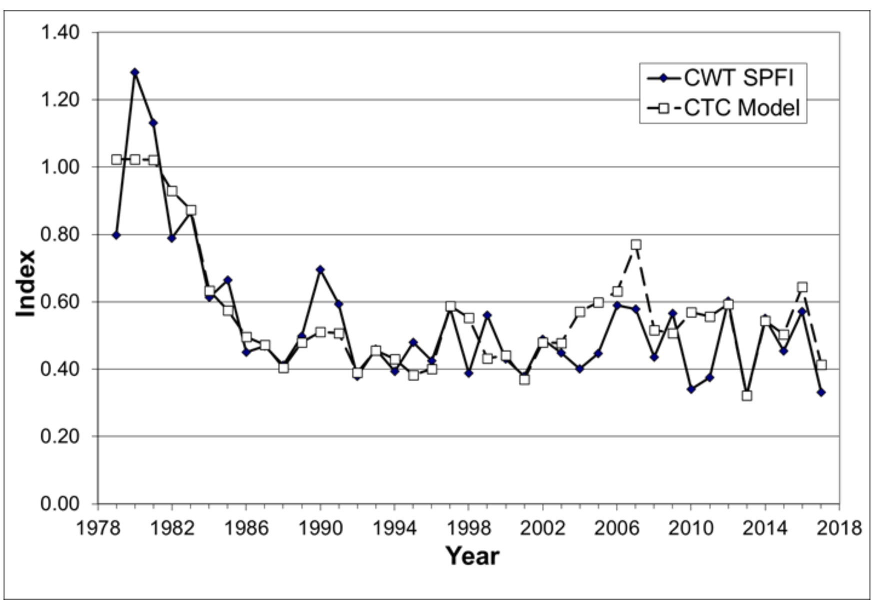


Figure 3.10 Estimated coded wire tag (CWT)-based stratified proportional fishery index (SPFI) and model landed catch fishery indices for the Southeast Alaska (SEAK) troll fishery through 2017.

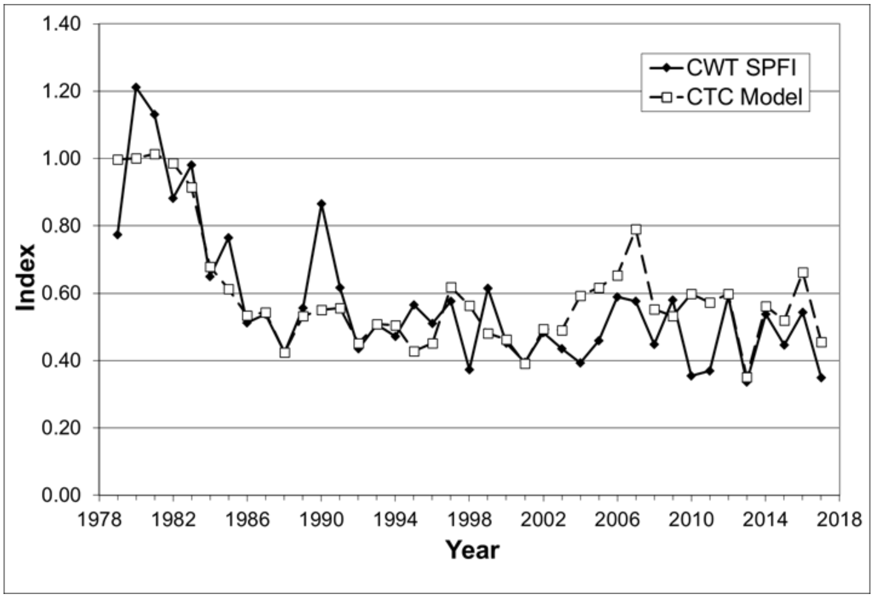


Figure 3.11 Estimated coded wire tag (CWT)-based stratified proportional fishery index (SPFI) and model total mortality fishery indices for the Southeast Alaska (SEAK) troll fishery through 2017.

The model-derived fishery mortality indices for NBC troll generally follow the same trend as the CWT-derived ROM FIs (Figure 3.12 and Figure 3.13). Since 1991, however, the model-based FIs exceeded the CWT-derived estimates in all but four years for both landed catch and total mortality indices. Differences between the two indices (CWT and model-based FIs) has been consistently greater since 2003 compared to preceding years. The SPFI has followed the same general pattern displayed by the other two FIs but has been lower in magnitude and the year-to-year fluctuations have been smaller in most years throughout the time series.

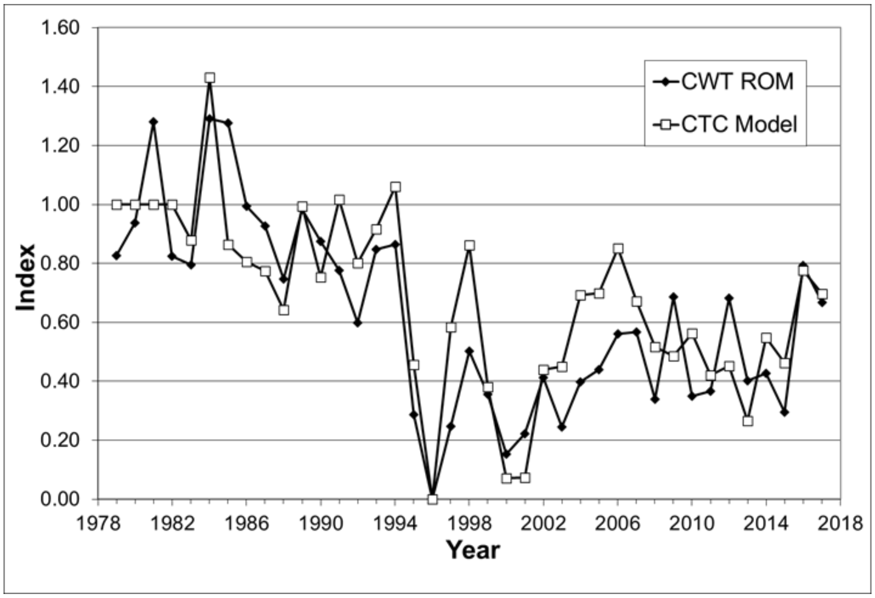


Figure 3.12 Estimated coded wire tag (CWT) ratio of means (ROM) and model landed catch fishery indices for the Northern B.C. (NBC) troll fishery through 2017.

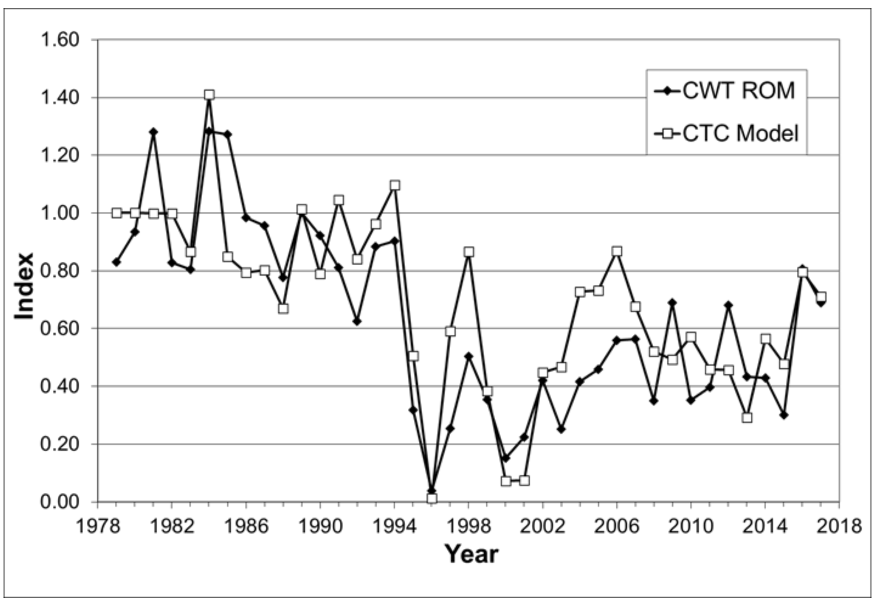


Figure 3.13 Estimated coded wire tag (CWT) ratio of means (ROM) and model total mortality fishery indices for the Northern B.C. (NBC) troll fishery through 2017.

For the WCVI troll fishery, correspondence between the model-derived FI and the CWT-based ROM FI was reasonably close from the start of the time series (1979) to the mid-1990s for both landed catch (Figure 3.14) and total mortality (Figure 3.15). Starting around 2000, model data-based and CWT-based ROM FIs diverged noticeably, with the CWT 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). Although the SPFI is considered to be a better approach for incorporating temporal and spatial changes in fishery catch patterns, between-year fluctuations have been much greater at times with the SPFI calculated for the WCVI troll fishery. Since about 2000, after the fishery management changes took place, the SPFI has tended to correspond more closely with the model data-based FI compared to the CWT-based FI (Figure 3.14 and Figure 3.15).

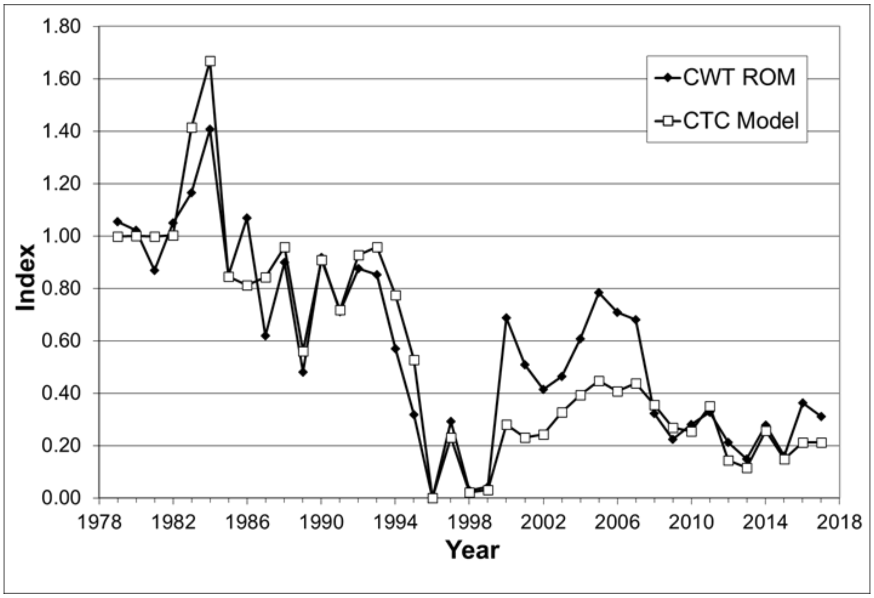


Figure 3.14 Estimated coded wire tag (CWT) ratio of means (ROM) and model landed catch fishery indices for the West Coast Vancouver Island (WCVI) troll fishery through 2017.

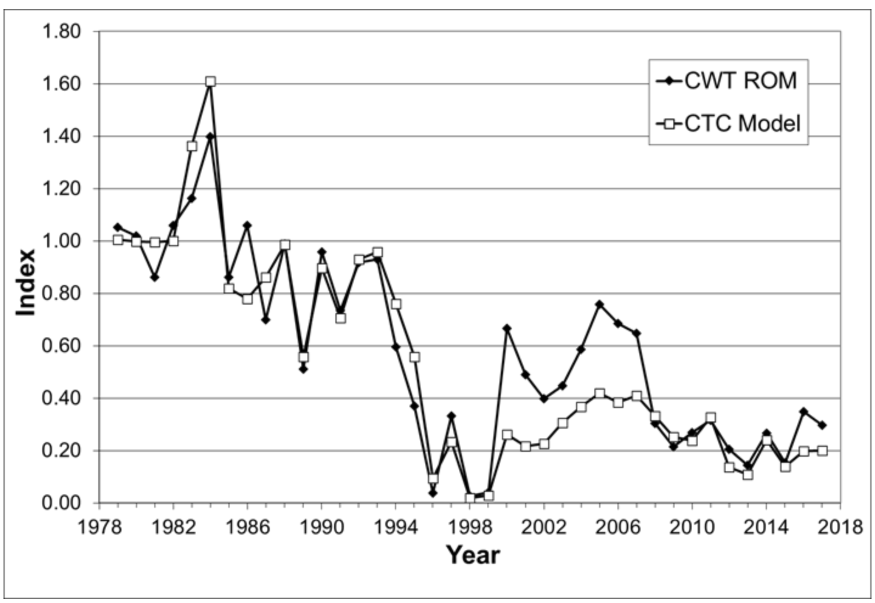


Figure 3.15 Estimated coded wire tag (CWT) ratio of means (ROM) and model total mortality fishery indices for the West Coast Vancouver Island (WCVI) troll fishery through 2017.

3.4.2 Stock Forecasts used in the PSC Coastwide Chinook Model

A major factor influencing the ability of the model to predict Chinook salmon abundance in AABM fisheries is the ability of the model to predict the returns of Chinook salmon (in terms of ocean escapement or spawning escapement) in the forecast year. During model calibration, agency forecasts are input to the model for all model stocks with available forecasts. Thus, for model stocks with external forecasts, the variation between model forecasts and actual returns can be broken into two parts: the ability of the model to match the agency forecasts used as inputs to the model, and the ability of the agency forecasts to accurately predict the actual return of Chinook salmon in the upcoming year.

A summary of model-produced and agency-produced forecasts for 1999–2018 is shown in Figure 3.16 and Appendix J. The relationship between the model indicator stocks, exploitation rate indicator stocks, and PST Annex stocks is shown in Appendix A. In the Appendix J tables, the column labeled *Model Fcst/Agency Fcst* shows the ratio of the model prediction and the agency forecast as a percentage. The column labeled *Agency Fcst/Post-season* shows the ratio of the agency forecast and the actual return as a percentage. The column labeled *Model Fcst/Post-season* shows the ratio of the return predicted by the model and the actual return as a percentage. A value of 100% would indicate that the predicted and actual values were the same.

Overall, the model forecasts are similar to the agency forecasts. This result is strongly influenced by the incorporation of the agency forecasts into the model calibration procedure. The average percent error by which model forecasts differ from agency forecasts is -2.4%, meaning that, on average, the agency forecasts were close to but slightly lower than the model forecasts. Relative to actual returns, both the agency and model forecasts were, on average, greater, with mean percent error of -7.0% and -6.8%, respectively.

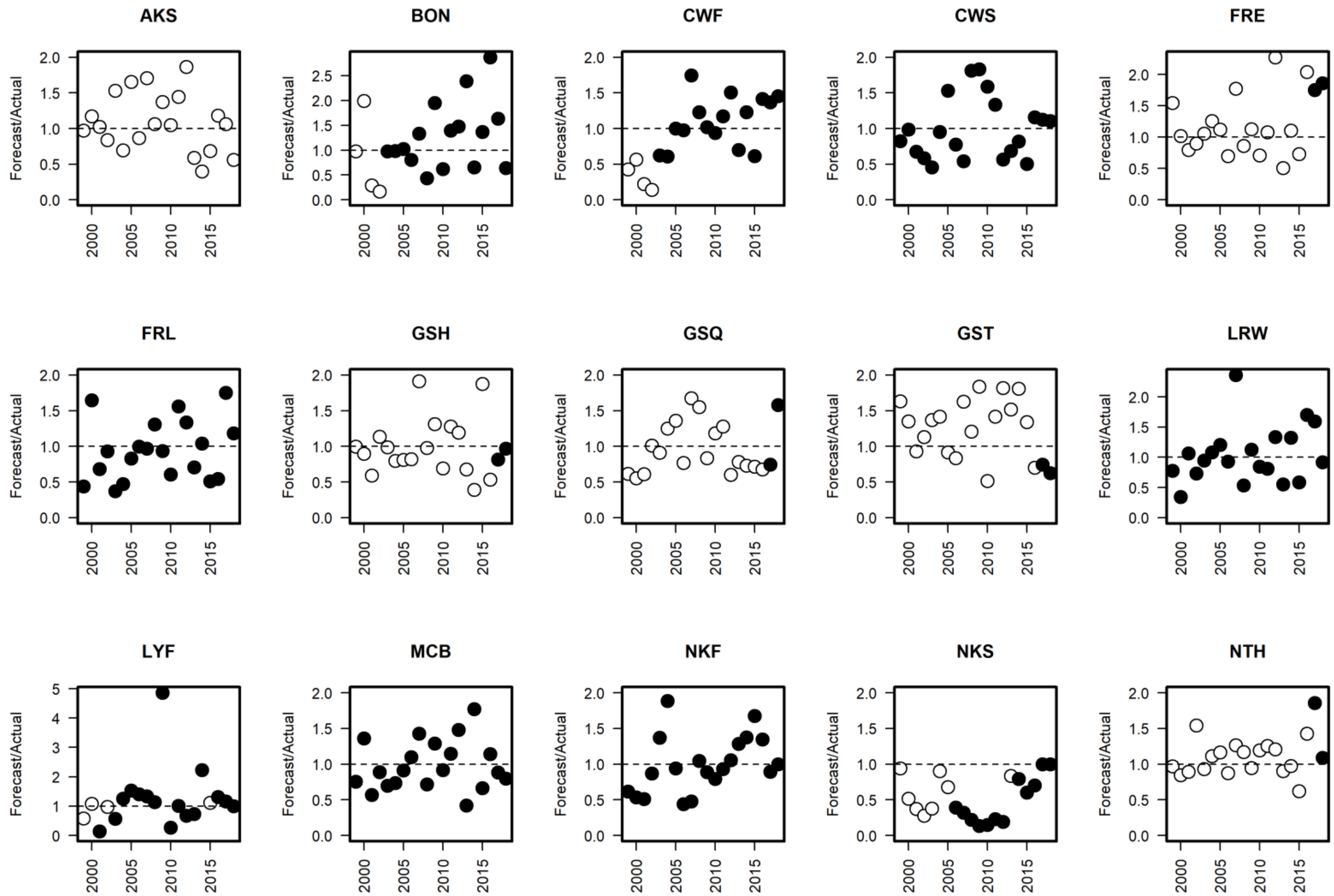


Figure 3.16 Forecast performance (forecast/actual) plots for Pacific Salmon Commission (PSC) Chinook Model stocks.

Note: Solid black circles correspond to years when calibrations were based on agency forecasts and unfilled (white) circles correspond to years when model-generated forecasts were used. Stock abbreviations follow those defined in Appendix J.

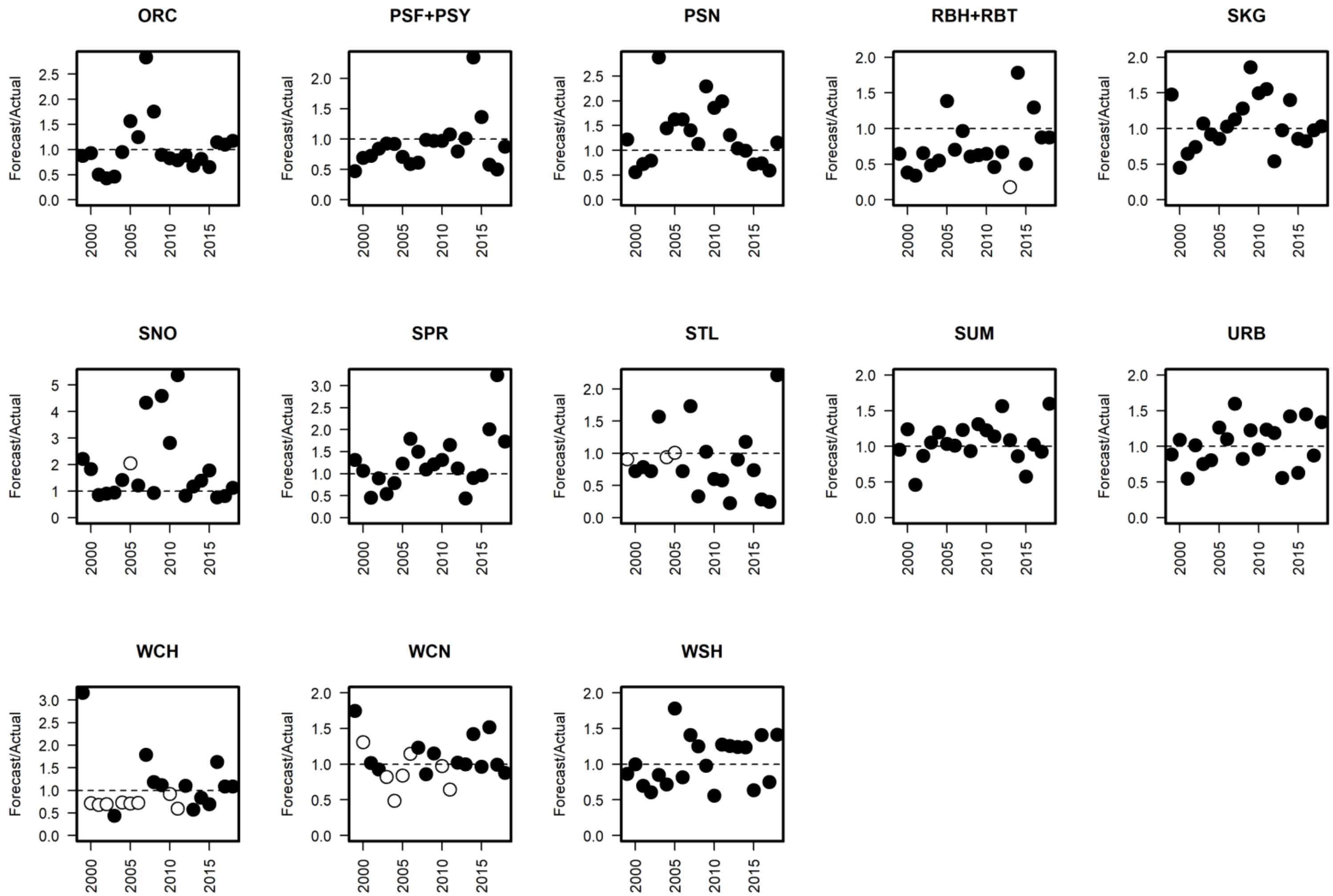


Figure 3.16 Page 2 of 2.

In the 2019 calibration of the PSC Coastwide Chinook Model, the aggregate abundance for 2018 was over-forecasted for SEAK and NBC and close to forecast for WCVI. For all three AABM fisheries the 2018 post-season AI values decreased relative to the pre-season forecasted AIs. The decrease in WCVI (1%) was minimal compared to SEAK (14%) and NBC (12%) where it was more substantial (Table 3.3). This result can be largely attributed to the fact that the majority of agency-provided forecasts used as input to the calibration procedure were higher than the actual return (Appendix J). Only one stock (AKS) lacked an agency forecast and used the forecast generated by the PSC Chinook Model, which was lower than the actual return (Figure 3.17).

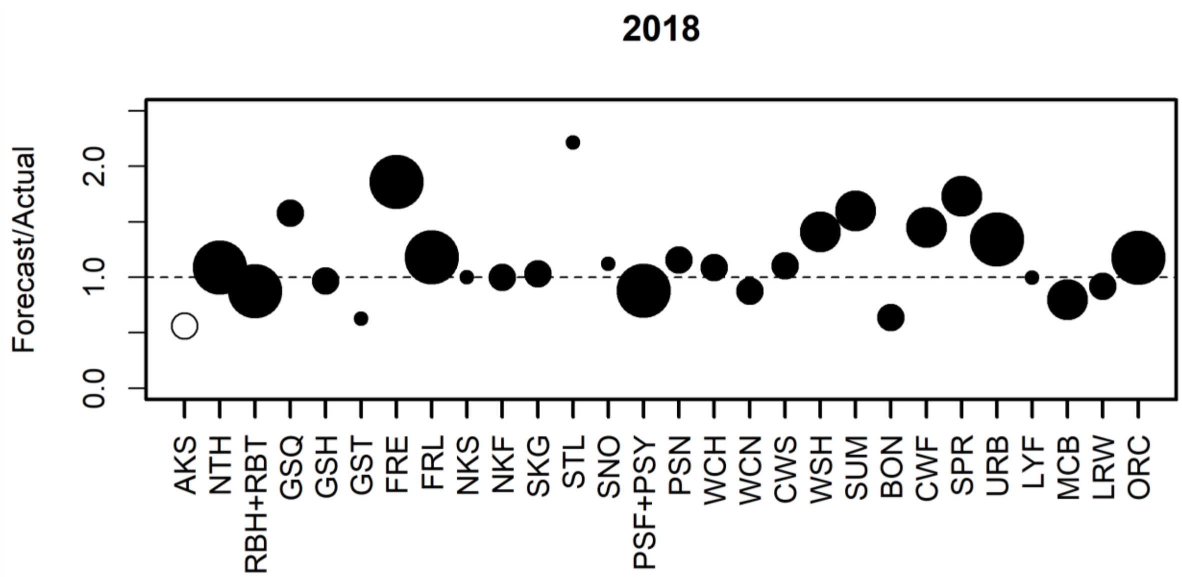


Figure 3.17 Ratio of the 2018 forecast to the actual return for stocks represented in the Pacific Salmon Commission (PSC) Chinook Model.

Note: Points lying above the dashed horizontal line returned lower than forecast; points lying below the dashed horizontal line returned greater than forecast. Filled (black) circles correspond to stocks with agency-supplied forecasts; unfilled (white) circles correspond to stocks with forecasts generated by the PSC Chinook Model. The 4 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 codes in Appendix J.

4. CWT ANALYSIS AND MARK-SELECTIVE FISHERIES

Chinook salmon released from Puget Sound hatcheries and spring-run hatchery Chinook salmon in the Columbia River have been mass marked (MM) since BY 1998. Mass marking of Columbia River fall Chinook salmon started with BY 2005, and for BY 2009 onwards most of the Chinook salmon production intended for harvest released in Washington and Oregon has been mass marked (SFEC 2009). Mark-selective fisheries have been in place in Puget Sound (including U.S. Strait of Juan de Fuca) since 2003, on the Columbia River since 2001, in some terminal fishing areas along the Oregon and Washington coast since 2008, and in B.C. Strait of Juan de Fuca since 2008. Additionally, small mark-selective Chinook salmon fisheries occurred in the ocean sport fishery off the Washington Coast (Areas 1–4) between 2010 and 2015 and in the Alaska troll fishery (during periods that would have otherwise been non-retention) during 2016 and 2017.

4.1 CATCH IN MSFS

Regulations for MSFs allow for the retention of salmon missing an adipose fin (i.e., fish that are marked) and require the release of fish with an intact adipose fin (i.e., fish that are unmarked). As a consequence, exploitation rates from MSFs are different between marked and unmarked Chinook salmon. CWT analysis based on recoveries of marked and tagged Chinook salmon will only reflect the exploitation on the marked fish. Because unmarked fish are not retained, and their CWTs not recovered, the exploitation rate of this group must be inferred using other analytical techniques. One method of estimating exploitation rates on unmarked fish is to express it as a function of the release mortality (RM) rate and encounter events in an MSF. The magnitude of the difference in exploitation rates between marked and unmarked in a stock depends on the number of encounters of the stock in MSFs compared to non-selective fisheries (NSF). As more encounters occur in MSFs than nonselective fisheries, CWT analysis of marked Chinook salmon recoveries will likely overestimate the exploitation rate on the unmarked group. Subsequently, the assumption that marked and tagged hatchery fish can properly represent the exploitation rate on associated natural stocks weakens with increased exposure to MSFs. Differences in return-to-escapement proportions between marked and unmarked components of a double index tag (DIT) release group can be tested for significance for stocks susceptible to MSFs.

The benefits of MSF regulations to reduce impacts on natural stocks as a conservation measure depend on the relative abundance of marked (though not necessarily tagged) fish available to the fishery. As mass marking of hatchery production increased in Washington and Oregon, so did the gradual implementation of MSFs. Beginning in 2010 and continuing through 2015, small-scale MSF fisheries for Chinook salmon on the Washington and Oregon coast (north of Cape Falcon, Oregon) occurred prior to the traditional summer period sport fishery. These 2-week sport MSFs north of Cape Falcon have started as early as May 30 and as late as June 18. From 2010–2015, landed catch was highest in 2012, with 7,382 hatchery Chinook salmon landed in Washington, and 290 landed in Oregon. Catch was lowest in 2015, with 1,135 hatchery Chinook salmon landed in Washington, and 36 landed in Oregon. In Washington, the number of released Chinook ranged from a low of 1,361 in 2015 to a high of 7,852 in 2012. In

Oregon, the number of released Chinook ranged from a low of 11 in 2015 to a high of 1,039 in 2011. No Washington or Oregon mark-selective Chinook fisheries have occurred north of Cape Falcon since 2015.

Puget Sound sport fisheries (including U.S. Strait of Juan de Fuca) began implementing MSF regulations in 2003. Since then the landed catch under MSF regulations has increased to equal nearly all the total landed catch in Puget Sound marine sport fisheries and a majority in freshwater fisheries (Figure 4.1). Implementation of MSF regulations began in 2001 on the Columbia River. Landed catch in sport fisheries during the spring run migration period are now almost entirely under MSF regulations, with a lower proportion during the summer and fall (Figure 4.2). In 2012, the first fall period MSF occurred in the mainstem Columbia River sport fishery, although MSFs occurred in the tributaries prior to 2012. MSFs have gradually increased during the summer/fall fisheries on the Columbia River, though the majority of the catches still occur under non-selective regulations.

In Oregon, an MSF occurs within the 15-fathom curve of Tillamook Bay from March until August. The sport MSF in this area began in 2006 and the commercial MSF began in 2011. An additional sport MSF for fall Chinook occurred in September and October during 2008–2011. At time of landing, catch from both the mark-selective “Tillamook bubble” fishery and the nonselective fishery outside of the bubble is mixed. Therefore, although numbers of landed catch and released Chinook are recorded, they cannot be assigned specifically to the individual MSFs occurring within the bubble.

In Canada, the Strait of Juan de Fuca MSF for recreationally caught Chinook has occurred from about the beginning of March to about mid-summer since 2008. These management measures were implemented for the protection of early-returning Fraser Chinook. In 2018, the MSF opening from March 8 to May 31 allowed retention of marked Chinook only above 67 cm (nose-to-fork length) in subareas 19-1 to 19-4; and, in subareas 20-4 to 20-7 (those waters near Victoria between Cadboro Point to Sombrio Point, southern Vancouver Island). Between 45-67 cm, both marked and unmarked fish could be retained. These same regulations remained in effect from June 1 – 28 with the exception that subarea 20-4 and that portion of 20-5 of 123 degrees 49.30 minutes west longitude (Otter Point) were closed to fishing for finfish. From June 29 to July 31, the size limit above which only marked fish could be retained was increased to 85 cm. During these periods 5,714 marked Chinook were retained, as well as 3,869 unmarked Chinook.

Alaska held its first experimental Chinook MSF in a coho-directed troll fishery from September 4–30, 2016. During this fishery, 457 marked Chinook salmon were retained. In 2017, Alaska conducted a second experimental MSF from July 5–21, also occurring during a coho-directed troll fishery. In 2017, 2,680 marked Chinook salmon were retained.

As an alternative to traditional MSFs, agencies have implemented “mixed” bag limit regulations whereby different proportions of marked to unmarked fish are allowed in the landed catch. In the most common configuration, mixed bag limits allow no more than 1 unmarked fish to be retained as part of the total bag limit. Since 2006, MSFs or variations of MSFs, have occurred in some terminal fishing areas along the Oregon and Washington coasts and in the B.C. portion of the Strait of Juan de Fuca. In 2011 and 2013, sport fisheries in the upper Columbia River for summer Chinook salmon were implemented under mixed-bag limit regulations. In recent years, Canada has implemented a variation of a mixed bag limit in the marine areas around the southern tip of Vancouver Island by allowing only hatchery fish (i.e., marked fish) to be retained above a certain total length measurement. The benefits of reduced exploitation on natural stocks is usually minor for mixed bag limit fisheries but mixed bag limits do allow for additional retention of hatchery origin fish.

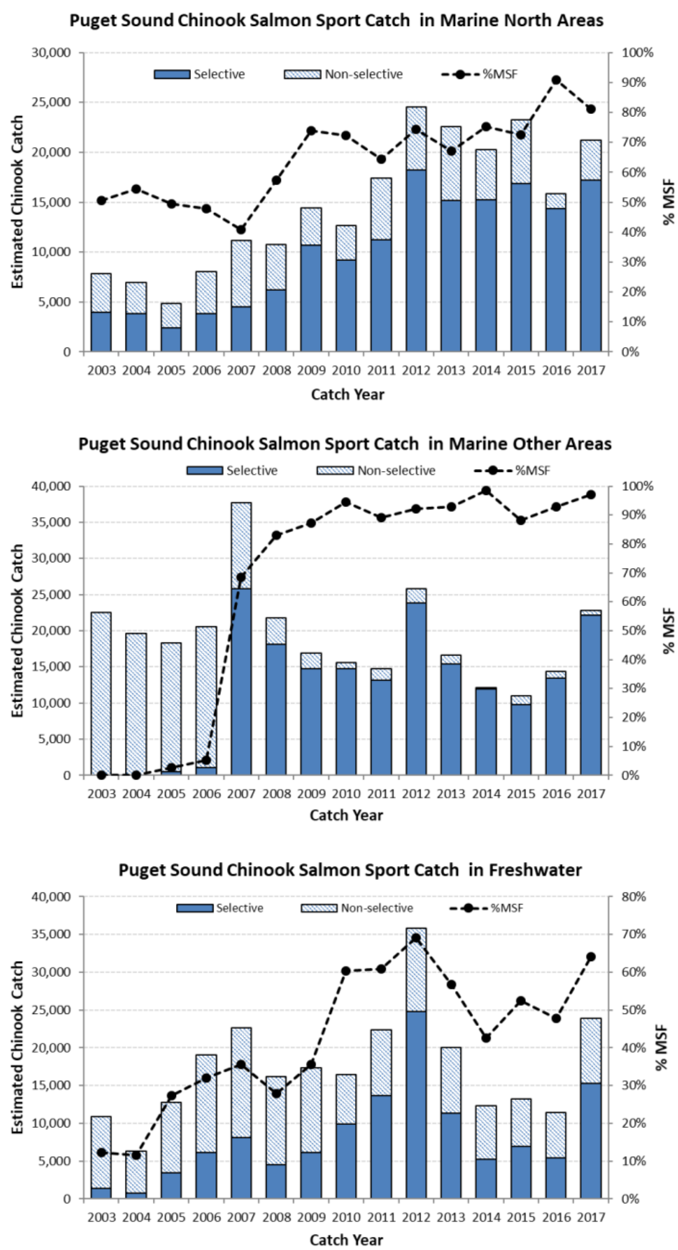


Figure 4.1. Estimated total number of Chinook salmon landed in mark-selective and non-selective fisheries (left y-axis) and percent of catch in mark-selective fisheries (MSFs) (right y-axis) in Puget Sound for catch years 2003–2017.

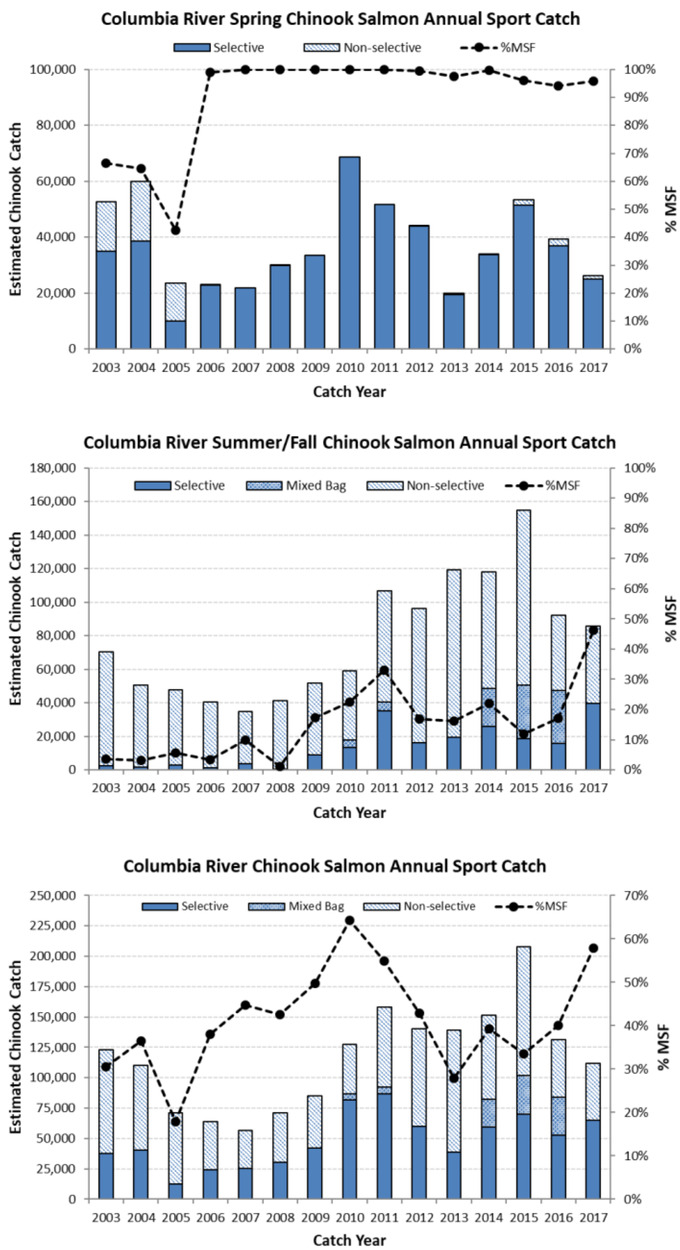


Figure 4.2. Estimated total catch (left y-axis) in Columbia River mark-selective and nonselective sport fisheries and catches during spring (May–Jun) and summer-fall (Jul–Dec) seasons and percent of catch in mark-selective fisheries (MSFs) (right y-axis) for catch years 2003–2017.

4.2 Methods to estimate the impact of MSFs on unmarked Chinook salmon stocks

The magnitude of impact of an MSF relative to the total exploitation of a stock can be measured using the percentage of the total landed catch in net, sport, and troll fisheries of tagged and marked PSC indicator stocks that occurs in MSFs. Percentages were calculated for the PSC indicator stocks (Table 4.1) by summarizing CWT recovery records obtained through a query of the Regional Mark Information System (RMIS) database according to three code values present in the adclip_selective_fishery data field – "N" for recoveries caught under non-selective fishery regulations, "S" for recoveries caught under MSF regulations, and "M" for recoveries caught under mixed-bag regulations. Figure 4.3 shows that, for stocks originating in Puget Sound, the proportion of marked harvest in MSFs for regional groupings of CWT indicator stocks increased from 2003 to 2012, then made a moderate decline. Use of the adclip_selective_fishery recovery field was the only feasible means of calculating the percentages, however, the accuracy of this field likely varies regionally. For example, CWT recoveries from the B.C. Juan de Fuca sport fishery have all been assigned the code "N" (for non-selective) regardless of whether MSF or mixed-bag regulations were in effect when and where individual recoveries were obtained. Thus, for stocks intercepted in the B.C. Juan de Fuca sport fishery, the percentages presented in Table 4.1 and Figure 4.3 are likely biased low.

4.2.1 Double Index Tag methods

PSC indicator stocks that have been double index tagged may be used to evaluate the impact of MSFs on the unmarked stocks represented by the unmarked tag group in a DIT pair[3]. A comparison of the unmarked-to-marked ratio, referred to as lambda (λ), at release and at escapement can be used in a test of the null hypothesis that there is no difference in proportional return of marked and unmarked groups. A positive test statistic occurs when a statistically higher proportion of unmarked fish return to hatchery escapement; this is consistent with the larger harvest of marked fish compared to unmarked fish through MSFs. A negative test statistic occurs when an equal or higher proportion of marked fish return, which could be indicative of sampling problems in the hatchery (i.e., the sampling procedure fails to detect all CWTs from unmarked fish present in the sample), or incorrect assumptions about release mortality rates, multiple encounters, or mark recognition errors. This is a concern when patterns occur over many BYs for a stock or hatchery. If stock-specific MSF impacts are small, then random variation in the CWT sampling procedures or simply random variability in processes, like survival, could result in both positive and negative test statistics in a random pattern across broods.

[3] A DIT group consists of at least 2 tag groups, 1 with the mass mark (or adipose fin clip) and 1 without the mark. These 2 tag groups are treated identically except for the mark, and differences in mortality should be due to the MSFs—assuming there is no mark mortality occurring prior to recruitment to the fisheries.

Table 4.1 Estimated landed catch of tagged and marked Pacific Salmon Commission (PSC) Chinook indicator stocks in B.C., Washington, and Oregon, in all net, troll, and sport fisheries for catch years 2009–2017 and the percent of the total tagged and marked catch landed in MSFs.
Note: percentages are based off the regional mark information system (RMIS) 'adclip_selective_fishery' field and do not include recoveries in mixed-bag fisheries.

REGION	STOCK	2009		2010		2011		2012		2013		2014		2015		2016		2017	
Southeast Alaska	AK Hatcheries	2,820	0%	2,031	0%	2,283	0%	2,304	0%	2,943	0%	2,529	0%	3,485	0%	2,439	0%	2,562	5%
	Chilkat	31	0%	61	0%	63	0%	41	0%	17	0%	36	0%	42	0%	3	0%	10	0%
	Stikine	58	0%	43	0%	73	0%	82	0%	45	0%	65	0%	46	0%	33	0%	51	0%
	Taku	73	0%	18	0%	39	0%	28	0%	20	0%	16	0%	51	0%	17	0%	19	0%
	Unuk	79	0%	90	0%	79	0%	80	0%	61	0%	67	0%	69	0%	64	0%	17	0%
SOUTHEAST ALASKA Total		**3,062**	**0%**	**2,243**	**0%**	**2,536**	**0%**	**2,536**	**0%**	**3,086**	**0%**	**2,714**	**0%**	**3,692**	**0%**	**2,555**	**0%**	**2,658**	**4%**
British Columbia	Atnarko Spring	0	0%	1	0%	42	0%	411	0%	666	0%	502	0%	466	0%	156	0%	17	0%
	Atnarko Summer	330	0%	238	0%	323	0%	312	0%	746	0%	1,006	0%	2,004	0%	1,303	0%	737	2%
	Big Qualicum	163	2%	156	0%	130	0%	211	2%	214	2%	844	1%	591	0%	504	2%	148	0%
	Chilliwack (Harrison Fall Stock)	689	4%	1,469	6%	1,003	9%	1,256	12%	3,675	7%	2,816	5%	1,572	4%	1,385	1%	1,767	2%
	Cowichan Fall	280	0%	476	3%	766	7%	1,551	5%	1,456	5%	1,400	3%	542	2%	864	4%	1,049	5%
	Nicola River Spring	88	4%	200	4%	98	0%	215	0%	158	0%	25	0%	248	0%	226	0%	139	0%
	Puntledge Summer	116	0%	129	0%	99	0%	64	0%	66	0%	131	0%	82	7%	127	0%	155	0%
	Quinsam Fall	140	0%	201	0%	309	0%	266	0%	164	0%	116	0%	395	0%	941	0%	984	0%
	Robertson Creek	800	0%	342	0%	1,513	0%	1,113	0%	412	0%	794	1%	1,555	0%	2,569	0%	3,901	0%
	Lower Shuswap River Summers	724	0%	862	0%	746	1%	695	2%	2,543	1%	1,917	1%	1,465	1%	752	1%	1,145	5%
	Chehalis (Harrison Fall Stock)	280	8%	442	7%	591	6%	321	12%	646	13%	635	5%	358	3%	385	2%	727	4%
	Kitsumkalum Summer	174	0%	241	0%	186	0%	75	0%	65	0%	91	0%	163	0%	216	0%	119	3%
BRITISH COLUMBIA Total		**3,790**	**2%**	**4,757**	**3%**	**5,806**	**3%**	**6,489**	**4%**	**10,811**	**4%**	**10,276**	**2%**	**9,441**	**1%**	**9,427**	**1%**	**10,888**	**2%**
North Puget Sound	Nooksack Spring Fingerling	305	6%	410	5%	219	4%	250	8%	404	6%	748	7%	456	6%	470	2%	830	3%
	Samish Fall Fingerling	866	10%	1,191	9%	819	4%	1,425	6%	1,160	7%	988	12%	563	7%	439	7%	984	4%
	Skagit Spring Fingerling	457	34%	615	23%	556	29%	804	25%	551	5%	526	12%	264	18%	643	17%	964	10%
	Skagit Spring Yearling	257	31%	238	35%	374	48%	488	41%	247	12%	251	7%	30	34%	0	0%	0	0%
	Skagit Summer Fingerling	505	4%	220	1%	288	11%	101	3%	143	5%	187	6%	273	8%	403	7%	604	8%
	Skykomish Summer Fingerling	85	39%	76	26%	204	52%	448	13%	212	16%	115	34%	181	31%	490	26%	323	26%
	Stillaguamish Fall Fingerling	275	10%	355	12%	427	10%	214	15%	225	20%	589	26%	188	20%	237	14%	359	21%
NORTH PUGET SOUND Total		**2,752**	**15%**	**3,106**	**14%**	**2,888**	**20%**	**3,729**	**16%**	**2,940**	**8%**	**3,403**	**13%**	**1,955**	**12%**	**2,683**	**13%**	**4,064**	**9%**

-continued-

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REGION	STOCK	2009		2010		2011		2012		2013		2014		2015		2016		2017	
South Puget Sound	George Adams Fall Fingerling	523	23%	961	18%	1,136	33%	2,808	20%	1,054	24%	753	21%	1,073	17%	971	22%	1,615	15%
	Green River Fall Fingerling	643	10%	411	14%	748	17%	362	28%	209	28%	119	17%	238	26%	266	32%	802	22%
	Grovers Creek Fall Fingerling	560	22%	590	33%	379	32%	940	30%	615	25%	641	33%	564	25%	609	37%	613	27%
	Nisqually Fall Fingerling	866	12%	999	18%	588	29%	748	44%	894	23%	507	23%	363	18%	528	26%	1,692	19%
	S. Puget Sound Fall Yearling	115	58%	53	61%	225	49%	180	45%	31	44%	6	100%	4	0%	2	0%	0	0%
SOUTH PUGET SOUND Total		**2,707**	**18%**	**3,014**	**21%**	**3,076**	**29%**	**5,039**	**27%**	**2,804**	**24%**	**2,026**	**25%**	**2,242**	**20%**	**2,376**	**28%**	**4,722**	**19%**
Washington Coast	Hoko Fall Fingerling	84	5%	78	0%	209	4%	153	5%	175	19%	292	5%	301	14%	231	15%	275	6%
	Queets Fall Fingerling	941	0%	1,135	0%	1,460	0%	1,989	0%	1,135	0%	1,188	1%	907	0%	856	4%	344	4%
	Tsoo-Yess Fall Fingerling	163	0%	94	6%	281	2%	185	0%	78	3%	109	0%	265	14%	254	1%	81	13%
WASHINGTON COAST Total		**1,188**	**0%**	**1,307**	**0%**	**1,950**	**1%**	**2,326**	**0%**	**1,388**	**3%**	**1,588**	**1%**	**1,472**	**5%**	**1,341**	**5%**	**699**	**6%**
Columbia River	Columbia Lower River Hatchery	371	5%	1,417	3%	485	4%	822	7%	393	6%	2,020	4%	1,153	4%	289	4%	417	3%
	Columbia Summers	2,110	6%	3,340	5%	2,694	10%	3,219	10%	3,328	34%	5,597	35%	7,206	5%	6,412	17%	3,683	15%
	Cowlitz Fall Tule	128	5%	213	5%	126	2%	140	8%	110	10%	187	40%	154	25%	233	7%	190	12%
	Hanford Wild	202	0%	231	3%	317	0%	452	1%	892	1%	1,243	0%	945	2%	846	1%	462	14%
	Lewis River Wild	99	0%	54	7%	160	5%	128	0%	157	32%	114	1%	98	2%	63	0%	24	15%
	Lyons Ferry	542	12%	923	15%	752	13%	1,067	19%	1,320	18%	996	8%	809	3%	898	7%	589	7%
	Spring Creek Tule	1,417	5%	3,369	2%	1,951	2%	2,258	5%	2,384	4%	4,982	2%	6,863	1%	2,018	2%	2,737	1%
	Upriver Brights	737	1%	657	8%	1,698	0%	3,481	0%	9,730	1%	9,656	1%	6,283	2%	5,863	1%	3,049	10%
	Willamette Spring	1,428	51%	4,189	77%	3,893	82%	2,882	68%	2,314	76%	4,936	58%	7,234	57%	2,767	52%	1,468	41%
COLUMBIA RIVER Total		**7,034**	**15%**	**14,393**	**26%**	**12,077**	**30%**	**14,450**	**18%**	**20,628**	**17%**	**29,731**	**18%**	**30,745**	**16%**	**19,389**	**14%**	**12,620**	**13%**
Oregon Coast	Elk River	990	0%	1,223	0%	925	0%	1,257	1%	2,916	1%	2,096	0%	2,686	0%	2,432	1%	953	2%
	Salmon River	1,417	41%	2,445	0%	2,742	0%	2,321	0%	3,514	2%	4,581	0%	5,439	0%	4,281	0%	1,615	3%
OREGON COAST Total		**2,407**	**24%**	**3,667**	**0%**	**3,668**	**0%**	**3,578**	**1%**	**6,430**	**2%**	**6,677**	**0%**	**8,125**	**0%**	**6,713**	**1%**	**2,568**	**3%**

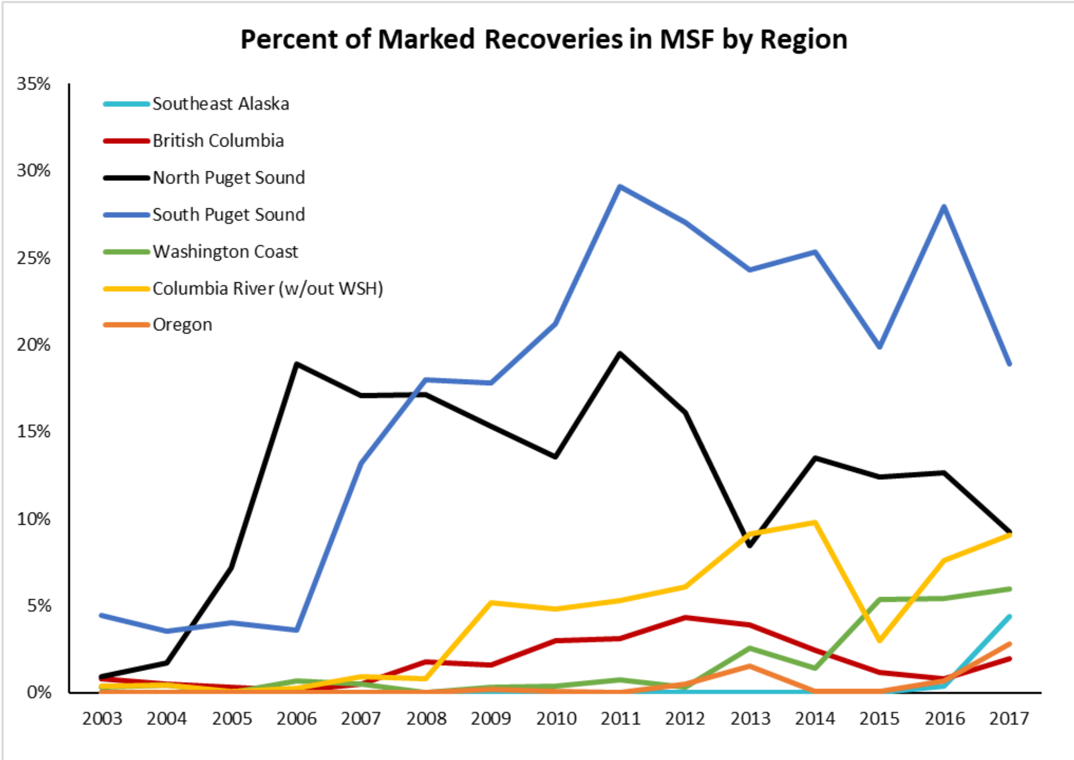

Figure 4.3. Percent of total fishery coded wire tag (CWT) recoveries in mark-selective fisheries (MSFs) for regional groupings of Chinook indicator stocks, 2003–2017.

Note: percentages are based off the regional mark information system (RMIS) 'adclip_selective_fishery' field and do not include recoveries in mixed-bag fisheries. The Columbia River group does not include the Willamette River Spring stock.

4.2.2 Single Index Tag Methods

Techniques to estimate reduced fishing impacts have largely involved DIT programs. However, this is a substantial issue for many of the stocks in B.C. or Alaska that do not currently have DIT programs, and for locations where DIT programs proved impractical (i.e., Chilliwack, Lower Shuswap, and Cowichan). Given these circumstances, an approach was developed in 2018 (CTC 2018) to estimate mortality distributions for natural stocks that have single index tag (SIT) indicator stocks under conditions where the MSF impacts mainly occur on mature SIT fish proximal to their terminal area. The method was applied to three SIT stocks from the Fraser River [Nicola (NIC), Lower Shuswap (SHU), and Middle Shuswap (MSH)].

The approach uses SIT CWT recoveries in MSFs to represent the number of unmarked pseudo-CWT fish encountered and released in the fishery and these pseudo-CWTs are multiplied by the survival rate (Survs,f = 1-RMs,f), where RM is the release mortality rate for legal-sized fish released in the fishery (e.g., 12.3% for ocean sport fisheries, Appendix F). The pseudo-CWT MSF survivors are subtracted from fishery-specific Total Mortality AEQ CWTs in the mortality distribution tables (MDT) and then added to the terminal run fisheries and escapement, since these are assumed to be mature fish that are encountered on their return migration:

$$MSF\ Survivors_{s,f,CY} = (CWT\ Recoveries_{s,f,CY} * Surv_f) \qquad \textit{Equation 4.1}$$

The estimated incidental CWT mortalities in these fisheries were not adjusted because those values represent the sum of release mortalities based on the minimum size limit and drop-off mortalities, and these impacts would be the same for marked and unmarked fish. After passage through the MSFs, the pseudo-CWT survivors were assumed to not be encountered in subsequent ocean fisheries and they were assumed to survive to the river mouth. Further analysis would be needed to represent additional mortalities due to multiple encounters in ocean fisheries. The pseudo-CWT survivors were then distributed to the terminal fisheries and escapement by using the proportions from the original MDTs, thus some of the pseudo-CWT survivors were harvested in terminal fisheries. Additional adjustments would be needed for any terminal MSFs, however all the Fraser River terminal fisheries were NSF from 2008–2017, and for the 2002 MSF at the mouth of the Nicola River, the pseudo-CWT survivors were added to the escapement.

The MSFs in marine waters of Southern B.C. and Washington have occurred mainly during the period when Fraser Spring and Summer stocks are returning to the Fraser River and there have been very few CWT recoveries outside of this timeframe (CTC 2018). In comparison, the Fraser fall stocks have been encountered throughout the year in these areas and there are more frequent CWT recoveries of age-2 and -3 fish (CTC 2018). The differences in the CWT recovery patterns by age indicate the MSFs in these areas encounter both immature and mature fish from the Fraser fall stocks, but mainly mature fish from the Fraser spring and summer stocks. Accordingly, this approach for SIT stocks was not appropriate for or applied to the fall stocks.

The MSF CWT recoveries were identified using a different approach for U.S. fisheries than Canadian fisheries because each country identifies MSF CWT recoveries differently in the RMIS and MRP databases. For U.S. fisheries, the RMIS *adclip_selective* field identified MSF CWT recoveries; however the Canadian MSF CWT recoveries cannot be identified correctly using this field. Thus for Canadian MSFs, the Fisheries and Oceans Canada (DFO) annual fishing plans and DFO Fishery Notices were reviewed to identify when and where MSF regulations were used. All Canadian ocean MSFs occurred in the Juan de Fuca (JDF) sport fishery (2008–2018), or in the Nicola River mouth sport MSF in 2002. For the Fraser spring and summer stocks, all U.S. MSF CWT recoveries occurred in sport fisheries either in Puget Sound or the North of Falcon areas.

For the Canadian JDF sport fishery, both MSF and NSF regulations were used for specific dates, fishery management subareas, and fish length categories; this necessitated the review of date, area, and fish length data for every JDF Sport CWT recovery with respect to the regulations described in the DFO Fishery Notices. Some JDF Sport recoveries had incomplete date, location, or fish length data. One recovery was within the time period and size range of the MSF, but the area recorded (Pacific fishery management area [PFMA] 20) omitted the subarea, and the MSF regulations occurred only in some subareas of PFMA 20. Two CWT recoveries were recorded in PFMA 20-7 (near Sooke, an area located west of Victoria, southern Vancouver Island), which was assumed to be part of the MSF area as described by points of land identifying the MSF regulation area in the Fishery Notice although 20-7 was not one of the subareas listed in the

Fishery Notice. Length was not recorded for 12 recoveries, four in 2017 and three in 2018, that were identifiable to the times and locations of the MSF regulations. Because these recoveries could not be accurately identified as caught in the MSF or NSF, the data analysis proceeded with two assumptions resulting in two MDTs. First all of the incomplete data recoveries were assumed to have been caught in the MSF. Second, all of these recoveries were assumed to be caught in the NSF. Reporting both sets of data provides a range of the MSF impacts and captures some of the uncertainty due to incomplete data recording. Among the CWT recoveries with dates during the MSF periods, three of seven Nicola CWTs, four of six Middle Shuswap CWTs and five of 13 Lower Shuswap CWTs had incomplete data.

The percentages between the original MDTs (representing the marked fish) and new MDTs (representing unmarked fish) were used to estimate the reduction in fisheries impacts and increased escapement for unmarked fish (Table 4.2–Table 4.). Mortality Distribution Table ERs did not change for other ocean NSFs. The average adjustments were minor, 0.5% or less, to the MDTs for these stocks in the MSFs, terminal fisheries, and escapement (Table 4.). These minor adjustments reflect the relatively small proportion of the total mortality that was measured in MSFs, similar to the findings for the analysis of several of the DIT stocks in Section 4.21 (Table 4.3). The largest adjustments occurred when the CWT recoveries within complete data were assumed to have been caught in MSFs (Table 4.).

Table 4.2 Percent distribution of Nicola River adult equivalent (AEQ) total fishing mortalities and escapement to represent unmarked fish when recoveries with incomplete data were assumed to have been caught in non-selective fisheries (NSFs).

Note: Troll, Net, and Sport (T,N,S) were combined for Southeast Alaska (SEAK), Northern B.C. (NBC), and West Coast Vancouver Island (WCVI) aggregate abundance-based management (AABM) fisheries; South of Falcon individual stock-based management (ISBM); and SEAK and Southern U.S. Terminal. The green shading identifies the calendar year exploitation rates (CYER) values where mark-selective fisheries (MSFs) did not change from the original mortality distribution tables (MDTs) for the marked stock and the yellow shading identifies revised CYERs.

Catch Year	Est # of CWT	Ages	AABM Fishery SEAK T,N,S	AABM Fishery NBC T,S	AABM Fishery WCVI T,S	ISBM Fishery NBC & CBC T,N,S	ISBM Southern B.C. T	ISBM Southern B.C. N	ISBM Southern B.C. S	ISBM N Falcon T	ISBM N Falcon S	ISBM S Falcon T & S	ISBM WAC N	ISBM Puget Sd N	ISBM Puget Sd S	Terminal Fishery SEAK T,N,S	Terminal Canada N	Terminal Canada S	Terminal U.S. South T,N,S	Escapement Stray	Escapement Esc.
2002	2319	3,4,5,6	0.0	1.8	0.6	0.2	0.0	0.0	1.1	0.7	0.2	0.1	0.0	0.0	0.0	0.0	4.0	0.6	0.0	0.0	90.6
2008	624	3,4,5,6	0.0	2.1	0.0	0.0	0.0	0.0	4.0	2.2	0.3	0.0	0.0	0.0	0.0	0.0	11.4	3.5	0.5	0.0	76.0
2009	293	3,4,5,6	0.0	0.3	0.0	0.0	0.0	0.0	8.2	3.4	0.0	0.0	0.0	0.0	2.8	0.0	19.0	20.4	0.0	0.0	45.9
2010	2328	3,4,5,6	0.4	1.7	0.1	0.0	0.0	0.0	1.8	0.8	0.0	0.0	0.0	0.0	0.2	0.0	4.6	0.0	0.0	0.0	90.5
2011	683	3,4,5,6	0.0	0.9	0.4	0.0	0.0	0.4	4.4	2.0	0.3	0.0	0.0	0.0	1.5	0.0	3.8	2.5	0.0	0.0	83.7
2012	723	3,4,5,6	0.0	1.4	0.0	0.0	0.0	0.6	4.1	8.2	0.0	0.6	0.0	0.0	0.0	0.0	17.2	0.8	0.0	0.0	67.2
2013	1466	3,4,5,6	0.0	1.2	0.2	0.2	0.0	0.5	4.6	3.3	0.3	0.0	0.0	0.0	1.0	0.0	1.6	0.0	0.0	0.0	87.0
2014	436	3,4,5,6	0.0	0.0	2.1	0.0	0.0	1.6	0.9	1.6	0.0	0.0	0.0	0.0	0.0	0.0	9.2	0.9	0.0	0.0	83.7
2015	1549	3,4,5,6	0.0	0.5	0.3	0.0	0.0	0.9	3.1	0.9	0.2	0.0	0.0	0.2	0.6	0.0	10.0	0.0	0.0	0.0	83.4
2016	973	3,4,5,6	0.2	1.7	0.9	0.0	0.0	0.7	10.2	1.0	0.0	0.0	0.0	0.0	0.0	0.0	10.1	0.0	0.0	0.0	75.1
2017	1086	3,4,5,6	0.0	1.0	1.2	0.0	0.0	0.2	2.4	1.8	0.0	0.0	0.0	0.0	0.0	0.0	7.7	0.0	0.0	0.0	85.6
2018	919	3,4,5,6	0.0	0.3	1.0	0.0	0.0	1.2	3.2	1.4	0.0	0.0	0.0	0.2	0.0	0.0	17.4	0.0	0.0	0.0	75.2
99-08	1259	3,4,5,6	0.0	1.4	1.6	0.0	0.0	0.0	3.1	0.8	0.1	0.1	0.0	0.0	0.0	0.0	12.1	6.9	0.0	0.0	73.9
09-18	1044	3,4,5,6	0.1	0.9	0.6	0.0	0.0	0.6	4.3	2.5	0.1	0.1	0.0	0.0	0.6	0.0	10.1	2.5	0.0	0.0	77.7

Table 4.3 Percent distribution of Nicola River adult equivalent (AEQ) total fishing mortalities and escapement to represent unmarked fish when recoveries with incomplete data were assumed to have been caught in mark-selective fisheries (MSFs).

Note: Troll, Net, and Sport (T,N,S) were combined for Southeast Alaska (SEAK), Northern B.C. (NBC), and West Coast Vancouver Island (WCVI) aggregate abundance-based management (AABM) fisheries; South of Falcon individual stock-based management (ISBM); and SEAK and Southern U.S. Terminal. The green shading identifies the calendar year exploitation rate (CYER) values where MSFs did not change from the original mortality distribution tables (MDTs) for the marked stock and the yellow shading identifies revised CYERs.

Catch Year	Est # of CWT	Ages	AABM Fishery			ISBM Fishery										Terminal Fishery				Escapement	
			SEAK T,N,S	NBC T,S	WCVI T,S	NBC & CBC T,N,S	Southern B.C. T	Southern B.C. N	Southern B.C. S	N Falcon T	N Falcon S	S Falcon T & S	WAC N	Puget Sd N	Puget Sd S	SEAK T,N,S	Canada N	Canada S	U.S. South T,N,S	Stray	Esc.
2002	2319	3,4,5,6	0.0	1.8	0.6	0.2	0.0	0.0	1.1	0.7	0.2	0.1	0.0	0.0	0.0	0.0	4.0	0.6	0.0	0.0	90.6
2008	624	3,4,5,6	0.0	2.1	0.0	0.0	0.0	0.0	4.0	2.2	0.3	0.0	0.0	0.0	0.0	0.0	11.4	3.5	0.5	0.0	76.0
2009	293	3,4,5,6	0.0	0.3	0.0	0.0	0.0	0.0	8.2	3.4	0.0	0.0	0.0	0.0	2.8	0.0	19.0	20.4	0.0	0.0	45.9
2010	2328	3,4,5,6	0.4	1.7	0.1	0.0	0.0	0.0	1.5	0.8	0.0	0.0	0.0	0.0	0.2	0.0	4.6	0.0	0.0	0.0	90.7
2011	683	3,4,5,6	0.0	0.9	0.4	0.0	0.0	0.4	4.4	2.0	0.3	0.0	0.0	0.0	1.5	0.0	3.8	2.5	0.0	0.0	83.7
2012	723	3,4,5,6	0.0	1.4	0.0	0.0	0.0	0.6	4.1	8.2	0.0	0.6	0.0	0.0	0.0	0.0	17.2	0.8	0.0	0.0	67.2
2013	1466	3,4,5,6	0.0	1.2	0.2	0.2	0.0	0.5	3.9	3.3	0.3	0.0	0.0	0.0	1.0	0.0	1.6	0.0	0.0	0.0	87.7
2014	436	3,4,5,6	0.0	0.0	2.1	0.0	0.0	1.6	0.9	1.6	0.0	0.0	0.0	0.0	0.0	0.0	9.2	0.9	0.0	0.0	83.7
2015	1549	3,4,5,6	0.0	0.5	0.3	0.0	0.0	0.9	3.1	0.9	0.2	0.0	0.0	0.2	0.6	0.0	10.0	0.0	0.0	0.0	83.4
2016	973	3,4,5,6	0.2	1.7	0.9	0.0	0.0	0.7	8.6	1.0	0.0	0.0	0.0	0.0	0.0	0.0	10.3	0.0	0.0	0.0	76.5
2017	1086	3,4,5,6	0.0	1.0	1.2	0.0	0.0	0.2	2.4	1.8	0.0	0.0	0.0	0.0	0.0	0.0	7.7	0.0	0.0	0.0	85.6
2018	919	3,4,5,6	0.0	0.3	1.0	0.0	0.0	1.2	3.2	1.4	0.0	0.0	0.0	0.2	0.0	0.0	17.4	0.0	0.0	0.0	75.2
99-08	1259	3,4,5,6	0.0	1.4	1.6	0.0	0.0	0.0	3.1	0.8	0.1	0.1	0.0	0.0	0.0	0.0	12.1	7.1	0.0	0.0	73.8
09-18	1044	3,4,5,6	0.1	0.9	0.6	0.0	0.0	0.6	4.0	2.5	0.1	0.1	0.0	0.0	0.6	0.0	10.1	2.5	0.0	0.0	78.0

Table 4.4 Percent distribution of Lower Shuswap River adult equivalent (AEQ) total fishing mortalities and escapement to represent unmarked fish when recoveries with incomplete data were assumed to have been caught in non-selective fisheries (NSFs).

Note: Troll, Net, and Sport (T,N,S) were combined for Southeast Alaska (SEAK), Northern B.C. (NBC), and West Coast Vancouver Island (WCVI) aggregate abundance-based management (AABM) fisheries; South of Falcon individual stock-based management (ISBM); and SEAK and Southern U.S. Terminal. The green shading identifies the calendar year exploitation rate (CYER) values where mark-selective fisheries (MSFs) did not change from the original mortality distribution tables (MDTs) for the marked stock and the yellow shading identifies revised CYERs.

			AABM Fishery			ISBM Fishery										Terminal Fishery				Escapement	
	Est					NBC &															
Catch	# of		SEAK	NBC	WCVI	CBC	Southern B.C.			N Falcon		S Falcon	WAC	Puget Sd		SEAK	Canada		U.S. South		
Year	CWT	Ages	T,N,S	T,S	T,S	T,N,S	T	N	S	T	S	T & S	N	N	S	T,N,S	N	S	T,N,S	Stray	Esc.
2008	1771	2,3,4,5	9.4	15.8	1.6	0.0	0.0	0.0	7.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.9	3.0	0.0	0.0	60.1
2009	1691	2,3,4,5	10.5	9.8	3.1	0.6	0.0	0.0	8.9	0.1	0.0	0.0	0.0	0.0	0.1	0.0	10.0	6.2	0.0	0.2	50.5
2010	2025	2,3,4,5	11.4	13.6	0.5	0.3	0.0	0.0	9.1	0.2	0.1	0.1	0.0	1.2	0.0	0.0	9.4	1.9	0.3	1.2	50.7
2011	1853	2,3,4,5	10.0	12.0	2.0	0.0	0.0	1.2	8.3	0.5	0.0	0.0	0.0	0.3	0.3	0.0	9.3	2.9	0.0	0.1	53.2
2012	1942	2,3,4,5	9.4	11.9	2.3	0.6	0.0	0.4	9.9	0.2	0.1	0.2	0.0	0.1	1.9	0.0	4.5	5.0	0.0	0.0	53.5
2013	8226	2,3,4,5	8.0	11.0	1.2	0.3	0.0	1.6	10.2	0.6	0.0	0.0	0.0	0.3	0.4	0.0	2.5	2.1	0.0	0.9	60.9
2014	4667	2,3,4,5	12.0	9.8	4.9	0.2	0.0	3.0	4.9	1.9	0.4	0.1	0.0	0.5	0.5	0.0	8.1	1.8	0.0	0.9	50.8
2015	5011	2,3,4,5	7.2	5.2	1.8	0.7	0.0	0.5	8.0	2.4	0.5	0.0	0.0	0.8	0.7	0.0	2.9	3.1	0.1	1.4	64.8
2016	2142	2,3,4,5	12.2	11.9	2.8	0.5	0.0	0.4	6.0	0.3	0.0	0.0	0.0	0.0	0.5	0.0	2.6	1.2	0.3	0.0	61.5
2017	3056	2,3,4,5	13.7	11.1	3.6	0.0	0.0	0.2	10.9	0.3	0.3	0.0	0.0	0.0	0.9	0.0	2.8	1.7	0.1	0.5	54.0
2018	5148	2,3,4,5	5.6	6.5	3.0	0.1	0.0	1.4	8.5	0.2	0.2	0.0	0.0	0.4	0.8	0.0	4.6	2.8	0.0	0.3	65.6
99-08	1259	2,3,4,5	16.3	11.9	0.9	1.3	0.0	0.1	6.8	0.1	0.0	0.0	0.0	0.3	0.0	0.0	6.1	2.4	0.0	0.2	53.5
09-18	3576	2,3,4,5	10.0	10.3	2.5	0.3	0.0	0.9	8.5	0.7	0.2	0.0	0.0	0.4	0.6	0.0	5.7	2.9	0.1	0.5	56.6

Table 4.5 Percent distribution of Lower Shuswap River adult equivalent (AEQ) total fishing mortalities and escapement to represent unmarked fish when recoveries with incomplete data were assumed to have been caught in mark-selective fisheries (MSFs).

Note: Troll, Net, and Sport (T,N,S) were combined for Southeast Alaska (SEAK), Northern B.C. (NBC), and West Coast Vancouver Island (WCVI) aggregate abundance-based management (AABM) fisheries; South of Falcon individual stock-based management (ISBM); and SEAK and Southern U.S. Terminal. The green shading identifies the calendar year exploitation rate (CYER) values where MSFs did not change from the original mortality distribution tables (MDTs) for the marked stock and the yellow shading identifies revised CYERs.

			AABM Fishery			ISBM Fishery											Terminal Fishery				Escapement	
	Est		SEAK	NBC	WCVI	NBC & CBC	Southern B.C.			N Falcon		S Falcon	WAC	Puget Sd		SEAK	Canada		U.S. South		
Catch Year	# of CWT	Ages	T,N,S	T,S	T,S	T,N,S	T	N	S	T	S	T & S	N	N	S	T,N,S	N	S	T,N,S	Stray	Esc.
2008	1771	2,3,4,5	9.4	15.8	1.6	0.0	0.0	0.0	7.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.9	3.0	0.0	0.0	60.1
2009	1691	2,3,4,5	10.5	9.8	3.1	0.6	0.0	0.0	8.9	0.1	0.0	0.0	0.0	0.0	0.1	0.0	10.0	6.2	0.0	0.2	50.5
2010	2025	2,3,4,5	11.4	13.6	0.5	0.3	0.0	0.0	8.8	0.2	0.1	0.1	0.0	1.2	0.0	0.0	9.5	1.9	0.3	1.2	51.0
2011	1853	2,3,4,5	10.0	12.0	2.0	0.0	0.0	1.2	8.3	0.5	0.0	0.0	0.0	0.3	0.3	0.0	9.3	2.9	0.0	0.1	53.2
2012	1942	2,3,4,5	9.4	11.9	2.3	0.6	0.0	0.4	9.9	0.2	0.1	0.2	0.0	0.1	1.9	0.0	4.5	5.0	0.0	0.0	53.5
2013	8226	2,3,4,5	8.0	11.0	1.2	0.3	0.0	1.6	10.2	0.6	0.0	0.0	0.0	0.3	0.4	0.0	2.5	2.1	0.0	0.9	60.9
2014	4667	2,3,4,5	12.0	9.8	4.9	0.2	0.0	3.0	4.9	1.9	0.4	0.1	0.0	0.5	0.5	0.0	8.1	1.8	0.0	0.9	50.8
2015	5011	2,3,4,5	7.2	5.2	1.8	0.7	0.0	0.5	8.0	2.4	0.5	0.0	0.0	0.8	0.7	0.0	2.9	3.1	0.1	1.4	64.8
2016	2142	2,3,4,5	12.2	11.9	2.8	0.5	0.0	0.4	6.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	2.6	1.2	0.3	0.0	62.0
2017	3056	2,3,4,5	13.7	11.1	3.6	0.0	0.0	0.2	10.8	0.3	0.3	0.0	0.0	0.0	0.9	0.0	2.8	1.7	0.1	0.5	54.1
2018	5148	2,3,4,5	5.6	6.5	3.0	0.1	0.0	1.4	8.2	0.2	0.2	0.0	0.0	0.4	0.8	0.0	4.6	2.8	0.0	0.3	65.9
99-08	1259	2,3,4,5	16.3	11.9	0.9	1.3	0.0	0.1	6.8	0.1	0.0	0.0	0.0	0.3	0.0	0.0	6.1	2.4	0.0	0.2	53.5
09-18	3576	2,3,4,5	10.0	10.3	2.5	0.3	0.0	0.9	8.4	0.7	0.2	0.0	0.0	0.4	0.6	0.0	5.7	2.9	0.1	0.5	56.7

Table 4.6 Percent distribution of Middle Shuswap River adult equivalent (AEQ) total fishing mortalities and escapement to represent unmarked fish when recoveries with incomplete data were assumed to have been caught in non-selective fisheries (NSFs).

Note: Troll, Net, and Sport (T,N,S) were combined for Southeast Alaska (SEAK), Northern B.C. (NBC), and West Coast Vancouver Island (WCVI) aggregate abundance-based management (AABM) fisheries; South of Falcon individual stock-based management (ISBM); and SEAK and Southern U.S. Terminal. The green shading identifies the calendar year exploitation rate (CYER) values where mark-selective fisheries (MSFs) did not change from the original mortality distribution tables (MDTs) for the marked stock and the yellow shading identifies revised CYERs.

			AABM Fishery			ISBM Fishery										Terminal Fishery				Escapement	
	Est		SEAK	NBC	WCVI	NBC & CBC	Southern B.C.			N Falcon		S Falcon	WAC	Puget Sd		SEAK	Canada		U.S. South		
Catch Year	# of CWT	Ages	T,N,S	T,S	T,S	T,N,S	T	N	S	T	S	T,S	N	N	S	T,N,S	N	S	T,N,S	Stray	Esc.
2011	58	2,3	8.6	10.3	0.0	0.0	0.0	1.7	5.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	25.9	1.7	0.0	0.0	46.6
2012	283	2,3,4	10.2	19.8	2.5	0.4	0.0	0.7	14.1	2.1	0.0	0.0	0.0	0.0	0.0	0.0	8.2	2.9	0.0	1.4	37.8
2013	1699	2,3,4,5	2.9	11.4	0.9	0.1	0.0	1.1	14.7	0.1	0.0	0.0	0.0	0.0	0.0	0.0	3.1	3.7	0.0	1.3	60.6
2014	1223	2,3,4,5	10.1	12.3	5.2	0.4	0.0	1.5	7.7	0.8	0.0	0.0	0.0	0.0	0.0	0.0	3.8	4.8	0.0	0.5	52.9
2015	2074	2,3,4,5	4.6	3.7	2.7	0.3	0.0	0.7	13.5	1.7	0.1	0.0	0.0	0.2	0.5	0.0	1.7	3.4	0.0	4.9	61.9
2016	408	2,3,4,5	3.9	11.3	0.7	2.5	0.0	0.5	14.2	0.7	0.0	0.0	0.0	0.0	0.0	0.0	9.8	0.7	0.0	4.9	50.7
2017	470	2,3,4,5	8.9	7.9	1.3	0.6	0.0	0.0	16.2	0.2	0.0	0.0	0.0	0.4	0.0	0.0	4.7	3.8	0.0	0.9	55.1
2018	1133	2,3,4,5	1.2	2.6	3.3	0.3	0.0	1.4	17.3	0.3	0.0	0.0	0.0	0.0	0.0	0.0	7.9	2.1	0.0	0.0	63.7
09–18	919	2,3,4,5	6.3	9.9	2.1	0.6	0.0	0.9	12.9	0.7	0.0	0.0	0.0	0.1	0.1	0.0	8.1	2.9	0.0	1.7	53.7

Table 4.7 Percent distribution of Middle Shuswap River adult equivalent (AEQ) total fishing mortalities and escapement to represent unmarked fish when recoveries with incomplete data were assumed to have been caught in mark-selective fisheries (MSFs).

Note: Troll, Net, and Sport (T,N,S) were combined for Southeast Alaska (SEAK), Northern B.C. (NBC), and West Coast Vancouver Island (WCVI) aggregate abundance-based management (AABM) fisheries; South of Falcon individual stock-based management (ISBM); and SEAK and Southern U.S. Terminal. The green shading identifies the calendar year exploitation rate (CYER) values where MSFs did not change from the original mortality distribution tables (MDTs) for the marked stock and the yellow shading identifies revised CYERs.

			AABM Fishery			ISBM Fishery										Terminal Fishery				Escapement	
	Est					NBC &													U.S.		
Catch	# of		SEAK	NBC	WCVI	CBC	Southern B.C.			N Falcon		S Falcon	WAC	Puget Sd		SEAK	Canada		South		
Year	CWT	Ages	T,N,S	T,S	T,S	T,N,S	T	N	S	T	S	T,S	N	N	S	T,N,S	N	S	T,N,S	Stray	Esc.
2011	58	2,3	8.6	10.3	0.0	0.0	0.0	1.7	5.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	25.9	1.7	0.0	0.0	46.6
2012	283	2,3,4	10.2	19.8	2.5	0.4	0.0	0.7	12.7	2.1	0.0	0.0	0.0	0.0	0.0	0.0	8.4	2.9	0.0	1.4	38.9
2013	1699	2,3,4,5	2.9	11.4	0.9	0.1	0.0	1.1	14.7	0.1	0.0	0.0	0.0	0.0	0.0	0.0	3.1	3.7	0.0	1.3	60.6
2014	1223	2,3,4,5	10.1	12.3	5.2	0.4	0.0	1.5	7.7	0.8	0.0	0.0	0.0	0.0	0.0	0.0	3.8	4.8	0.0	0.5	52.9
2015	2074	2,3,4,5	4.6	3.7	2.7	0.3	0.0	0.7	13.5	1.7	0.1	0.0	0.0	0.2	0.5	0.0	1.7	3.4	0.0	4.9	61.9
2016	408	2,3,4,5	3.9	11.3	0.7	2.5	0.0	0.5	14.2	0.7	0.0	0.0	0.0	0.0	0.0	0.0	9.8	0.7	0.0	4.9	50.7
2017	470	2,3,4,5	8.9	7.9	1.3	0.6	0.0	0.0	15.1	0.2	0.0	0.0	0.0	0.4	0.0	0.0	4.8	3.9	0.0	0.9	56.0
2018	1133	2,3,4,5	1.2	2.6	3.3	0.3	0.0	1.4	16.6	0.3	0.0	0.0	0.0	0.0	0.0	0.0	7.9	2.1	0.0	0.0	64.3
09–18	919	2,3,4,5	6.3	9.9	2.1	0.6	0.0	0.9	12.5	0.7	0.0	0.0	0.0	0.1	0.1	0.0	8.2	2.9	0.0	1.7	54.0

Table 4.8 Average absolute changes in Nicola, Lower Shuswap and Middle Shuswap calendar year exploitation rates (CYERs) (2002, 2008–2018) when coded wire tag (CWT) recoveries with incomplete data were assumed to have been caught in non-selective fisheries (NSFs) or mark-selective fisheries (MSFs).

Indicator Stock	Southern B.C. Sport	Puget Sound Sport	North of Falcon Sport	Terminal Net	Terminal Sport	Esc.
Caught in NSF						
Nicola	-0.3%	-0.1%	0.0%	+0.1%	~0.0%	+0.3%
Lower Shuswap	-0.2%	-0.2%	~0.0%	~0.0%	~0.0%	+0.3%
Middle Shuswap	-0.1%	-0.1%	-0.1%	~0.0%	~0.0%	+0.2%
Caught in MSF						
Nicola	-0.5%	-0.1%	0.0%	+0.1%	~0.0%	+0.5%
Lower Shuswap	-0.3%	-0.3%	~0.0%	~0.0%	~0.0%	+0.4%
Middle Shuswap	-0.5%	-0.1%	-0.1%	+0.1%	~0.0%	+0.5%

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