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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
AI	Abundance Index
ADF&G	Alaska Department of Fish & Game
AEQ	Adult Equivalent
AUC	Area-Under-the-Curve
AWG	Analytical Working Group of the CTC
BY	Brood Year
BYER	Brood Year Exploitation Rate
DFO	Department of Fisheries and Oceans Canada
CLB	Calibration
CNR	Chinook Nonretention
CRITFC	Columbia River Intertribal Fish Commission
CTC	Chinook Technical Committee
CWTIP	Coded Wire Tag Improvement Program
CWTIT	Coded Wire Tag Improvement Team
CY	Calendar Year
CWT	Coded Wire Tag
DIT	Double Index Tag
ERA	Exploitation Rate Analysis
FI	Fishery Index
EV	Environmental Variable scalar
FNC	First Nations Caucus
IM	Incidental Mortality
LC	Landed Catch
ISBM	Individual Stock Based Management
MSE	Mean Squared Error
MSF	Mark-Selective Fishery
NA	Not Available
NBC	Northern B.C. Dixon Entrance to Kitimat including Haida Gwaii
NM	Nautical Mile
NMFS	National Marine Fisheries Service
NWIFC	Northwest Indian Fisheries Commission
ODFW	Oregon Department of Fish & Wildlife
PSC	Pacific Salmon Commission
PST	Pacific Salmon Treaty
QIN	Quinault Nation
ROM	Ratio of Means
SEAK	Southeast Alaska Cape Suckling to Dixon Entrance
SPS	South Puget Sound
SPFI	Stratified Proportional Fishery Index
UAF	University of Alaska Fairbanks
USFWS	U.S. Fish & Wildlife Service
WA/OR	Ocean areas off Washington and Oregon North of Cape Falcon
WCVI	West Coast Vancouver Island excluding Area 20
WDFW	Washington Department of Fish and Wildlife

EXECUTIVE SUMMARY

The Pacific Salmon Treaty (PST) requires the Chinook Technical Committee (CTC) to report annual catches, harvest rate indices, estimates of incidental mortality (IM) and exploitation rates for all Chinook 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 U.S. under Chapter 3 of the Treaty. This report contains four sections: Exploitation Rate Analysis (ERA), model calibration and output, evaluation of mark-selective fisheries (MSFs), and program improvements to the coastwide coded wire tag (CWT) program. Additionally, this report contains the results of the annual exploitation rate assessment of CWT data through 2011 (U.S. stocks) and 2012 (Canadian stocks), the preseason Chinook model calibration results for 2013 (CLB 1308), postseason Chinook model calibration results through 2012 (CLB 1309), and the CWT Improvement program results from 2012 and planned projects for 2013. Results include the abundance indices (AIs) for the aggregate abundance-based management (AABM) fisheries and individual stock base management (ISBM) indices for each country.

AABM Abundance Indices and Associated Catches

The pre- and postseason 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 2009 PST Agreement specifies that the AABM fisheries are to be managed through the use of the AIs. Each calibration provides the postseason AIs for the previous year and the preseason AIs for the current year. Preseason AIs are used to estimate the total allowable catch limits in the upcoming fishing season. Subsequently, AIs and associated allowable catches from the first postseason model calibration for a fishing year are used to track catch overages and underages, per PST subparagraph 11(a)(i).

The 2009 Agreement specifies an allowable catch for each AI for each fishery. The maximum allowable treaty catch (total catch minus any hatchery add-on and exclusion catch) by fishery and year and the observed treaty catches are shown in Table 2.

Table 1 Abundance Indices for 1999–2013 for the SEAK, NBC, and WCVI AABM fisheries. Postseason values for each year are from the first postseason calibration following the fishing year.

Year	SEAK		NBC		WCVI	
	Preseason	Postseason	Preseason	Postseason	Preseason	Postseason
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]		1.10[1]		0.77[1]	

[1] Due to changes in calibration procedures (reviewed in section 3.1.4), 2012 postseason (CLB 1309) and 2013 preseason (CLB 1308) AIs are based on different calibrations; the procedures and assumptions CLB 1309 mirror those used during the 2012 preseason calibration.

Table 2 Preseason allowable catches for 2009–2013, and postseason allowable catches and observed catches for 2009–2012 for AABM fisheries. Postseason values for each year are from the first postseason calibration following the fishing year.

PST Treaty Allowable and Observed Catches									
	SEAK (T, N, S)[1]			NBC (T, S)			WCVI (T, S)		
Year	Preseason Allowable Catch	Postseason Allowable Catch	Observed Catch	Preseason Allowable Catch	Postseason Allowable Catch	Observed Catch	Preseason Allowable Catch	Postseason Allowable Catch	Observed Catch
2009	218,800	176,000	227,667[2]	143,000	139,100	109,470	107,800	91,300	124,617
2010	221,800	215,800	229,355[2]	152,100	160,400	136,613	143,700	142,300	139,047
2011	294,800	283,300	292,028[2]	182,400	186,800	122,660	196,800	134,800	204,232
2012	266,800	205,100	241,015[2]	173,600	149,500	120,307	133,300	113,800	134,468
2013	176,000			143,000			115,300		

[1] T = troll, N = net, and S = sport.

[2] Values changed because the method used to partition gillnet catch into large and nonlarge fish has changed. This change affects the computation of the terminal exclusion, add-on, and treaty catch.

Table 3 shows the differences between the postseason allowable catches and the observed treaty catches in AABM fisheries for 2009–2012, and the cumulative deviation for those years. In SEAK, the 2012 catch was 17.5% above the postseason allowable catch, and the cumulative differences were 2.5% above. In NBC, the 2012 catch was 19.5% below the preseason allowable catch and the cumulative differences were 25.1% below. In WCVI, the 2012 catch was 18.2% above and the cumulative differences were 1.5% below the postseason allowable catch. The SEAK, NBC, and WCVI AABM fisheries have been over the preseason allowable catch 10 (SEAK), 3 (NBC), and 9 (WCVI) of the last 14 years.

Table 3 *Deviations in numbers of Chinook salmon caught and percentages from allowable catches derived from the postseason AI (Table 2) for PST AABM fisheries in 2009–2012. Postseason values for each year are from the first postseason calibration following the fishing year.*

Year	SEAK		NBC		WCVI	
	Number of Fish	Percent Difference	Number of Fish	Percent Difference	Number of Fish	Percent Difference
2009	51,667	29.4%	-29,630	-21.3%	33,317	36.5%
2010	13,555	6.3%	-23,787	-14.8%	-3,253	-2.3%
2011	8,728	3.1%	-64,140	-34.3%	69,432	51.5%
2012	35,915	17.5%	-29,193	-19.5%	20,668	18.2%
Cum.	**109,865**	**12.5%**	**-146,750**	**-22.5%**	**120,164**	**20.7%**

Overages and underages in AABM catches, relative to the first postseason calibration for a fishing year (Table 3), can arise due to the inseason management system, errors in the preseason 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 preseason and postseason calibrations (Table 4). Regarding the inseason management system in 2012, the actual landed catch was less than the preseason allowable catch by 25,785 Chinook salmon in SEAK and by 53,293 in NBC. For WCVI, the actual landed catch was 1,168 more than the preseason allowable catch. In terms of the postseason allowable catches for evaluation of the provisions of the PST (subparagraph 11(a)(i)), actual catches exceeded the postseason allowable catches by 35,915 Chinook salmon in SEAK and by 20,668 in WCVI. Actual landed catch in NBC was 29,193 fish less than the postseason allowable catch.

Table 4 Deviations in actual landed catch (LC), allowable landed catch determined from preseason model calibration (PreALC), and allowable landed catch determined from postseason model calibration (PostALC) for AABM fisheries from 1999 to 2012. Postseason values for each year are from the first postseason calibration following the fishing year. The difference between LC and PreALC represents the consequences of the management system employed in the year; the difference in PreALC and PostALC represents consequences of the forecast procedures and data used in forecasting the PreALC by the PSC Chinook Model. The difference in LC and PostALC captures the effects of both processes.

	SEAK			NBC			WCVI		
Year	LC–PreALC	PreALC–PostALC	LC–PostALC	LC–PreALC	PreALC–PostALC	LC–PostALC	LC–PreALC	PreALC–PostALC	LC–PostALC
2009	8,867	42,800	51,667	-33,530	3,900	-29,630	16,817	16,500	33,317
2010	7,555	6,000	13,555	-15,487	-8,300	-23,787	-4,653	1,400	-3,253
2011	-2,772	11,500	8,728	-59,740	-4,400	-64,140	7,432	62,000	69,432
2012	-25,785	61,700	35,915	-53,293	24,100	-29,193	1,168	19,500	20,668

ISBM Indices

For ISBM fisheries, the 2009 Agreement specifies that Canada and the U.S. will reduce base period exploitation rates on specified stocks by 36.5% and 40%, equivalent to ISBM indices of 63.5% and 60% percent, respectively. This requirement is referred to as the *general obligation* and does not apply to stocks that achieve their CTC agreed escapement goal. The 2009 Agreement 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 which occurred in the years 1991–1996 (Paragraph 8 (c)). This requirement is referred to as the *additional obligation*.

Postseason ISBM Indices for 2011 and 2012

Postseason ISBM indices were calculated for all stocks for 2011, and for Canadian stocks in the Canadian ISBM fishery for 2012. For 2011, six of the seven Canadian ISBM indices that could be calculated from CWT data were reduced more than required under the Agreement (Table 5). Only the WCVI ISBM index (0.650) exceeded the general obligation (0.635). Since there is no CTC-agreed escapement goal for this stock aggregate, the general obligation applies. For 2012, three of the four Canadian ISBM indices that could be calculated from CWT data were reduced more than required under the Agreement, and only the WCVI ISBM index (0.738) exceeded the general obligation (Table 3.12).

Three of the 12 U.S. ISBM indices for 2011 were reduced more than required under the 2009 Agreement. The other nine U.S. CWT-based ISBM indices exceeded either the general obligation or the additional obligation (Table 6). Seven of these stocks have CTC-agreed escapement goals and all met or exceeded their respective escapement goals, and thus are exempted from the general obligation. Nooksack and Grays Harbor stocks, both without agreed escapement goals, exceeded the general obligation. Since there are no CTC-agreed escapement goal for these stocks, the general obligation applies.

Table 5 ISBM indices based on 2011 and 2013 PSC Chinook Model, 2011 CWT analysis, and the 2013 indices predicted from the 2013 PSC Chinook Model, for the stock groups applicable to all British Columbia ISBM fisheries as listed in Attachment IV of the Treaty.

Stock Group	Escapement Indicator Stock	2011 Model Indices for 2011	2013 Model Indices for 2011	CWT Indices for 2011	2013 Model Indices for 2013
Lower Strait of Georgia	Cowichan[1]	0.367	0.227[2]	0.147[3]	0.362[2]
	Nanaimo	NA		NA[4,5]	
Fraser Late	Harrison River[1]	0.193	0.261	0.092[6]	0.286
North Puget Sound Natural Springs	Nooksack	0.732	0.208	0.014	0.273
	Skagit	0.731	0.208	NA	0.273
Upper Strait of Georgia	Klinaklini, Kakweikan, Wakeman, Kingcome, Nimpkish	0.578	0.165	0.032	0.649
Fraser Early (Spring and Summers)	Upper Fraser, Mid Fraser, Thompson	0.222	0.110	NA	0.238
West Coast Vancouver Island Falls	WCVI (Artlish, Burman, Kauok, Tahsis, Tashish, Marble)	0.491	0.778	0.650	0.227
Puget Sound Natural Summer/Falls	Skagit	0.745	0.174	NA	0.429
	Stillaguamish	0.793	0.247	0.246	0.561
	Snohomish	0.744	0.175	NA	0.423
	Lake Washington	0.752	0.225	NA	0.419
	Green River	0.756	0.225	0.300	0.419
North/Central B.C.	Yakoun, Nass, Skeena, Area 8	0.598	0.163	NA	0.496

[1] Stock or stock group with a CTC-agreed escapement goal.

[2] Although model-based indices were previously calculated separately for Cowichan and Nanaimo, these did not adequately represent impacts on either Lower Strait of Georgia stock because the model-based data represent an aggregate of the two stocks, and methods do not currently exist to correctly disaggregate these data for calculation of the ISBM values. Until such methods are developed, a single index value only will be reported representing the aggregate.

[3] An inconsistency was discovered between the approaches used to calculate the model-based and CWT-based indices. The former included harvest rates for terminal sport while the latter did not. Terminal sport harvest rates are now included in the calculation of both indices. Further review is yet required to determine whether the base period terminal sport harvest rates obtained from analyses of Big Qualicum CWT recoveries adequately represent impacts that would have occurred on Cowichan Chinook.

[4] Not available (NA) because of insufficient data (lack of stock-specific tag codes, base period CWT recoveries, etc.).

[5] Several problems have been identified in the approach previously used to calculate the CWT-based indices for Nanaimo Chinook. Until these problems are resolved, indices for this stock will not be reported.

[6] The terminal sport harvest rates for Chilliwack Hatchery Chinook, the indicator stock, were removed from the calculation for the Harrison River naturals because sport harvest has been essentially zero on the natural population.

Table 6 ISBM indices based on 2011 and 2013 PSC Chinook Model, 2011 CWT analysis, and the 2013 indices predicted from the 2013 PSC Chinook Model, for the stock groups applicable to all Southern U.S. fisheries as listed in Attachment V of the Treaty.

Stock Group	Escapement Indicator Stock	2011 Model Indices for 2011	2013 Model Indices for 2011	CWT Indices for 2011	2013 Model Indices for 2013
Washington Coastal Fall Naturals	Hoko	0.419	1.505	NA[1]	0.608
	Grays Harbor	0.549	0.765	0.923	0.547
	Queets[2]	0.327	0.565	NA	0.532
	Hoh[2]	0.760	0.437	2.003	0.802
	Quillayute[2]	1.058	1.469	NA	1.442
Columbia River Falls	Upriver Brights[2]	0.841	1.129	2.862	0.971
	Deschutes[2]	1.044	0.687	0.798	0.718
	Lewis[2]	0.426	0.760	0.432	0.538
Puget Sound Natural Summer/Falls	Skagit	0.789	NC[3]	NA	1.015
	Stillaguamish	0.169	NC	0.195	0.213
	Snohomish	0.211	NC	NA	0.231
	Lake Washington	0.387	NC	NA	0.404
	Green River	0.236	NC	0.439	0.331
Fraser Late	Harrison River[2]	0.497	0.542	NA	0.887
Columbia R Summers	Mid-Columbia Summers[2]	1.398	1.795	5.376	1.571
Far North Migrating Oregon Coastal Falls	Nehalem[2]	2.146	1.376	1.210	1.475
	Siletz[2]	0.643	1.105	1.068	0.679
	Siuslaw[2]	1.427	1.240	1.108	1.443
North Puget Sound Natural Springs	Nooksack	0.484	NC	0.741	0.330
	Skagit	0.271	NC	NA	0.337

[1] Not available (NA) because of insufficient data (lack of stock-specific tag codes, base period CWT recoveries, etc).
[2] Stock with a CTC-agreed escapement goal.
[3] Not able to calculate (NC) from 2013 Fisheries Regulation Assessment Model harvest projections.

Preseason ISBM Indices for 2013

Of the 13 ISBM indices for Canada, only the index for Upper Strait of Georgia was predicted to exceed the general obligation of 0.635 for Canadian ISBM fisheries in 2013 (Table 5). Since there is no CTC-agreed escapement goal for this stock aggregate, the general obligation would apply. Among the stocks with CTC-agreed escapement goals, only the ISBM index for Harrison was predicted to exceed the additional obligation of 0.250.

Eleven of the 20 U.S. ISBM indices are predicted to be above the general obligation of 0.600 or the additional obligation (Table 6). Where relevant, all of the corresponding stocks except Fraser Late are expected to meet their CTC-agreed escapement goals.

Coded Wire Tag Improvement Activities

A summary of the Coded Wire Tag Improvement Program (CWTIP) for 2012 is presented in Chapter 5. The goal of the CWTIP is to improve CWT-based estimates used for management of Chinook salmon stocks in the geographic area covered by the PST. The 2012 season represents the fourth year of the program for Canada and the third year of the program for the U.S. The Chapter 5 summary includes, over the years of the program to date, a summary of spending, performance and benefits of the CWTIP, as well as emerging and long-term issues facing the coastwide CWT program.

In 2012, the Commission approved $3 million in funding for projects. Summaries for individual projects are provided in Appendix L. Canadian projects included increased tagging for 12 CWT indicator stocks; increased escapement sampling for six stocks; program elements necessary for the Atnarko indicator stock in Central British Columbia fishing area; a substantial investment in upgrading the CWT reporting system; and improvements in sport and First Nations sampling and recovery rates, coordination and infrastructure (see Appendix Table L1). U.S.-funded projects included tagging and sampling for two CWT indicator stocks (the Stikine and Elk river stocks), CWT processing equipment for the Makah Tribe, CWT equipment (improved hand-held wands) for electronic sampling in Washington and Oregon, hand-held wands in SEAK to reduce costs of processing CWTs in commercial fisheries, estimation of CWTs in terminal sport fisheries in Puget Sound, sampling of ocean troll and sport fisheries in Washington and Oregon, data reporting improvements for the SEAK spring troll fishery, and improving the timeliness of CWT reporting in Washington (see Appendix Table M2).

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 fisheries and stocks harvested within the Treaty area. To fulfill this obligation, the CTC uses a Chinook model to generate key outputs of relevance to the PSC's annual Chinook fishery management cycle. The PSC Chinook Model is calibrated each year, incorporating preseason 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 PSC Chinook 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 at the heart of the PST Chinook salmon management process, because preseason AIs determine the preseason estimates of the total allowable catches for each of the three AABM fisheries. These preseason estimates of the total allowable catch drive the inseason management of AABM fisheries, because no reliable mechanism exists to update the AIs inseason. In addition to generating preseason AIs, the PSC Chinook Model provides other information of immediate relevance to PSC management, most notably postseason AIs and preseason ISBM indices. The first postseason AI estimates are used to determine the final total allowable catches to which the AABM fisheries are held accountable. The preseason ISBM indices are used to inform fishery management plans. Postseason ISBM indices are computed through a separate process using the CWT data that comes out of the exploitation rate analysis (ERA), to which ISBM fisheries are held accountable.

This report describes the methods and results of the cohort analysis used to estimate exploitation rates from CWT data (Section 2), and the PSC Chinook Model calibration (Section 3). The results of the preseason model calibration for 2013 are based on the ERA using CWT data through catch year 2011 (2012 for Canadian stocks); coastwide data on catch, spawning escapements, and age structure through 2012; and forecasts of Chinook salmon returns expected in 2013. Additionally, this report includes reviews of recent Chinook-directed MSFs (Section 4) and summarizes the activities associated with the implementation coastwide CWTIP prescribed under the 2009 Agreement (Section 5).

Of particular interest to PST implementation, this report includes, among other model outputs: (1) estimated postseason AIs for 1979 through 2012 and the preseason projection for 2013 for the AABM fisheries; (2) estimated ISBM indices, previously referred to as nonceiling indices, in this report, for 1999–2011 and modeled ISBM projections for the 2013 ISBM fisheries; (3) estimated stock composition for 1979–2012 and a projection for 2013 for the AABM and other fisheries; and (3) 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 and ISBM model indices from the final preseason calibration. 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 graphical summary of forecast error for Chinook model stocks. CWT data quality and model calibration issues, as well as their resolution, are detailed in Appendix K, and Appendix L contains narratives for projects that were funded by the CWTIP and active during fiscal year 2012.

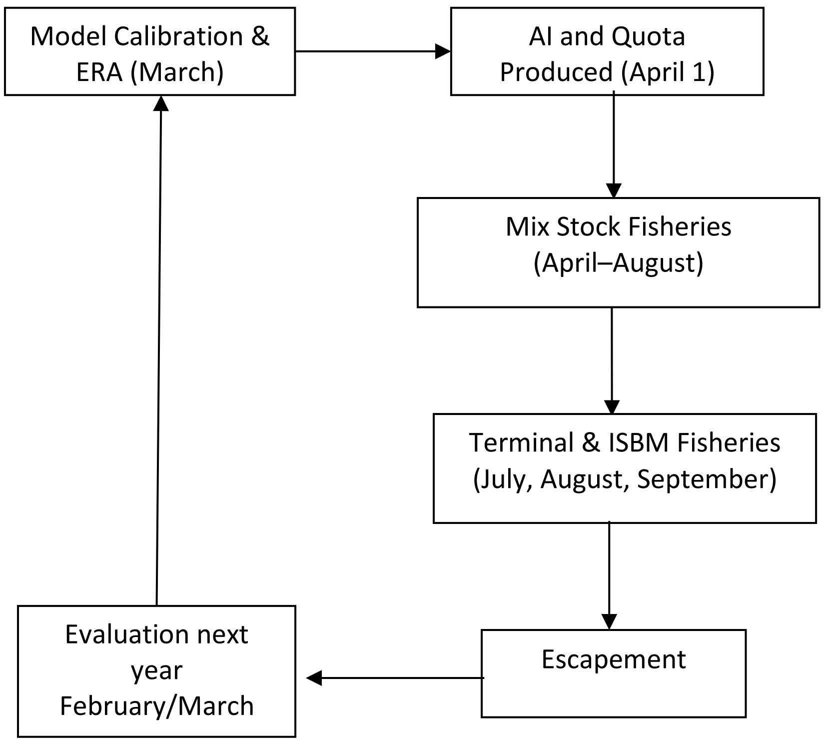

Figure 1.1 PST Chinook management process and fishery timings.

2 Exploitation Rate Analysis

The CTC currently monitors 45 CWT-tagged exploitation rate indicator stocks (Figure 2.1; Table 2.1). The exploitation rate assessment is performed through 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 analysis provides stock-specific estimates of BY total, age- and fishery-specific exploitation rates, maturation rates, age 2 or 3 survival indices, 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.

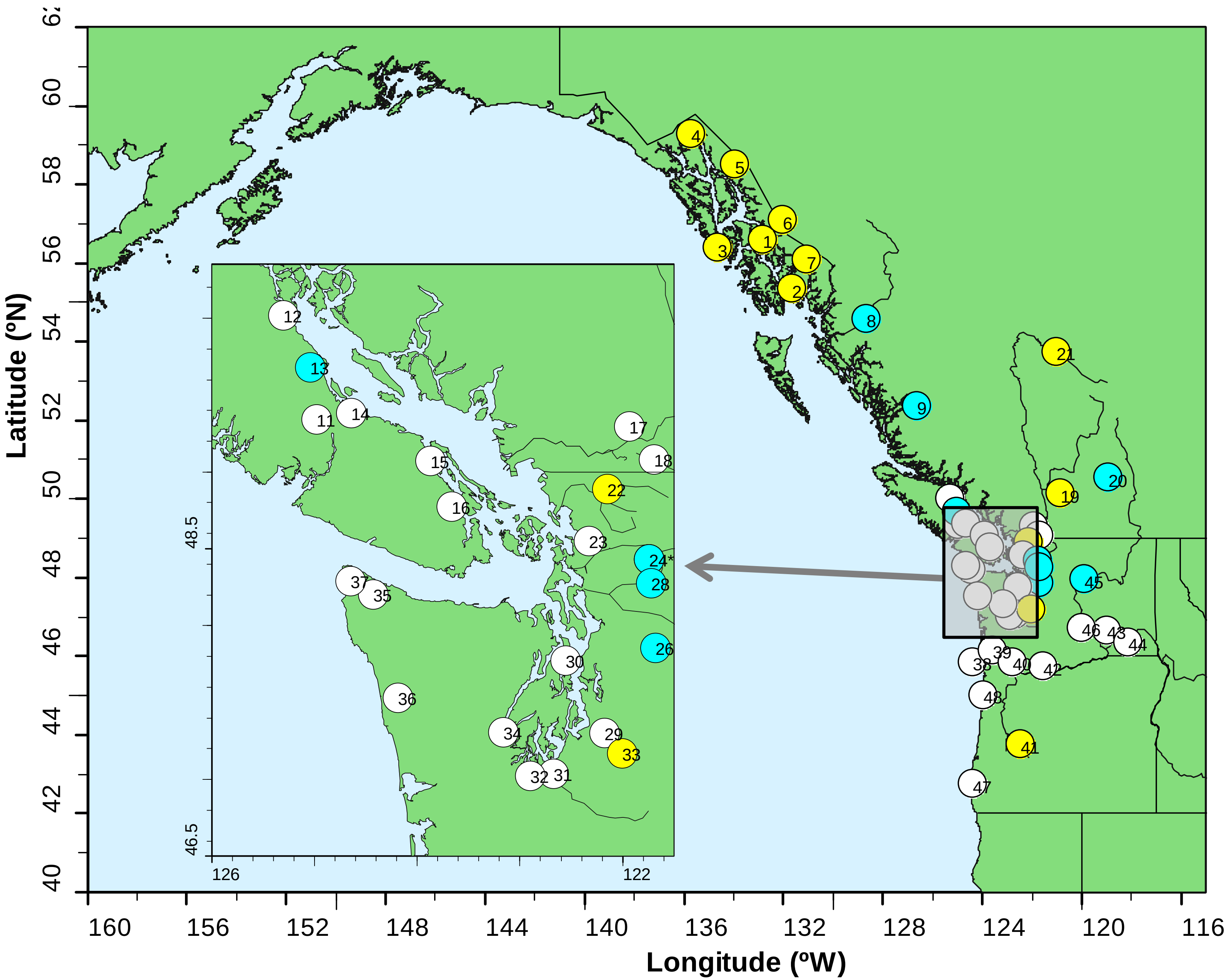

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Figure 2.1 Geographical location of all past and present Chinook salmon CWT indicator stocks.

Note: Color of the filled circles indicates adult run timing: yellow = spring, aquamarine = summer and white = fall. The southern B.C. and Puget Sound area, where concentration of the CWT indicators is greatest, is shown in expanded view. Numbered circles indicate the CWT indicators as follows:

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

Note: See Table 2.1 for the full stock names associated with each abbreviation. Not all stock indicators listed above are current. Only indicator stocks run now are in Table 2.1.

Table 2.1 Current CWT exploitation rate indicator stocks, their 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	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
	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
	Sooes 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, ERA tag groups are a combination of fingerlings and yearlings.
[4] Subyearlings have been CWT-tagged since BY 1986, except for BYs 1993–1997.

Table 2.2 The CWT exploitation rate indicator stocks used in the ERA and the data derived from them: fishery, ISBM and survival indices, brood year exploitation rates (BYER), and stock catch distribution (Dist) with quantitative escapement estimates (Esc) and tagging during base years 1979–1982.

Exploitation Rate Indicator Stock	Fishery Index	ISBM Index	BYER[1]	Survival Index	Dist	Esc	Base Tagging
Alaska Spring (AKS)	Yes	—	Ocean	Yes	Yes	Yes	Yes
Chilkat (CHK)	—	—	Total	Yes	Yes	Yes	—
Taku (TAK)	—	—	Total	Yes	Yes	Yes	—
Unuk (UNU)	—	—	Total	Yes	Yes	Yes	—
Atnarko (ATN)	Yes	No	Total	Yes	Yes	Yes	Yes
Kitsumkalum (KLM)	—	—	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
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
Nicola (NIC)	—	—	Total	Yes	Yes	Yes	—
Nooksack Spring Fingerling (NSF)	—	—	—[2]	—	Yes	Yes	—
Nooksack Spring Yearling (NKS)	—	Yes	—[2]	Yes	Yes	Yes[3]	—
Samish Fall Fingerling (SAM)	Yes	—	Ocean	Yes	Yes	Yes[3]	Yes
Skagit Spring Fingerling (SKF)	—	—	Ocean	—	Yes	Yes	—
Skagit Spring Yearling (SKS)	—	—	Ocean	Yes	Yes	Yes[3]	—
Skagit Summer Fingerling (SSF)	—	—	Ocean	—	Yes	Yes	—
Skykomish Summer Fingerling (SKY)	—	Yes	—[2]	—	Yes	—	—
Stillaguamish Summer Fingerling (STL)	—	Yes	—[2]	—	Yes	—	—
Nisqually Fall Fingerling (NIS)	—	—	—[2]	—	Yes	—	Yes
South Puget Sound Fall Fing. (PSF)	Yes	Yes	Ocean	Yes	Yes	Yes[3]	Yes
South Puget Sound Fall Yearling (PSY)	Yes	—[4]	—[4]	Yes	Yes	Yes[3]	Yes
White River Spring Yearling (WRY)	—	—	—[2]	Yes	Yes	Yes[3]	Yes
George Adams Fall Fingerling (GAD)	Yes	—[4]	—[4]	Yes	Yes	Yes[3]	Yes
Elwha Fall Fingerling (ELW)	—	—	—[2]	Yes	Yes	—	—
Hoko Fall Fingerling (HOK)	—	—	Total	Yes	Yes	Yes	—
Queets Fall Fingerling (QUE)	—	Yes	Total	Yes	Yes	—	Yes
Sooes Fall Fingerling (SOO)	—	—	Total	Yes	Yes	Yes	—
Columbia Lower River Hatchery (LRH)	Yes	—	—[4]	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)	Yes	—	—[4]	Yes	Yes	Yes	—
Willamette Spring (WSH)	Yes	—	Ocean	Yes	Yes	Yes	Yes
Columbia Summers (SUM)	Yes	Yes	Total	Yes	Yes	Yes	—
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	—

[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] Insufficient escapement data for ERA.
[3] Only hatchery rack recoveries are included in escapement.
[4] Stock of hatchery origin not used to represent naturally spawning stock.

2.1 ERA Methods

2.1.1 Assumptions of the CWT ERA Analyses

Assumptions for the cohort analysis and other procedures used in the ERA are summarized below. Detailed discussions of assumptions and model parameters have been reported previously (CTC 1988). Analytical results are estimates of fishery indices for AABM fisheries, the nonceiling index for ISBM fisheries, and maturation rates for some PSC Chinook Model stocks. Primary assumptions of the cohort analysis are listed below.

1. CWT recovery data are obtained in a consistent manner from year to year or can be adjusted to make them comparable. 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. Use of ratios may reduce or eliminate the effect of data biases that are consistent from year to year.
2. For ocean-age-2 and older fish, natural mortality varies by age but is constant across years. Natural mortality probabilities 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).
3. All stocks within a fishery have the same size distribution at age that is constant across years.
4. The spatial and temporal catch distribution of sublegal-size fish of a given age and stock is the same as that for legal-size fish of that stock and age.
5. Incidental mortality rates per encounter are constant between years. The rates vary by fish size (legal or sublegal) and fishery, and are published by the CTC (1997) for troll and sport fisheries. The rates used in CLB 1209 are listed in Appendix G.
6. The procedures for estimating the mortality of CWT fish of legal size during periods of Chinook salmon nonretention (CNR) assume that the stock distribution in any year remains unchanged from the period of legal catch retention in the same year. However, gear and/or area restrictions during CNR fisheries are believed to reduce the number of encounters of legal-size fish. 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 troll fishery. This factor corresponds to the proportion of fishing areas that remain open during nonretention periods. A selectivity factor was not required for the SEAK troll fishery since an independent estimate of legal and sublegal encounters has been provided annually.
7. Maturation rates for BYs in which all ages have not matured (incomplete broods) are equal to the average of completed BYs. Maturation rates are stock specific.
8. Recoveries of age 4 (age 5 for spring stocks) and older Chinook salmon in ocean net

fisheries are assumed to be mature fish.

9. 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.
10. CWT recoveries used in the ERA are from adipose-clipped tagged 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., a minimum of 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 type of analysis performed are shown in Table 2.2. Relationships between the exploitation rate indicator stocks, model stocks, and PST Annex stocks are provided in Appendix A.

For AABM fisheries, fishery indices are presented for both reported catch and total mortality; only total mortality indices are presented for the ISBM fisheries. The difference between reported catch and total mortality is IM, which includes mortality of legal-size fish in 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 Chinook model and the CWT cohort analysis. Legal and sublegal fishery specific mortality rates are applied to the following types of Chinook salmon encounters.

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

The procedures used to estimate IM in the PSC Chinook Model have been described by the CTC

Analysis Work Group[1] and CTC (2004).

2.1.2 Brood Year Exploitation Rates

Brood year exploitation rates (BYER) provide a measure of the cumulative impact of fisheries upon all age classes of a stock and brood. The BYER was 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*

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*

See Table 2.3 for a description of notation.

The numerator of the BYER may be partitioned into components for AEQ reported catch and AEQ IM, with each component occurring in either ocean fisheries or terminal fisheries.

The exploitation rate on an indicator stock will differ from the exploitation rate on the wild stock it represents if the indicator stock is subject to terminal fisheries directed at harvesting surplus hatchery production. This difference was addressed by including only ocean fisheries in the computation of the BYER for indicator stocks that had terminal fisheries targeting hatchery fish. The method selected for each exploitation rate indicator stock is given in Table 2.2. BYERs were not computed for incomplete BYs.

2.1.3 Brood Year Survival Rates

The BY survival of CWT-tagged smolts 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 freshwater following release. Two measures of survival indices or patterns are computed: (1) survival to the age 2 (age 3 for yearling stocks) cohort based on CWT recoveries, and (2) the environmental variable (EV)

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[1] Chinook Technical Committee Analysis Work Group. Unpublished. Draft 1991 PSC Chinook Model Documentation. Chinook Technical Committee Analysis Workgroup.

determined from the calibration of the PSC Chinook model (described in the Model methods section). 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 EV parameter, however, provides a more current measure of the survival rates expected in BYs contributing to present and future fisheries.

For CWT data, 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 for the estimated age-3 cohort.

$$CohSurv_{BY,a=2or3} = \frac{Cohort_{BY,a=2or3}}{TotCWTRelease_{BY}} \qquad \textit{Equation 2.3}$$

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

$$Cohort_{BY,a} = \frac{\sum_{f=1}^{Numfisheries} TotMorts_{BY,a,f} + Esc_{BY,a} + Cohort_{BY,a+1}}{1 - NM_a} \quad . \qquad \textit{Equation 2.4}$$

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

$$Cohort_{BY,\max age-1} = \frac{\sum_{f \in Preterminal} TotMorts_{BY,\max age-1,f} + \dfrac{Esc_{BY,\max age-1} + \sum_{f \in Terminal} TotMorts_{BY,\max age-1,f}}{AvgMatRte_{\max age-1}}}{1 - NM_{\max age-1}} \quad . \qquad \textit{Equation 2.5}$$

For each stock, the survival rate for each BY is divided by the average survival rate for all BYs to create a survival index for each BY as

$$CohSurvIndex_{BY,a=2or3} = \frac{CohortSurv_{BY,a=2or3}}{LongTermAvgCohortSurvival} \quad . \qquad \textit{Equation 2.6}$$

Table 2.3 Parameter definitions for all equations except those used for the 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 equivalent 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 year for average
CY_{start} =	start year for average
$d_{t,s,a}$=	distribution parameter for timestep *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*
NMa =	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*
$TotCWTRelease_{BY}$ =	number of CWT fish released in the indicator group in brood year *BY*

2.1.4 Stock 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 three 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 2.7

Mortality distribution tables may not indicate the true distribution of an indicator stock. For example, closure of a fishery would result in no CWT recoveries but this would not necessarily indicate zero abundance of the stock in that fishing area.

2.1.5 Fishery Indices

When the PST was negotiated 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 while an index greater than 1.0 represents an increase. While the determination of allowable catch 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 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 2.8

while 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 2.9

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

$$FI_{f,CY} = \frac{\sum_{s\in\{S\}}\sum_{a\in\{A\}} ER_{s,a,f,CY}}{\left(\frac{\sum_{BPYR=79}^{82}\sum_{s\in\{S\}}\sum_{a\in\{A\}} ER_{s,a,f,BPYR}}{4}\right)}. \qquad \textit{Equation 2.10}$$

For AABM fisheries, indices are presented for troll gear only, although the catch limitations also apply to recreational fisheries and net fisheries in SEAK and the recreational fisheries in NBC and WCVI. As in past years, recoveries from the troll fishery were 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 for 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 fishery index should reflect both changes in harvest rates and stock distribution. Three general, desirable characteristics were identified:

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 harvest rate index (SPFI) was the most accurate and precise in 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 (Equation 2.11), and the result is substituted into Equation 2.12 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 2.11

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

Equation 2.12

The resulting unique solution is inserted into the following equations to compute the yearly harvest rates for each strata and the overall fishery.

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

Equation 2.13

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

Equation 2.14

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

Equation 2.15

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

Equation 2.16

Table 2.4 Parameter descriptions for equations used for the 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 in 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, 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 non-ceiling 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 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	North 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

$$ISBMIdx_{CY} = \frac{\sum_{f \in \{F\}} \sum_{a=Minage}^{Maxage} \left(TotMorts_{CY,f,a} * AEQ_{BY=CY-a,a,f} \right)}{\sum_{f \in \{F\}} \sum_{a=Minage}^{Maxage} \left(BPISBMER_{f,a} * Cohort_{BY=CY-a,a} \right)}, \qquad \textit{Equation 2.17}$$

where

$$BPISBMER_{f,a} = \frac{\sum_{BPER=79}^{82} \frac{\left(TotMorts_{BPER,f,a} * AEQ_{BY=BPER-a,a,f} \right)}{Cohort_{BY=BPER-a,a}}}{4}. \qquad \textit{Equation 2.18}$$

Direct application of the PSC Chinook salmon model alone or CWT data alone was not possible in the computation of all ISBM indices; some fisheries required a finer resolution than the CTC model currently provides, or some terminal fisheries target only marked hatchery fish, which makes the estimated CWT-based exploitation rate nonrepresentative of the untagged stocks. In those instances the following methods were used.

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

Many ISBM fisheries or stock/fishery combinations have no preseason predictions of harvest rates and some have no abundance forecasts. In those cases, the previous year's harvest rates were assumed.

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. While 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 three wild CWT indicator stocks in SEAK and one hatchery CWT indicator stock used in CTC analyses. The three wild stocks are the Chilkat River (CHK), Taku River (TAK), and Unuk River (UNU). The SEAK wild stocks are not currently used to represent a Chinook Model stock, but were proposed for model stocks in 1998 and data sets were developed and maintained since in anticipation of this task. The SEAK hatchery indicator stock, Alaska Spring (AKS), is composed of tag recoveries released from five SEAK hatcheries (Little Port Walter, Crystal Lake, Neets Bay, Deer Mountain, and Herring Cove), and it is used to represent the Alaska Southern Southeast model stock, for which the escapement and age structure data comes from six wild stocks: the Unuk, Chickamin, Blossom, Keta, and King Salmon rivers, and Andrew Creek stocks. The SEAK wild and hatchery stocks enter the ocean as yearlings, and age 3 is the youngest age at which CWTs are recovered. The CHK time series begins in BY 1999, while the TAK and UNU time series begin earlier but contain BYs where no tagging occurred. The AKS time series begins in BY 1976 and includes every year since.

2.2.1.1 *Brood Year Exploitation Rates*

The BYERs computed for CHK, TAK, and UNU include recoveries from ocean and terminal fisheries. The BYER computed for AKS does 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 terminal areas. The BYERs for SEAK wild stocks are relatively low (usually less than 20% for CHK and TAK, and less than 30% for UNU; Figure 2.2; Table 2.6). The AKS BYER is usually above 30%, but has been at or below 30% for the last three complete BYs (Figure 2.2; Table 2.6). The percentage of the AKS BYER that is incidental mortalities has decreased substantially since the 1980s and early 1990s. The last complete BY for AKS has the second lowest BYER in the time series (Figure 2.2; Table 2.6).

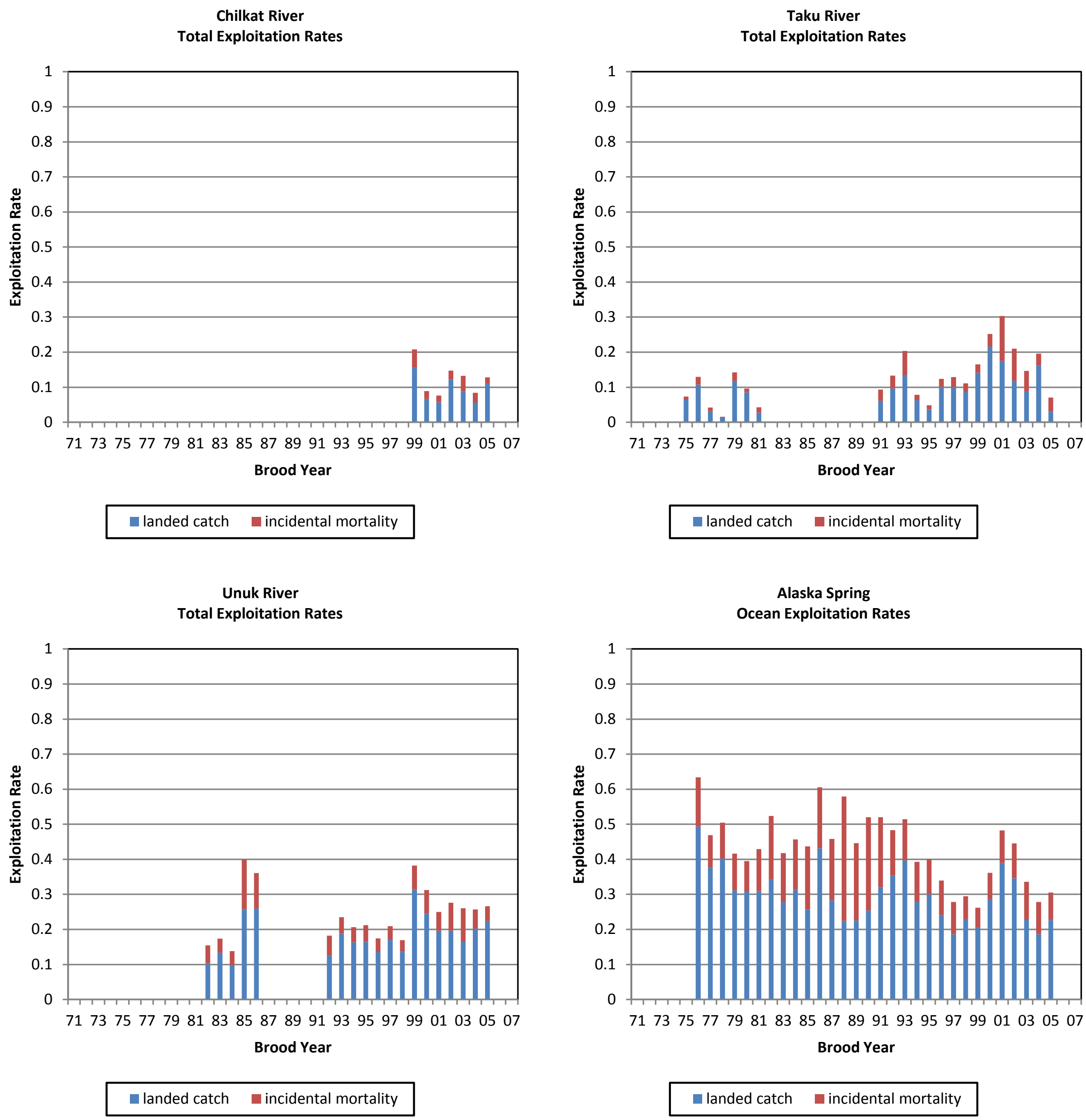


Figure 2.2 Brood year exploitation rate for SEAK stocks. Catch and incidental mortality are shown. Only completed brood years are included.

Table 2.6 Summary of statistics generated by the 2012 CWT cohort analysis for SEAK 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 Agreement periods 1999–2008 and 2009–present.

						CY % Escapement[1]		
		BYER (total mortality)		**Survival rate**		**1999–2008**	**2009–present**	
Stock	**Indicator Stock Name**	Mean (range)	Last complete BY	Mean (range)	Last complete BY	Mean (range)	Mean (range)	Last CY (if ≠ current)
AKS	Alaska Spring[2]	43% (26–63%)	31%	8.88% (2.15–25.54%)	6.11% (2005)	49% (33–62%)	57% (56–59%)	57%
CHK	Chilkat River	12% (8–21%)	13%	11.55% (1.60–29.86%)	19.27% (2007)	86% (80–93%)	85% (77–95%)	83%
TAK	Taku River	13% (2–30%)	7%	9.75% (2.91–26.41%)	5.43% (2005)	84% (61–94%)	85% (78–94%)	83%
UNU	Unuk River	24% (14–40%)	27%	5.81% (2.04–13.28%)	4.14% (2005)	76% (62–85%)	74% (71–78%)	73%

[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.

2.2.1.2 *Survival Rates*

The survival rate of all SEAK stocks is computed as the survival to age 3 because the fish enter the ocean as yearlings. The Chilkat River survival rates range from around 2–6% and the survival rate was 5% for the last complete BY. The Taku River can have extremely good survival rates (>25%), but has been below the long-term average (3–8%) for the most recent five complete BYs. The survival rate on the Unuk River has historically been above 10%, but has been below average at 2–4% for the most recent five complete BYs. The observed survival for the AKS stock has ranged from 26% for BY 1976 to 2% for BY 1977 with an average survival of 9%. The most recent five complete BYs for AKS have an average survival rate of 8%, with the last complete BY (2005) having a survival rate of 6% (Figure 2.3; Table 2.6).The AKS survival rate index for the most recent two BYs is lower than 1.0, indicating that survival is below the long-term average (Figure 2.4; Table 2.6).

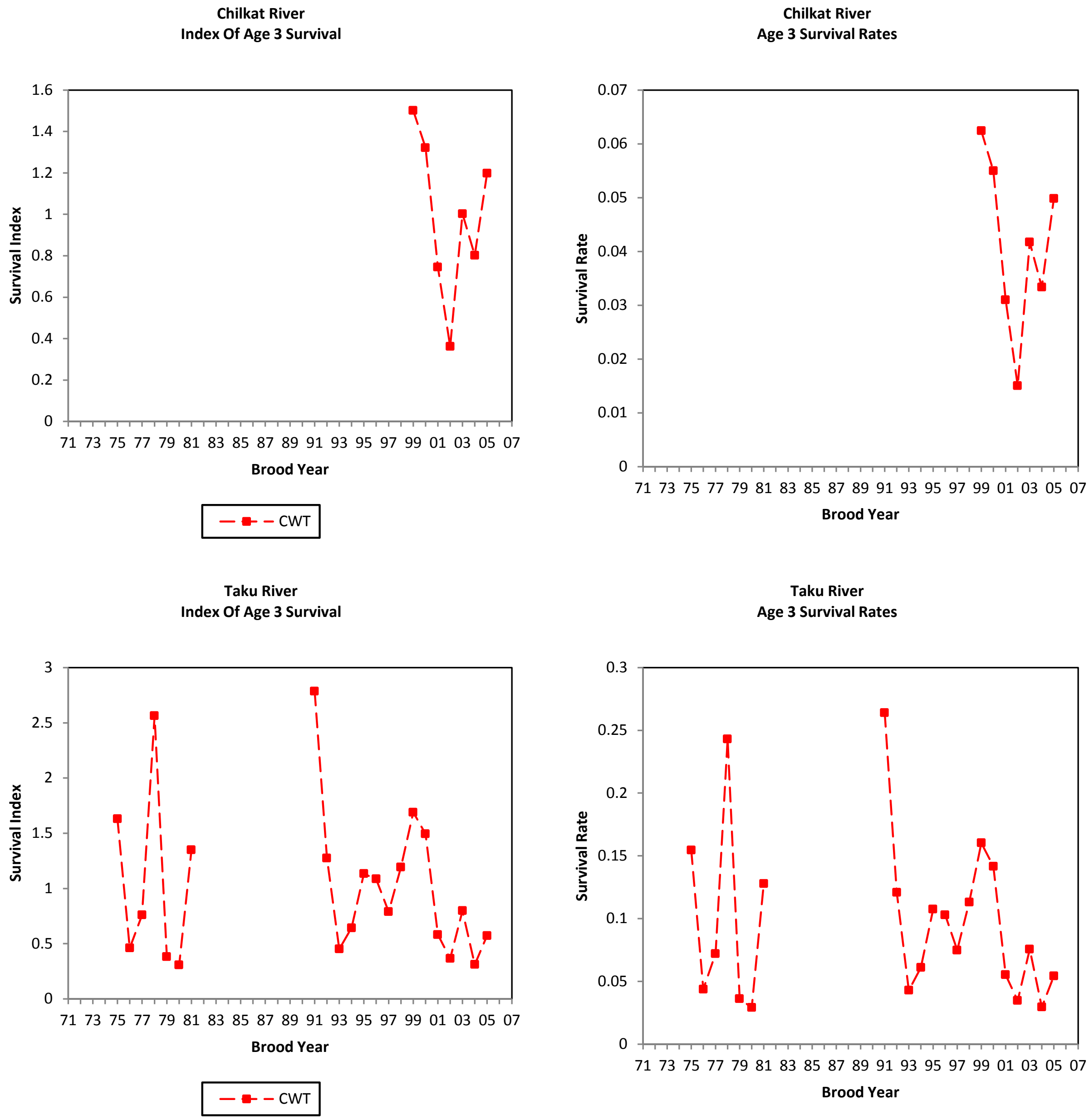


Figure 2.3 CWT survival and EV indices and survival rate for Chilkat and Taku stocks.

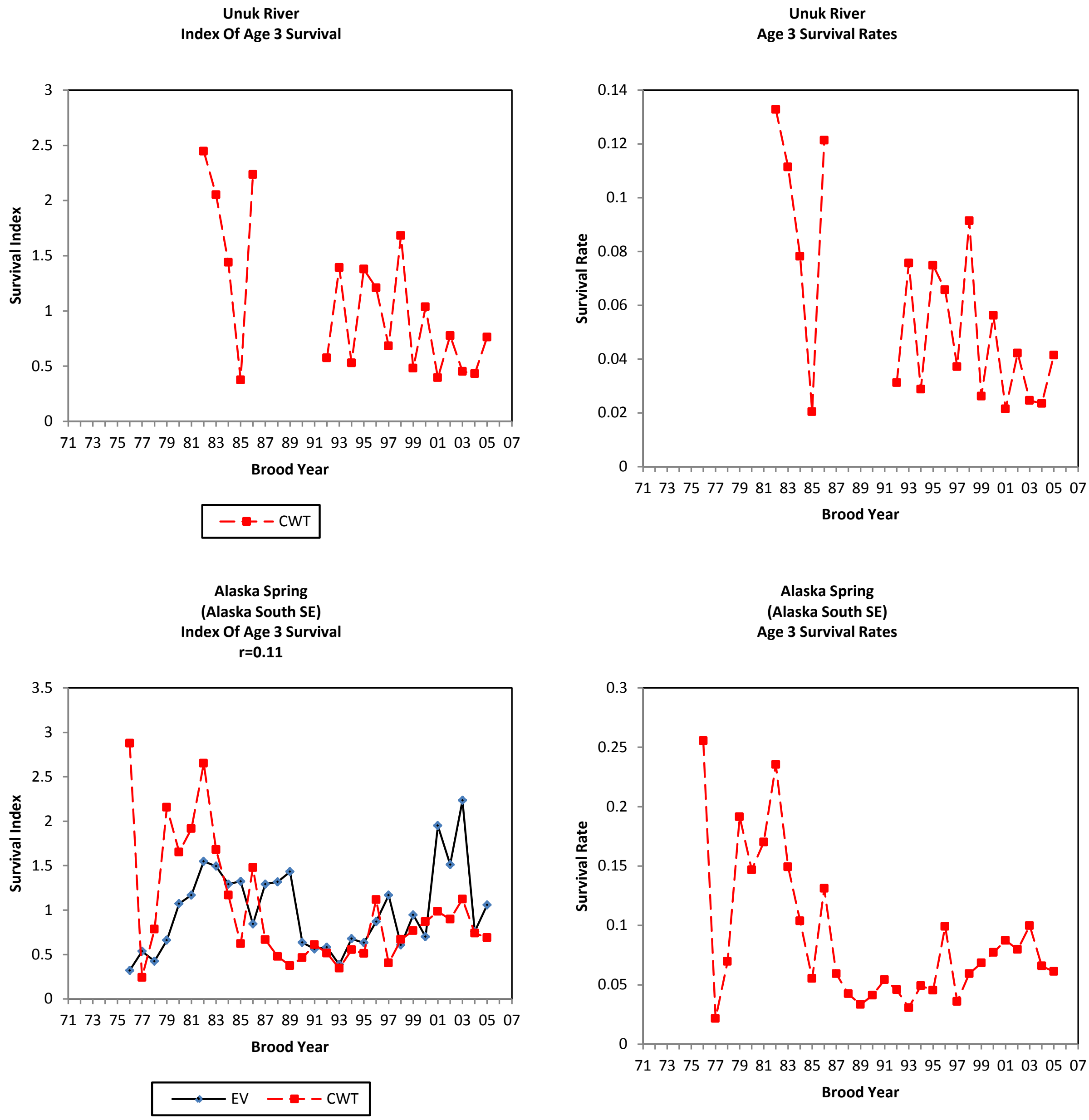


Figure 2.4 CWT survival and EV indices and survival rate for Unuk and Alaska Spring stocks. r: Pearson correlation coefficient between CWT and EV survival indices.

2.2.1.3 *Mortality Distributions*

A high percentage of CHK mortalities (average of 86%; Figure 2.5; Table 2.6; Appendix C4), TAK mortalities (1999–2011 average of 84%; Figure 2.5; Appendix C42) and UNU mortalities (1999–2011 average of 75%; Figure 2.5; Table 2.6; Appendix C43) occur after fisheries (i.e., within the escapement), with the remaining mortalities caught in the SEAK AABM sport, troll, and net fisheries. Of the SEAK AABM fisheries, the SEAK net fishery catches a higher percentage of CHK fish (average of 7%) and TAK fish (1999–2011 average of 9%) while the SEAK troll fishery catches a higher percentage of UNU fish (1999–2011 average of 13%). A few UNU mortalities have occurred in the Canadian net fishery in some years. Approximately 51% of AKS mortalities occur on at hatcheries for the 1999–2011 time period, with the remaining mortalities occurring in the SEAK AABM fisheries and the SEAK terminal net and terminal sport fisheries. The SEAK AABM troll fishery accounts for an average of 21% of the AKS total mortalities for the 1999–2011 time period, while the SEAK AABM sport and terminal sport account for an average of 9% (sport) and 11% (terminal sport) of the mortalities (Figure 2.5; Table 2.6; Appendix C1).

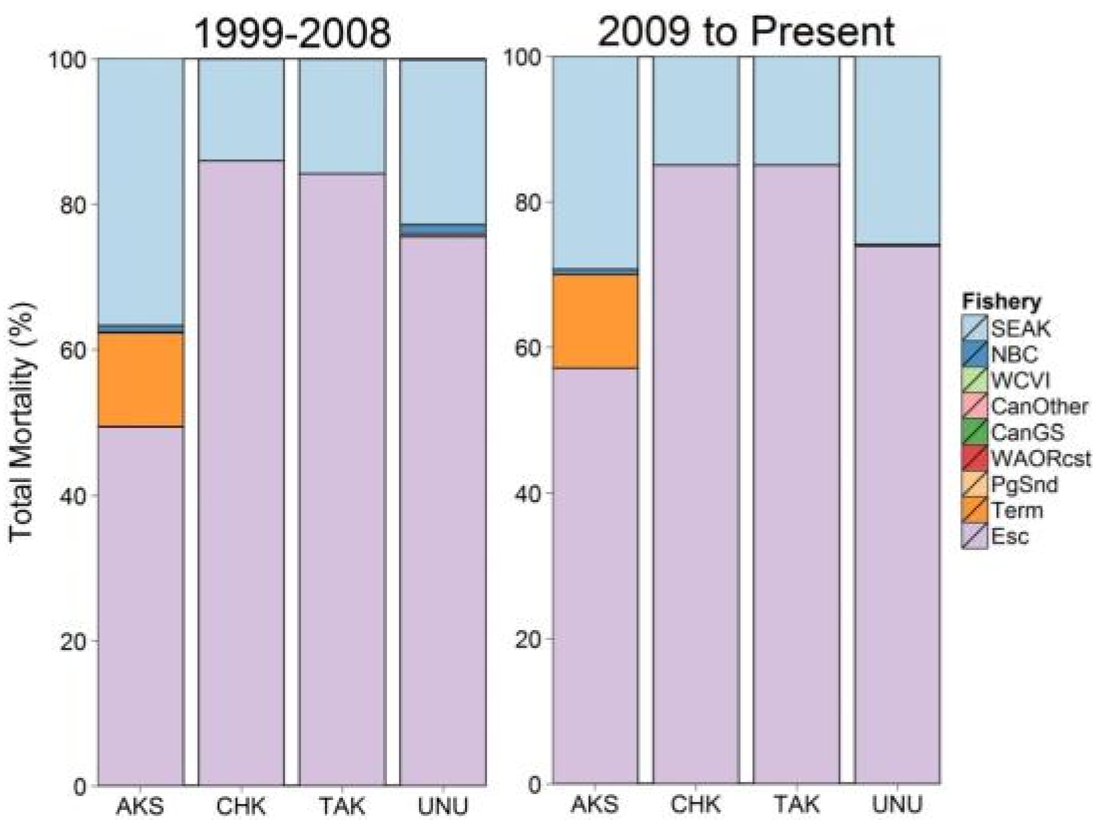


Figure 2.5 Distribution of total mortality for SEAK indicator stocks for the current (2009–present) and previous (1999–2008) agreement periods.

2.2.2 North and Central British Columbia Stocks

There are two hatchery CWT indicator stocks for North/Central B.C., Kitsumkalum and Atnarko. Atnarko (ATN) is composed of tag recoveries from the Snootli Hatchery and is not currently used to represent a Chinook Model stock. The Kitsumkalum hatchery indicator stock (KLM) is composed of tag recoveries from the Deep Creek hatchery, and it is used to represent the North/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, while 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 ocean fisheries and terminal fisheries. While the BYER for KLM has been generally decreasing from levels greater than 60% in 1979–1980 to approximately 31% in 2006, the BYER for ATN has been generally increasing from approximately 32% in 1986 to approximately 56% in 2006 (Figure 2.6). KLM BYER averaged 42% and ranged from 23% for BY 2004 to 67% for BY 1979, whereas ATN BYER averaged 41% and ranged from 30% for BY 1990 to 59% for BY 2000. Incidental mortalities have tended to make up an increasing proportion of the KLM BYER, averaging 19% of the total mortality with a range of 11–28%. In the case of ATN, the percentage of the BYER that is IM shows no tendency, averaging 11.5% with a range of 7–16%.

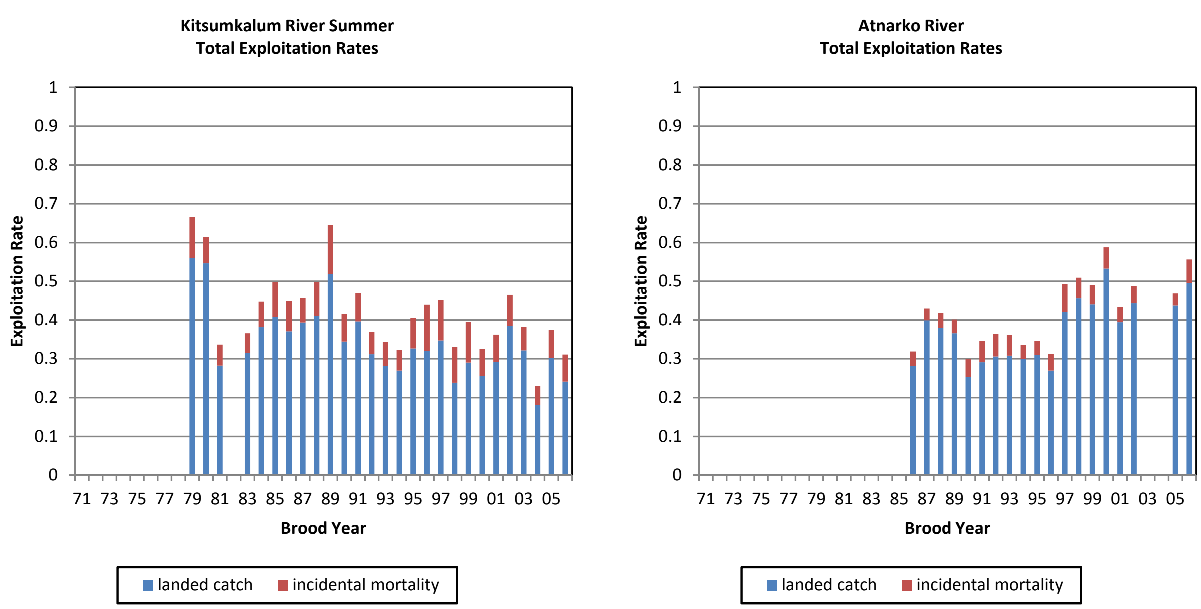


Figure 2.6 Total brood year exploitation rate for North and Central B.C. stocks. Catch and incidental mortality are shown. Only completed brood years are included.

2.2.2.2 *Survival Rates*

The survival rate of KLM is survival to age 3 because the fish enter the ocean as yearlings while the survival rate of ATN is survival to age 2 because the fish enter the ocean as subyearlings. The KLM survival rates have averaged 1.0% and ranged from around 0.1–2.4% with a survival rate of 1.1% for the last complete BY. In the case of ATN, survival rates have averaged 2.3% and ranged from around 0.5–4.9% with a survival rate of 1% for the last complete BY (Figure 2.7). The EV index and the survival index are poorly correlated in both KLM and ATN with r = 0.13 (KLM) and r = 0.40 (ATN).

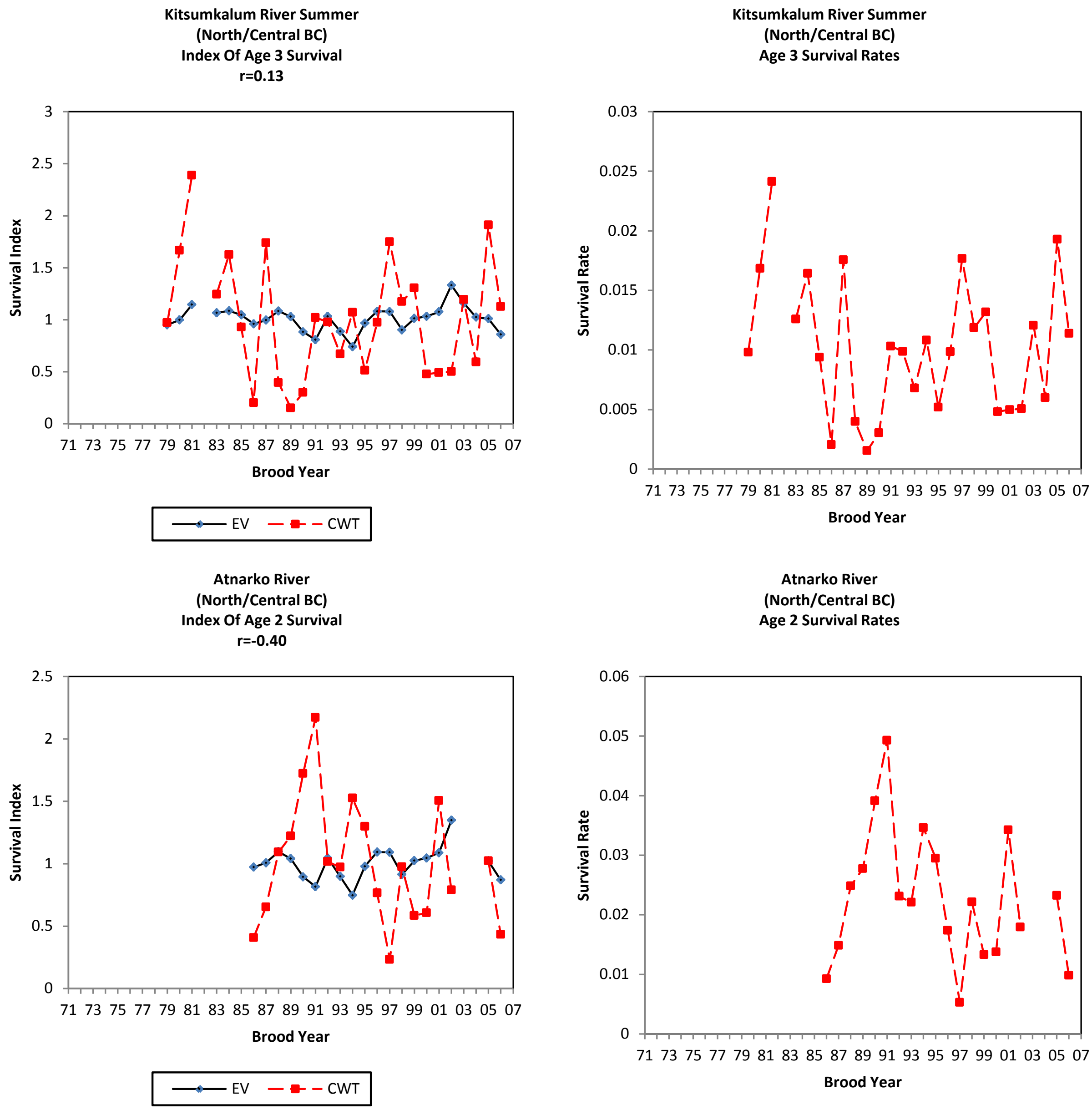


Figure 2.7 CWT survival and EV indices and survival rate for North and Central B.C. stocks. r: Pearson correlation coefficient between CWT and EV survival indices.

2.2.2.3 *Mortality Distributions*

An average of 56% of the KLM total mortality (Figure 2.8; Appendix C15) and 58% of the ATN mortality (Figure 2.8; Appendix C2) occurred in the escapement during the entire mortality distribution time series, which begins in 1984 for KLM and 1990 for ATN. The average mortality in the escapement increases to 61% in KLM and slightly decreases to 56% in ATN during 1999–2012. Most of the remaining mortalities in KLM are associated to catch and IM in the SEAK AABM troll (1999–2012 average: 12%) and the NBC AABM sport (1999–2012 average: 10%) fisheries. NBC AABM troll and ISBM Canada net fisheries used to be important mortality components for KLM during 1979–1984 with 19% (AABM troll) and 24% (ISBM Canada) of the total mortality but their relevance diminishes to approximately 2% (AABM troll) and 6%, (ISBM Canada) during 1999–2012. In the case of ATN, most of the fishing mortality is associated to catch and IM in the SEAK AABM troll (1999–2012 average: 9%), the NBC AABM sport (1999–2012 average: 8%), and the ISBM terminal net fisheries (1999–2012 average: 18%). ISBM Canada net fisheries used to be important mortality components for ATN during 1985–1998 with 13–17% of the total mortality but their relevance diminishes to approximately 3% during 1999–2012.

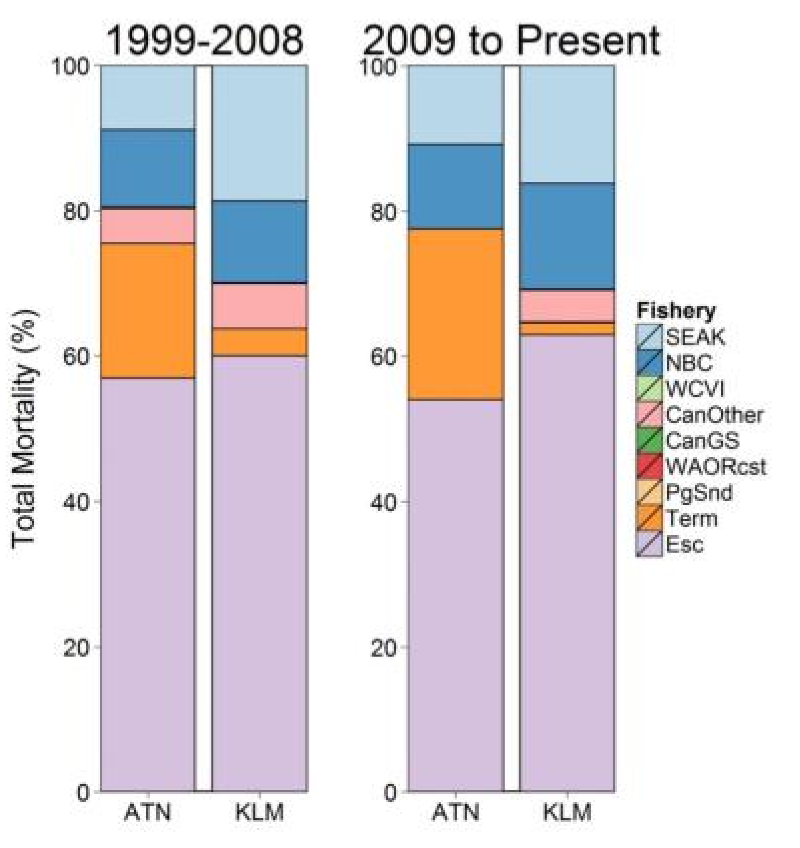


Figure 2.8 Distribution of total mortality for North and Central B.C. indicator stocks for the current (2009–present) and previous (1999–2008) agreement periods.

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 2007.

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 77% for BY 1973 to approximately 37% for BY 2007 (Figure 2.9). 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 45% and ranged from 25% for BY 1998 to 77% for BY 1973. The 17% IM experienced by BY 1992 is entirely attributed to CWT recoveries of sublegal fish. The percentage of the RBT BYER that is IM increased exponentially during the first 10 years of the time series from approximately 14% for BY 1973 to 68% for BY 1983. It then decreased substantially to approximately 20%, then increased exponentially again for the following eight BYs to approximately 59% 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 IM averages approximately 26% for the entire time series.

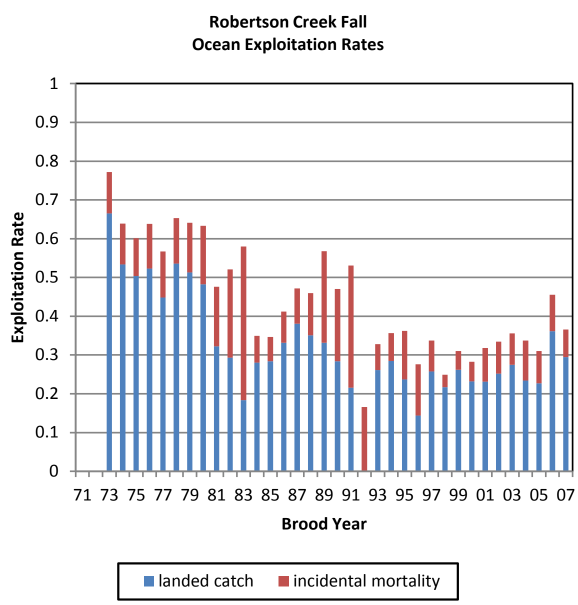


Figure 2.9 Brood year ocean exploitation rates for Robertson Creek Fall. Catch and incidental mortality are shown. Only completed brood years are included.

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 5.0% and ranging from around 0.01% for BY 1992 to 21.1% for BY 1974, with a survival rate of 4.4% for the last complete BY (Figure 2.10). In addition to BY 1992, BYs 1983, 1995, 1996, and 1997 have also experienced extremely low survival rates. The EV index and the survival index are moderately correlated with r = 0.66.

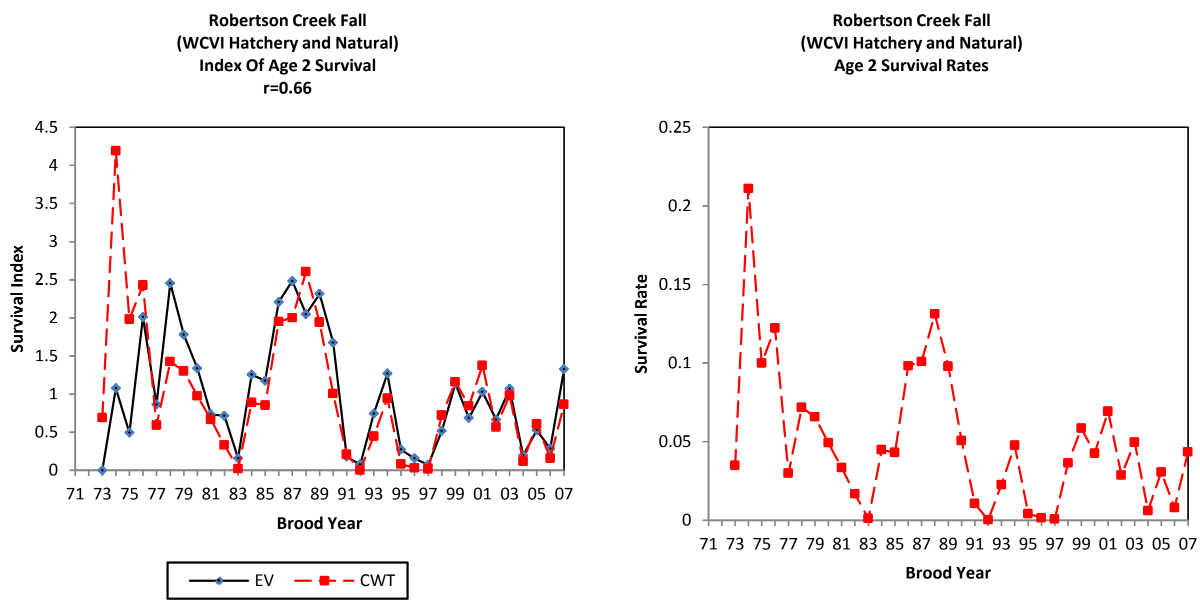


Figure 2.10 CWT survival and EV indices and survival rate for Robertson Creek Fall. r: Pearson correlation coefficient between CWT and EV survival indices.

2.2.3.3 *Mortality Distributions*

An average of 36% of the RBT total mortality (Figure 2.11; Appendix C28) occurred in the escapement during 1979–2012. The RBT average mortality in the escapement increased to 44% during 1999–2012. Most of the remaining mortalities in this stock are associated to catch and IM in the SEAK AABM troll (1999–2012 average: 12%), ISBM terminal net (1999–2012 average: 12%) and sport (1999–2012 average: 11%) 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 its relevance diminished to approximately 3% during 1999–2012. The ISBM Canada net fishery was also an important RBT mortality component during 1979–1984 with around 6% of the total mortality, but its contribution effectively became 0% during 1999–2012.

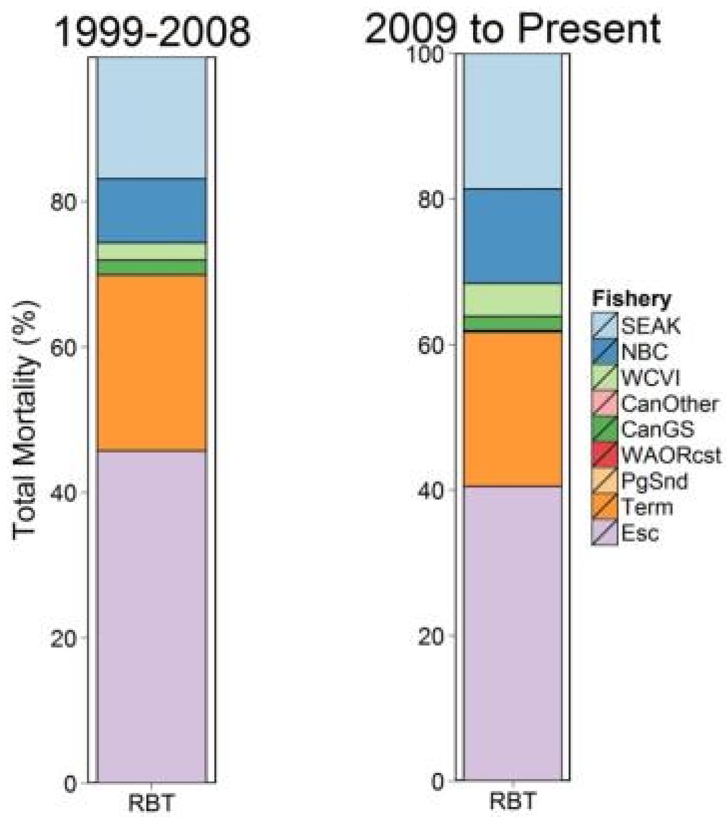


Figure 2.11 Distribution of total mortality for the WCVI indicator stock (Robertson) for the current (2009–present) and previous (1999–2008) agreement periods.

2.2.4 Strait of Georgia Stocks

Strait of Georgia model stocks are segregated into upper Strait of Georgia (GSQ) and lower Strait of Georgia (GST for wild Chinook and GSH for hatchery Chinook). There is one hatchery CWT indicator stock for upper Strait of Georgia (Quinsam [QUI]), two for lower Strait of Georgia Natural (Cowichan [COW] and Nanaimo [NAN]), and two for lower Strait of Georgia 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 while PPS and BQR are composed of tag recoveries from the Puntledge and Big Qualicum hatcheries. Strait of Georgia Chinook enter the ocean as subyearlings and age 2 is the youngest age at which CWTs are recovered. The QUI time series begins in BY 1974, COW in 1985, NAN in 1979, PPS in 1975, and BQR in 1973. NAN time series not only starts later than the other Strait of Georgia stocks but also exhibits several gaps.

2.2.4.1 *Brood Year Exploitation Rates*

The BYERs computed for Strait of Georgia stocks include recoveries from ocean fisheries and terminal fisheries. There is a general declining tendency for BYERs of the indicator stock for upper Strait of Georgia (Figure 2.12) as well as for most of the indicator stocks for lower Strait of Georgia (Figure 2.13). The BYER for QUI has decreased from approximately 71% in 1974 to approximately 37% in 2006, averaging 58% and ranging from 31% for BY 2004 to 84% for BY

1977 (Figure 2.12). The percentage of the QUI BYER that is IM increased consistently during the first 17 years of the time series reaching 57% for BY 1991, and then decreasing substantially to average levels for subsequent BYs. Similar exploitation rate patterns occurred for all lower Strait of Georgia indicator stocks, except for COW (Figure 2.13) for which BYERs generally decreased from BY 1985 to BY 1995, and generally increased in subsequent BYs. COW BYER averaged approximately 70% and ranged from 37% for BY 1995 to 89% for BY 1985. The percentage of the COW BYER that is IM increased consistently during the first 11 years of the time series reaching 47% for BY 1995, and averaged approximately 33% for the entire time series. BYERs of the other three lower Strait of Georgia indicator stocks, BQR, NAN, and PPS, decreased from exploitation rate levels of 80–90% to exploitation rate levels of 25–35%. The lowest BYERs for these stocks were experienced by BY 2007 in BQR (33%), by BY 2001 in NAN (36%), and by BY 1998 in PPS (12%). The percentage of the BYER that is IM in these three stocks increased consistently during the first 15–20 years of the time series and averaged 23% in BQR, 33% in NAN, and 25% in PPS.

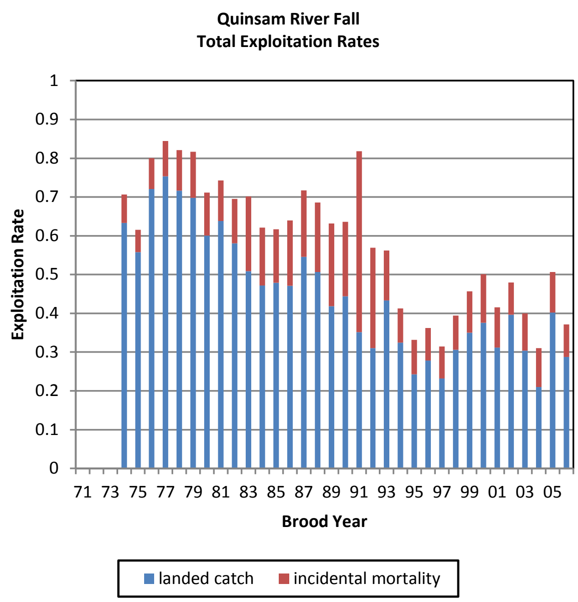


Figure 2.12 Total brood year exploitation rate for Quinsam River Fall. Catch and IM are shown. Only completed brood years are included.

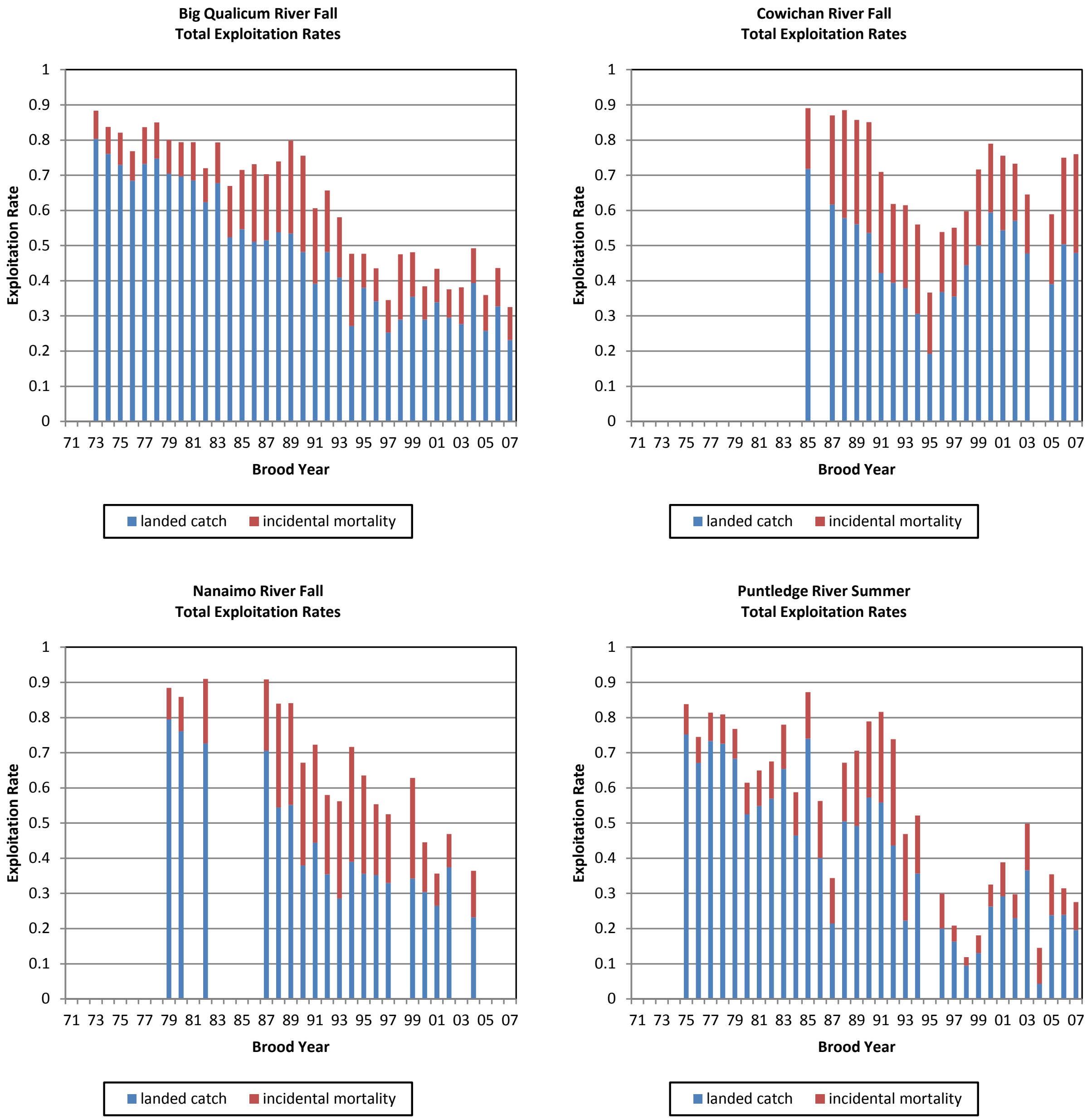


Figure 2.13 Total brood year exploitation rate for Lower Strait of Georgia stocks. Catch and incidental mortality are shown. Only completed brood years are included.

2.2.4.2 *Survival Rates*

The survival rates of Strait of Georgia CWT indicator stocks represent survival to age 2 because fish enter the ocean as subyearlings. All these stocks show a clear declining trend in survival rates and moderate correlations between survival and EV indices, except for NAN with a correlation coefficient of 0.39. The QUI survival rates have averaged 2.3% and ranged from around 0.2% for BY 2006 to 9.3% for BY 1976 (Figure 2.14). In the case of lower Strait of Georgia CWT indicator stocks, BQR survival rates have averaged 2.7% with a range of approximately 0.1–25.6% (the highest observed for Strait of Georgia stocks), COW survival rates have averaged 2.0% with a range of approximately 0.3–7.0%, NAN survival rates have averaged 2.2% with a range of approximately 0.6–5.8%, and PPS survival rates have averaged 1.2% with a range of approximately 0.1–12.4% (Figure 2.15). The survival rate for the last completed brood of the time series was 0.2% for QUI, 0.5% for BQR, 0.7% for COW, 3.0% for NAN, and 0.8% for PPS.

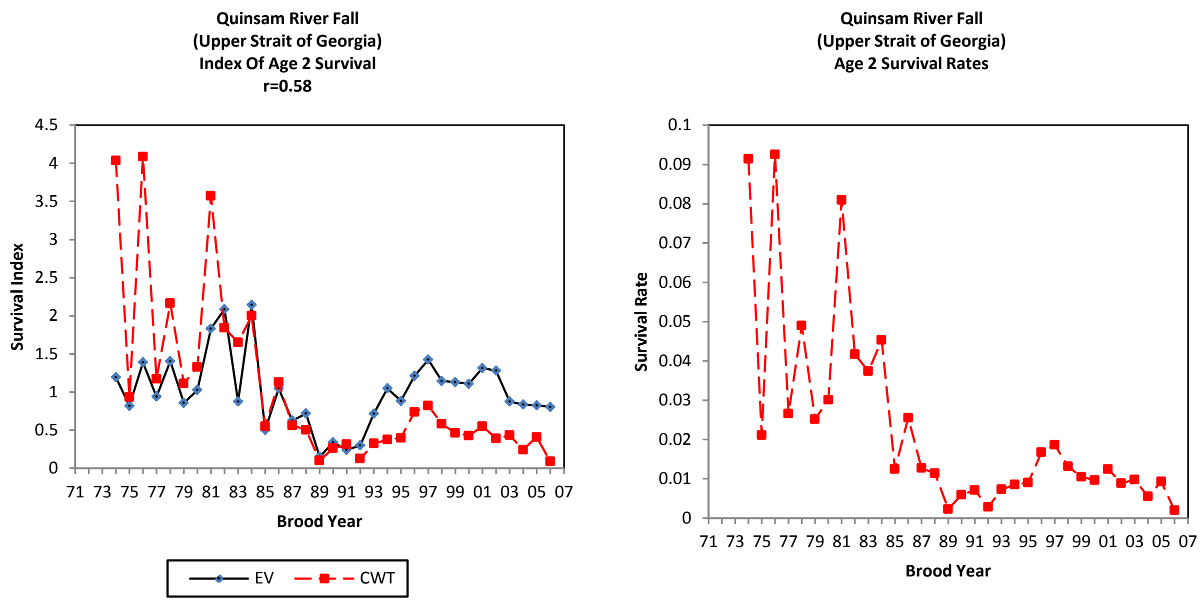


Figure 2.14 CWT survival and EV indices and survival rate for Quinsam River Fall. r: Pearson correlation coefficient between CWT and EV survival indices.

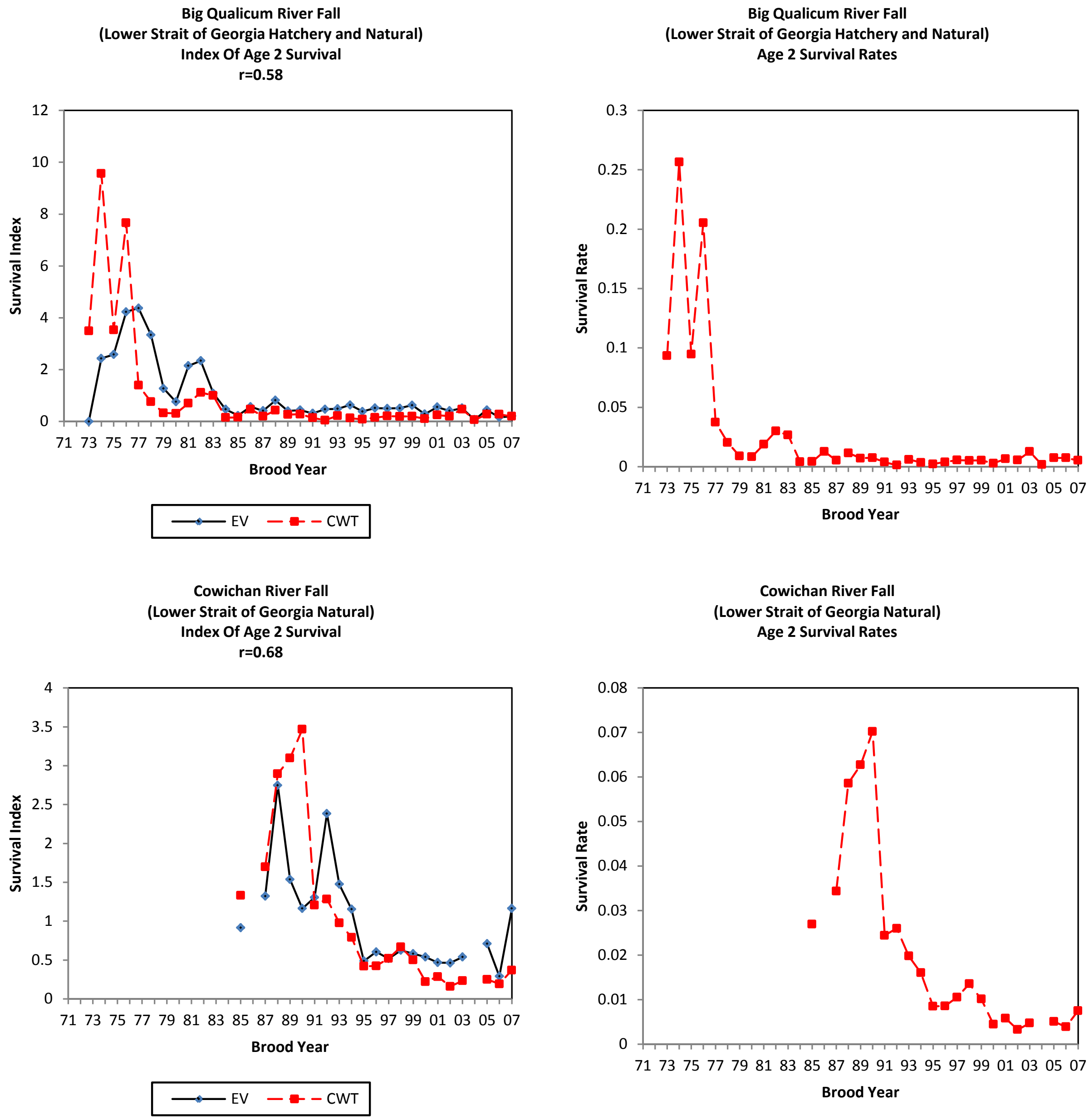


Figure 2.15 CWT survival and EV indices and survival rate for Lower Strait of Georgia stocks. r: Pearson correlation coefficient between CWT and EV survival indices.

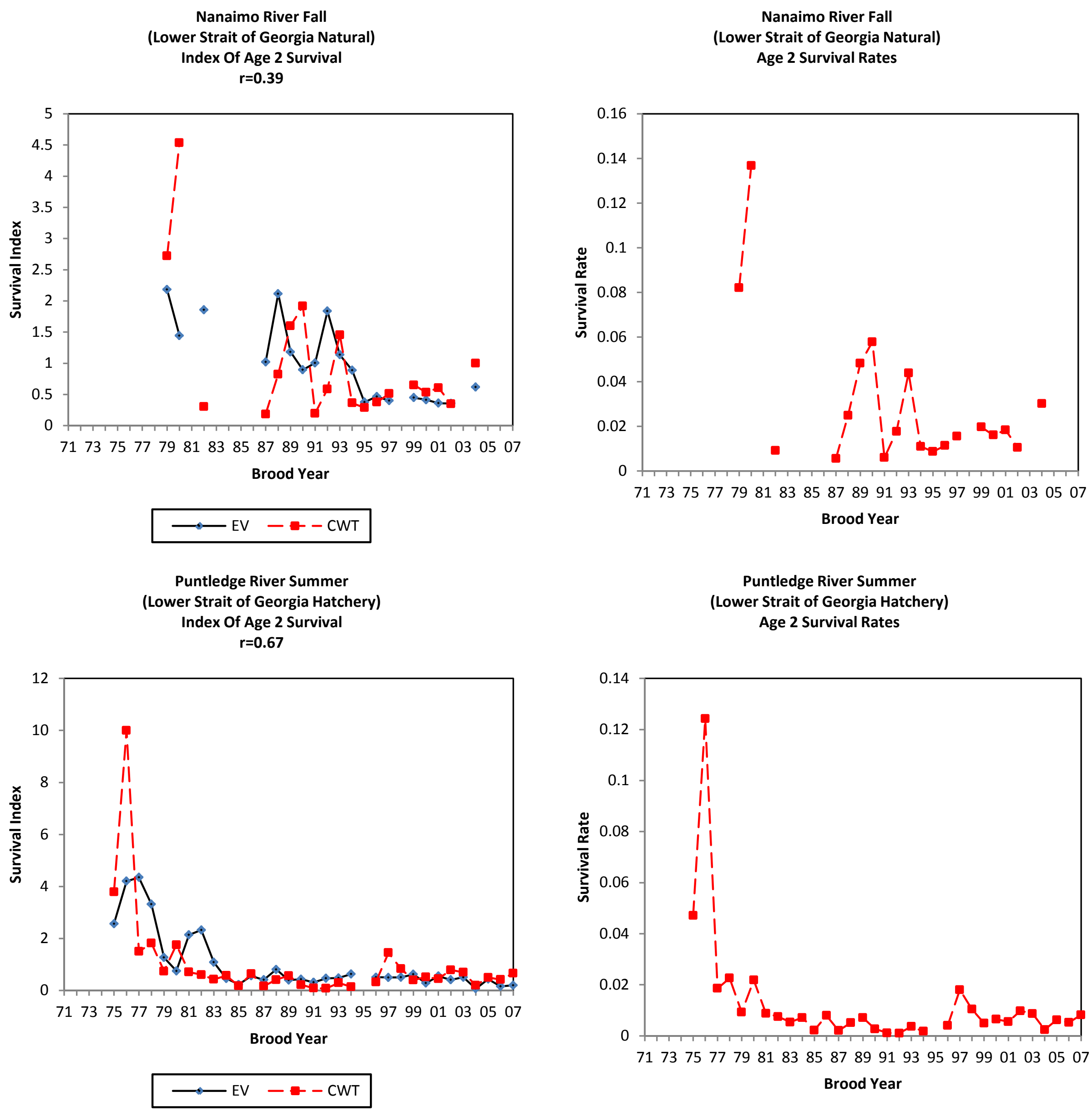


Figure 2.15   Page 2 of 2.

2.2.4.3 *Mortality Distributions*

Total mortality in the upper Strait of Georgia indicator stock QUI (Figure 2.16; Appendix C26) averaged 44% in the escapement during 1979–2012, and increased to 59% during 1999–2012. Most of the remaining mortalities in this stock are associated to catch and IM in the SEAK AABM troll (1999–2012 average: 14%) and NBC AABM sport (1999–2012 average: 14%) fisheries. The NBC AABM troll and ISBM Canada troll and net fisheries used to be important mortality components for QUI during 1979–1995 with 7–10% of the total mortality in NBC AABM troll, 5–10% in ISBM Canada troll, and 16–22% in ISBM Canada sport. Average Chinook mortality in these fisheries diminishes during 1999–2012 to approximately 1% for NBC AABM troll, 0% for the ISBM Canada troll, and 1% for the ISBM Canada sport. The ISBM Strait of Georgia sport fishery was a particularly important QUI mortality component during 1996-1998 with around 9% of the total mortality but its contribution has diminishes to 4% during 1999–2012.

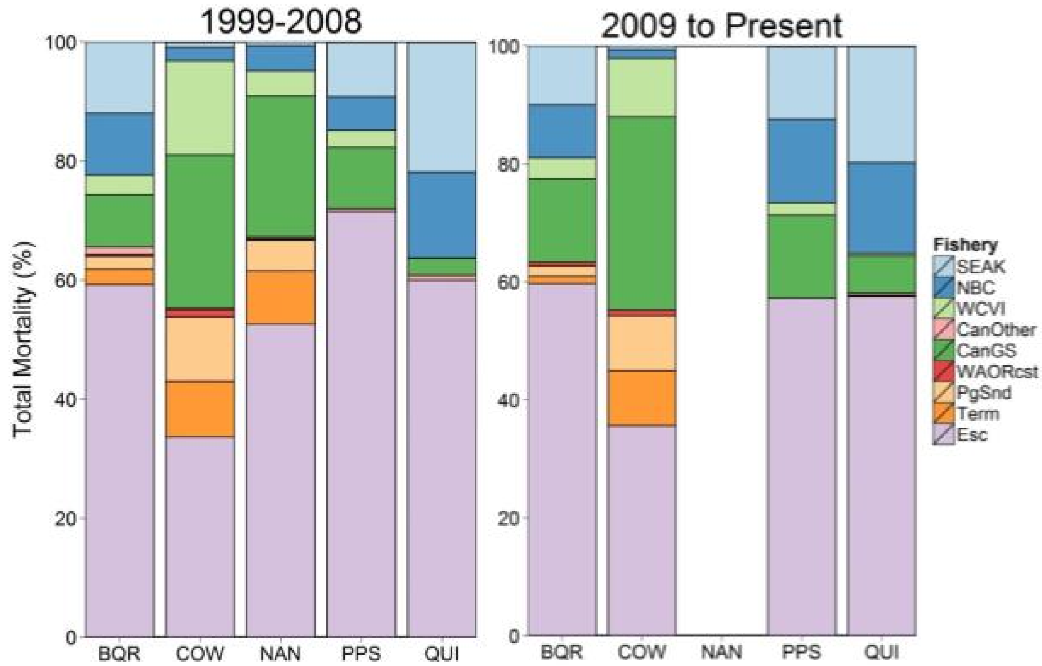


Figure 2.16 Distribution of total mortality for upper and lower Strait of Georgia indicator stocks for the current (2009–present) and previous (1999–2008) agreement periods.

Among the lower Strait of Georgia indicator stocks, an average of 42% of the BQR total mortality (Figure 2.16; Appendix C3), 32% of the COW total mortality (Figure 2.16; Appendix C6), 41% of the NAN total mortality (Figure 2.16; Appendix C20), and 50% of the PPS total mortality (Figure 2.16; Appendix C25) occurred in the escapement during 1979–2012 (note that COW mortality distribution time series begins in 1990 and that of NAN is truncated to 1984–2006). During 1999-2012, the average mortality in the escapement increases to 59% in BQR, to 34% in COW, to 53% in NAN, and 67% in PPS. Most of the remaining mortalities in BQR are associated to catch and IM in the ISBM Strait of Georgia sport (1999–2012 average: 10%), the SEAK AABM troll (1999–2012 average: 8%), and the NBC AABM sport (1999–2012 average: 8%) fisheries. The ISBM Canada net and troll fisheries used to be important mortality components for BQR during 1979–1995 with 10–15% (net) and 3–8% (troll) of the total mortality but their relevance diminishes to less than 1% during 1999–2012. The ISBM Strait of Georgia troll fishery was also important during 1979–1984, averaging 15% of the BQR total mortality, but its contribution becomes effectively 0% during 1999–2012. In the case of COW, total fishing mortality is dominated by the ISBM Strait of Georgia sport fishery (1999–2012 average: 28%), but the WCVI AABM troll (1999–2012 average: 9%), the ISBM Puget Sound net (1999–2012 average: 7%), and the ISBM terminal net (1999–2012 average: 7%) fisheries are also important COW mortality components. The ISBM Strait of Georgia 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 1999–2012. Similar to COW, most of NAN fishing mortality has been dominated by the ISBM Strait of Georgia sport fishery (1984–2006 average: 34%). ISBM Canada net and troll fisheries were important mortality components for NAN in the past with 19% (net) and 13% (troll) of the total mortality in 1984, but their relevance diminished to mortality levels of 0% (net) and 3% (troll) during 1999–2006. Lastly, most of PPS fishing mortality is associated to catch and IM in the ISBM Strait of Georgia sport (1999–2012 average: 11%), the NBC AABM sport (1999–2012 average: 8%), and the SEAK AABM troll (1999–2012 average: 8%) fisheries. ISBM Strait of Georgia troll and ISBM Canada troll and net fisheries used to be important mortality components for PPS during 1979–1984 with 14% of the total mortality associated to ISBM Strait of Georgia troll, 10% to ISBM Canada troll, and 11% to ISBM Canada net. During 1999–2012, their relevance diminished to mortality levels of 0% for both the ISBM Strait of Georgia troll and the ISBM Canada troll fisheries, and less than 1% for ISBM Canada net fisheries.

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 one for Fraser Early subyearling Summer-run type (Lower Shuswap [SHU; age 0.3]). There is no CWT indicator for Fraser Early yearling Summer-run type, 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 is comprised of releases of Dome Creek stock from the Penny Hatchery. SHU is composed of tag recoveries of Lower Shuswap River Chinook from 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 are Summer Chinook, entering the ocean as subyearlings, whereas the NIC and DOM stocks are Spring Chinook, 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, and SHU with BY 1984. Unlike the other Fraser River stocks with time series ending with BY 2007, 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 2.17). 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 and SHU (Figure 2.18). Between BY 1981 and BY 2007, the BYERs decreased from approximately 71% to 27% for CHI and from approximately 86% to 21% for HAR. CHI BYER averaged 44% and ranged from 23% for BY 2002 to 83% for BY 1982, whereas HAR BYERs averaged 53% and ranged from 21% for BY 1995 to 91% for BY 1982.

Within BYERs, the percentage of the BYER represented by IM for CHI averaged 22% and increased consistently during the first 15 years of the time series, reaching 36% for BY 1995, and then decreased substantially to average levels for subsequent BYs. Similarly, the percentage of the HAR BYER that results from IM also averaged 22% and increased consistently during the first 15 years of the time series, reaching 41% for BY 1995, and then decreased substantially to average levels for subsequent BYs.

Exploitation rate patterns differed for the three indicator stocks representing Fraser Early. DOM BYER averaged approximately 57% and ranged from 16% for BY 1986 to 80% for BY 1996. The percentage of the DOM BYER that is attributed to IM remained relatively stable, averaging approximately 15% for the entire time series, and reached its lowest values for BYs 1988 (4%) and 2000 (0.5%). Not including 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 average approximately 26%, and range from approximately 10% for BY 2006 to approximately 47% for BY 1988. The estimates of IM remained relatively stable, averaging approximately 11% for the entire time series, and ranging from 5% for BY 2000 to 21% for BY 1990. Lastly, BYER for SHU averaged approximately 53%, and ranged from 30% for BY 1997 to 79% for BY 1988. SHU BYER IM has remained relatively stable, averaging approximately 21% for the entire time series and ranging from 14% for BY 1990 to 37% for BY 1997.

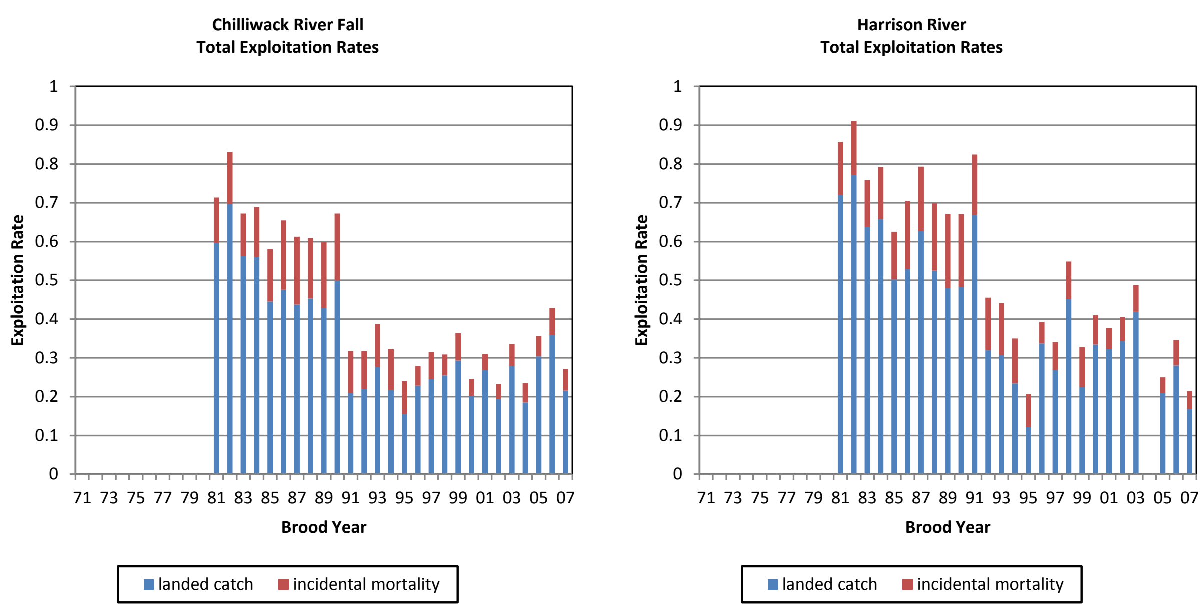
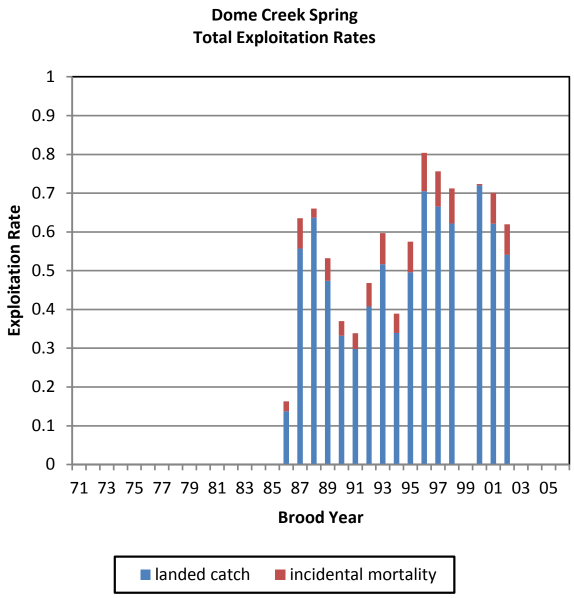
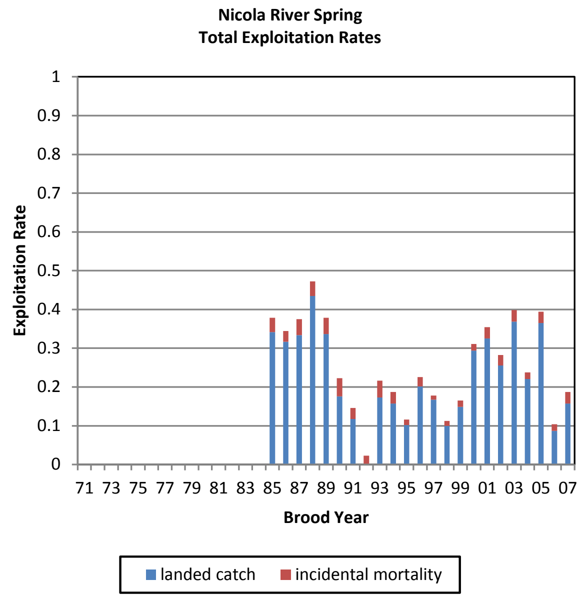


Figure 2.17 Total brood year exploitation rate for Fraser Late stocks. Catch and incidental mortality are shown. Only completed brood years are included.





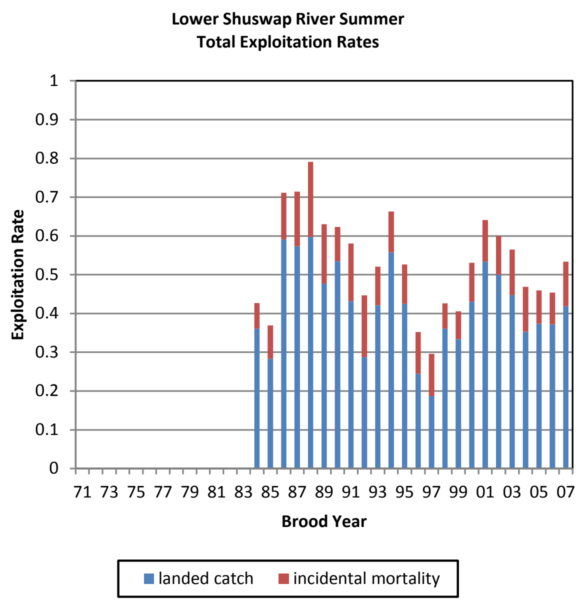


Figure 2.18 Total brood year exploitation rate for Fraser Early stocks. Catch and incidental mortality are shown. Only completed brood years are included.

2.2.5.2 *Survival Rates*

Estimated survival rates for CHI, HAR, 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. Moderate correlations exist between survival and EV indices for CHI and HAR; $r = 0.68$ for the CHI and $r = 0.45$ for HAR. Correlations between EV and survival indices for Fraser Early indicator stocks are weak, however, with $r \leq 0.25$ for each of the indicators.

For CHI, survival averaged 11.6%, with a range of 1.6–29.9% (the highest observed for any Fraser River stock). Estimated survival rates for HAR averaged approximately 3.6%, and ranged from 0.4% in BY 1981 to a high of 23.6% for BY 1991 (Figure 2.19). For the Fraser Early indicator stocks, DOM survival rates averaged 1.2% and ranged from a low of 0.2% for BY 1994 to 2.5% for BY 1993. NIC survival rates averaged 3.8% with a range of 0.1–14.4%, and the SHU survival rates averaged 3.3% with a range of 0.7–8.4% (Figure 2.20). The survival rate for the last completed brood of the time series was 19.3% for CHI, 5.8% for HAR, 1.4% for NIC, and 2.2% for SHU. DOM has been discontinued, and survival for the last completed BY (2002) was 0.4%.

The strength of the association between the standardized CWT survival indices and the model EVs provides some insights about the representation of the components of specific model stocks. The Fraser Late model stock appears to represent the survival conditions for the CHI more closely than for HAR based on the higher EV survival indices correlation coefficients; this may be a result of the CHI being used to represent the model stock (Figure 2.18). For the Fraser Early model stock, the EVs have a low association with the survival rates for NIC and SHU, but essentially no association with DOM. These low associations for the Fraser Early model stock indicate that one or more aspects of these stocks are poorly represented in the model.

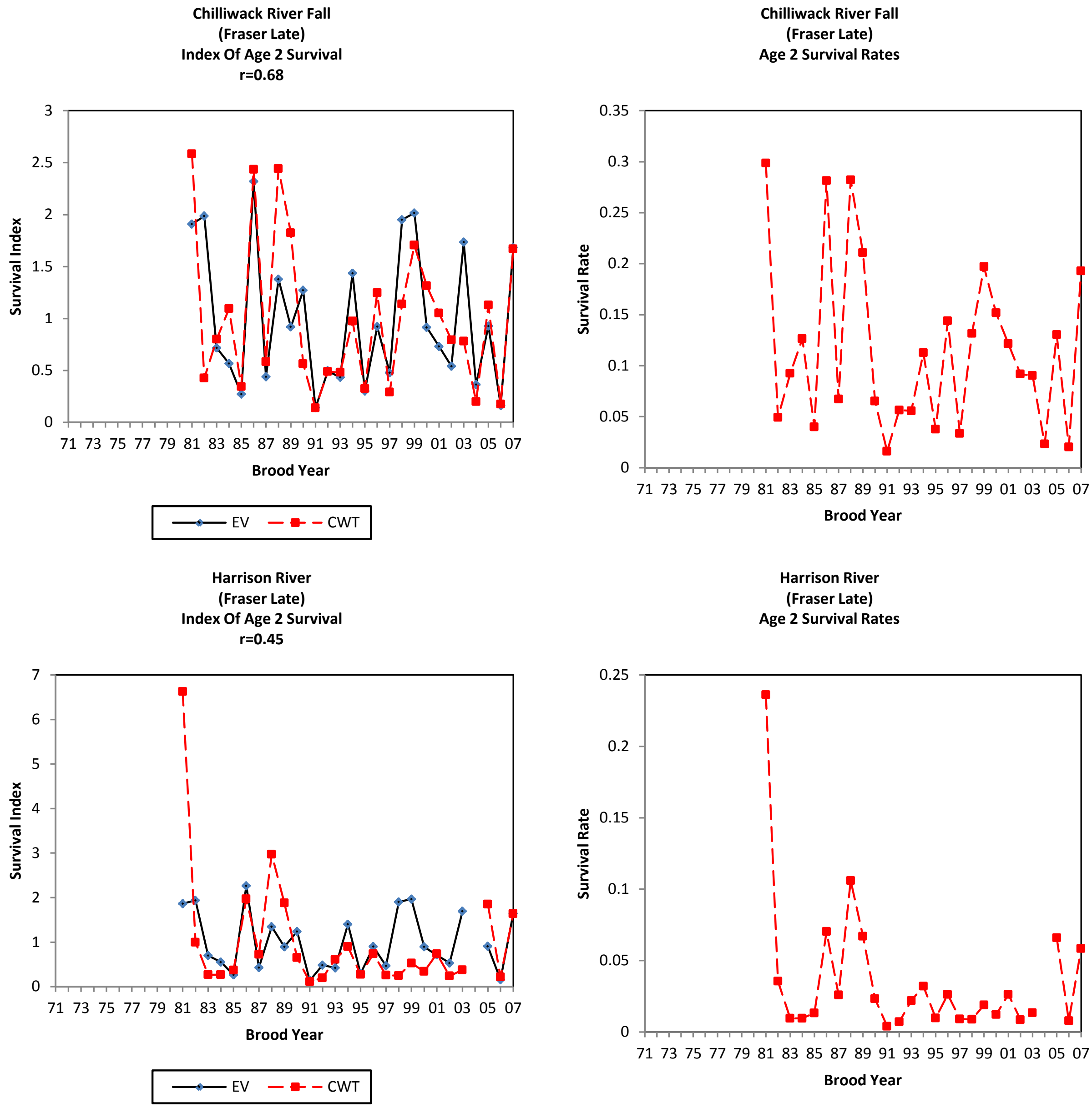


Figure 2.19 CWT survival and EV indices and survival rate for Fraser Late stocks. r: Pearson correlation coefficient between CWT and EV survival indices.

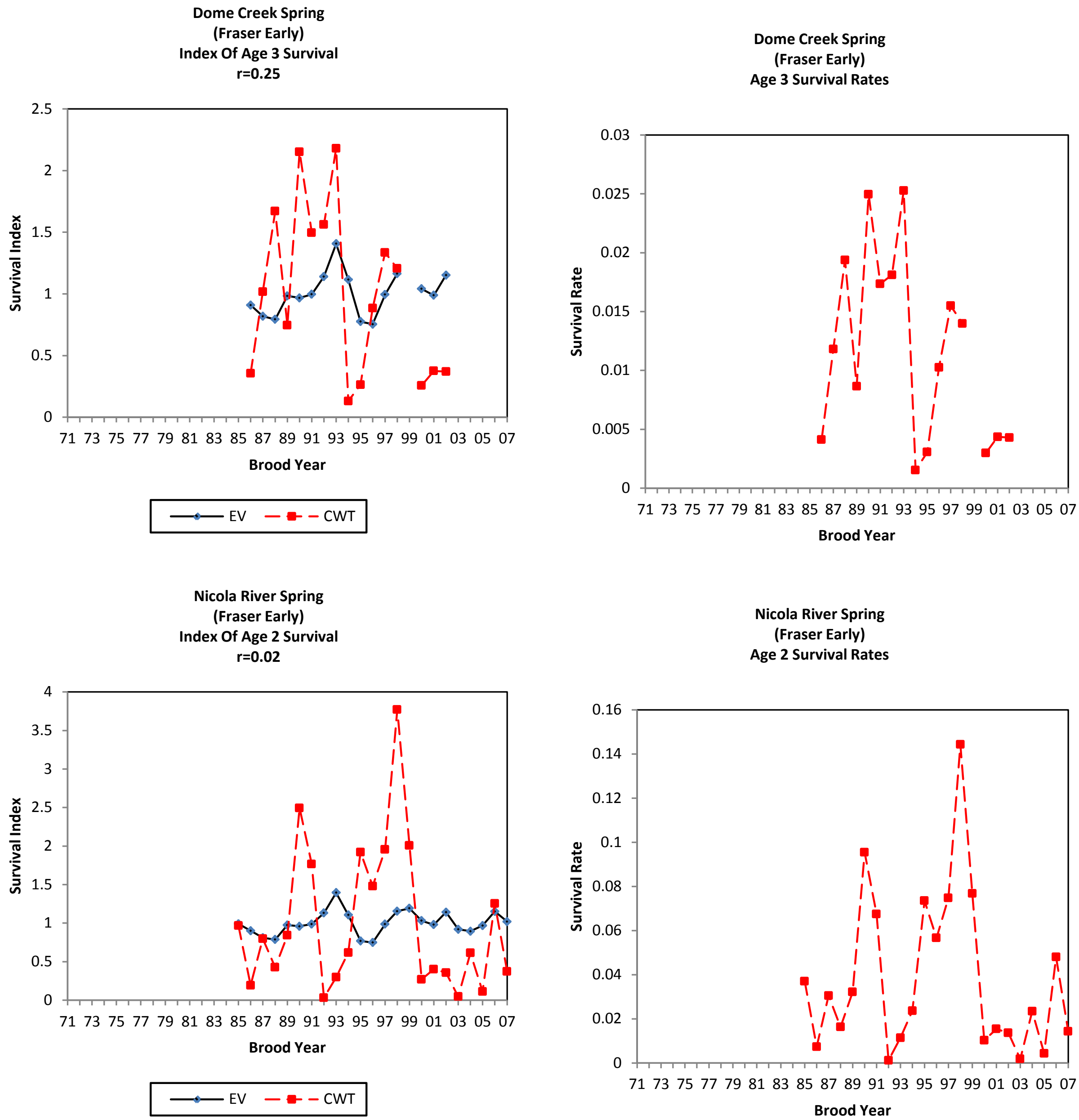


Figure 2.20 CWT survival and EV indices and survival rate for Fraser Early stocks. r: Pearson correlation coefficient between CWT and EV survival indices.

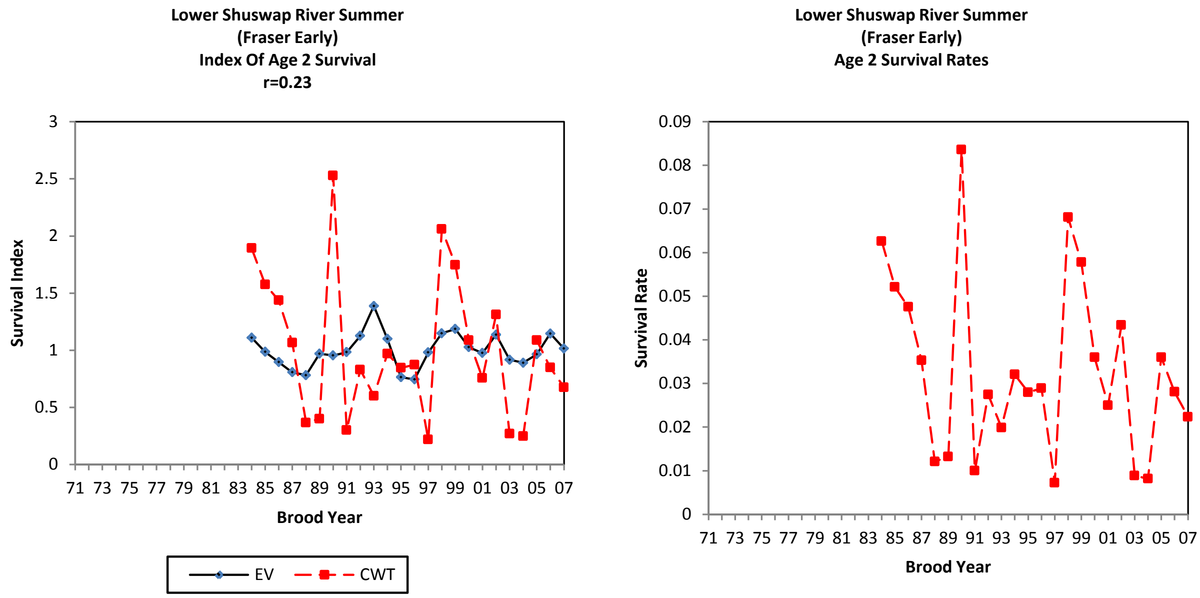


Figure 2.20 Page 2 of 2.

2.2.5.3 *Mortality Distributions*

For the Fraser Late indicator stocks, escapement represented an average of 57% of the CHI total mortality (Figure 2.21; Appendix C5) and 50% of the HAR mortality (Figure 2.21; Appendix C13) between 1985 and 2012 (mortality distribution time series for both stocks began in 1985). From 1999 to 2012, the average proportion of mortality represented by escapement increased to 70% for CHI and to 64% for HAR. For the CHI indicator, fishing mortality was attributed to catch and IM in the ISBM terminal sport (1999–2012 average: 6%), the ISBM WA/OR coast troll (1999–2012 average: 5%), the ISBM Strait of Georgia sport (1999–2012 average: 5%), and the WCVI AABM troll (1999–2012 average: 5%) fisheries. Between 1985 and 1998, the ISBM Strait of Georgia troll fishery was an important component of the total mortality for CHI (average 6%); however, that fishery for Chinook ceased from 1999 onward. For HAR, most of the fishing mortality is associated with catch and IM in the WCVI AABM troll (1999–2012 average: 10%) and the ISBM WA/OR coast troll (1999–2012 average: 8%) fisheries. The ISBM Strait of Georgia sport fishery used to be an important mortality component for HAR during 1985–1998 with 15–19% of the total mortality, but diminished to average mortality levels of 6% during 1999–2012. There is only limited terminal recreational fishing opportunity on HAR.

Among the Fraser Early indicator stocks, an average of 41% of the DOM total mortality (Figure 2.21; Appendix C8), 73% of the NIC total mortality (Figure 2.21; Appendix C21), and 47% of the SHU total mortality (Figure 2.21; Appendix C30) are represented by escapement during 1988–2012 (note that the DOM mortality distribution time series is truncated to 1991–2006; the NIC time series began in 1989, and SHU series began in 1988). The proportion of the average mortality represented by escapement decreased to 31% for DOM, increased to 76% for NIC and 52% for SHU during 1999–2012 (1999–2007 for DOM). Fishing mortality for DOM was predominantly attributed to catch and IM in the ISBM Canada net fishery (1999–2012 average:

44%), followed by the ISBM Strait of Georgia sport fishery (1999–2012 average: 14%). For NIC, the majority of the total fishing mortality occurred as catch and IM in the ISBM terminal sport (1999–2012 average: 8%) and the ISBM Canada net (1999–2012 average: 8%) fisheries. From 1996 to 1998, the ISBM Puget Sound sport fishery used to be an important component of the mortality for NIC (averaging approximately 4%); however, that contribution declined to an average of less than 1% during 1999–2012. Lastly, most of the fishing mortality for SHU is associated with catch and IM in the SEAK AABM troll (1999–2012 average: 11%), NBC AABM sport (1999–2012 average: 8%), and the NBC AABM troll (1999–2012 average: 7%) fisheries. ISBM Strait of Georgia sport and ISBM Canada net fisheries are also important mortality components for SHU, each averaging 6% during 1999–2012.

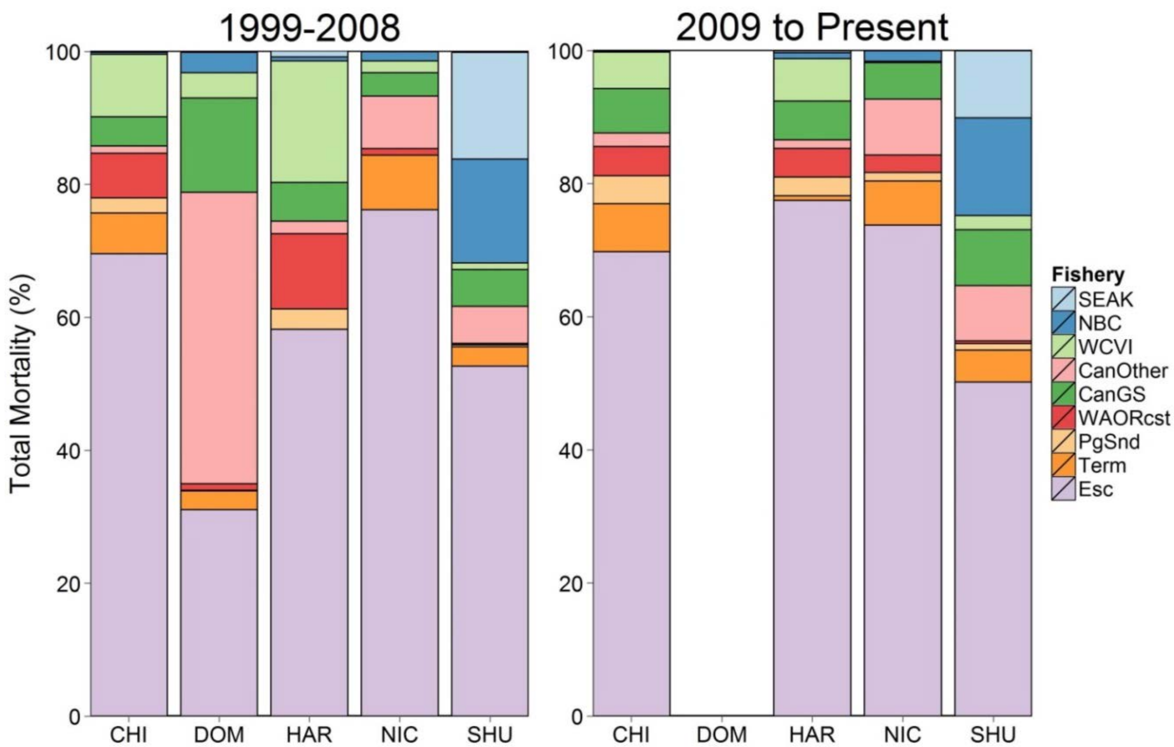


Figure 2.21 Distribution of total mortality for the Fraser River indicator stocks for the current (2009–present) and previous (1999–2008) agreement periods.

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. 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 the largest average BYERs (greater than 65%). As in most Canadian indicator stocks, BYERs of Strait of Georgia have been generally declining, except for COW, which experienced a 76% BYER for the last complete BY. In addition to COW, other Canadian stocks that have experienced increasing BYERs are ATN and DOM, with BYERs for the last complete BY

(56% for ATN and 62% for DOM) being greater than their long-term average (Table 2.7). On the other extreme, Fraser Early indicator stock NIC has experienced the lowest BYERs among Canadian indicator stocks with an average of 26% across all complete BYs and 19% BYER for its last complete BY.

Average survival rates to age 2 (to age 3 for KLM and DOM) are 5% or less for all Canadian indicator stocks, except for CHI, which has the largest average survival rate at 11.6% (Table 2.7). CHI also exhibits the largest estimated survival rate (29.9%) for any given BY among all Canadian stocks. Other stocks with 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, except for CHI, which experienced a survival rate for the last complete BY that is greater than the average and as large as 19.3%. The lowest survival rate for the last complete BY among all Canadian indicator stocks was 0.2% for QUI. This was also QUI's lowest survival rate across all BYs.

Differences in average escapement percentages of the total mortality between Agreement periods 1999–2008 and 2009–2012 were small in most cases (Table 2.7). Important differences occurred only for PPS and HAR. Average escapement percent decreased from 72% during 1999–2008 to 57% during 2009–2012 in PPS, whereas it increased from 58% to 78% in HAR. In terms of the range in escapement percentages observed during the two Agreement periods, in addition to PPS and HAR for which change in average escapement percent reflects important differences in escapement percent range, SHU experienced a substantially wider escapement percent range during 1999–2008 (35–74%) than during 2009–2012 (49–51%). Nonetheless, SHU's average escapement percent was similar (53% for 1999–2008, and 51% for 2009–2012) for those two periods.

Table 2.7 Summary of statistics generated by the 2012 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 in the escapement for Agreement periods 1999–2008 and 2009–present.

		BYER (total mortality)		**Survival rate**		**CY % Escapement[1]**		
						1999–2008	**2009–current**	
Region	**Indicator Stock**	Mean (range)	Last complete BY	Mean (range)	Last complete BY	Mean (range)	Mean (range)	Last CY (if ≠ current)
North/ Central B.C.	Kitsumkalum (KLM)	42% (23–67%)	31%	1.0% (0.1–2.4%)	1.1% (2006)	60% (48–68%)	63% (53–70%)	53%
	Atnarko (ATN)	41% (30–59%)	56%	2.3% (0.5–4.9%)	1.0% (2006)	57% (41–76%)	54% (44–74%)	74%
WCVI	Robertson Creek (RBT)	45%[2,3] (25–77%)	37%	5.0% (0.01–21.1%)	4.4% (2007)	46% (20–84%)	41% (32–61%)	31%
Georgia Strait	Quinsam (QUI)	58% (31–84%)	37%	2.3% (0.2–9.3%)	0.2% (2006)	60% (48–77%)	58% (53–63%)	54%
	Big Qualicum (BQR)	62% (33–88%)	33%	2.7% (0.1–25.6%)	0.5% (2007)	59% (50–74%)	60% (51–65%)	51%
	Cowichan (COW)	70% (37–89%)	76%	2.0% (0.3–7.0%)	0.7% (2007)	34% (24–59%)	36% (18–52%)	37%
	Nanaimo (NAN)	66% (36–91%)	36%	2.2% (0.6–5.8%)	3.0% (2004)	53% (39–75%)	NA	75% (2006)
	Puntledge (PPS)	54% (12–87%)	28%	1.2% (0.1–12.4%)	0.8% (2007)	72% (48–89%)	57% (17–76%)	17%
Fraser River	Chilliwack (CHI)	44% (23–83%)	27%	11.6% (1.6–29.9%)	19.3% (2007)	70% (60–78%)	70% (67–76%)	68%
	Harrison (HAR)	53% (21–91%)	21%	3.6% (0.4–23.6%)	5.8% (2007)	58% (37–77%)	78% (76–80%)	77%
	Dome (DOM)	57% (16–80%)	62%	1.2% (0.2–2.5%)	0.4% (2002)	31% (15–44%)	NA	43% (2006)
	Nicola (NIC)	26%[2] (10–47%)	19%	3.8% (0.1–14.4%)	1.4% (2007)	76% (55–89%)	74% (52–91%)	72%
	Lower Shuswap (SHU)	53% (30–79%)	53%	3.3% (0.7–8.4%)	2.2% (2007)	53% (35–74%)	51% (49–51%)	51%

[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.

2.2.7 Washington Coast Stocks

Coded wire tagged Chinook are currently released from three separate facilities on the Washington Coast and are used by the CTC to represent natural fall Chinook 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 Department of Natural Resources Salmon River Hatchery) and Sooes 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). Additionally, Chinook releases from the Washington Department of Fish and Wildlife (WDFW) Elwha Hatchery (ELW) were formerly used in the annual ERA, but releases of adipose clipped + CWT Chinook have been insufficient for analysis since BY 1994. Queets, Sooes, and Hoko indicators 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 Sooes records starting in 1985 and Queets records starting in 1977.

2.2.7.1 *Brood Year Exploitation Rates*

BYER patterns for Hoko, Queets, and Sooes are considered in terms total exploitation (ocean and terminal; Figure 2.22; Table 2.8). BYERs for Hoko and Sooes indicator stocks have tracked closely for the entirety of their time series (series mean: Hoko 0.34, Sooes 0.41) with relatively higher values (*ca.* 0.60) being observed for the first two BYs on record (1985–1986), and BYERs varying between *ca*. 0.10 and 0.50 thereafter (most recent [2006] BY: Hoko 0.34, Sooes 0.47). Approximately one quarter of all fishery-related mortality for HOK and SOO is in the form of nonlanded, incidental impacts. Across its 29 complete BY, the total BYER for the Queets indicator stock has averaged 0.62, ranging between 0.37 and 0.81, and displaying no discernible temporal trend. The BYER for the last complete Queets BY (2006) is 0.54.

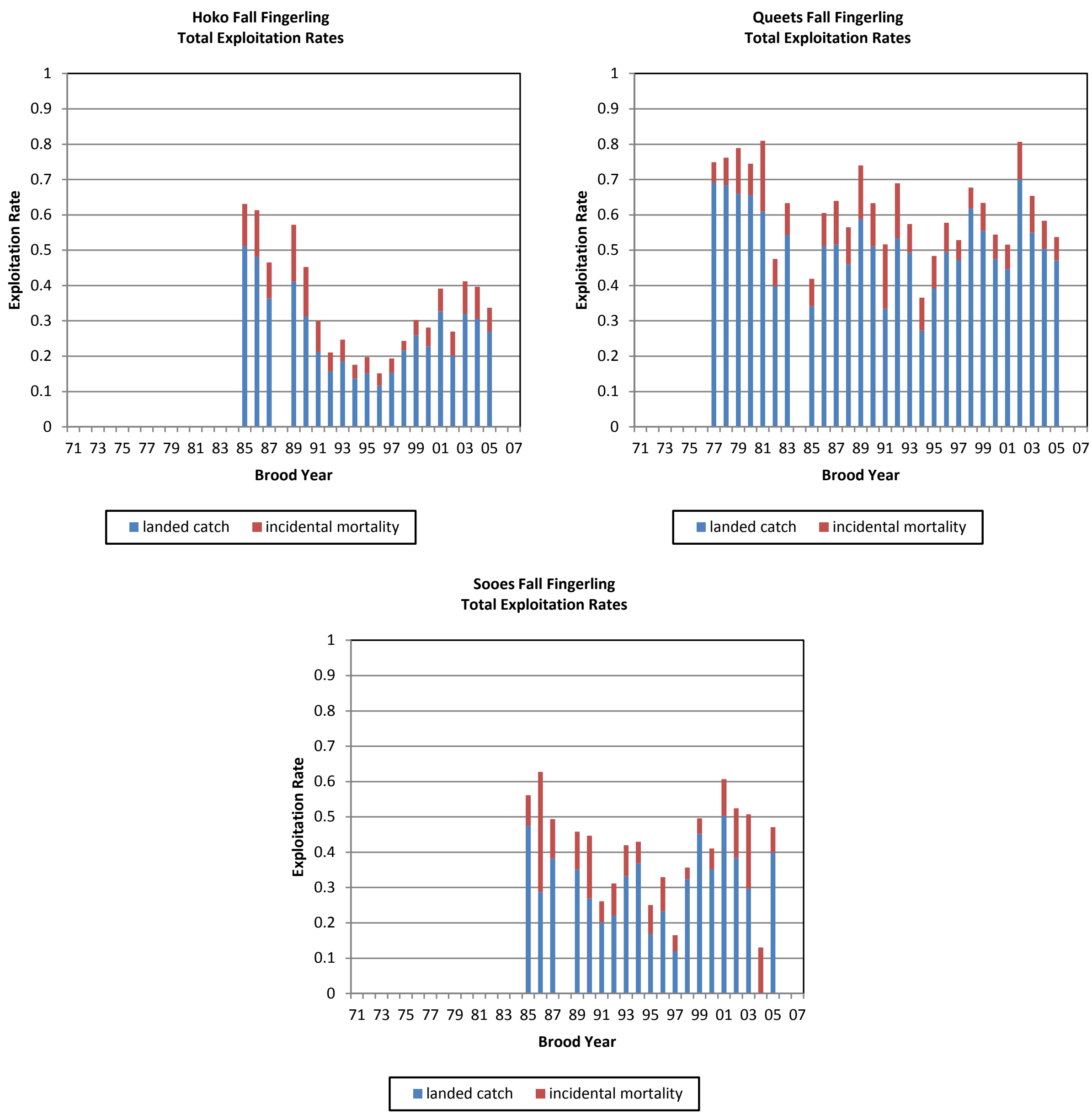


Figure 2.22 Brood year exploitation rate in terms of landed catch and incidental mortality for Washington coast indicator stocks.

Table 2.8 Summary of statistics generated by the 2012 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 Agreement periods 1999–2008 and 2009–present.

		BYER (total mortality)		Survival rate		CY % Escapement[1]		
						1999–2008	2009–present	
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	34% (15–63%)	34%	1.38% (0.12–3.20%)	0.93% (2005)	70% (45–89%)	79% (70–86%)	82%
QUE	Queets	62% (37–81%)	54%	2.21% (0.53–4.45%)	4.11% (2005)	40% (19–70%)	38% (36–40%)	36%
SOO	Sooes	41% (13–63%)	47%	0.51% (0.01–1.57%)	0.61% (2005)	57% (29–83%)	71% (64–75%)	73%

[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.

2.2.7.2 *Survival Rates*

CWT data indicate that release-to-age-2 survival for Chinook on the Washington Coast indicator stocks is highly variable across stocks and years (Figure 2.23; Table 2.8). Sooes 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 0.5%, but it has ranged more than two orders of magnitude (0.01–1.5%). The Queets Chinook indicator stock exhibits the highest survival rates among the three indicator stocks, with a range of 0.5–4.5%, and a mean of 2.2%. Hoko Chinook survival rates lie between these extremes with a mean of 1.4% and a range of 0.1–3.2%. Across their entire time series, there is little evidence of a long-term trend in early marine survival and limited evidence of covariation among stocks, i.e., SOO versus QUE correlation coefficient R = 0.63; SOO-HOK and QUE-HOK R = 0.29. In terms of more recent performance, the survival rates of all three indicator stocks have declined considerably from the series-wide highs observed for the 1999 BY with some rebounding in the Queets stock, but only the most recent BY is increasing for Hoko and Sooes.

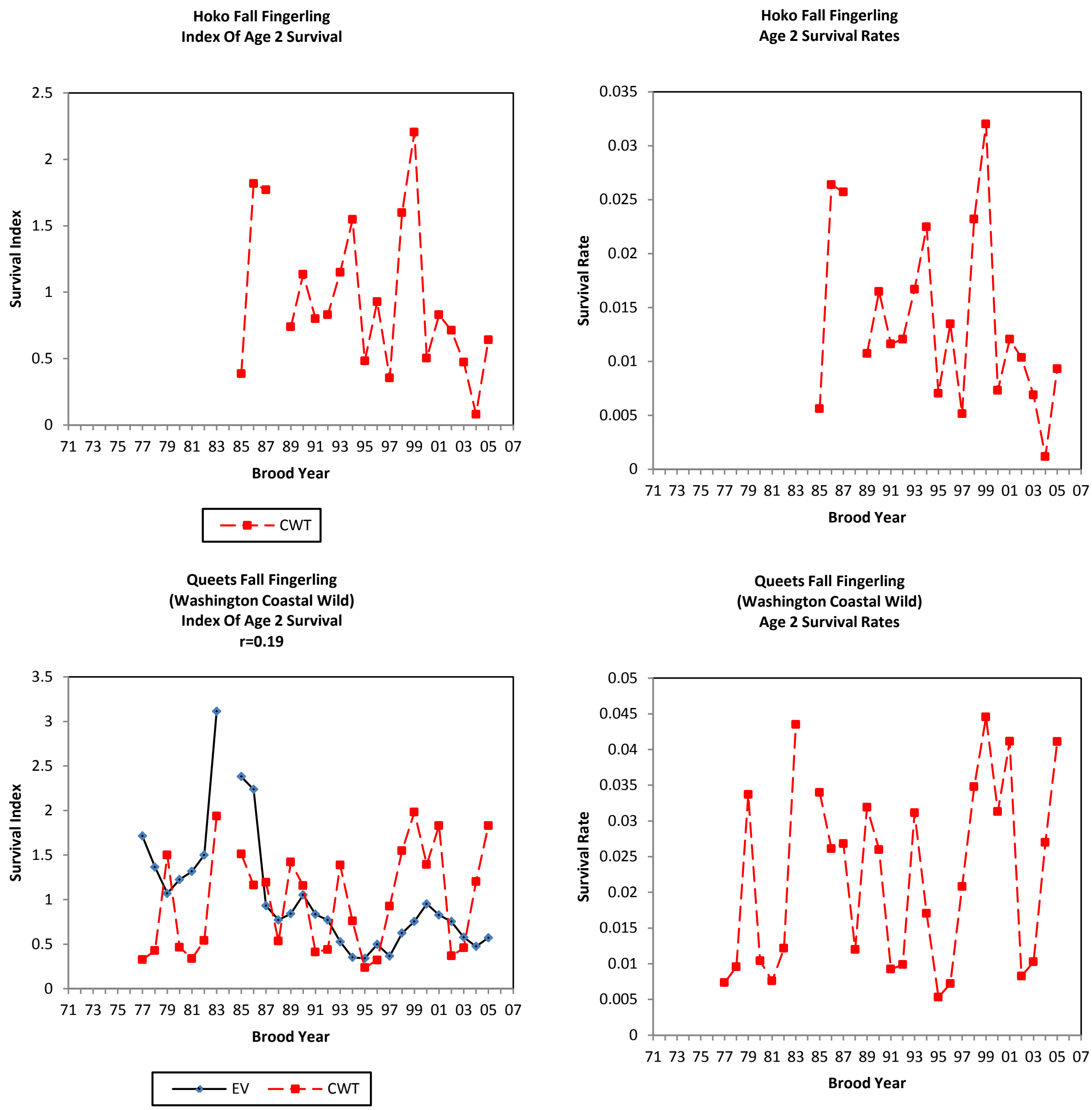
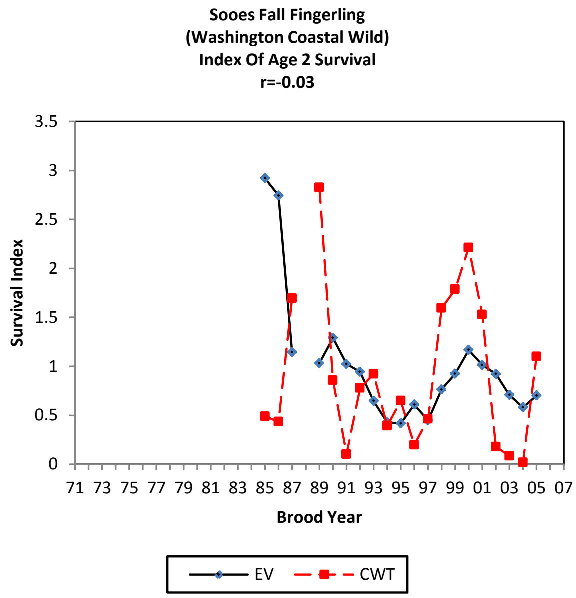
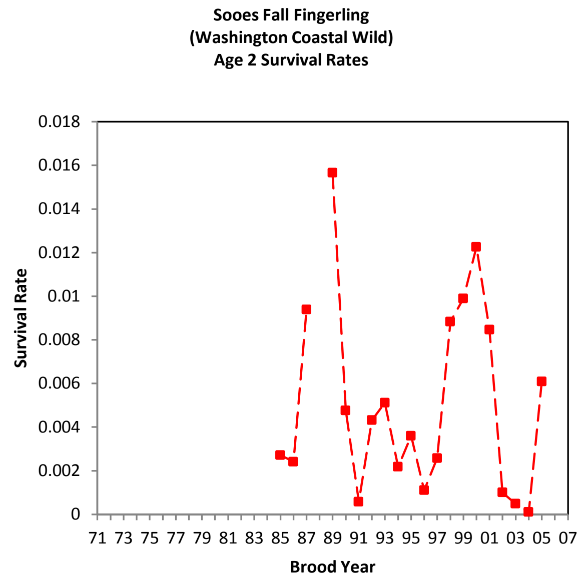


Figure 2.23 CWT survival index and survival rate for Hoko, Queets, and Sooes Fall Fingerling stocks. r: Pearson correlation coefficient between CWT and EV survival indices.





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2.2.7.3 *Mortality Distributions*

Washington coastal indicator stocks exhibit a mortality distribution consistent with a far north migration pattern. On average, 86% of all fishery-related mortality, which accounts for approximately a third of total mortality, results from fisheries occurring north of the U.S. and Canada border. The majority of these mortalities occur in the SEAK and NBC AABM troll fisheries (Figure 2.24; Appendix C14, C27, and C34). Whereas southern U.S. fishery-related mortalities are virtually nonexistent (1–5%) for the Hoko and Sooes indicator stocks, terminal net fisheries targeting Queets River fall-run Chinook account for 17% of the annual mortality distribution, on average. Escapement recoveries for the three stocks have averaged between *ca*. 40% (Queets) and 70–80% (Hoko) of the total distribution in recent years (Table 2.8). Lastly, beyond reductions in mortality occurring in the WCVI troll fishery (all three stocks), modest increases occurring in Strait of Georgia sport (HOK and SOO), and a shift towards a higher escapement fraction prior to the 1999 Agreement (Appendix C), there is limited evidence of a systematic shift in mortality distributions for these stocks between the current (2009) and prior agreement period (1999; Figure 2.24).

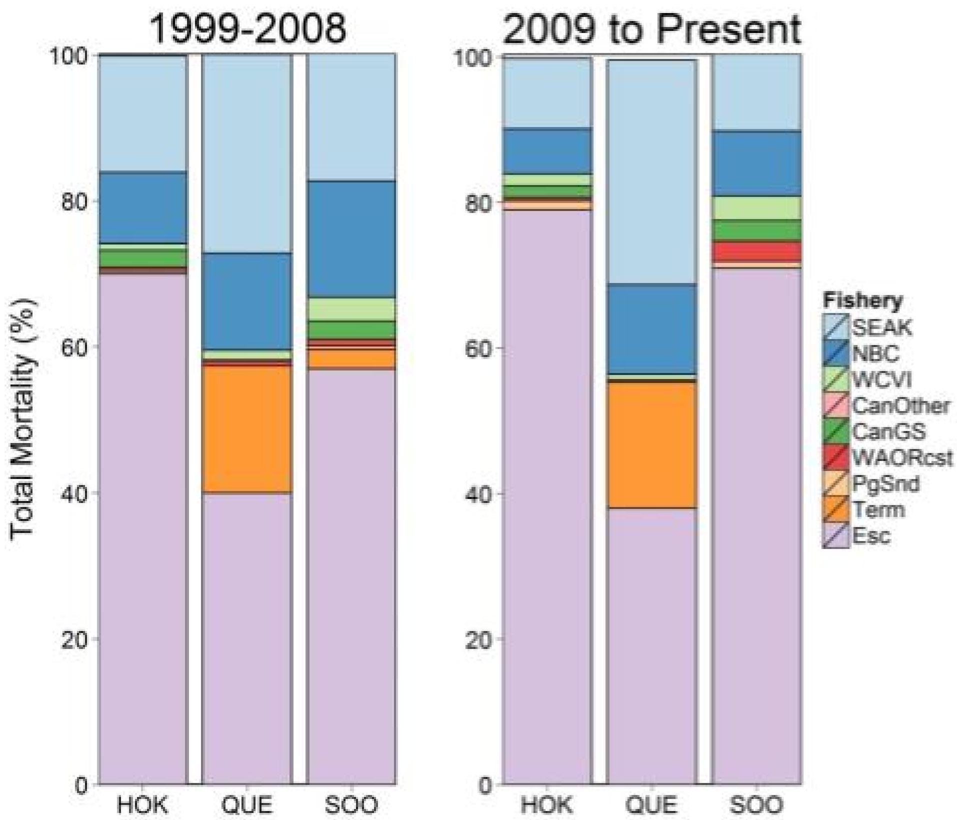


Figure 2.24 Distribution of total mortality for Washington Coast indicator stocks for the previous (1999–2008) and current (2009–present) agreement periods.

2.2.8 Washington Salish Sea Stocks

There are 14 CWT indicator stock groups analyzed within the Washington Salish Sea. The analysis on two additional stocks, Squaxin Net Pens and University of Washington accelerated rearing production, was discontinued with the phase out of these production units. 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. Except for one stock, White River Spring yearlings, these CWT indicator groups are adipose clipped (marked), and therefore available for retention mark-selective sport fisheries, which have been expanding in marine and freshwater fisheries in the Salish Sea since 2003. Current marine nontribal sport fisheries within Puget Sound are almost exclusively under mark-selective regulations. Consequently, estimates of fishing mortality from these adipose clipped CWT recoveries will likely overestimate the fishing mortality on unmarked natural fish that must be released. Because of different terminal fishery structure for these indicator groups due to mark-selective fisheries or directed fisheries on hatchery surplus, BYERs are expressed in terms of ocean fisheries for all of these indicators. The portion of the fishery impacts in marine area mark-selective sport fisheries are included in the ocean exploitation rate estimates presented below. Salish Sea origin stocks have the highest exposure to differential harvest rates from mark-selective fisheries; consequently, the BYER estimates may be biased high with respect to the exploitation rates on natural stocks. 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 Attachment IV and V. Releases of yearling spring Chinook salmon into the Nooksack River was discontinued following the 1996 BY. The Nooksack Spring hatchery program is primarily for the purpose of natural supplementation and also supports a small tribal subsistence fishery in the river. The SAM stock indicator does not represent an associated natural stock but is important for evaluating the large hatchery production program from Samish Hatchery. The Skagit Spring program is primarily for harvest augmentation; the returning fish are subjected to a fairly intensive MSF in the area near the hatchery. The primary purpose for the Skagit summer fingerling group is fishery evaluation on the natural stock in the system. Brood stock for this program is captured on the spawning grounds. The yearling program in the Skagit River has been discontinued. The last release was the 2010 BY, released in spring of 2012.

2.2.8.1.1 Brood Year Exploitation Rates

The BYER for NSF has been on an increasing trend since the start of releases in the early 1990s, reaching 56% in 2007 (Figure 2.25). Since 1995, the ocean fishery BYERs for the other northern Puget Sound indicator stocks show no trend for SAM (range 29–48%) and SSF (range 21–41%), but during BYs 1995–2007 show a declining trend for SKS (41–20%) and SKF (42–17%; Figure 2.26; Figure 2.27). The BYER for SAM includes fishery mortalities in the Bellingham Bay terminal net fishery.

The most recent five-year average BYERs for current programs are 54% for NSF, 22% for SKF, 27% for SKS, 34% for SAM and 30% for SSF.

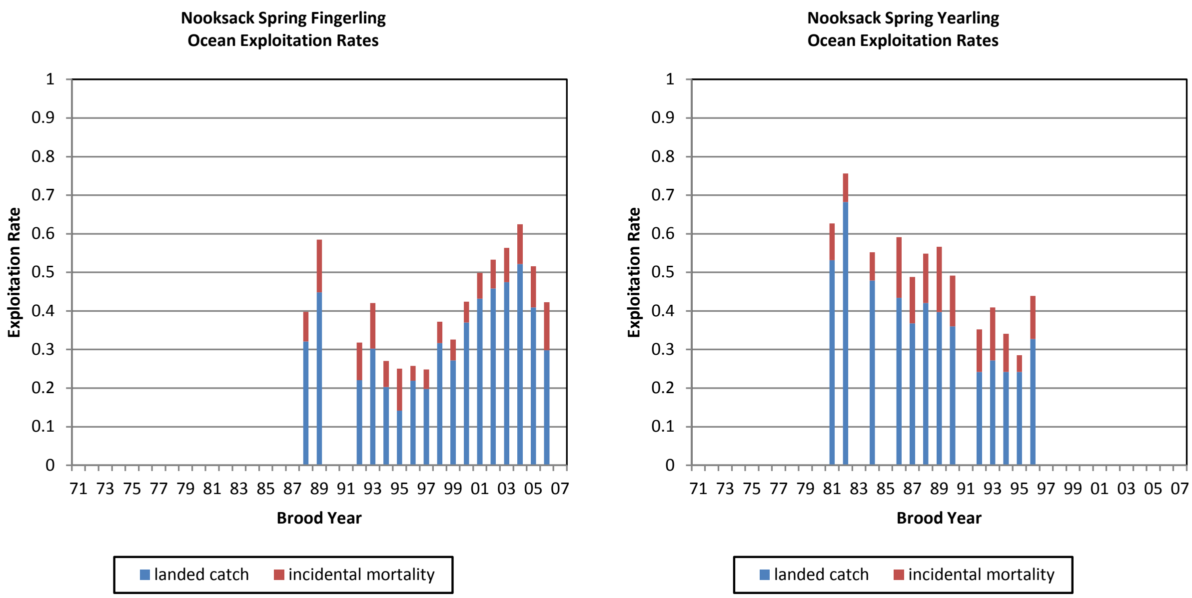


Figure 2.25 Brood year exploitation rate in terms of landed catch and incidental mortality for Nooksack Spring Fingerling and Nooksack Spring Yearling CWT indicator stocks.

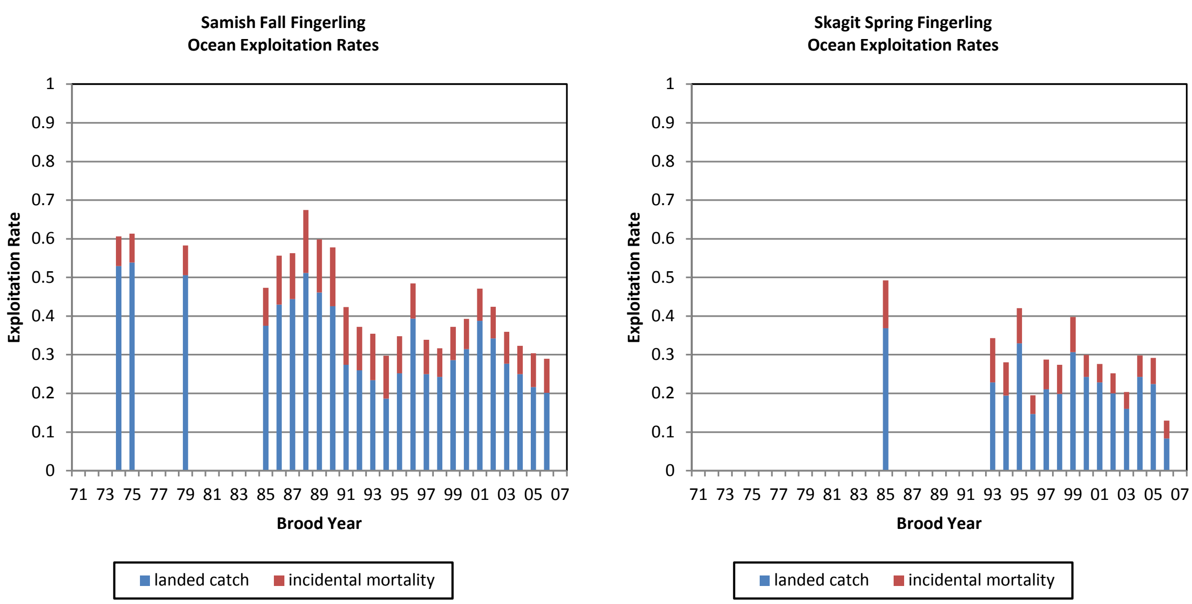


Figure 2.26 Brood year exploitation rate in terms of landed catch and incidental mortality for Samish Fall Fingerling and Skagit Spring Fingerling CWT indicator stocks.

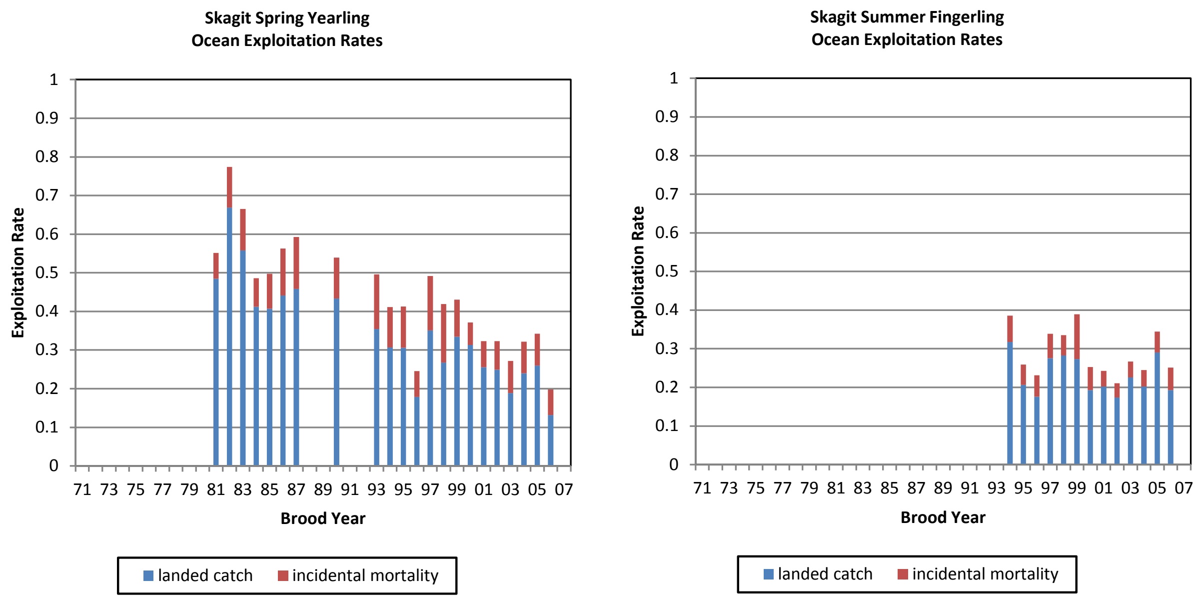


Figure 2.27 Brood year exploitation rate in terms of landed catch and incidental mortality for Skagit Spring Yearling and Skagit Summer Fingerling CWT indicator stocks.

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 (Figures 2.28–2.33). More recently, survival rates have been in the range of 1–5%. The survival index and the EV were moderately correlated for SAM (r = 0.64) and poorly correlated for NSF (r = 0.19) and NKS (r = 0.10).

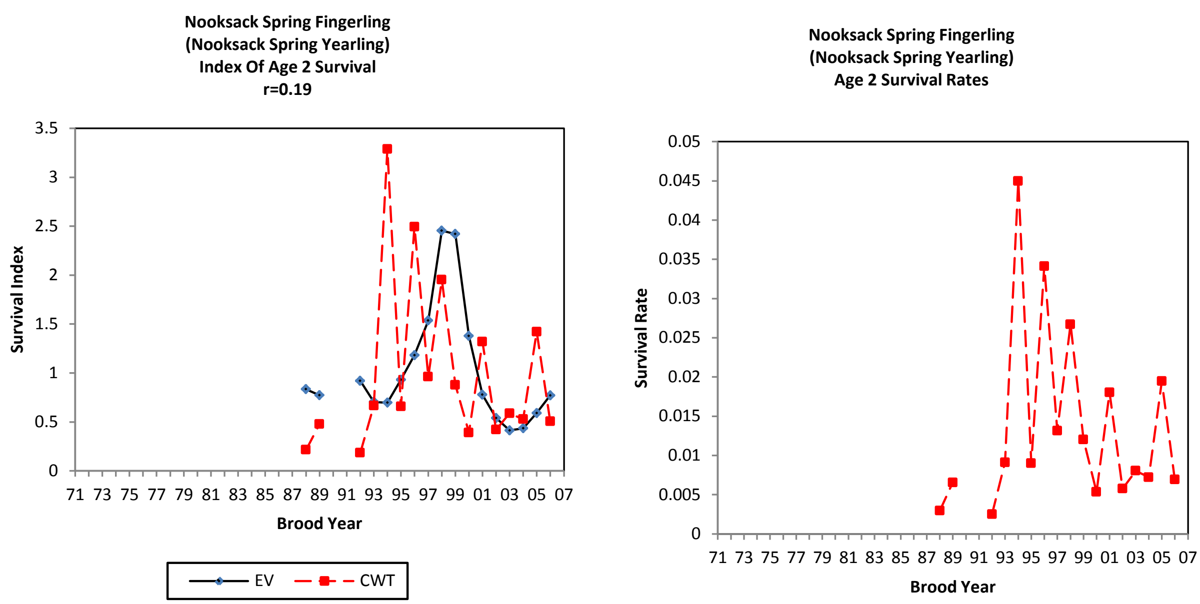


Figure 2.28 CWT survival and EV indices and survival rate for Nooksack Spring Fingerling stock. r: Pearson correlation coefficient between CWT and EV survival indices.

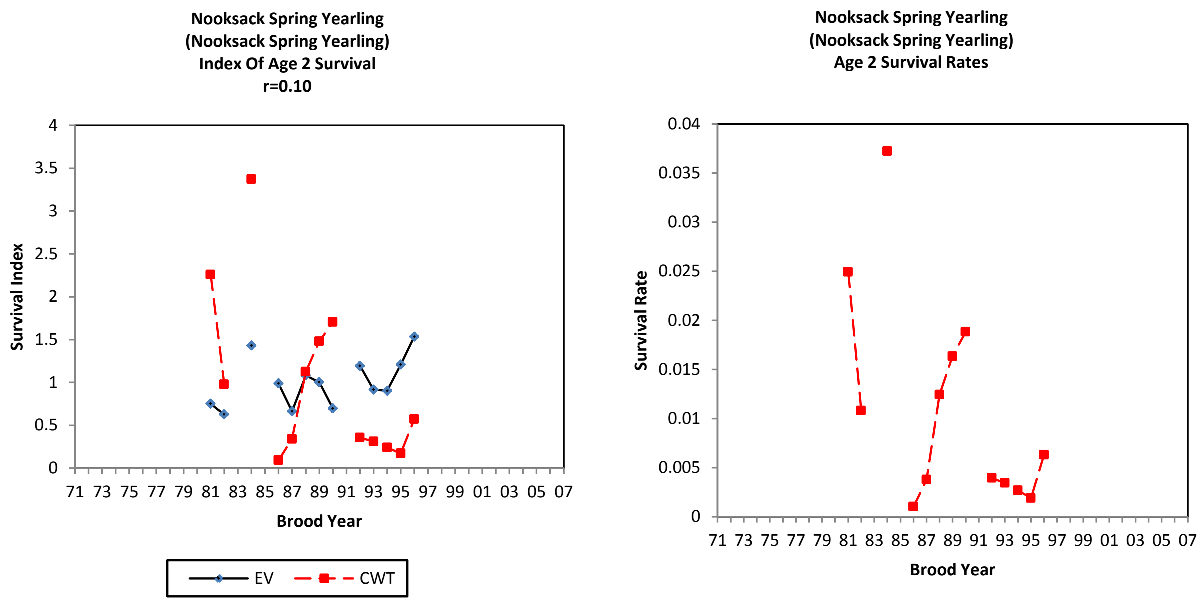


Figure 2.29 CWT survival and EV indices and survival rate for Nooksack Spring Yearling stock. r: Pearson correlation coefficient between CWT and EV survival indices.

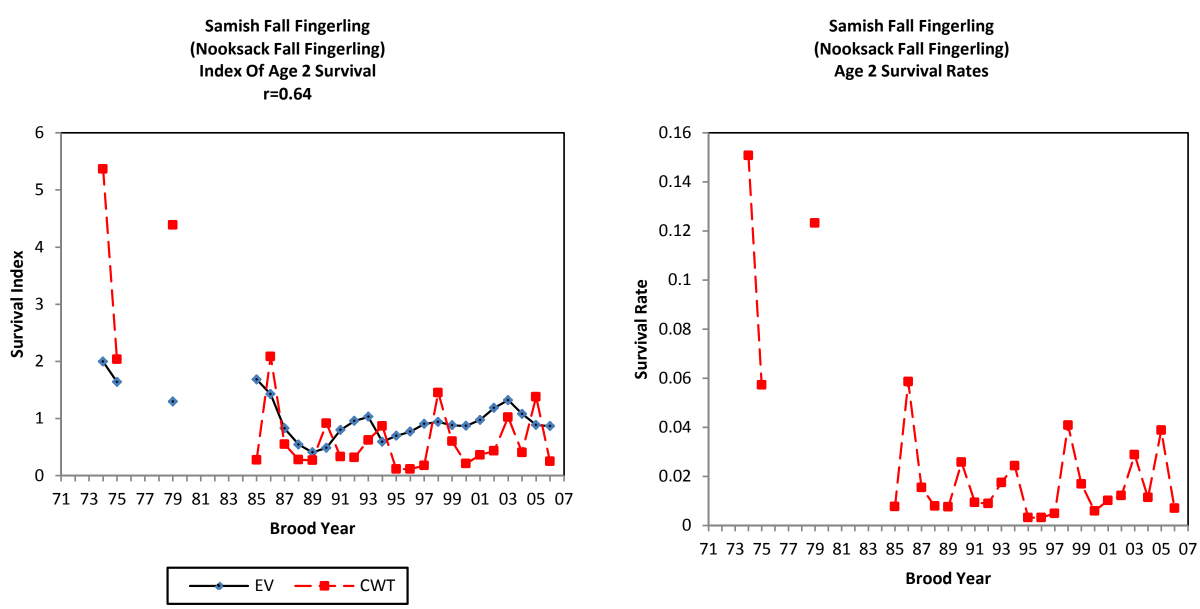


Figure 2.30 CWT survival and EV indices and survival rate for Samish Fall Fingerling stock. r: Pearson correlation coefficient between CWT and EV survival indices.

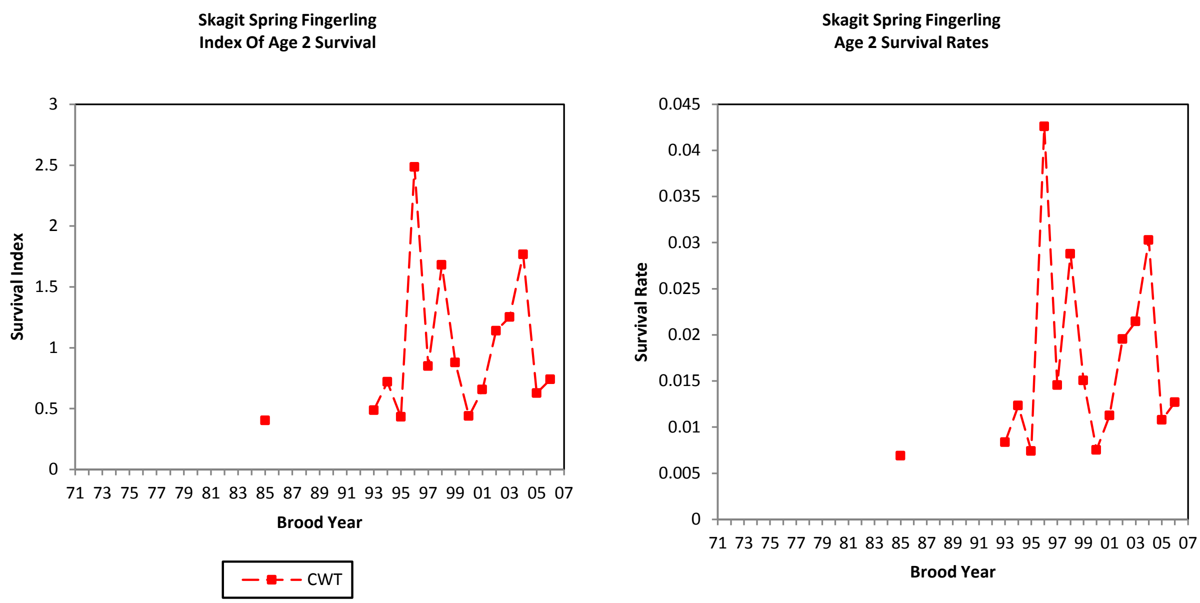


Figure 2.31 CWT survival index and survival rate for Skagit Spring Fingerling stock.

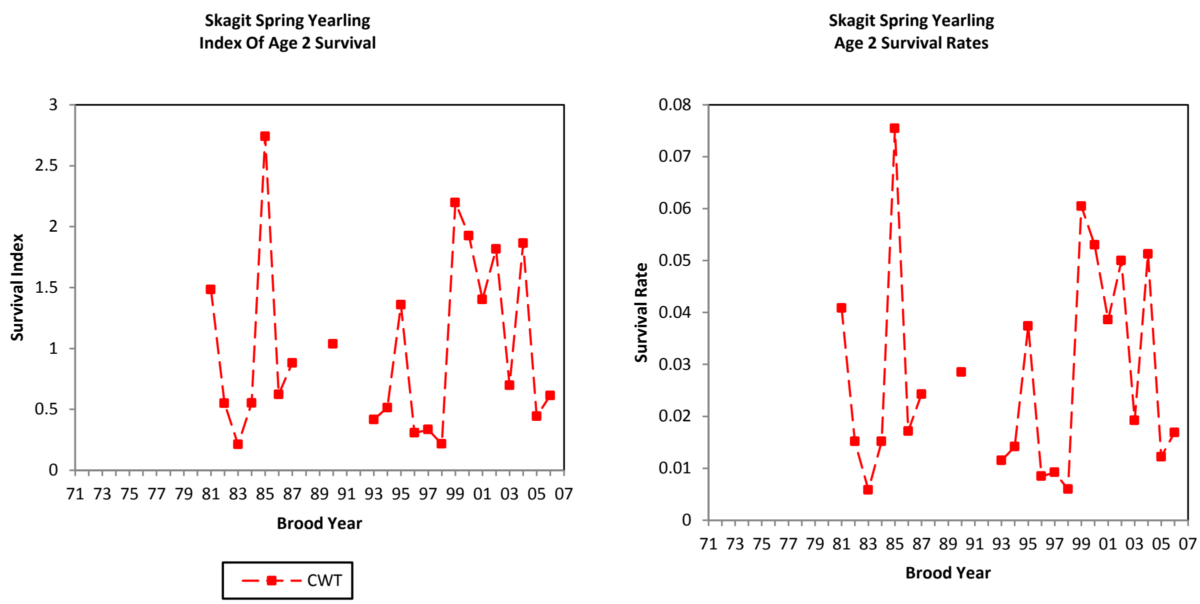
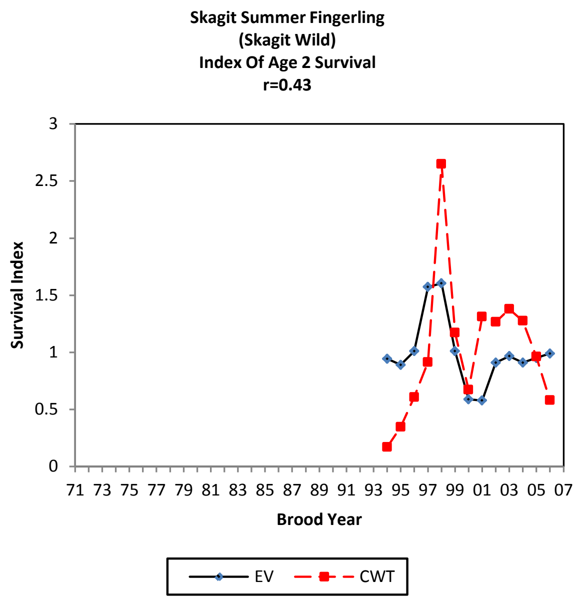


Figure 2.32 CWT survival index and survival rate for Skagit Spring Yearling stock.



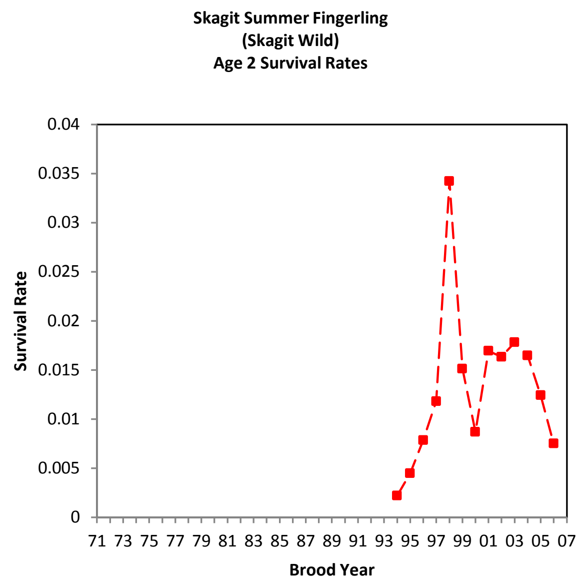


Figure 2.33 CWT survival and EV indices and survival rate for Skagit Summer Fingerling stock. r: Pearson correlation coefficient between CWT and EV survival indices.

2.2.8.1.3 Mortality Distributions

Percent distribution in total AEQ fishery mortality for the North Puget Sound stocks during 1999–2011 averaged 40% for NKS (Appendix C23; one year only, 1999), 46% for NSF (Appendix C24), 75% for SAM (Appendix C29), 39% for SKF (Appendix C31), 52% for SKS (Appendix C32) and 40% for SSF (Appendix C39; Figure 2.34).

Because of their location and northerly ocean migration, the majority of fishing mortality on North Puget Sound stocks is in Canadian and northern Puget Sound fisheries. Mortality in Canadian fisheries occurs primarily in WCVI, averaging 26% during catch years 1999–2011, while northern Puget Sound fisheries account for 19%, on average, in the same period. Although SSF experienced the highest fishery mortality in SEAK among all Salish Sea stocks (9%) during 1999–2011; for the combined North Puget Sound stock group, the percent mortality in fisheries in SEAK and along the Washington and Oregon coast is low, averaging approximately 2% for these years in each area. Within Puget Sound, the primary fishery intercepting these stocks is the marine sport fisheries, which are now almost exclusively under mark-selective regulations. A significant state and tribal net fishery within Bellingham Bay targets SAM, contributing the majority of the percentage of the value shown under *Puget Sound Net* in Appendix C29. 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. Percentage of fishing mortality in Puget Sound marine and freshwater net fisheries is low, with the exception of SAM and the Skagit River during 2008–2011, when abundance of Skagit Summer/Fall Chinook salmon was high and there was a corresponding directed river net fishery.

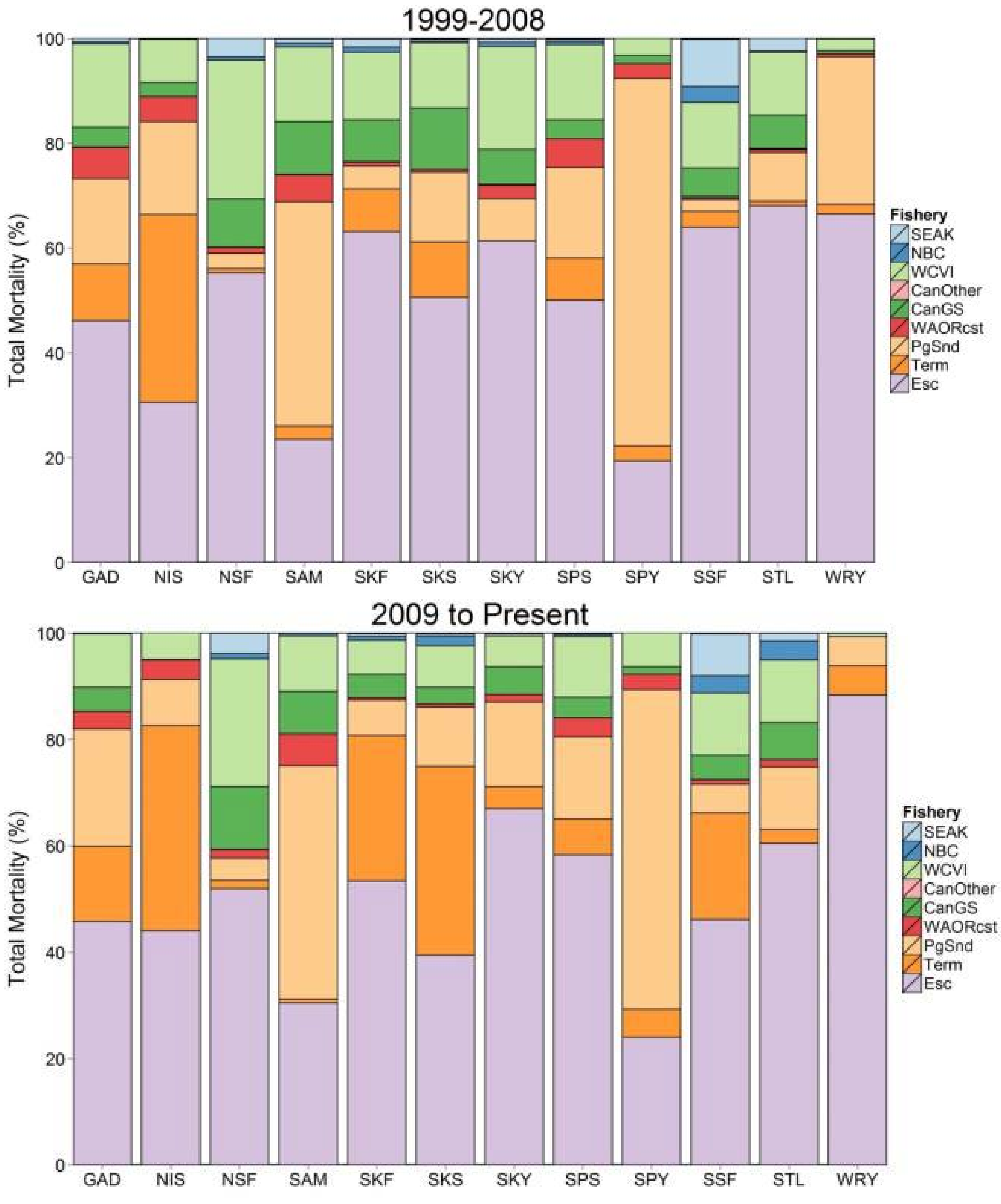


Figure 2.34 Distribution of total mortality for Washington Salish Sea indicator stocks for the previous (1999–2008) and current (2009–present) agreement periods.

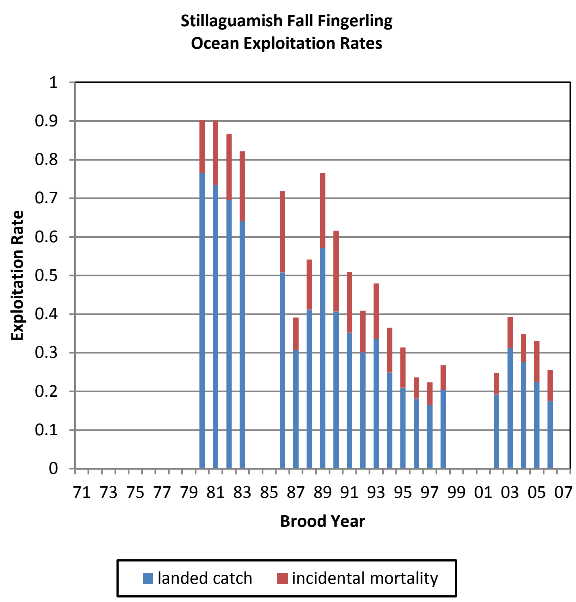
For the aggregate group, the distribution of fishing mortality between fisheries north or south of the U.S. and Canada border has shifted slightly during 1999–2011. Fisheries north of the border accounted for an average of 27% of the mortality during 1999–2003 and 20% of the mortality during 2007–2011. During these same years, the fisheries south of the U.S. and Canada border averaged 13% (1999–2003) and 27% (2007–2011) mortality. The increase in recent years for southern U.S. fisheries is primarily due to the implementation of MSFs beginning 2003 and the net fishery in the Skagit River. The percentage distribution in escapement has declined from an average of 62% in 1999–2003 to 53% in 2007–2011.

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 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. The Stillaguamish Fall CWT program is primarliy for the purpose of fishery evaluation, and some natural supplementation. Brood stock for this program is captured on the spawning grounds. The Skykomish program, which uses returns of summer run fish to the Wallace Salmon Hatchery for brood stock, is primarily 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

The ocean fishery BYERs have declined dramatically for STL—from 90% for 1980 BY to 37% in 2007 (Figure 2.35). The rates for SKY have only been available starting with the 2000 BY, where BYERs have declined from 42% to 30% (Figure 2.35).



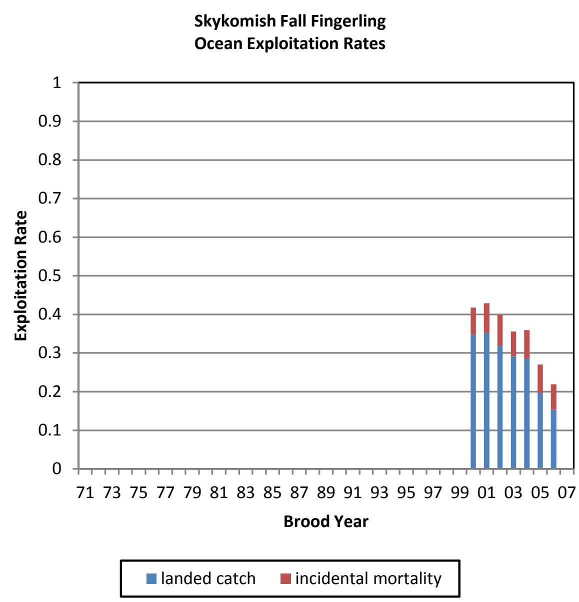


Figure 2.35 Brood year exploitation rate in terms of landed catch and incidental mortality for Stillaguamish Fall and Skykomish Summer Fingerling CWT indicator stocks.

2.2.8.2.2 Survival Rates

Survival rates to age 2 for STL ranged from a low of 0.3% for the 1980 BY to a high of 6.4% in 1990 (Figure 2.36). Cohort survival to age 2 for SKY ranged from 0.4% in 2005 to 1.9% 2004,

(Figure 2.37). The survival index and the EV was moderately correlated for STL with Pearson correlation coefficient of 0.45. The small number of years available for SKY prohibit comparisons between the survival index and the EV.

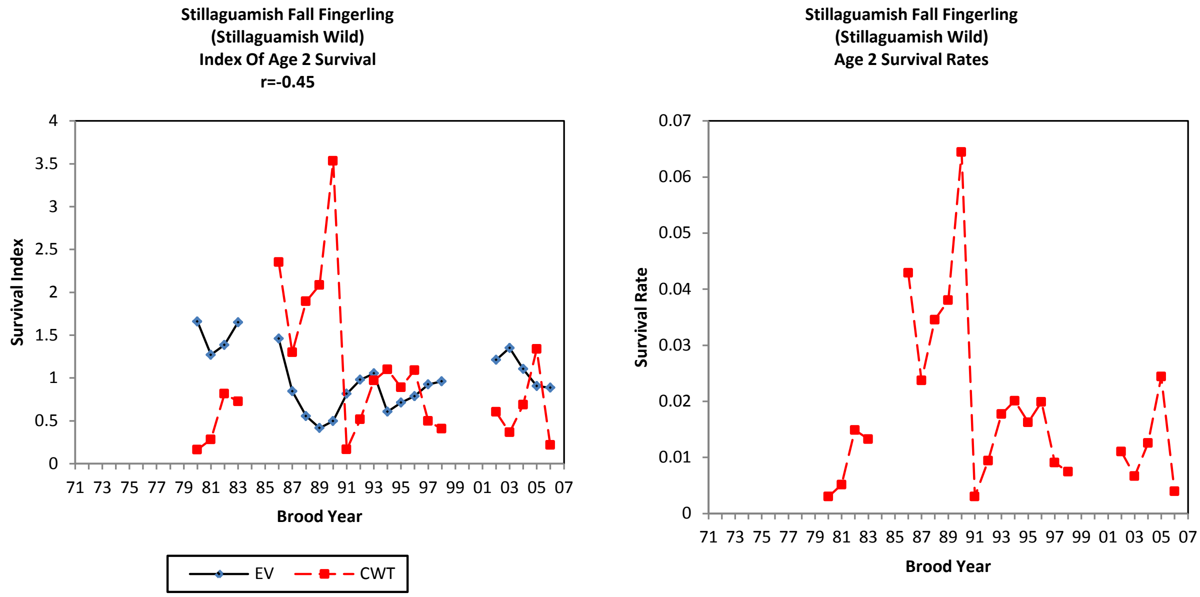


Figure 2.36   CWT survival and EV indices, and survival rates for Stillaguamish Fall Fingerling stock. r: Pearson correlation coefficient between CWT and EV survival indices.

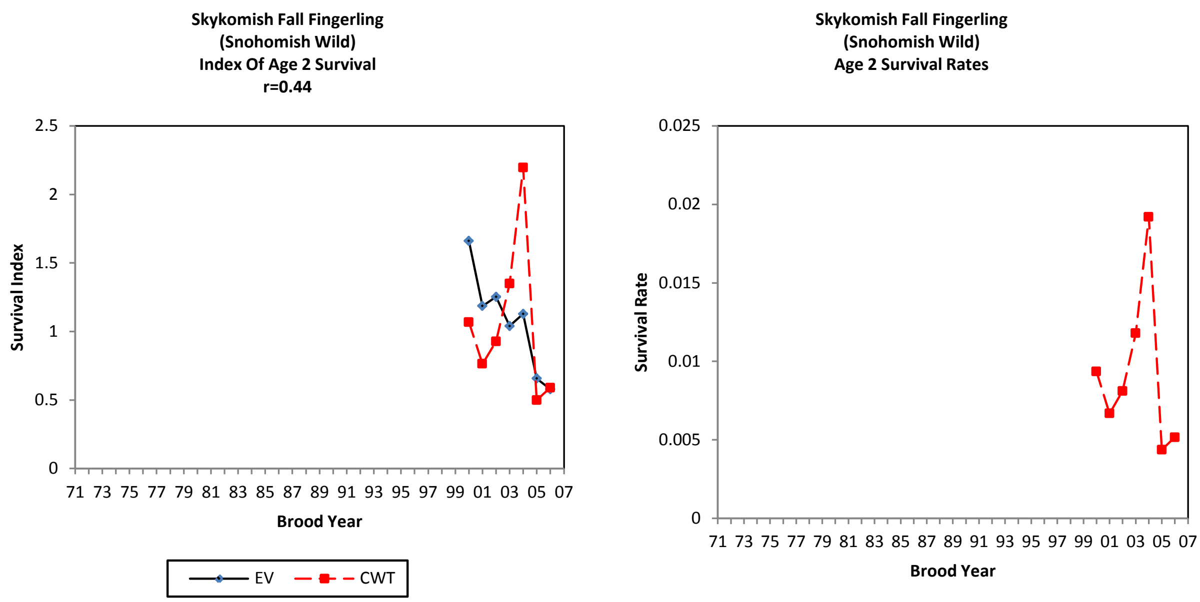


Figure 2.37   CWT survival and EV indices and survival rate for Skykomish Fall Fingerling stock. r: Pearson correlation coefficient between CWT and EV survival indices.

2.2.8.2.3 Mortality Distributions

Percent distribution in total AEQ fishery mortality for the Central Puget Sound stocks during 1999–2011 averaged 37% for SKY (Figure 2.34; Appendix C33), and 34% for STL (Figure 2.34;

Appendix C40). Similar to North Puget Sound stocks, percentage of fishing mortality is very low in SEAK (<3% each) and highest in Canadian fisheries, averaging 21% during 2004–2011 for SKY and 20% for STL during the years with data (1999–2001 and 2006-2011). The average percent mortality in Puget Sound fisheries during 1999–2011 of 13% for SKY and 12% for STL is lower than that for the North Puget Sound group because of the lack of 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.

During 1999–2011, the two combined stocks experienced an increase in the percentage of mortality in fisheries both north and south of the U.S. and Canada border. For the first three years of this period, fisheries north of the border had 17% of the fishery mortality, and fisheries south of the border had 8% of the fishery mortality. For 2007–2011, percent mortality in northern fisheries increased to an average of 21%. The increase in the southern U.S. fisheries to 17% during 2007–2011 is primarily due to mark-selective sport fisheries and would not correctly represent impacts on natural stocks. The percentage distribution in escapement for the two stocks has declined from an average of 75% in 1999–2001 to 63% in 2007–2011.

2.2.8.3 *South Puget Sound*

Indicator stocks in South 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. The SPS indicator is the best representative of mixed stock fishery mortalities in Green River and Lake Washington of those listed as part of the Puget Sound Natural Summer/Falls stock group in Attachment IV and V. However, because of directed terminal fisheries on the two components of SPS indicator, the SPS stock is not suitable for assessing these fishery types. In addition, because stocks originating in South Puget Sound are exposed to a higher level of mark-selective fishing, exploitation rates measured from marked tag recoveries will likely 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 73% for the 1975 BY to a low of 23% for the 1995 BY (Figure 2.38). 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 1980 BYER for NIS and WRY were in the vicinity of 50–70%. Since 2000, BYERs averaged 27% for NIS and 15% for WRY (Figure 2.39). A total fishery BYER for SPS and NIS would include additional mortalities from inriver fisheries that can be significant for these indicators.

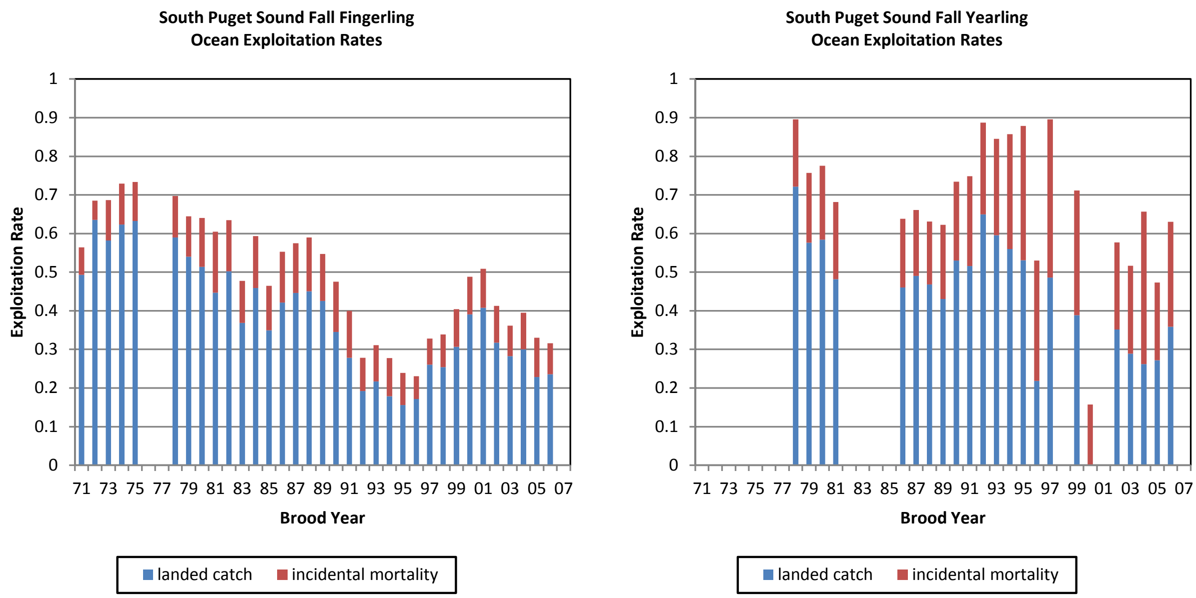


Figure 2.38 Brood year exploitation rate in terms of landed catch and incidental mortality for South Puget Sound Fall Fingerling and Yearling indicator stocks.

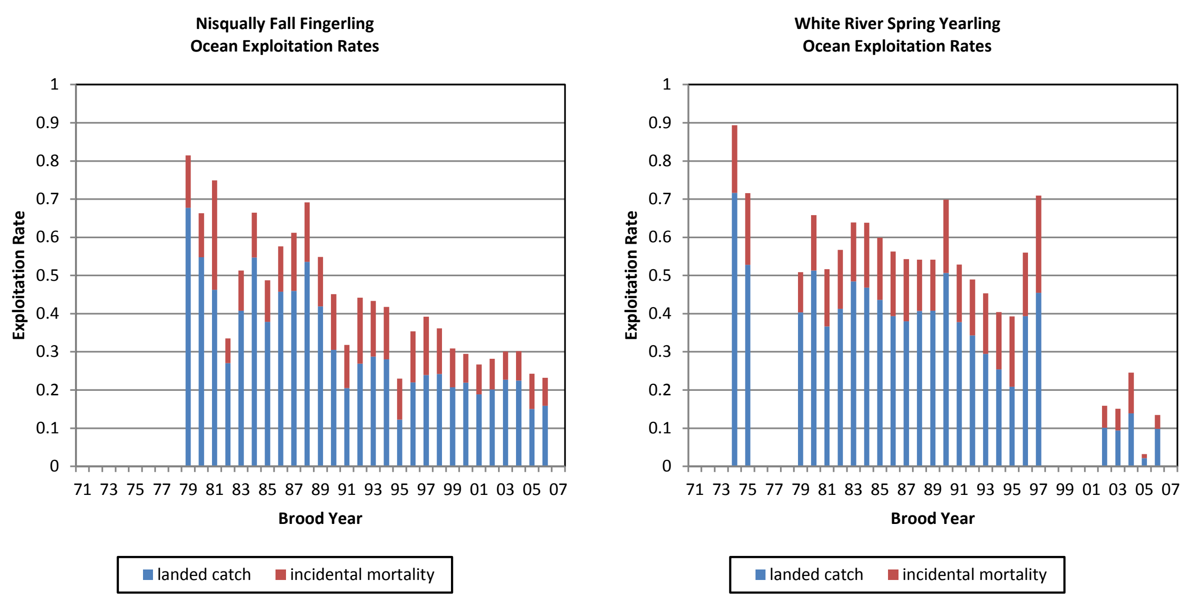


Figure 2.39 Brood year exploitation rate in terms of landed catch and incidental mortality for Nisqually Fall Fingerling and White River Spring Yearling CWT indicator stocks.

2.2.8.3.2 Survival Rates

Survival rates from release to age 2 for SPS ranged from a low of 0.5% for 1980 BY to a high of 9.5% for 1975 BY (Figure 2.40). With the exception of the 1985 BY where the survival rate was 15%, the rates for SPY have been low and often less than 1% (Figure 2.41). Survival for NIS ranged from a low of 0.1% for 1987 BY to a high of 4.5 % for 2004 BY (Figure 2.42). Survival for

WRY ranged from a low of 0.04% for 1975 BY to a high of 15.4% for the 1985 BY (Figure 2.43). The survival index and the EV was poorly correlated for SPS with Pearson correlation coefficient of 0.32 and not correlated for SPY (r = 0.01) or WRY (r = 0.13).

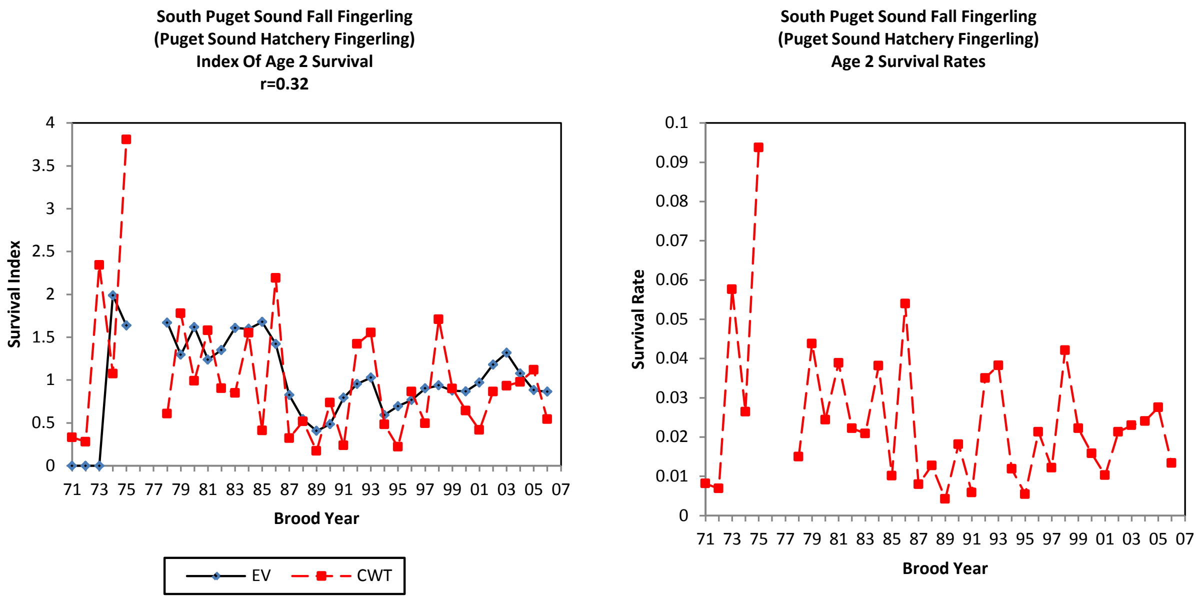


Figure 2.40 CWT survival and EV indices and survival rate for South Puget Sound Fall Fingerling stock. r: Pearson correlation coefficient between CWT and EV survival indices.

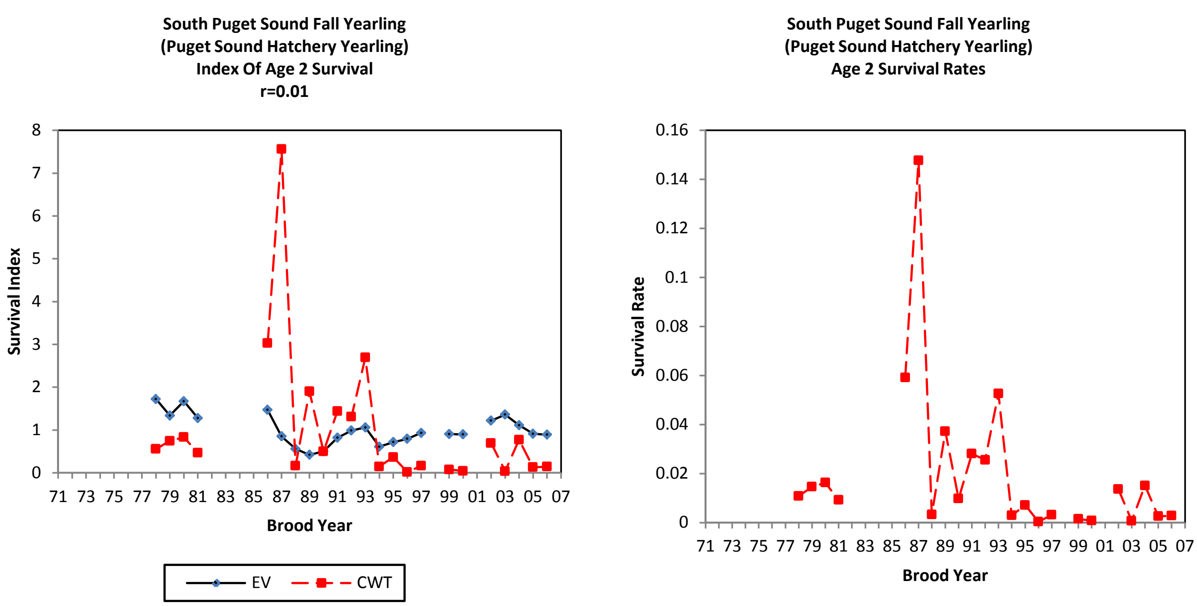


Figure 2.41 CWT survival and EV indices and survival rate for South Puget Sound Fall Yearling stock. r: Pearson correlation coefficient between CWT and EV survival indices.

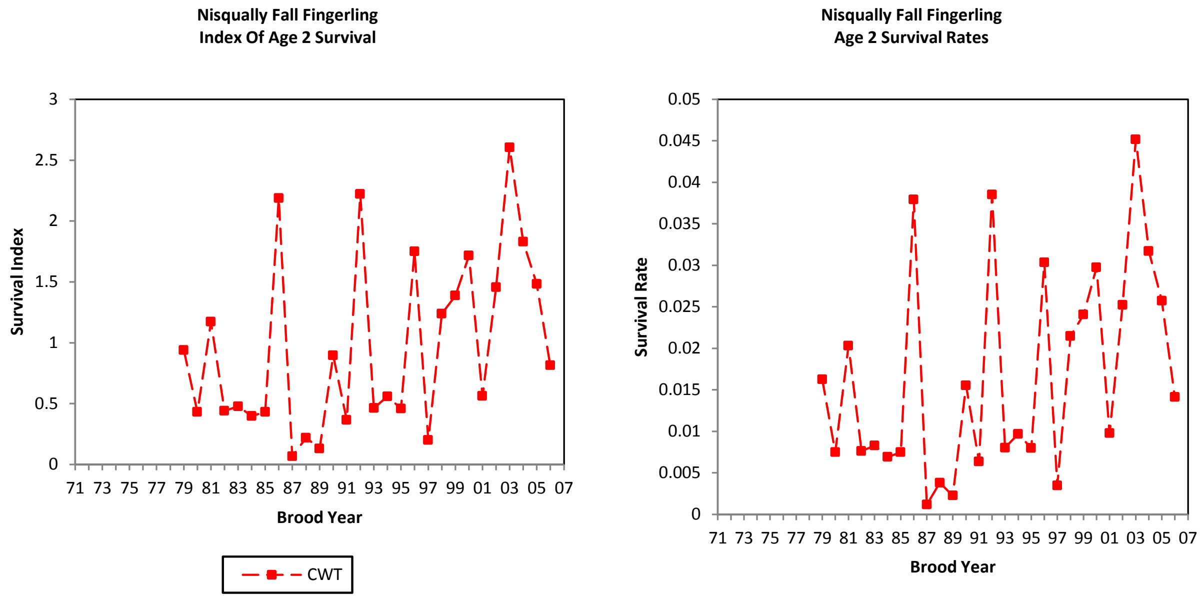


Figure 2.42 CWT survival index and survival rate for Nisqually Fall Fingerling stock.

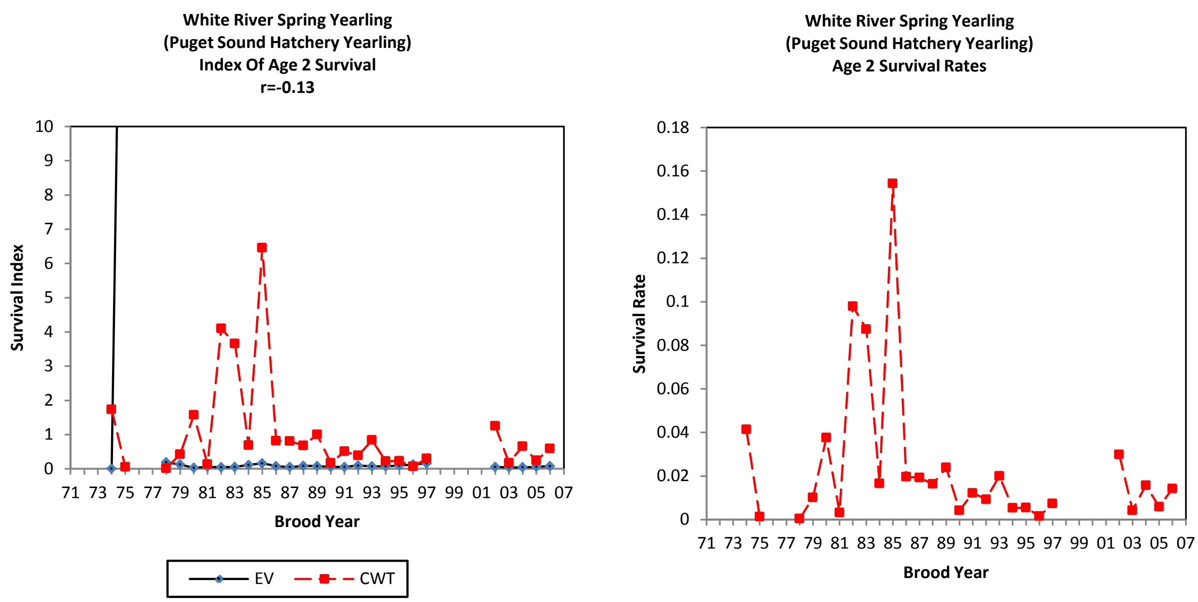


Figure 2.43 CWT survival index and survival rate for White River Spring Yearling stock.

2.2.8.3.3 Mortality Distributions

Percent distribution in total AEQ fishery mortality for the South Puget Sound stocks during 1999–2011 averaged 36% for SPS (Figure 2.34; Appendix C36), 79% for SPY (Figure 2.34; Appendix C37), 66% for NIS (Figure 2.34; Appendix C22) and 25% for WRY (Figure 2.34; Appendix C45). 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 14%), in Canadian fisheries (primarily WCVI). The fall fingerling stocks (SPS and NIS) have a higher mortality in Puget Sound fisheries than the North 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.

During 1999–2011, the distribution of fishing mortality for SPS and NIS has remained stable. Fisheries north of the U.S. and Canada border comprised approximately 14% in 1999–2003 and 12% in 2007–2011. Fisheries south of the U.S. and Canada border comprised 46% in 1999–2003 and 42% in 2007–2011. Corresponding to these fisheries, the percentage in escapement was 40% in 1999–2003 and 46% in 2007–2011.

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 southern end of 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 1989 to a low of 38% for the 1992 and 1993 BYs (Figure 2.44). The BYER for GAD ranged from a high of 80% in 1989 to a low of 23% in 1994 (Figure 2.44). A total fishery BYER for GAD would include additional mortality associated with the significant river fisheries that occur in most years.

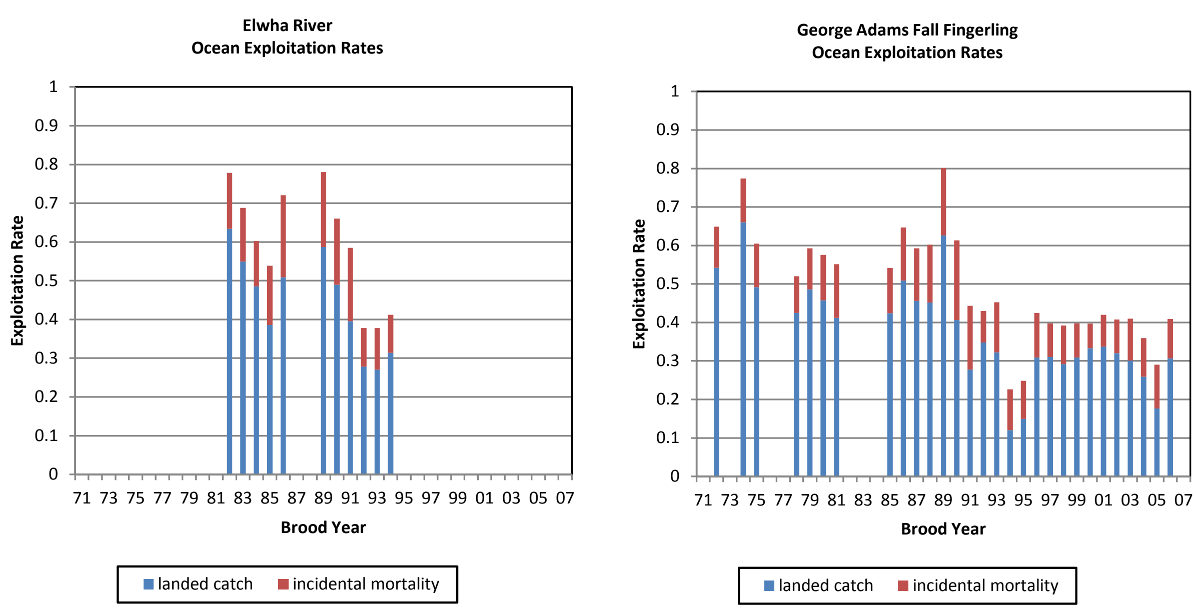


Figure 2.44 Brood year exploitation rate in terms of landed catch and incidental mortality for Elwha and George Adams (Skokomish River) Fall Fingerling CWT indicator stocks.

2.2.8.4.2 Survival Rates

Survival rates of ELW were initially approximately 2% in the first three years of tagging (1982–1984), plummeted in 1985 to less than 1%, and remained there until the program was discontinued (Figure 2.45). Survival rates for GAD averaged 1.2% during 1985–2006, and ranged from a low of 0.04% for BY 1990 to a high of 6.3% for BY 1978 (Figure 2.46).

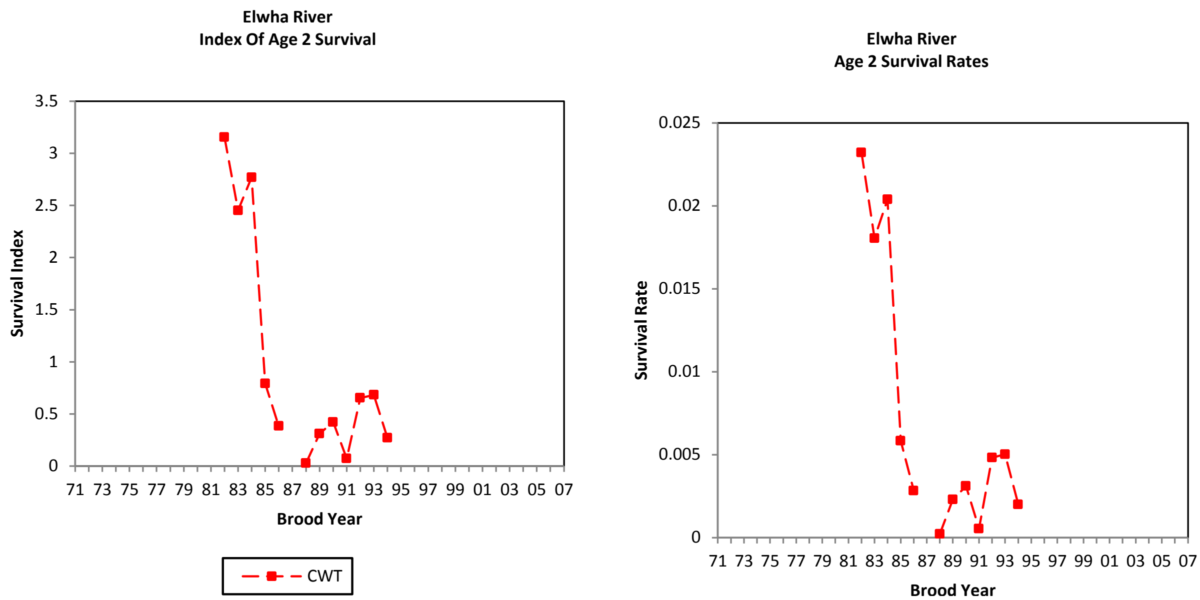


Figure 2.45 CWT survival index and survival rate for Elwha River stock.

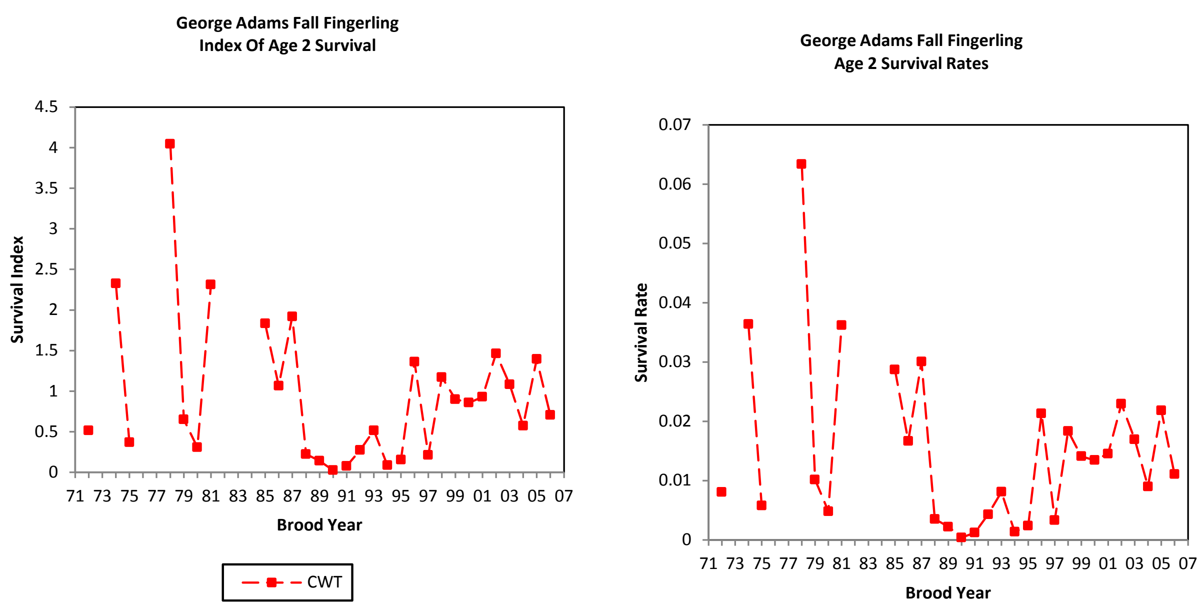


Figure 2.46 CWT survival index and survival rate for George Adams (Skokomish River) Fall Fingerling stock.

2.2.8.4.3 Mortality Distributions

The last year of data for measuring percent distribution in total AEQ fishery mortality for ELW is 1997 (Figure 2.34; Appendix C10). During 1986–1997, fisheries in Alaska comprised 9% of the mortality, Canada 32%, Washington and Oregon coast 3%, and Puget Sound 23%, primarily in the Juan De Fuca sport fishery. Escapement of ELW averaged 36% during this period. For GAD during 1999–2011, fisheries in Alaska comprised 1% of the fishery and escapement distribution, Canada 19%, Washington and Oregon coast 5%, and Puget Sound 29% (Figure 2.34; Appendix C11). Escapement of GAD during 1999–2011 averaged 46%.

Distribution of fishing mortality for GAD during 1999–2011 between Alaska, Canada and the southern U.S. was shifted slightly by a reduction in fisheries north of the U.S. and Canada border from 22% during 1999–2003 to 14% during 2007–2011. Fisheries mortality percentage south of the U.S. and Canada border has increased from an average of 32% during 1999–2003 to 40% during 2007–2011. Escapement of GAD is unchanged between the beginning and ending five-year period of 1999–2011.

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 mark-selective 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 38% (per stock average range of 30–45%) for the fall fingerling stocks (SAM, SSF, STL, SKY, SPS, NIS, ELW, and GAD) and 37% (range 28–42%) 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 one of the fall fingerling stocks (SSF) and two of the spring stocks (NKF and NKS).

Survival rates to age 2 for Washington Salish Sea Stocks were typically 1–3% for most indicators and 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 1.1–2.85%, 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.

Calendar year escapement for fall fingerling stocks varies between the stocks with significant terminal fisheries that have average escapements of 25–46% (SAM, SPS, NIS, and GAD) to stocks that do not have significant terminal fisheries where escapement is 60–66% (SSF, STL, and SKY; Table 2.9). The mean escapement for spring stocks has ranged from 48% for SKY to

75% for WRY. Relative to the average escapement during 1999–2011, the escapement in the last calendar year is higher for SAM, SPS, NIS Fall Fingerling stocks and WRY Spring stock.

Table 2.9 Summary of statistics generated by the 2011 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.

							CY % Escapement[1]		
			BYER (total mortality)		Survival rate		1999–2008	2009–present	
Subregion	Stock Abbrev.	Indicator Stock Name	Mean (range)	Last complete BY	Mean (range)	Last complete BY	Mean (range)	Mean (range)	Last CY (if ≠ current)
North Puget Sound	NSF	Nooksack Spring Fingerling[2]	41% (25–63%)	42%	1.40% (0.3–4.5%)	0.70% (2006)	55% (37–81%)	52% (50–55%)	50%
	NKS	Nooksack Spring Year[2]	50% (29–76%)	44%	1.10% (0.1–3.7%)	0.60% (1996)	60%	--	--
	SAM	Samish Fall Fingerling[2]	44% (29–67%)	29%	2.80% (0.3–15.1%)	0.70% (2006)	23% (13–31%)	30% (27–37%)	27%
	SKF	Skagit Spring Fingerling[2]	30% (13–49%)	13%	1.70% (0.7–4.3%)	1.30% (2006)	63% (46–78%)	53% (47–58%)	58%
	SKS	Skagit Spring Yearling[2]	44% (20–77%)	20%	2.80% (0.6–7.5%)	1.70% (2006)	51% (31–68%)	39% (39–40%)	39%
	SSF	Skagit Summer Fingerling[2]	29% (21–39%)	25%	1.30% (0.2–3.4%)	0.80% (2006)	64% (54–76%)	46% (33–60%)	46%
Central Puget Sound	STL	Stillaguamish Fall Fingerling[2]	50% (22–90%)	26%	1.80% (0.3–6.4%)	0.40% (2006)	68% (45–83%)	61% (55–64%)	64%
	SKY	Skykomish Fall Fingerling[2]	35% (22–43%)	22%	0.90% (0.4–1.9%)	0.50% (2006)	61% (56–75%)	67% (54–78%)	54%
South Puget Sound	SPS	South Puget Sound Fall Fingerling[2]	49% (23–73%)	32%	2.40% (0.4–9.4%)	1.30% (2006)	50% (34–70%)	58% (49–67%)	59%
	SPY	South Puget Sound Fall Yearling[2]	69% (16–90%)	63%	2.00% (0.03–14.8%)	0.30% (2006)	19% (2–47%)	24% (1–56%)	1%
	NIS	Nisqually Fall Fingerling[2]	44% (23–81%)	23%	1.70% (0.1–4.5%)	1.40% (2006)	31% (11–56%)	44% (35–55%)	55%
	WRY	White Spring Yearling[2]	50% (3–89%)	13%	2.50% (0.04–15.4%)	1.40% (2006)	67% (48–84%)	88% (83–94%)	94%
Juan de Fuca/Hood Canal	ELW	Elwha[2]	59% (38–78%)	41%	0.70% (0.02–2.3%)	0.20% (1994)	--	--	--
	GAD	George Adams Fall Fingerling[2]	49% (23–80%)	41%	1.50% (0.04–6.3%)	1.10% (2006)	46% (37–63%)	46% (40–51%)	46%

[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 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 four fall Chinook CWT indicator stocks for the Lower Columbia River: Columbia Lower River Hatchery Tule (LRH, released recently from Big Creek/Bonneville Hatchery), Cowlitz Hatchery Tule (CWF), Spring Creek Hatchery Tule (SPR), and Lewis River wild bright (LRW). There are two fall and one summer Chinook CWT indicator stocks for the Upper Columbia River: Columbia Upriver Bright fall Chinook (URB, from Priest Rapids Hatchery), Hanford Wild Bright fall Chinook (HAN, from Hanford Reach), and Columbia Summers (SUM, from Wells Hatchery, includes fingerlings and some yearling releases). There is one fall Chinook CWT indicator stock for the Snake River tributary, Lyons Ferry Hatchery Bright. These enter the ocean as a combination of fingerlings and yearlings; the fingerlings (LYF) are employed in this analysis. A single spring Chinook indicator stock originates in the Willamette River tributary (WSH). Juveniles are released primarily as yearlings by the Oregon Department of Fish and Wildlife from several Willamette basin hatcheries. Despite differences in outmigration age, age 2 is the youngest age recovered for all the Columbia River stocks. The CWT time series begins with the following BYs: 1975 for SUM, URB and WSH; 1976 for LRH; 1977 for CWF, LRW, and SPR; 1984 for LYF; and 1986 for HAN. The time series for LRW and LYF were interrupted by missing BYs (either no adipose fin clipped releases or no subyearling releases).

2.2.9.1 *Brood Year Exploitation Rates*

There were several general patterns in the BYER computed for Columbia River Stocks (Figure 2.47; Table 2.10). For all except CWF and WSH, BYERs include recoveries from both ocean and terminal fisheries; CWF and WSH Chinook experience different terminal harvest impacts than their wild counterparts.

The three hatchery stocks in the lower Columbia River (CWF, LRH, and SPR) showed decline in BYER from highs during the late 1970s (CWF: 65% for 1977; LRH: 83% for 1976; SPR: 93% for 1973) to lows during the early to mid-1990s (CWF: 11% for 1991; LRH: 19% for 1993; SPR: 48% for 1995) with recent BYERs in between the two extremes. Average BYERs were 39% for CWF, 58% for LRH, and 72% for SPR. Incidental mortality rates averaged 7% (CWF), 10% (LRH), and 12% (SPR) of the total BY return, with ranges 3–11% (CWF), 3–23% (LRH), and 6–17% (SPR). The percentage of the BYER (landed catch + IM) that was estimated as IM averaged 19% (CWF: range 8–51%), 18% (LRH: range 9–32%), and 17% (SPR: range 12–22%) of total fishing mortality. For LRH, but not the two other stocks, IM appears to have declined substantially in recent years (average of 19% of BYER through 1998 versus 13% since 1999).

The LRW bright stock in the lower Columbia River and SUM stock in the upper Columbia River also experienced decline to particularly low BYERs in the 1990s (lowest were 16% for LRW in 1996, and 21% for SUM in 1992 and 1993), followed by increase to rates similar to those before the 1990s. For LRW the highest BYER was observed in 2007 (69%), and for SUM the highest BYER was observed in 1998 (74%). Average BYERs were 43% for LRW and 52% for SUM. Incidental mortality averaged 7% (range 2–10%) for LRW and 7% (range 3–14%) for SUM, as a percentage of the total BY return. As a part of BYER, IM averaged 16% for LRW (range 9–35%) and 15% for SUM (range 7–36%). Incidental mortality did not appear to show a trend over time for LRW, but for SUM it appeared to be somewhat greater up to 1998 (17%) than afterwards (12%).

A somewhat similar pattern to that for LRW and SUM was observed for URB upriver bright hatchery stock, except the URB BYERs reached low levels in the late 1970s (low of 24% in 1978) and highest levels in the 1980s (high of 81% in 1984). The overall average BYER was 56%. Incidental mortality ranged from 5–18%, averaging 9% of the total BY return. Incidental mortality made up an average of 17% of total fishing mortality in BYERs (range 10–45%), and it did not appear to show any time trend.

Releases of CWT fish for HAN (an upriver bright wild stock like URB) began with the 1984 BY, and BYERs decreased fairly steadily through the late 1990s, increased rapidly through the mid-2000s, and then decreased again. The lowest BYER was 42% in 1998, the highest was 78% in 2004, and the average was 57%. Incidental mortality ranged from 3–11% and averaged 8% of the total returns and 14% of total fishing mortality (range from 7–21%), and did not appear to have a trend over the time series.

Releases of CWT fish for LYF began with the 1984 BY, and BYERs decreased fairly steadily through the 1990s, then mostly increased through the 2000s. The lowest BYER was 30% in 2004, the highest was 80% in 2007, and the average was 49%. Incidental mortality ranged from 6–14% and averaged 9% of the estimated total return, and averaged 19% of the total fishing mortality (range 13–37%), and did not appear to have a trend over the time series.

Although BYERs were multimodal for WSH, a spring stock on the Willamette River (Figure 2.48), almost all values for the 1970s and 1980s were higher than those for the 1990s and 2000s. But compared to the summer and fall run stocks, the entire time series of BYERs for this spring run stock were substantially lower. The highest BYER was observed for the 1983 BY (29%), the lowest for the 2004 BY (3%), and the average was 12%; only the Taku (10%) and Chilkat (11%) stocks, also spring run, have similarly low contribution rates to ocean fisheries. Incidental mortality for WSH ranged from 1–6%, averaging 3% of the total return, but was relatively high, averaging 27% of the estimated total fishing mortality. Also, IM appeared to be marginally higher in years up to 1998 (29% of BYER) than afterwards (23% of BYER).

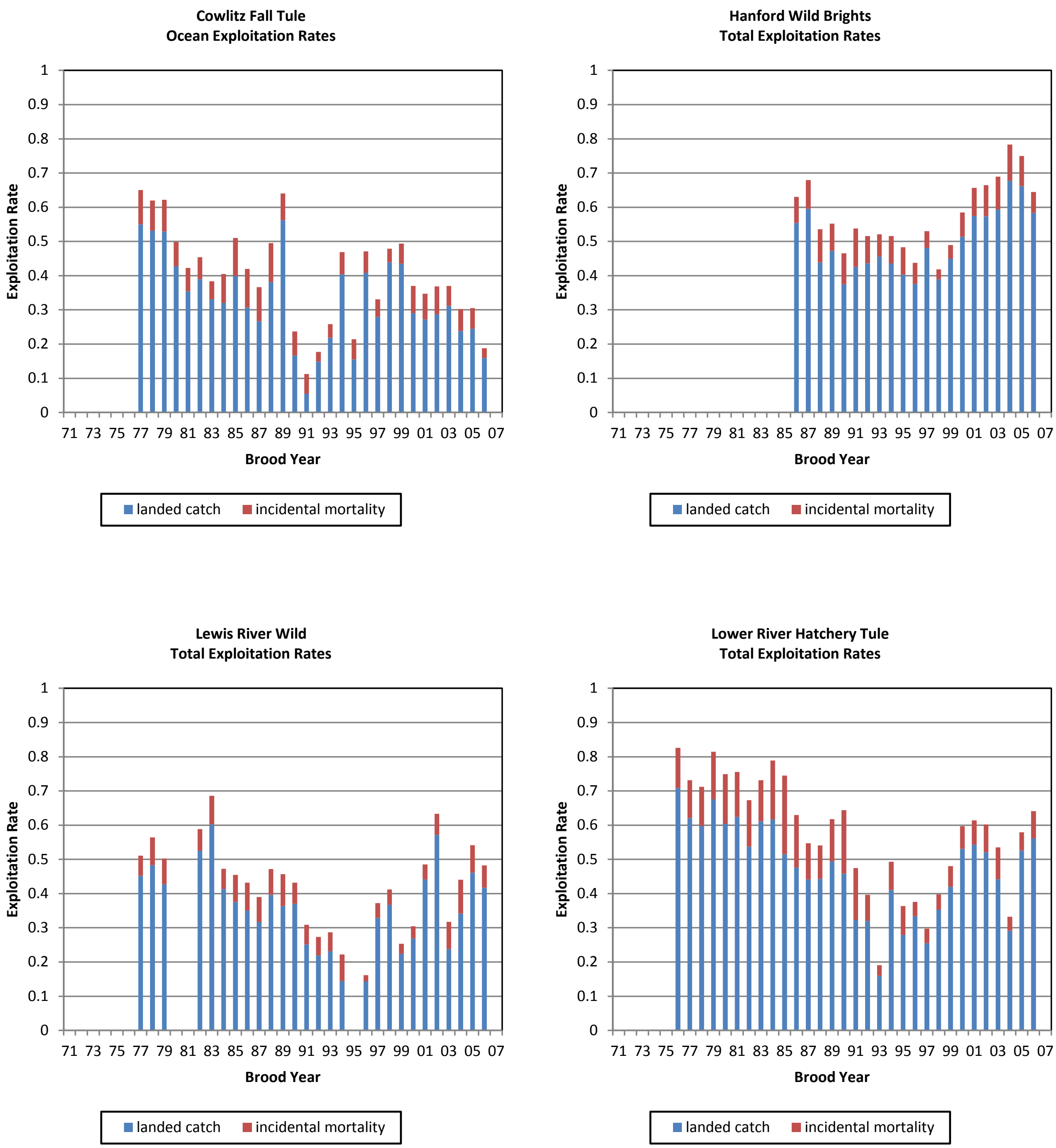


Figure 2.47 Brood year exploitation rate for summer and fall Columbia River Stocks. Catch and incidental mortality are shown. Only completed brood years are included.

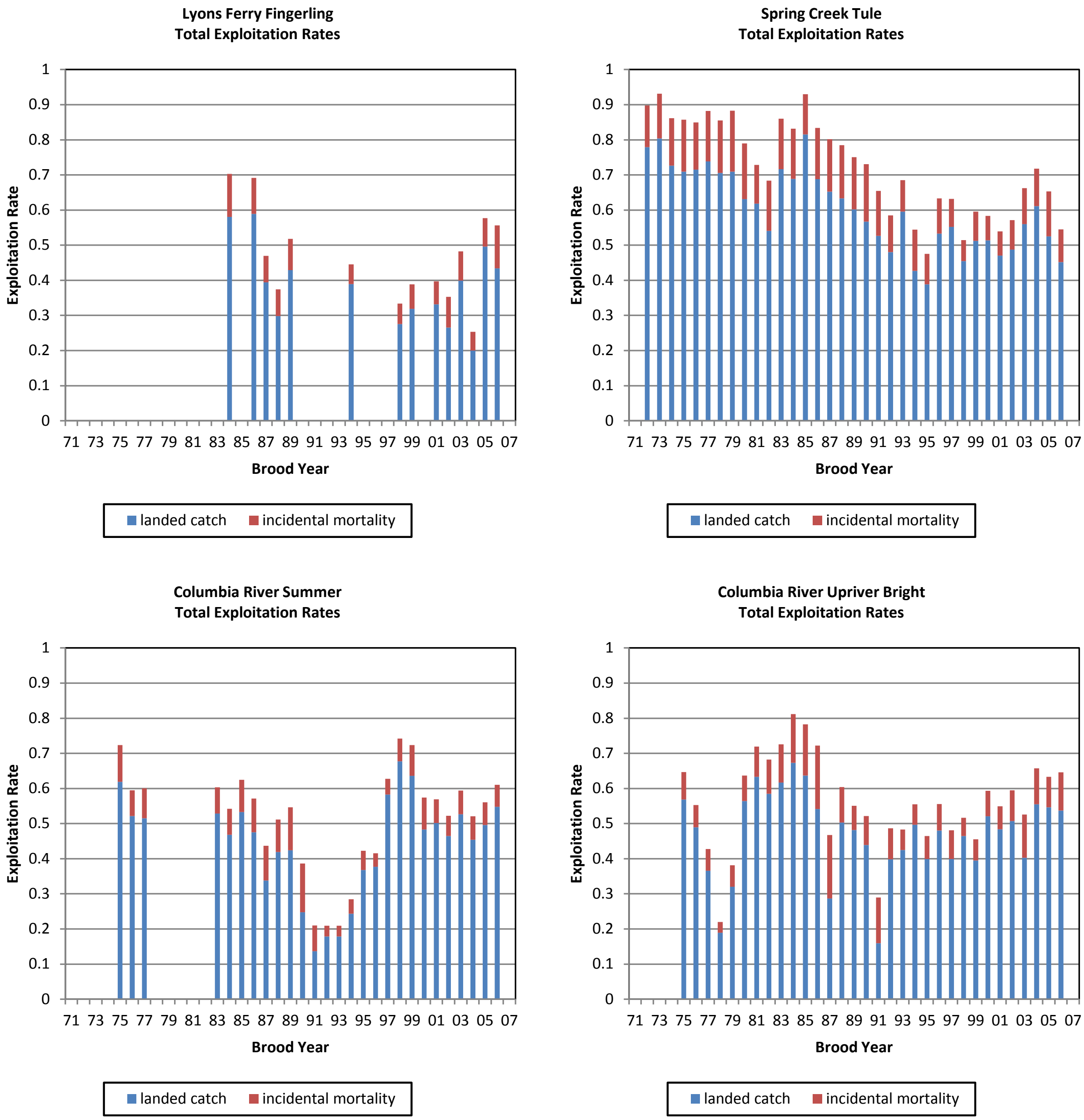


Figure 2.47   Page 2 of 2.

Table 2.10 Summary of statistics generated by the 2012 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 Agreement periods 1999–2008 and 2009–present.

		BYER (total mortality)		**Survival rate**		**CY % Escapement[1]**		
						1999–2008	**2009–present**	
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]	40% (11–65%)	19%	0.67% (0.06–3.56%)	0.67% (2006)	52% (25–68%)	73% (64–90%)	90%
HAN	Hanford Wild Brights	58% (42–78%)	64%	1.09% (0.19–4.42%)	0.59% (2006)	44% (28–56%)	31% (11–46%)	36%
LRH	Lower River Hatchery Tule	58% (19–83%)	64%	1.13% (0.02–9.48%)	0.47% (2006)	52% (38–70%)	32% (27–40%)	40%
LRW	Lewis River Wild	42% (16–69%)	48%	2.23% (0.22–6.96%)	0.61% (2006)	58% (39–81%)	46% (32–64%)	32%
LYF	Lyons Ferry Fingerling	47% (25–70%)	56%	1.18% (0.08–4.05%)	0.27% (2006)	54% (40–74%)	21% (13–37%)	13%
SPR	Spring Creek Tule	72% (48–93%)	54%	1.98% (0.13–8.47%)	0.44% (2006)	38% (30–50%)	33% (27–42%)	27%
SUM	Columbia Summer	52% (21–74%)	61%	1.33% (0.07–4.84%)	0.47% (2006)	42% (28–59%)	45% (38–52%)	38%
URB	Columbia River Upriver Bright	56% (22–81%)	65%	1.98% (0.09–7.56%)	0.14% (2006)	47% (40–62%)	42% (31–57%)	40%
WSH	Willamette Spring Hatchery[2]	12% (3–29%)	5%	3.0% (0.6–7.4%)	1.6% (2005)	64% (51–73%)	53% (43–60%)	43%

[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.

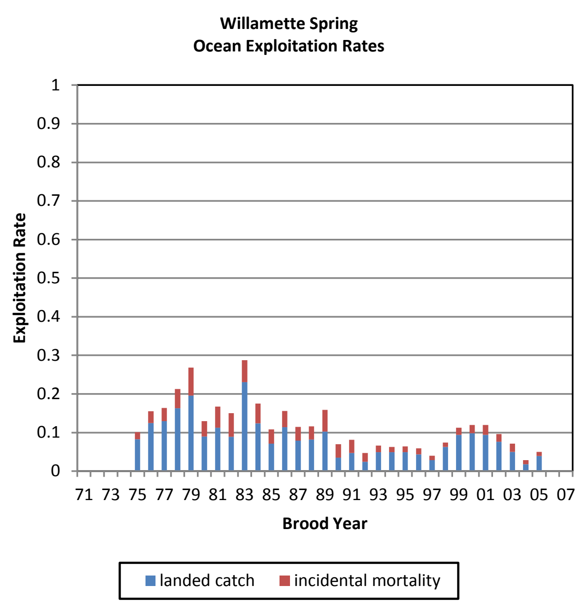


Figure 2.48 Brood year exploitation rate for Willamette Spring Chinook. Catch and incidental mortality are shown. Only completed brood years are included.

2.2.9.2 *Survival Rates*

There appears to be an increasing trend in relative survival during the recent years for the SUM stock, but for the other Columbia River fall Chinook stocks, it is difficult to discern any pattern other than variability over time (Figure 2.49). There is some correlation between the EV index from the Chinook Model and the survival index from CWT recovery analysis for some Columbia River fall Chinook stocks, particularly for the CWF, LRH and SPR stocks.

The survival rate of Willamette Spring Chinook, from release to age 3 (i.e., due to the stock's entry into the ocean as yearlings) has varied widely across the last 30 BYs (Figure 2.50). WSH survival rates have averaged around 3% and ranged from 0.6–7.4%. The most recently complete BY registered a 1.6% survival rate. The EV and survival index are weakly correlated with r = 0.32.

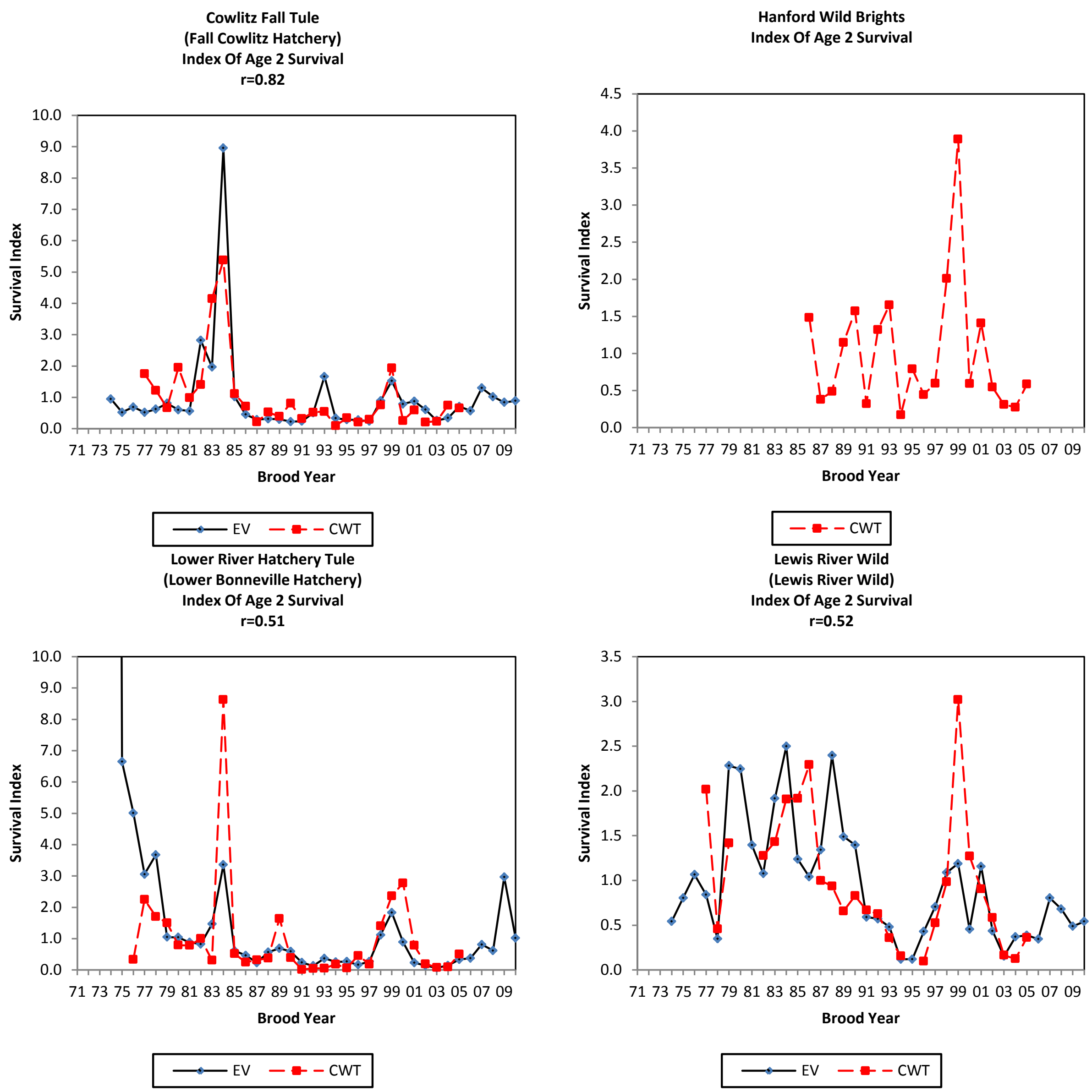
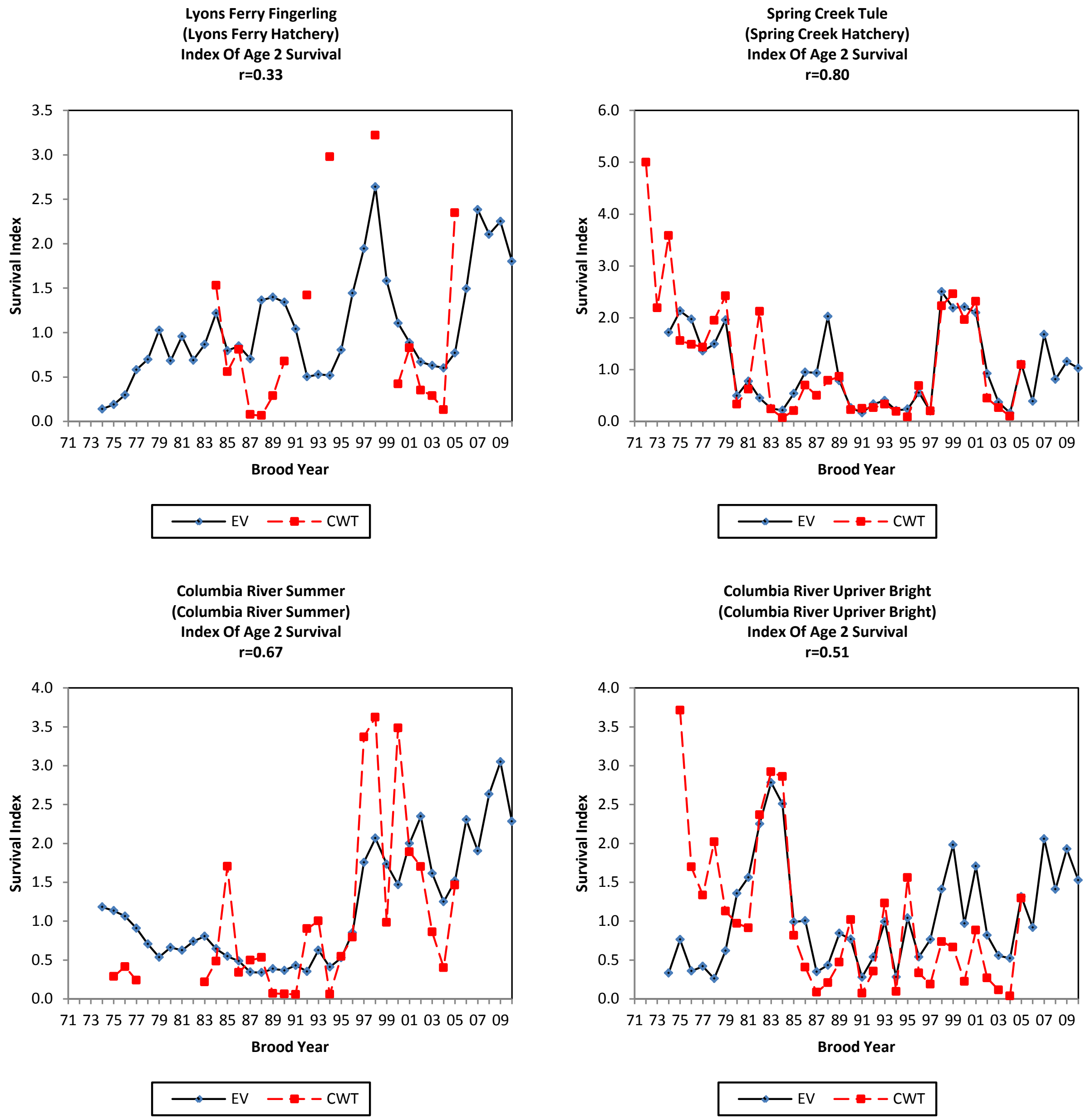


Figure 2.49 CWT survival and EV indices and survival rate for summer and fall Columbia River Chinook stocks. r: Pearson correlation coefficient between CWT and EV survival indices.



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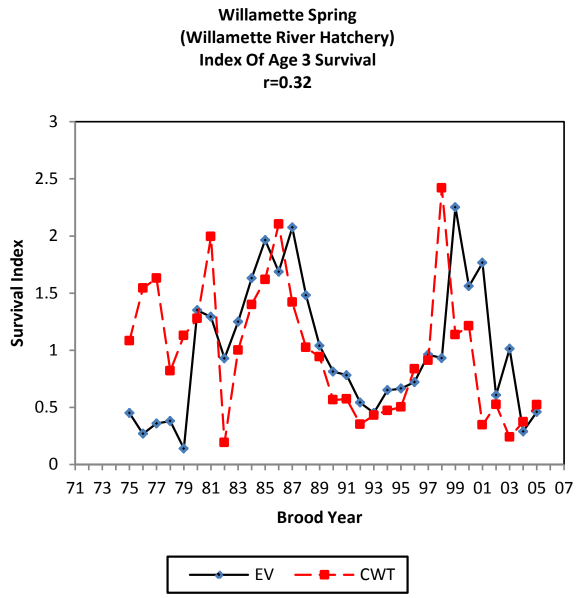


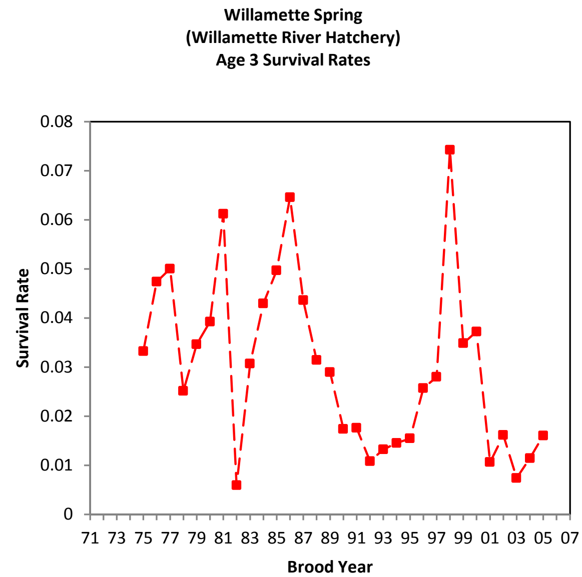


Figure 2.50 CWT survival and EV indices and survival rate for the Willamette River Spring Chinook indicator stock. r: Pearson correlation coefficient between CWT and EV survival indices.

2.2.9.3 *Mortality Distributions*

For the Cowlitz Fall Tule CWF stock, escapement generally made up a slightly greater proportion of total mortality than did fisheries impacts. Since the 1999 PST Agreement, the escapement was larger during the recent time period (56.5%, 1999–2011) than it was during the long-term time period (51.4%, 1981–2011). Most of the catch in the recent average was distributed among four fisheries: 12.2% WA/OR Coast troll, 6.8% WA/OR Coast sport, 5.4% terminal sport, and 5.3% WCVI troll. In the long-term average distribution, terminal net had a larger impact than terminal sport: 11.2% WA/OR Coast troll, 8.7% WCVI troll, 6.1% terminal net, 5.8% WA/OR Coast sport, and 4.6% terminal sport. During 1979–1984, WCVI Troll, WA/OR Coast sport and terminal net had considerably greater impacts: 19.4% WCVI troll, 10.4% WA/OR Coast sport, and 10.1% terminal net. Details on the smaller fisheries can be found in Appendix C7. Please refer to Figure 2.51 for a graphical display of mortality distribution results for CWF and remaining stocks.

For the upriver bright wild HAN stock, escapement generally made up a smaller proportion of total run than did fisheries impacts. Escapement was slightly higher during the recent time period (42.8%, 1999–2011) than it was during the long-term time period (41.1%, 1990–2011). Most of the catch in the recent average was distributed among three fisheries: 17.6% terminal net, 16.6% SEAK troll, and 8.3% terminal sport. The long-term average was similar but SEAK troll had the biggest impact: 18.0% SEAK troll, 17.8% terminal net, and 9.8% terminal sport. During 1985–1995, WCVI troll also had significant impacts (7.1%). Details on the smaller fisheries can be found in Appendix C12.

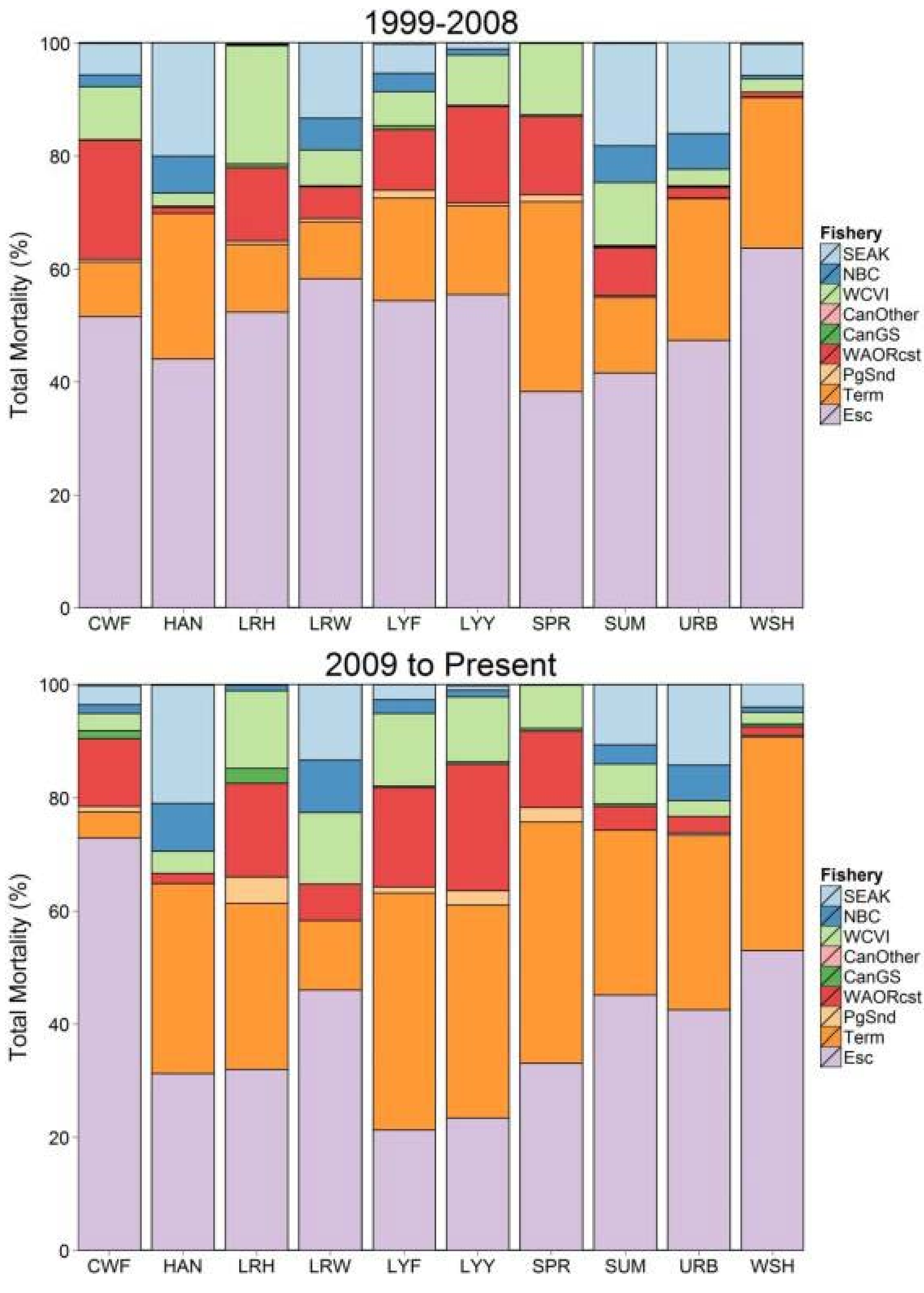


Figure 2.51 Distribution of total mortality for Columbia River indicator stocks for the current (2009–present) and previous (1999–2008) agreement periods.

For the Lower River Tule LRH stock, escapement generally made up a somewhat smaller percentage of total run than did fisheries impacts. Escapement was higher during the recent time period (47.7%, 1999–2011) than it was during the long-term time period (43.4%, 1979–2011. Most of the catch in the recent average was distributed among four fisheries: 13.2% terminal net, 12.0% WCVI troll, 9.5% WA/OR Coast troll, and 7.4% WCVI sport. The long-term average catch, however, was distributed mostly among three fisheries with WCVI troll and WA/OR Coast troll playing a larger role: 18.2% WCVI troll, 12.1% WA/OR Coast troll, and 8.8% terminal net; WCVI sport had considerably less long-term impact (4.0%). Details on the smaller fisheries can be found in Appendix C16.

For the lower river bright LRW stock, escapement generally made up a greater proportion of total run than did fisheries impacts. Escapement percentages were similar during both the recent time period (55.4%, 1999–2011) and the long-term time period (56.8%, 1981–2011). There were two fisheries that took 5% or more of the total run in the recent average: 12.6% SEAK troll and 6.3% terminal sport (Columbia River). On the other hand, there were four such fisheries in the long-term average: 9.8% SEAK troll, 7.9% terminal sport, 6.7% terminal net, and 5.7% WCVI troll. During the 1985–1995 period, terminal net had considerably higher impact (12.0%). Details on the smaller fisheries can be found in Appendix C17.

For the Snake River LYF stock, escapement generally made up a smaller proportion of the total run than did fisheries impacts. Escapement levels were similar for both the recent time period (43.4%, 1999–2011) and the long-term time period (43.1%, 1989–2011). There were four fisheries with 5% or more of the distribution in the recent average: 21.1% terminal net, 8.0% WA/OR Coast troll, 5.5% WCVI troll, and 5.0% terminal sport. The long-term average distribution had somewhat higher impacts by WA/OR Coast troll, otherwise impacts were similar: 19.5% terminal net, 8.9% WA/OR Coast troll, 8.5% WCVI troll, and 4.2% terminal sport. During 1985–1995, WCVI troll had considerably greater impact (15.2%) and terminal sport had substantially less impact (2.4%). Details on the smaller fisheries can be found in Appendix C18.

For the Spring Creek Hatchery Tule SPR stock, escapement generally made up a much smaller proportion of total calendar year run than did fisheries impacts. The percentage of escapement was higher during the recent time period (37.1%, 1999–2011) than it was during the long-term time period (29.9%, 1979–2011). There were three fisheries with 5% or more of the total run in the recent average, with impacts dominating in terminal net: 33.1% terminal net, 10.0% WA/OR Coast troll, and 8.0% WCVI troll. Combined, these three fisheries had greater impacts in the long-term average, resulting in the lower escapement percentage: 29.5% terminal net, 13.9% WCVI troll, and 12.4% WA/OR Coast troll. During 1979–1984, five fisheries had more than 5% impact: 25.4% WCVI troll, 23.3% terminal net, 17.3% WA/OR Coast troll, 5.9% WA/OR Coast sport, and 5.4% Puget Sound sport. Details on the smaller fisheries can be found in Appendix C35.

For the upriver SUM stock, escapement generally made up a somewhat smaller proportion of total calendar year run than did fisheries impacts. Escapement distribution was marginally less during the recent time period (42.5%, 1999–2011) than it was during the long-term time period (47.3%, 1979–2011). There were five fisheries with 5% or more of the total run in the recent average: 14.5% SEAK troll, 9.4% terminal net, 7.9% WCVI troll, 7.6% terminal sport and 6.3% WA/OR Coast troll. There were four such fisheries in the long-term average: 13.1% SEAK troll, 9.5% WCVI troll, 7.2% terminal net and 5.8% WA/OR Coast troll. During 1979–1984, only three fisheries had 5% or more impact, and in all three cases the impacts were considerably higher than in the recent or long-term averages: 24.1% SEAK troll, 17.6% WCVI troll, and 8.6% NBC troll. Details on the smaller fisheries can be found in Appendix C41.

For the upriver right URB stock, escapement generally was less than fisheries impacts. Relative escapement was higher during the recent time period (46.2%, 1999–2011) than it was during the long-term time period (43.7%, 1979–2011). There were three fisheries with 5% or more of the total run in the recent average: 17.6% terminal net, 13.5% SEAK troll and 8.9% terminal sport. However, there were five fisheries in the long-term average with 5% or greater impact: 19.4% terminal net, 13.3% SEAK troll, 6.0% North Central British Columbia troll, 5.3% terminal sport, and 5.2% WCVI troll. During 1979–1984, SEAK troll (18.0%) had greater impact but terminal net (10.0%) and terminal sport (0.4%) had considerably lower impact. Details on the smaller fisheries can be found in Appendix C44.

For the Willamette Spring Hatchery WSH stock, escapement percentages were less than fisheries impacts. Percentages of escapements were higher during the recent time period (61.2%, 1999–2011) than they were during the long-term time period (55.0%, 1979–2011). There were two fisheries with 5% or more of the total run in the recent average: 22.6% terminal sport, and 6.7% terminal net. There were three such fisheries in the long-term average: 24.7% terminal sport, 6.6% SEAK troll, and 6.0% terminal net. During 1979–1984, NBC troll (7.5%) had much greater impact but terminal sport (17.6%) had lower impact. Details on the smaller fisheries can be found in Appendix C46.

2.2.9.4 *Regional Summary for Columbia River Stocks*

Columbia River stocks' BYERs over the full time series of CWT data showed a wide range (Table 2.10). They were particularly high for SPR (mean 72%, range 48–93%) and particularly low for WSH (mean 12%, range 3–29%); however, the latter do not include terminal fishing, also the case for CWF. At the midpoint of the mean BYERs (i.e., four stocks with lower mean BYER, four with higher mean BYER) was SUM (mean 52%, range 21–74%). For the last complete BY, BYER was again lowest for WSH (7%) but was higher for LYF (80%), LRH (73%), and LRW (69%), than for SPR (68%). The midpoint value of BYER for the last complete BY was again that for SUM (63%). Four stocks (CWF, HAN, SPR, and WSH) had BYERs lower in the last complete BY than the time series mean. The other five stocks (LRH, LRW, LYF, SUM, and URB) had last complete BYER higher than the time series mean.

Survival rates also varied widely over the time series (Table 2.10). Both the lowest and highest survivals were observed for LRH (range 0.02–9.5%). The narrowest survival range was observed for HAN (0.2–4.0%). The lowest and highest means were estimated for CWF (0.7%) and WSH (3.0%), the latter being the only stock that has primarily yearling releases. The stock with the midpoint mean survival was SUM (1.3%), and its survival range was fairly typical (0.07–4.8%). For most stocks, survival was relatively low for the last complete BY: seven stocks (HAN, LRW, LYF, SPR, SUM, URB, and WSH) had survival lower than the time series mean, one stock (CWF) had survival equal to the time series mean, and one stock (LRH) had survival greater than the time series mean.

We compared escapement percentages between the groups of years (1999–2008, 2009–

present) following the last two Agreements (Table 2.10). During 1999–2008, the lowest mean escapement percentage was observed for SPR (mean 38%, range 30–50%, the narrowest range), and the highest mean escapement percentage was observed for WSH (mean 64%, range 51–73%). At the midpoint were CWF (mean 52%, range 25–68%, the widest range) and LRH (mean 52%, range 38–71%). During 2009–present, the lowest mean escapement percentage was observed for LYF (mean 21%, range 13–37%), and the highest mean escapement percentage was observed for CWF (mean 73%, range 64–90%). For the three stocks that had escapement goals established before 1999 (LRW, SUM, URB), the goal was not met for only LRW in four years (1999, 2007–2009).

2.2.10 North Oregon Coast Stocks

There are two hatchery-origin CWT indicator stocks representing the production of Chinook 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 is used to indicate those metrics ascribed to the Northern Oregon Coast aggregate, while the ELK release group indicates those metrics affiliated with the Mid-Oregon Coast aggregate. There have been relatively consistent releases of a CWT group of Chinook from the SRH since 1976, with the exception of no releases in 1981. There has 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 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. The ELK CWT group has benefited from the support of the Coded Wire Tag Improvement Team (CWTIT) program for the past several years. Without the support of this, or a similar, program, it is unlikely that either the release group size or their terminal recoveries can be supported into the foreseeable future.

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 2.52; Table 2.11). The BYER has averaged 37% (range 63–21%) for the SRH releases. Data representing both BY 1977 and 1978 from the ELK hatchery are anomalous and not likely indicative of reasonable portrayals of this stock. BYER for the ELK has averaged 28% (range 18–44%), 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.

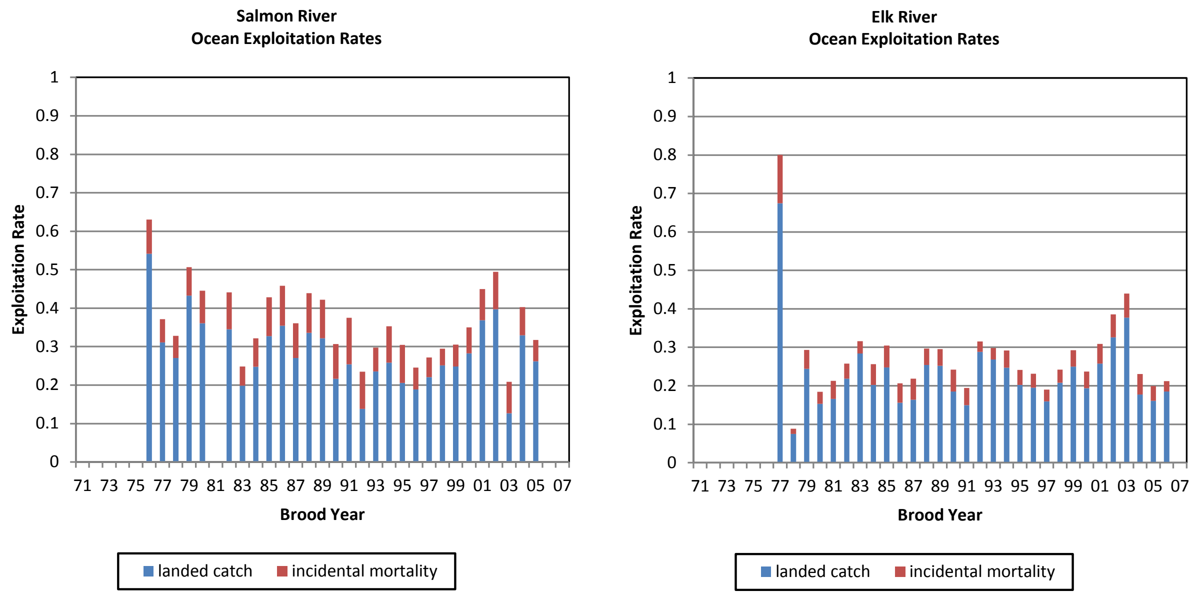


Figure 2.52 Brood year exploitation rate (ocean only) for Oregon Coast CWT indicator stocks. Catch and incidental mortality are shown. Only completed brood years are included.

Table 2.11 Summary of statistics generated by the 2012 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 in the escapement for Agreement periods 1999–2008 and 2009–present.

						CY % Escapement[1]		
		BYER (total mortality)		**Survival rate**		**1999–2008**	**2009–present**	
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]	28% (9–80%)	21%	9.8% (1.1–33.9%)	17.8% (2006)	55% (32–72%)	56% (36–68%)	36%
SRH	Salmon River[2]	37% (21–63%)	32%	5.7% (1.1–10.7%)	3.3% (2005)	38% (18–56%)	35% (31–40%)	40%

[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. Survival rates for ELK have been variable and averaged 9.8%, with a range of 1–34% (Figure 2.53; Table 2.11). Generally, ELK has had quite robust survival, averaging approximately 10%. This is among the highest average survival tracked coastwide by the CTC, exceeded only by the average survival displayed by CHI (12%). Survival rates for SRH have been generally declining with a long-term average of 5.7%, with survival from the first three BYs averaging 7%, while the last three complete BY survivals averaged 3%. Still, comparatively SRH has relatively robust ocean survival compared to many of the other stocks tracked coastwide by the CTC. The EV index and the survival index are weakly correlated for the ELK with r = 0.33. The EV index and the survival index are moderately correlated for the SRH with r = 0.60.

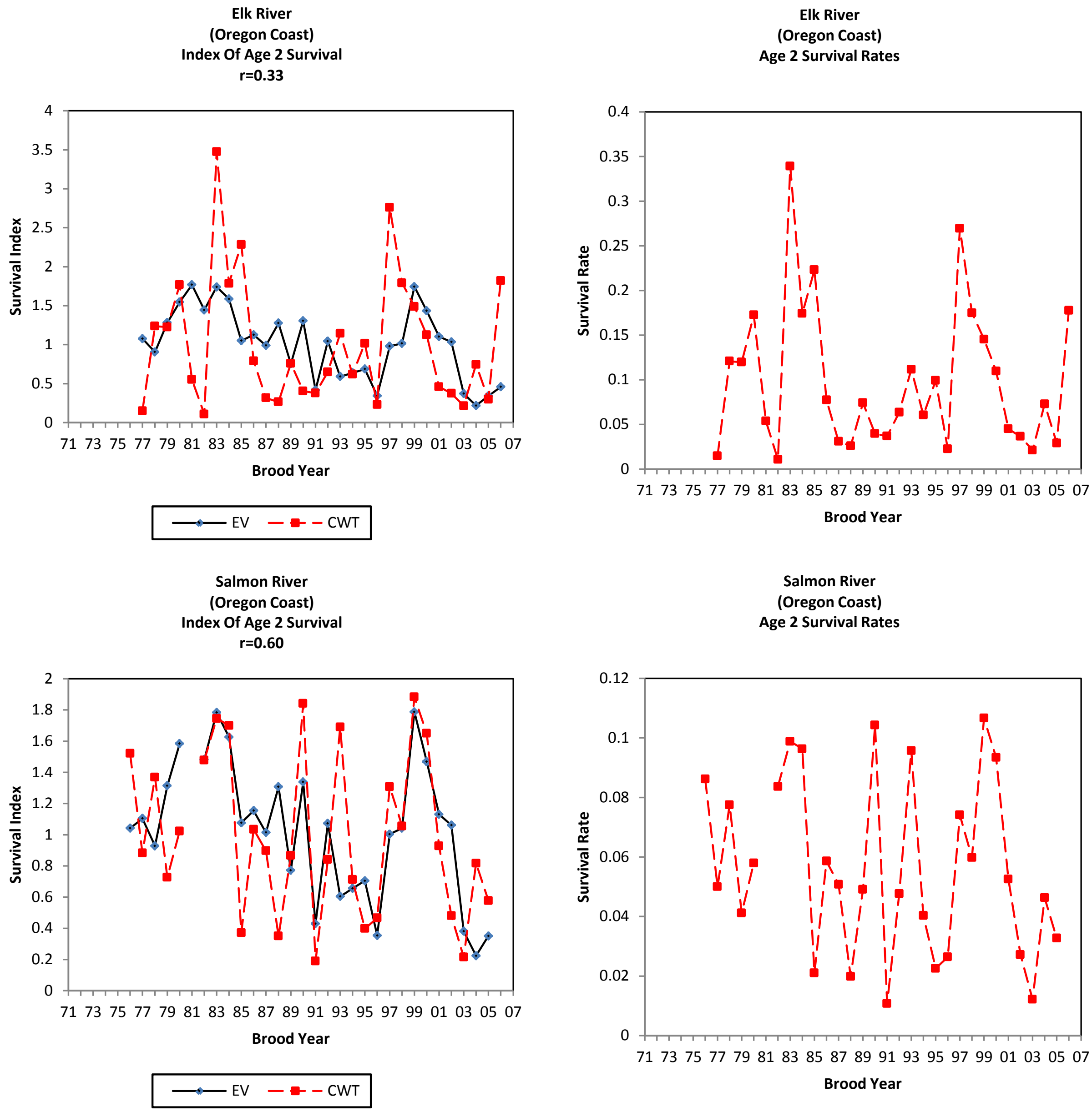


Figure 2.53 CWT survival and EV indices and survival rate for Oregon Coast indicator stocks. r: Pearson correlation coefficient between CWT and EV survival indices.

2.2.10.3 *Mortality Distributions*

An average of 37% of SRH (Appendix C38) mortality is attributed to escapement for the 1979–2011 time series (Table 2.11), and an average of 47% of the ELK (Appendix C9) mortality is attributed to escapement for the 1981–2011 time series (Table 2.11). *Mortality to escapement* is the proportion of recruitments which occurred during a BY's lifetime between fisheries and spawning escapement. Both stocks exhibit slight variation in the proportion of the recruitment which escapes to spawn through the time series, but there is no visible trend. Judging from 1999–2011 calendar year data, the largest impacts on the SRH stock occur in SEAK troll fisheries (18%), NBC troll (8%), NBC sport (4%) and terminal sport (28%). During the same time period, the largest impacts on the ELK stock occur in SEAK troll (7%), NBC troll (4%), ISBM troll WA/OR (17%), and terminal sport fisheries (14%). 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%: 1999–2011). These impact distributions are displayed graphically in Figure 2.54.

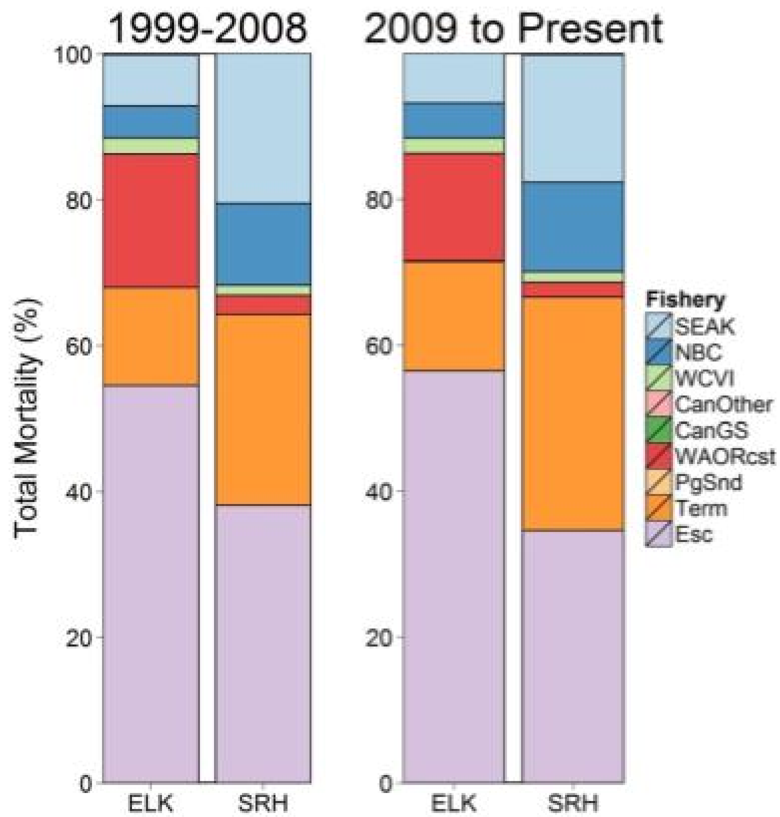


Figure 2.54 Distribution of total mortality for Oregon Coast indicator stocks for the current (2009–present) and previous (1999–2008) agreement periods.

3 Model Calibration and Output

Results from the annual calibration of the PSC Chinook model are used to calculate (1) preseason AIs for the three AABM fisheries, (2) postseason AIs for the previous year, and (3) preseason ISBM indices. The preseason AIs for 2013 are used to estimate the allowable 2013 catch of Treaty Chinook salmon for AABM fisheries. Postseason AIs are used to determine the previous (2012) season's allowable catches and to evaluate compliance in AABM fisheries. For the ISBM fisheries, the Agreement specifies that Parties will limit total AEQ mortality in ISBM fisheries to no greater than 63.5% for Canada and 60% for the U.S. relative to that observed in the base period 1979–1982 on the indicator stocks identified in Attachments IV and V for stocks not achieving their management objectives. The ISBM index is used to estimate annual exploitation rates relative to the base period for those fisheries. Forecasts of the 2013 ISBM indices are computed using the PSC Chinook model. Postseason ISBM indices for 2011 (all ISBM stocks) and 2012 (Canadian ISBM stocks) are computed using results of the ERA. The Agreement specifies that the postseason ISBM indices estimated through ERA of CWT recoveries will be used to assess compliance in ISBM fisheries; however, postseason indices are computed on a two-year lag because some CWT data are reported two years later. Additionally, postseason CWT-based ISBM indices provide insight on the performance of the (preseason) 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 2013, the model used was the same as used during the PST negotiations (CLB 9812), with the actual catches, escapements, and other data through 2012 added. In addition, CTC-agreed escapement goals were used where available and the form of the Ricker production function was adjusted for those stocks with newly agreed goals (e.g., Harrison River fall Chinook salmon).

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 preseason forecasts and postseason estimates become available, since model predictions are sensitive to preseason forecasts and postseason 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 and available abundance forecasts for the current year. 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 nonretention): 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. Additional discussion of the productivity parameters may be found in the draft model documentation (CTC AWG 1991).
5. FCS (forecast): Agency supplied annual estimates of terminal run sizes or escapements as well as preseason 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 2013, management agencies used two general methods to predict terminal returns or escapements.
    a. Sibling Models: Empirical relationships between abundance (commonly measured as terminal run size) of age *a* fish in calendar year CY and the comparable abundance of age *a*+1 fish in year CY+1 are used to predict abundance in 2012 from data collected in previous years (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 in 2013 (forecast type R 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. 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 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 conversion factors 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. The interdam loss factor is equal to one minus the conversion factor.

8. IM (changes in incidental mortality rates): The IM file contains the incidental mortality rates by fishery for legal and sublegal fish that differ from those used in the base period due to alterations in gear, regulations, or fishery conduct.
9. MAT (maturity and AEQ factors): The MAT 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 estimates replace the base period rates in the BSE file. The annual estimates are obtained from the annual ERA. 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 nonvulnerable): 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.
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, 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 Months when agencies are able to provide final return estimates for the previous year and preseason forecasts of abundance for the next fishing year.

Model Stock	Month Final Return Estimate Available	Month(s) Forecast Available
Alaska South SE	January	None
North/Central B.C.	November	None
WCVI Natural	January	February
WCVI Hatchery	January	February
Upper Strait of Georgia	January	None
Lower Strait of Georgia Hatchery	December	None
Lower Strait of Georgia Natural	December	None
Fraser Early	January	None
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	February

[1] Normally forecasts are not available for the model calibration, but these were available in 2012.

[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]	Preseason Age-specific	Postseason Age-specific	
Alaska South SE	C	-	Yes	Calibrated to escapement
North/Central B.C.	C	-	No	Calibrated to terminal run
WCVI Hatchery + Natural (RBH and RBT model stocks)	S	Yes	Yes	Robertson Creek Hatchery forecasts plus expansion for other WCVI stocks based on ratio of terminal run sizes
Upper Strait of Georgia	C	-	Partial	Calibrated to escapement
Lower Strait of Georgia Hatchery	C	-	Yes	Calibrated to escapement to GSH hatchery systems and Squamish River
Lower Strait of Georgia Natural	C	-	Yes	Calibrated to escapement to Cowichan and Nanaimo Rivers
Fraser Early	C	-	No	Calibrated to terminal run
Fraser Late	S	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	S	Yes	Yes	Weighted average age composition from four index rivers

[1]Externally provided forecast type codes are S = sibling; R = return rate; C = model internally estimated projection.

3.1.2 Calibration Procedures

An objective of the calibration procedure is to estimate stock and BY specific EV scalars. The calibration uses an iterative algorithm to estimate the EV scalars for each BY and model stock to account for annual variability in natural mortality in the initial year of ocean residence. EV scalars are used to adjust age-1 abundances estimated for each stock and BY from escapements in combination with the base period spawner-recruit functions. Fishing impacts and natural mortalities are then applied through model processes. 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.

EVs are estimated through the following steps for stocks calibrated to age-specific terminal run sizes:

1. Predicted terminal runs 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 and the model predicted terminal run 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 until the absolute change in the EVs for all stocks is less than a predetermined tolerance level (0.05). The tolerance level can be changed if more precise agreement is desired:

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

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 in each iteration and also the type of convergence criteria. For the 2013 preseason calibration, in each iteration EVs were estimated for all BYs. 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 2013 calibration was completed in two stages 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 1979–2011 using updated catch and escapement data through 2011. Average exploitation rate scalars ($\overline{FP}$) were then computed and used as input values for the 2012 and 2013 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):

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

Equation 3.5

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 2012, 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)
4. Patterns in the EVs compared with marine survival patterns generated by the annual ERA
5. Comparison of CWT-based and model estimates of fishery harvest rate indices,
6. Comparison of model estimates of mortality distributions for individual stocks to those generated from the annual CWT-based ERA
7. Comparison of model estimated AIs to the AIs previously estimated by model CLB 9812

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 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.

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 stocks. However, since the implementation of the 1999 PST Agreement, the primary purpose of the Chinook model has been to enable abundance-based management in the PST through the production of fishery abundance indices. The PSC Chinook Model generates preseason projections of abundance indices (AIs) for the SEAK, NBC, and WCVI AABM fisheries and postseason estimates of the AIs that enable evaluations of AABM performance (i.e., pre- versus postseason AI and allowable catch comparisons). For each AABM fishery (*f*), an abundance index (AI) is computed for the upcoming fishing year (*CY*) as

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

where $Cohort_{s,a,CY}$ and $Cohort_{s,a,BP}$ are preseason (projected) and base period (*BP*, fishing years 1979–1982) abundances of model stocks (*s*), by age (*a*), respectively. Thus, the AI is simply a ratio of the estimated total catch at present and base period abundance levels given a base period fishing pattern. Given the preseason AI projections, the estimated allowable catches are then set for the three AABM fisheries according to the terms specified in Appendix B of Chapter 3, Annex IV of the 2009 Chinook Agreement.

In addition to generating AIs, the Chinook model provides other information of immediate relevance to PSC management, as well as for use in efforts aimed at assessing its accuracy. First, the Chinook model provides fishery-specific projections of AEQ total mortality for model stocks, thereby allowing for estimation of potential ISBM fishery harvests on a preseason basis. Additionally, these mortality estimates provide a means for computing a Chinook model analog to CWT exploitation rates which can be compared for model validation/verification purposes. Second, the model provides estimates on the stock composition of AABM and ISBM fishery catches, thereby providing a means to quantitatively estimate the relative contribution different stocks make to particular fisheries during the current as well as past fishing year.

3.1.4 Changes from Previous Calibration Procedures

Since 2007 there has been a consistent positive bias in the preseason AI forecasts in all three AABM fisheries. Previous investigations by the AWG into discrepancies in the model estimates of the stock and age-specific cohort sizes between the pre- and postseason calibrations suggested there were overestimation problems with several driver stocks in the model. In addition, previous investigations of the stock- and age-specific maturation rates of stocks in the ERA indicated that there were definite trends in several stocks of increasing maturation rates of the younger ages in recent years. These investigations suggested that the assumptions used in the model calibration process—consisting of recent five-year average EVs (spawner-recruit production scalars) and long-term average maturation rates for forecasting the recent incomplete broods—were likely contributing to the overestimation problem in the AABM AIs. In order to determine if a different combination of EV and maturation rate averages could reduce the bias in the preseason AI estimates, a series of retrospective analyses were performed by recalibrating the 2004–2012 Chinook model calibrations for a number of EV and maturation rate combinations. Combinations consisting of three-year, five-year and long-term average maturation rates and one-year through five-year average EVs were run. However, since the analysis for each combination required 27 runs of the Chinook model (9 years × 3 runs per year) not every possible combination of EVs and maturation rates was run. Several combinations that were unlikely to reduce the bias in the preseason AIs were omitted. The average mean squared errors (MSE) of the preseason versus first postseason AIs for each of the three AABM fisheries were compared, as well as the preseason and postseason AIs versus the *finals* (average of the third through eighth postseason AIs) MSEs. The combinations that produced the lowest and second to lowest MSEs were identified for each AABM fishery (Table 3.3). The minimum average MSE occurred with the one-year EV and five-year average maturation rate combination for eight of the nine AABM fishery versus pre/post comparisons (3 AABM fisheries × 3 comparison types).

The results of this investigation resulted in a change in the EV and maturation rate assumptions used for the 2013 preseason calibration. The 2013 preseason calibration used one-year EV and five-year average maturation rates for all of the model stocks. However, since the 2012 preseason Chinook model calibration was done with five-year average EVs and long-term average maturation rates, the 2012 postseason calibration was done using the same five-year average EVs and long-term average maturation rates for consistency. This resulted in two separate 2013 Chinook model calibrations. CLB 1308 was the preseason calibration for 2013 which used the one-year EVs and five-year average maturation rates, and CLB 1309 was the postseason calibration for 2012 that used the five-year average EVs and long-term average maturation rates. Given this departure from previous preseason calibrations, the AWG will continue to monitor the influence of EV and maturation assumptions on AI projections.

Table 3.3 MSE for differences between pre- and postseason AIs as a function of maturation rate and environmental variant (EV) averaging periods for SEAK, NBC, and WCVI AABM fisheries, 2004–2012.

SEAK

Preseason to Post-Season Years 3-8 Average

Mat. Rate	EV Average Years				
Average Years	1	2	3	4	5
3	0.0658		0.0681		0.0648
5	0.0500	0.0507	0.0521		0.0497
LTA[1]	0.0795	0.0793	0.0786	0.0763	0.0754

First Post-Season to Post-Season Years 3-8 Average

Mat. Rate	EV Average Years				
Average Years	1	2	3	4	5
3	0.0214		0.0215		0.0215
5	0.0118	0.0119	0.0119		0.0119
LTA[1]	0.0226	0.0229	0.0230	0.0230	0.0231

Preseason to First Post-Season

Mat. Rate	EV Average Years				
Average Years	1	2	3	4	5
3	0.0147		0.0158		0.0149
5	0.0129	0.0131	0.0136		0.0129
LTA[1]	0.0206	0.0203	0.0202	0.0193	0.0200

NBC

Preseason to Post-Season Years 3-8 Average

Mat. Rate	EV Average Years				
Average Years	1	2	3	4	5
3	0.0447		0.0464		0.0479
5	0.0308	0.0325	0.0326		0.0339
LTA[1]	0.0568	0.0608	0.0597	0.0598	0.0603

First Post-Season to Post-Season Years 3-8 Average

Mat. Rate	EV Average Years				
Average Years	1	2	3	4	5
3	0.0186		0.0188		0.0188
5	0.0115	0.0117	0.0118		0.0119
LTA[1]	0.0236	0.0245	0.0245	0.0245	0.0247

Preseason to First Post-Season

Mat. Rate	EV Average Years				
Average Years	1	2	3	4	5
3	0.0103		0.0109		0.0114
5	0.0070	0.0084	0.0082		0.0086
LTA[1]	0.0116	0.0125	0.0120	0.0124	0.0129

WCVI

Preseason to Post-Season Years 3-8 Average

Mat. Rate	EV Average Years				
Average Years	1	2	3	4	5
3	0.0236		0.0241		0.0249
5	0.0172	0.0174	0.0176		0.0184
LTA[1]	0.0179	0.0181	0.0183	0.0187	0.0191

First Post-Season to Post-Season Years 3-8 Average

Mat. Rate	EV Average Years				
Average Years	1	2	3	4	5
3	0.0031		0.0031		0.0031
5	0.0027	0.0026	0.0026		0.0026
LTA[1]	0.0027	0.0023	0.0023	0.0023	0.0023

Preseason to First Post-Season

Mat. Rate	EV Average Years				
Average Years	1	2	3	4	5
3	0.0105		0.0107		0.0110
5	0.0100	0.0102	0.0101		0.0103
LTA[1]	0.0132	0.0135	0.0134	0.0135	0.0138

Lowest MSE

Second Lowest MSE

[1] LTA = Long term average.

3.2 Model Calibration Results

3.2.1 Overview of 2013 Calibration Process

The CTC AWG met in Seattle during the week of March 19, 2013, to produce the Chinook model calibration for use in the upcoming fishing year. Several different model calibrations were completed, each differing in key input files. Calibrations 1301–1309 were run and discussed during the face-to-face meeting, and differed primarily in how their EVs and maturation rates were calculated and/or included various forecast and/or CNR file updates (Appendix K). The AWG converged on calibration 1309 for the 2012 postseason fishery assessment and calibration 1308 as the best representation of the model's estimation of preseason fisheries conduct. After the close of the meeting, further questions arose regarding the WCVI forecast—the accuracy and the effect on the model's performance. Two additional calibrations that addressed this issue, calibrations 1310 and 1311, were produced and discussed remotely during the following week. Calibrations 1310 and 1311 included a bias correction to the WCVI forecast. Following full bilateral CTC discussions, calibrations 1309 and 1308 were ultimately chosen as the final postseason (2012) and preseason (2013) calibrations. On April 4, the CTC produced its annual memo describing the year's calculated pre- and postseason AIs based on these model calibrations and circulated it amongst the PSC and associated management agencies.

3.2.2 AABM Fishery Calibration Results

3.2.2.1 *AABM Abundance Indices and Associated Catches*

The PST specifies that the AABM fisheries are to be managed through the use of the preseason AIs, where a specific estimate of the allowable harvest level corresponds to a given AI for each fishery. The preseason AIs that were used to establish harvest management targets are listed in Table 3.4. The 2013 preseason AI for the SEAK troll fishery is 1.20, for the NBC troll fishery it is 1.10, and for the WCVI troll fishery is 0.77. 2013 was the fifth year of the 2009 Agreement that reduced catches and associated harvest rates in Southeast Alaska (15%) and West Coast of Vancouver Island (30%) AABM fisheries from the allowable AABM catch levels in the 1999 PST Agreement in response to coastwide conservation concerns. The NBC AABM fishery retained the same allowable catch and harvest rates of the 1999 PST Agreement. If the CTC determines that inseason methods provide an improved estimate of the abundance relative to preseason indicators alone, inseason adjustments of preseason catch limits are permitted.

The postseason AI is a more accurate estimate of the abundance index for the AABM fisheries, and is used to compute the final allowable catch for each fishery. The final allowable catch is used to evaluate overage or underage of the landed catch relative to the harvest rate objective. Postseason AIs for 1999–2012 are listed in Table 3.4.

Table 3.4 Abundance Indices for 1999–2013 for the SEAK, NBC, and WCVI AABM fisheries. Postseason values for each year are from the first postseason calibration following the fishing year.

	SEAK		NBC		WCVI	
Year	**Preseason**	**Postseason**	**Preseason**	**Postseason**	**Preseason**	**Postseason**
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]		1.10[1]		0.77[1]	

[1] Due to changes in calibration procedures (reviewed in section 3.1.4), 2012 postseason (CLB 1309) and 2013 preseason (CLB 1308) AIs are based on different calibrations; the procedures and assumptions CLB 1309 mirror those used during the 2012 preseason calibration.

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 Agreement. The allowable treaty catch by fishery and year based on pre- and postseason AIs and the observed treaty catches are given in Table 3.5 and are shown in Figures 3.1– 3.6; in Figure 3.1–3.3, the solid line represents the relationship between AIs and allowable catch under Table 1 of the annex.

Table 3.5 Preseason allowable catches for 1999–2013, and postseason allowable catches and observed catches for 1999–2012, for AABM fisheries. Postseason values for each year are from the first postseason calibration following the fishing year.

PST Treaty Allowable and Observed Catches									
	SEAK (T, N, S)[1]			NBC (T, S)[1]			WCVI (T, S)[1]		
Year	Preseason Allowable Catch	Postseason Allowable Catch	Observed Catch	Preseason Allowable Catch	Postseason Allowable Catch	Observed Catch	Preseason Allowable Catch	Postseason Allowable Catch	Observed Catch
1999	192,800	184,200	198,842	145,600	126,100	86,726	128,300	107,000	36,413
2000	189,900	178,500	186,493	130,000	123,500	31,900	115,500	86,200	101,438
2001	189,900	250,300	186,919	132,600	158,900	43,500	141,200	145,500	117,670
2002	356,500	371,900	357,133	192,700	237,800	150,137	203,200	196,800	165,036
2003	366,100	439,600	379,519	197,100	277,200	191,657	181,800	268,900	175,821
2004	383,500	418,300	417,019[2]	243,600	267,000	241,508	192,500	209,600	216,624
			421,666						
2005	416,400	387,400	390,336[3]	246,600	240,700	243,606	188,200	179,700	202,662
2006	346,800	354,500	361,283[3]	223,200	200,000	215,985	160,400	145,500	146,883
2007	329,400	259,200	327,989[3]	178,000	143,000	144,235	143,300	121,900	139,150
2008	170,000	152,900	171,983[3]	124,800	120,900	95,647	162,600	136,900	145,726
2009[4]	218,800	176,000	227,667[3]	143,000	139,100	109,470	107,800	91,300	124,617
2010	221,800	215,800	229,355[3]	152,100	160,400	136,613	143,700	142,300	139,047
2011	294,800	283,300	292,028[3]	182,400	186,800	122,660	196,800	134,800	204,232
2012	266,800	205,100	241,015[3]	173,600	149,500	120,307	133,300	113,800	134,468
2013	176,000			143,000			115,300		

[1] T = troll, N = net, and S = sport.

[2] The lower value resulted from subtracting a disputed terminal exclusion catch for the Stikine River in 2004. Catch accounting has since been defined in the Transboundary Agreement.

[3] Values changed because the method used to partition gillnet catch into large and nonlarge fish has changed. This change affects the computation of the terminal exclusion, add-on, and treaty catch.

[4] This is the first catch year in which fisheries operated under the provisions of the 2009 Agreement.

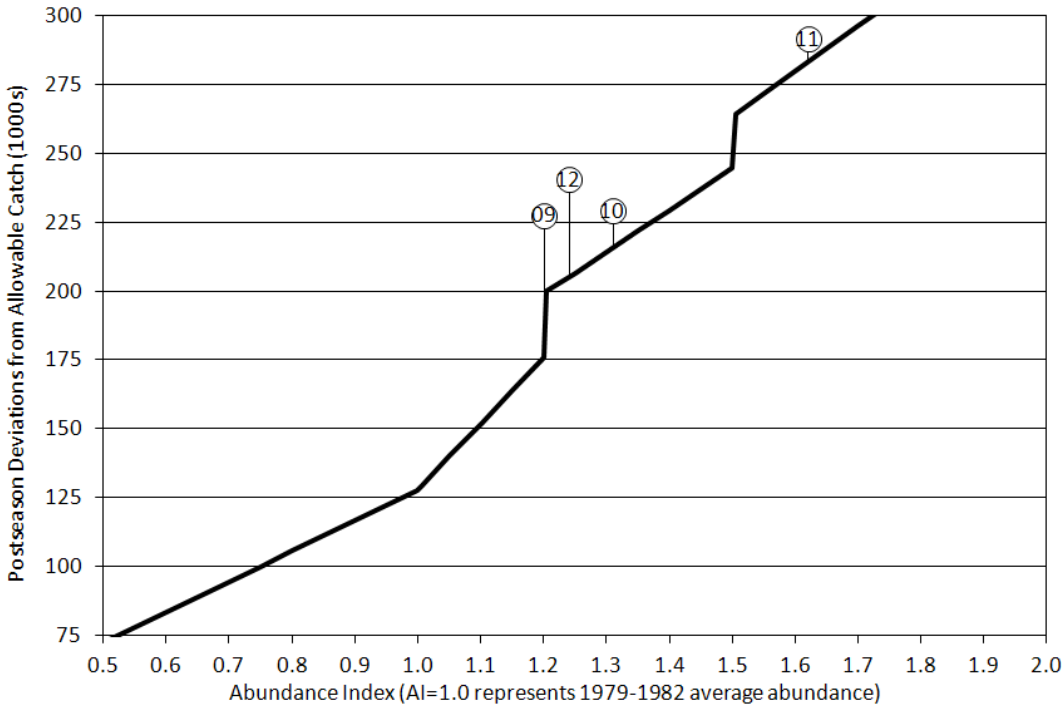


Figure 3.1 Postseason deviations from allowable catch levels in the SEAK AABM fishery.

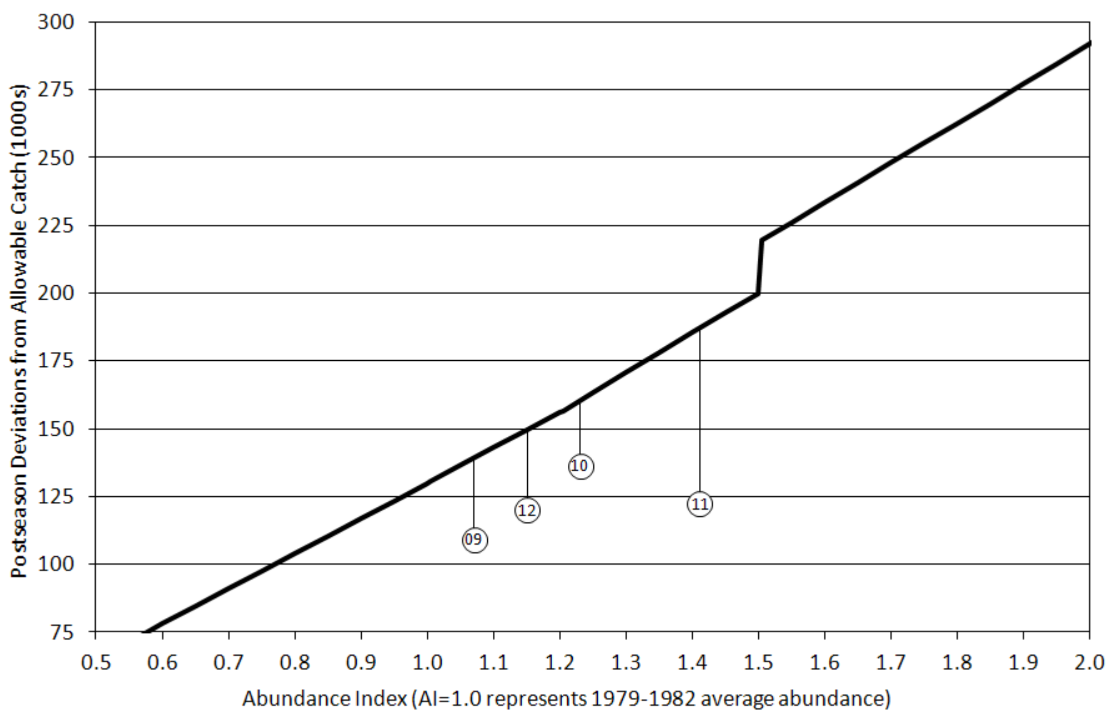


Figure 3.2 Postseason deviations from allowable catch levels in the NBC AABM fishery.

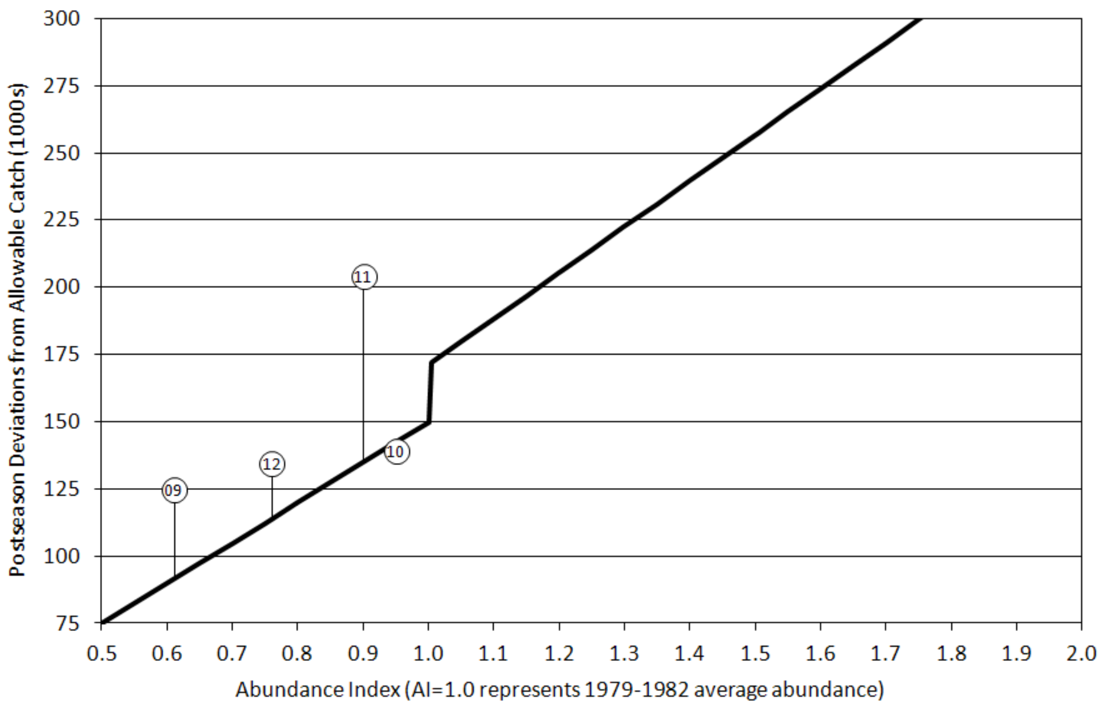


Figure 3.3 Postseason deviations from allowable catch levels in the WCVI AABM fishery.

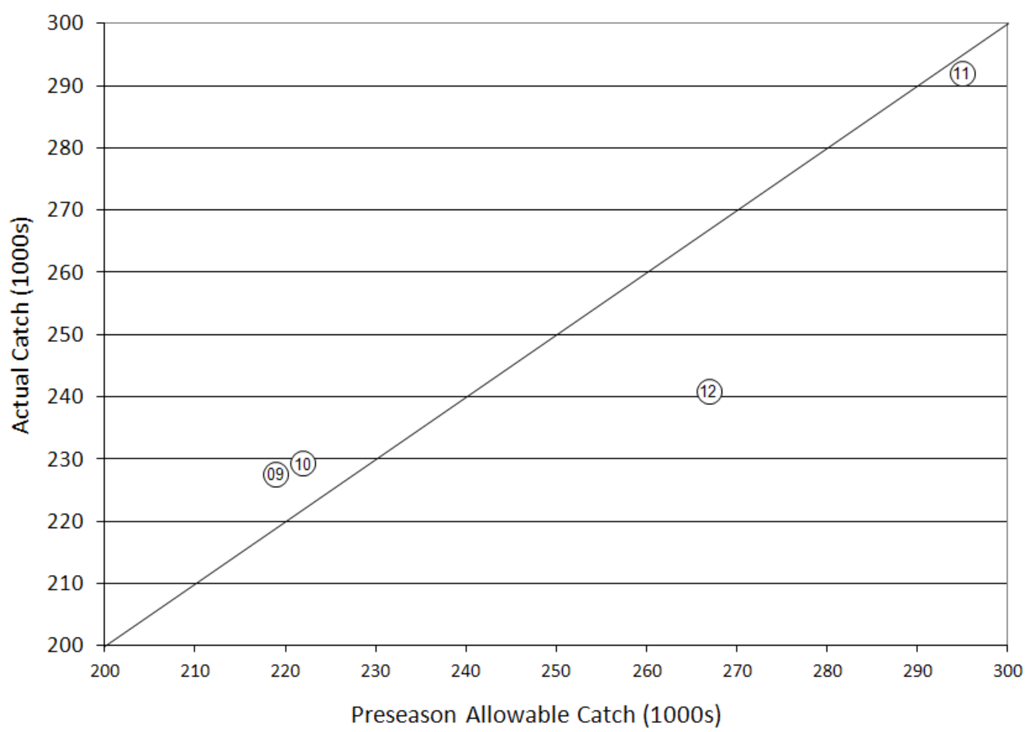


Figure 3.4 Deviations from preseason allowable catch in the SEAK AABM fishery.

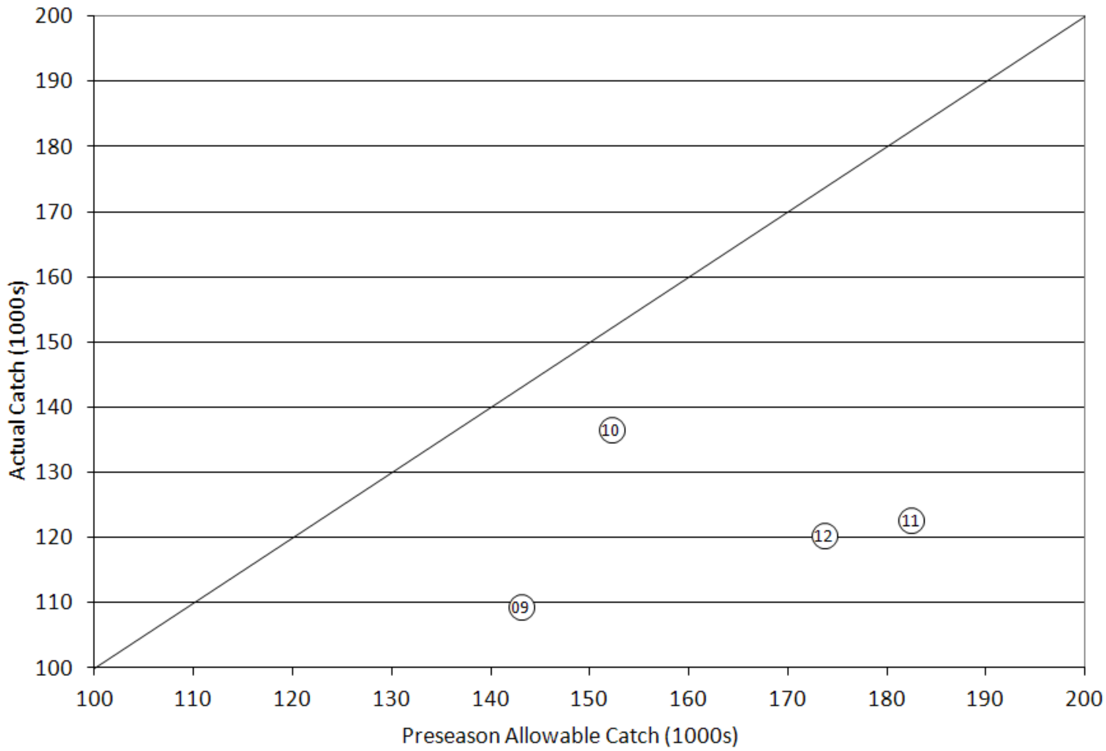


Figure 3.5 Deviations from preseason allowable catch in the NBC AABM fishery.

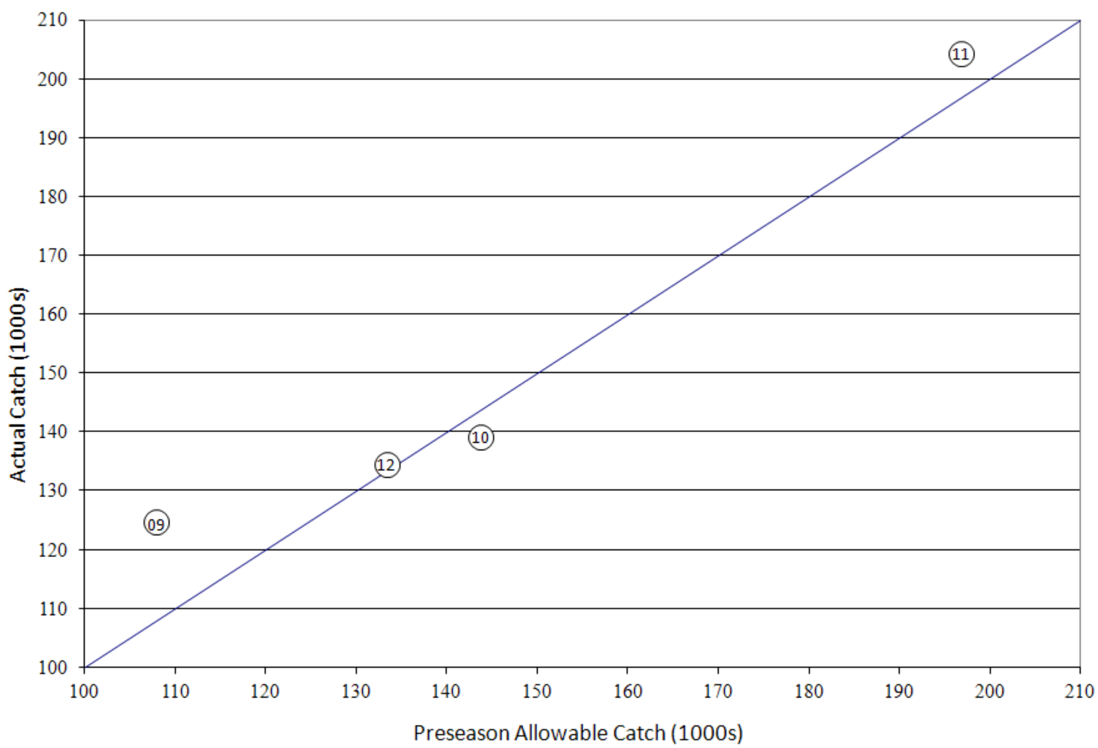


Figure 3.6 Deviations from preseason allowable catch in the WCVI AABM fishery.

3.2.2.2 *Stock composition of abundances available in AABM fisheries, 1979–2013*

The majority of catches in each AABM fishery are often comprised of only a small subset of the 30 model stocks listed in Appendix A. Figures 3.7–3.9 show the relative abundance for each major stock (resulting from CLB 1308). In general, postseason AIs had a peak during the late 1980s (1987–1989) and another in 2003 and 2004.

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, North/Central B.C., and Fraser Early (Figure 3.7). The *Other* category is mainly Washington Coast Hatchery and Natural, Columbia River Summers, and Upper Strait of Georgia.

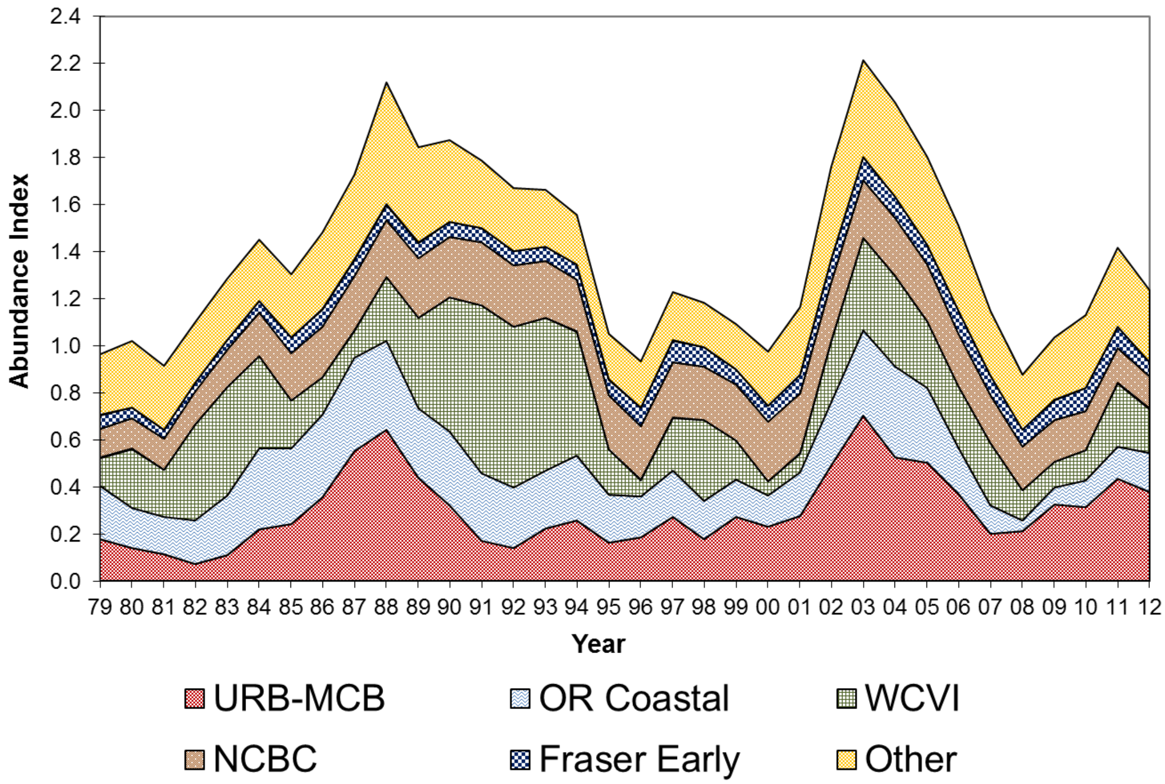


Figure 3.7 Stock composition of the annual abundance indices for the SEAK troll fishery from CLB 1309.

The major model stock groups contributing to the NBC AABM fishery AIs are Oregon Coastal, URB-MCB, WCVI Natural and Hatchery, North/Central B.C., and Fraser Early (Figure 3.8). The *Other* category consists primarily of Washington Coast Hatchery and Natural, Willamette Springs, and Upper Strait of Georgia stocks.

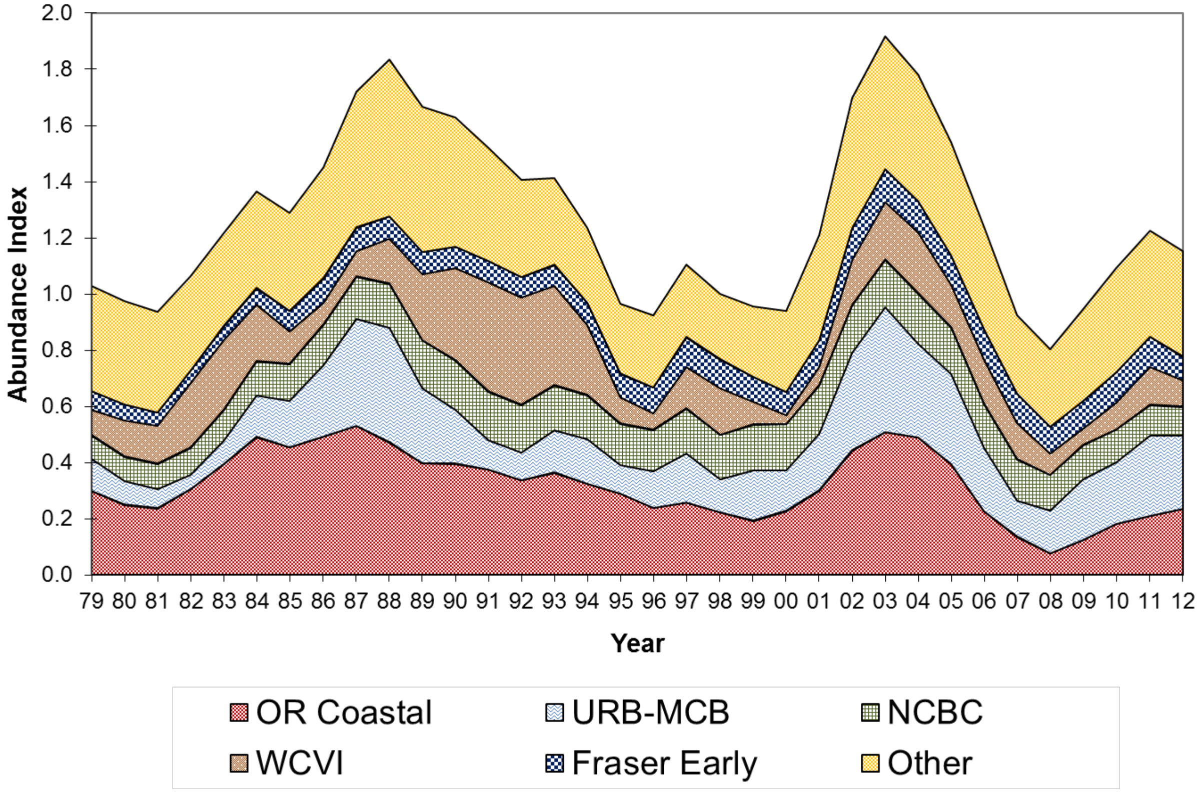


Figure 3.8. Stock composition of the abundance indices for the Northern B.C. troll fishery from CLB 1309.

The major model stock groups in the AI for the WCVI fishery are Columbia River Tules, Puget Sound, Fraser Lates, URB-MCB, and WCVI Natural and Hatchery (Figure 3.9). The *Other* category is comprised primarily of Oregon Coast, Columbia Summers, and Washington Coastal.

For model-generated stock composition details for all fisheries (AABM + ISBM), please see Appendix E.

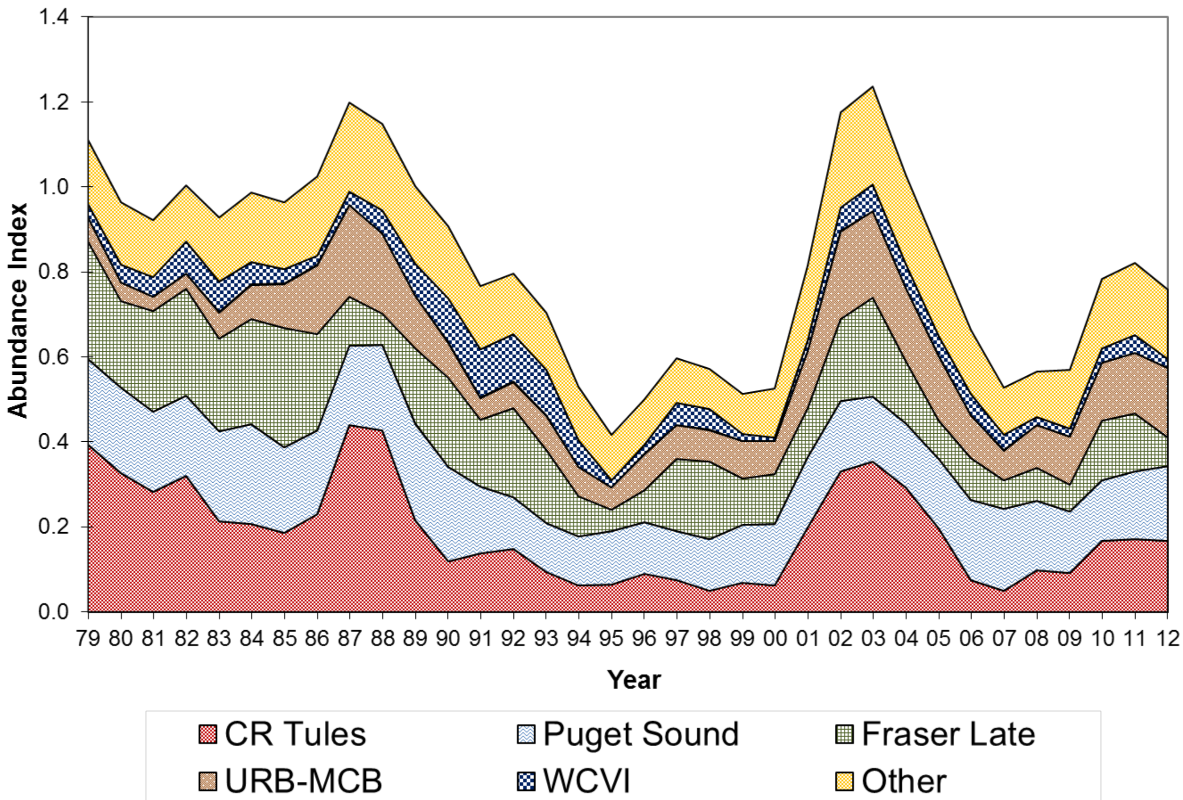


Figure 3.9. Stock composition of the abundance indices for the WCVI troll fishery from CLB 1309.

3.2.2.3 *Pre- versus Postseason AI Changes (Overages and Underages)*

Until an approach for full implementation of overage/underage provisions has been developed and accepted by the PSC, the Commissioners have instructed the CTC to track and report overages and underages relative to agreed-upon harvest objectives.

Per Treaty subparagraph 11(a)(i), AIs and associated allowable catches from the first postseason model calibration for a given fishing year are used to track catch overages and underages. Table 3.6 shows the annual differences between the postseason allowable catches and the observed catches in AABM fisheries for 1999–2012, as well as the cumulative differences. In SEAK, the 2012 catch was 17.5% above the postseason allowable catch, and the cumulative differences were 2.5% above the cumulative postseason allowable catch. In NBC, the 2012 catch was 19.5% below the preseason allowable catch and the cumulative differences were 25.1% below the cumulative postseason allowable catch. In WCVI, the 2012 catch was 18.2% above and the cumulative differences were 1.5% below the cumulative postseason allowable catch. The SEAK, NBC, and WCVI AABM fisheries have been over the preseason allowable catch 10 (SEAK), 3 (NBC), and 9 (WCVI) of the last 14 years.

Overages and underages in AABM catches, relative to the first postseason calibration for a fishing year (Table 3.6), can arise due to imprecision in the inseason management system, errors in the preseason 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 the preseason and postseason calibrations (Table 3.7). In 2012, regarding the inseason management system, the actual landed catch was less than the preseason allowable catch by 25,785 Chinook salmon in SEAK and by 53,293 in NBC. For WCVI, the actual landed catch was 1,168 more than the preseason allowable catch. In terms of the postseason allowable catches for evaluation of the provisions of the PST (subparagraph 11(a)(i)), actual catches exceeded the postseason allowable catches by 35,915 Chinook salmon in SEAK and by 20,668 in WCVI. Actual landed catch in NBC was 29,193 fish less than the postseason allowable catch.

Table 3.6 Deviations in numbers of Chinook salmon caught and percentages from allowable catches derived from the postseason AI for PST AABM fisheries *in 1999–2012. Postseason values for each year are from the first postseason calibration following the fishing year.*

	SEAK		NBC		WCVI	
Year	**Number of Fish**	**Percent Difference**	**Number of Fish**	**Percent Difference**	**Number of Fish**	**Percent Difference**
1999	14,642	7.9%	–39,374	–31.2%	–70,587	–66.0%
2000	7,993	4.5%	–91,600	–74.2%	15,238	17.7%
2001	–63,381	–25.3%	–115,400	–72.6%	–27,830	–19.1%
2002	–14,767	–4.0%	–87,663	–36.9%	–31,764	–16.1%
2003	–60,081	–13.7%	–85,543	–30.9%	–93,079	–34.6%
2004	–1,281	–0.3%[1]	–25,492	–9.5%	7,024	3.4%
	3,366	0.8%				
2005	2,936	0.8%	2,906	1.2%	22,962	12.8%
2006	6,783	1.9%	15,985	8.0%	1,383	1.0%
2007	68,789	26.5%	1,235	0.9%	17,250	14.2%
2008	19,083	12.5%	–25,253	–20.9%	8,826	6.4%
2009[2]	51,667	29.4%	–29,630	–21.3%	33,317	36.5%
2010	13,555	6.3%	–23,787	–14.8%	–3,253	–2.3%
2011	8,728	3.1%	–64,140	–34.3%	69,432	51.5%
2012	35,915	17.5%	–29,193	–19.5%	20,668	18.2%
Cum.	90,579	2.5%	–596,949	–25.1%	–30,413	–1.5%
	95,227	2.6%				

[1] The upper 2004 value resulted from subtracting a disputed terminal exclusion catch for the Stikine River in 2004. Catch accounting has since been defined in the Transboundary Agreement.

[2] This is the first catch year in which fisheries operated under the provisions of the 2009 Agreement; cumulative deviations span the entire record that is displayed.

Table 3.7 Deviations in actual landed catch (LC), allowable landed catch determined from preseason model calibration (PreALC), and allowable landed catch determined from postseason model calibration (PostALC) for AABM fisheries 1999–2012. Postseason values for each year are from the first postseason calibration following the fishing year. The difference between LC and PreALC represents the consequences of the management system employed in the year. The difference in PreALC and PostALC represents consequences of the forecast procedures and data used in forecasting the PreALC by the PSC Chinook Model. The difference in LC and PostALC captures the effects of both processes.

Year	SEAK			NBC			WCVI		
	LC–PreALC	PreALC–PostALC	LC–PostALC	LC–PreALC	PreALC–PostALC	LC–PostALC	LC–PreALC	PreALC–PostALC	LC–PostALC
1999	6,042	8,600	14,642	–58,874	19,500	–39,374	–91,887	21,300	–70,587
2000	–3,407	11,400	7,993	–98,100	6,500	–91,600	–14,062	29,300	15,238
2001	–2,981	–60,400	–63,381	–89,100	–26,300	– [illegible]	–23,530	–4,300	–27,830
2002	633	–15,400	–14,767	–42,563	–45,100	–87,663	–38,164	6,400	–31,764
2003	13,419	–73,500	–60,081	–5,443	–80,100	–85,543	–5,979	–87,100	–93,079
2004	33,519 38,166	–34,800 –34,800	–1,281[1] 3,366	–2,092	–23,400	–25,492	24,124	–17,100	7,024
2005	–26,064	29,000	2,936	–2,994	5,900	2,906	14,462	8,500	22,962
2006	14,483	–7,700	6,783	–7,215	23,200	15,985	–13,517	14,900	1,383
2007	–1,411	70,200	68,789	–33,765	35,000	1,235	–4,150	21,400	17,250
2008	1,983	17,100	19,083	–29,153	3,900	–25,253	–16,874	25,700	8,826
2009[2]	8,867	42,800	51,667	–33,530	3,900	–29,630	16,817	16,500	33,317
2010	7,555	6,000	13,555	–15,487	–8,300	–23,787	–4,653	1,400	–3,253
2011	–2,772	11,500	8,728	–59,740	–4,400	–64,140	7,432	62,000	69,432
2012	–25,785	61,700	35,915	–53,293	24,100	–29,193	1,168	19,500	20,668

[1] The upper 2004 value resulted from subtracting a disputed terminal exclusion catch for the Stikine River in 2004. Catch accounting has since been defined in the Transboundary Agreement.

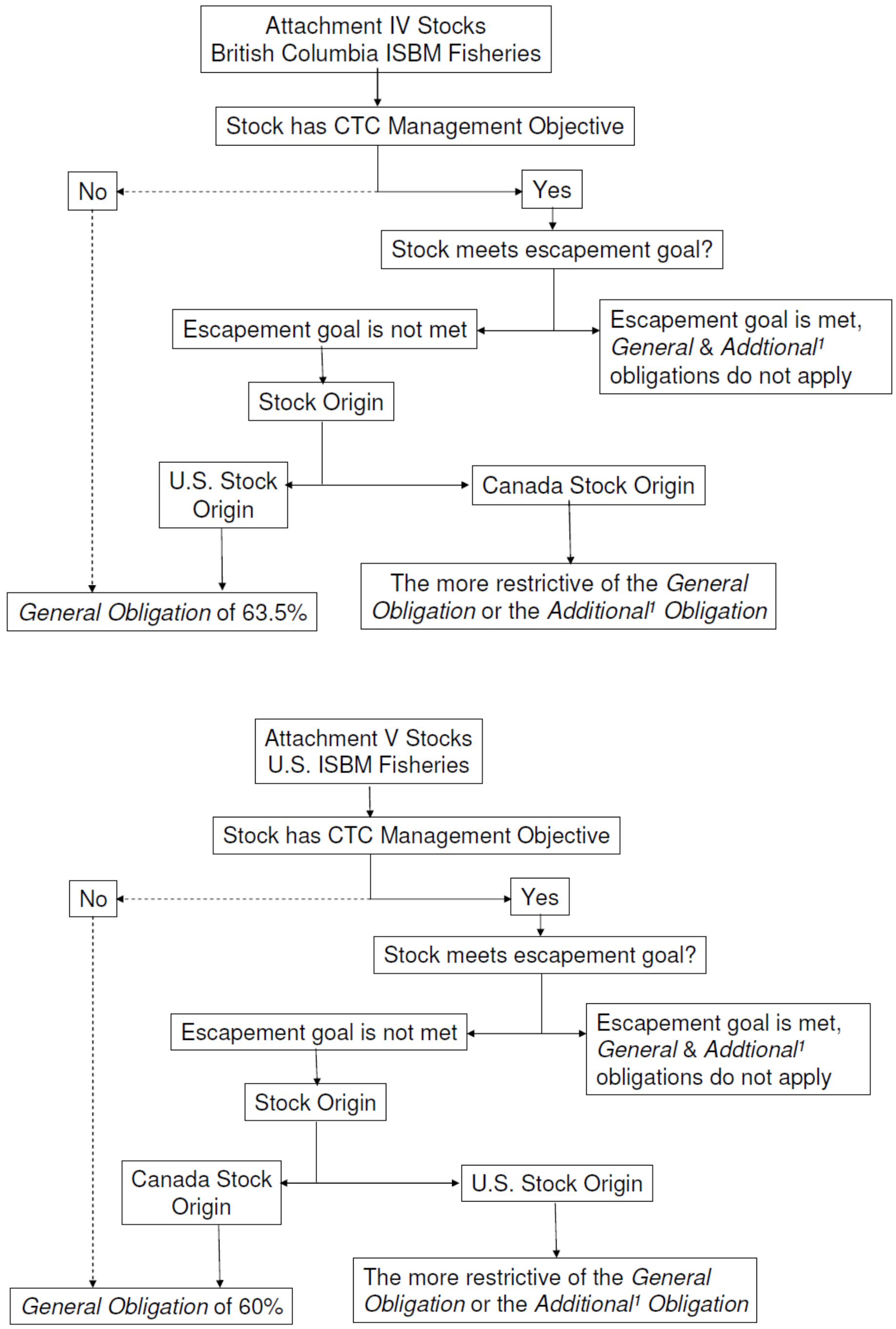
[2] This is the first catch year in which fisheries operated under the provisions of the 2009 Agreement.

3.2.3 ISBM Fishery Calibration Results

3.2.3.1 *ISBM Indices by Stock*

For ISBM fisheries, 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 goals. The Treaty also specifies that for those stocks whose 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 1991–1996 ISBM exploitation rate (Paragraph 8 (c)). This requirement is referred to as the *additional obligation*. Comparing the general obligation to the additional obligation for stocks with CTC-agreed escapement goals is necessary if the goals are not met for ISBM fisheries harvesting stocks that spawn in the same country. Of relevance is whether or not the average 1991–1996 index value is less than the general obligation, if not, the 1991–1996 average is not applicable. Figure 3.10 shows the sequence of decisions leading to the implementation of ISBM general and additional obligations for stocks in Attachments IV and V in the 2009 Agreement.

Estimated ISBM fishery indices are shown in Table 3.8 for Canadian fisheries and Table 3.9 for U.S. fisheries. Both tables present CWT-based indices for 2011, and Chinook model-based predicted indices for 2013. The 2009 Agreement specifies that the indices be assessed postseason using the CWT-based estimates; 2011 is the most recent analysis available for all stocks (see section 3.5.3 for an analysis of a subset of ISBM fisheries/stocks for 2011). CWT-based indices for 1999–2011 and model-based indices for 1999–2013 are presented in Appendix B.



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

Figure 3.10 Flow diagrams depicting the sequence of decisions leading to the implementation of ISBM general and additional obligations for stocks in Attachments IV and V of Chapter 3 of the 2009 PST Agreement according to Paragraph 8 of the Chinook Chapter.

Table 3.8 ISBM indices based on 2011 and 2013 PSC Chinook Model, 2011 CWT analysis and the 2013 indices predicted from the 2013 PSC Chinook Model for the stock groups applicable to all B.C. ISBM fisheries as listed in Attachment IV of the Treaty.

Stock Group	Escapement Indicator Stock	2011 Model Indices for 2011	2013 Model Indices for 2011	CWT Indices for 2011	2013 Model Indices for 2013
Lower Strait of Georgia	Cowichan[1]	0.367	0.227[2]	0.147[3]	0.362[2]
	Nanaimo	NA		NA[4,5]	
Fraser Late	Harrison River[1]	0.193	0.261	0.092[6]	0.286
North Puget Sound Natural Springs	Nooksack	0.732	0.208	0.014	0.273
	Skagit	0.731	0.208	NA	0.273
Upper Strait of Georgia	Klinaklini, Kakweikan, Wakeman, Kingcome, Nimpkish	0.578	0.165	0.032	0.649
Fraser Early (Spring and Summers)	Upper Fraser, Mid Fraser, Thompson	0.222	0.110	NA	0.238
West Coast Vancouver Island Falls	WCVI (Artlish, Burman, Kauok, Tahsis, Tashish, Marble)	0.491	0.778	0.650	0.227
Puget Sound Natural Summer Falls	Skagit	0.745	0.174	NA	0.429
	Stillaguamish	0.793	0.247	0.246	0.561
	Snohomish	0.744	0.175	NA	0.423
	Lake Washington	0.752	0.225	NA	0.419
	Green River	0.756	0.225	0.300	0.419
North/Central B.C.	Yakoun, Nass, Skeena, Area 8	0.598	0.163	NA	0.496

[1] Stock or stock group with a CTC-agreed escapement goal.

[2] Although model-based indices were previously calculated separately for Cowichan and Nanaimo, these did not adequately represent impacts on either Lower Strait of Georgia stock because the model-based data represent an aggregate of the two stocks and methods do not currently exist to correctly disaggregate these data for calculation of the ISBM values. Until such methods are developed, a single index value only will be reported representing the aggregate.

[3] An inconsistency was discovered between the approaches used to calculate the model-based and CWT-based indices. The former included harvest rates for terminal sport while the latter did not. Terminal sport harvest rates are now included in the calculation of both indices. Further review is yet required to determine whether the base period terminal sport harvest rates obtained from analyses of Big Qualicum CWT recoveries adequately represent impacts that would have occurred on Cowichan Chinook.

[4] Not available (NA) because of insufficient data (lack of stock-specific tag codes, base period CWT recoveries, etc).

[5] Several problems have been identified in the approach previously used to calculate the CWT-based indices for Nanaimo Chinook. Until these problems are resolved, indices for this stock will not be reported.

[6] The terminal sport harvest rates for Chilliwack Hatchery Chinook, the indicator stock, were removed from the calculation for the Harrison River naturals because sport harvest has been essentially zero on the natural population.

Table 3.9 ISBM indices based on 2011 and 2013 PSC Chinook Model, 2011 CWT analysis and the 2013 indices predicted from the 2013 PSC Chinook Model for the stock groups applicable to all Southern U.S. fisheries as listed in Attachment V of the Treaty.

Stock Group	Escapement Indicator Stock	2011 Model Indices for 2011	2013 Model Indices for 2011	CWT Indices for 2011	2013 Model Indices for 2013
Washington Coastal Fall Naturals	Hoko	0.419	1.505	NA[1]	0.608
	Grays Harbor	0.549	0.765	0.923	0.547
	Queets[2]	0.327	0.565	NA	0.532
	Hoh[2]	0.760	0.437	2.003	0.802
	Quillayute[2]	1.058	1.469	NA	1.442
Columbia River Falls	Upriver Brights[2]	0.841	1.129	2.862	0.971
	Deschutes[2]	1.044	0.687	0.798	0.718
	Lewis[2]	0.426	0.760	0.432	0.538
Puget Sound Natural Summer Falls	Skagit	0.789	NC[3]	NA	1.015
	Stillaguamish	0.169	NC	0.195	0.213
	Snohomish	0.211	NC	NA	0.231
	Lake Washington	0.387	NC	NA	0.404
	Green River	0.236	NC	0.439	0.331
Fraser Late	Harrison River[2]	0.497	0.542	NA	0.887
Columbia River Summers	Mid-Columbia Summers[2]	1.398	1.795	5.376	1.571
Far North Migrating Oregon Coastal Falls	Nehalem[2]	2.146	1.376	1.210	1.475
	Siletz[2]	0.643	1.105	1.068	0.679
	Siuslaw[2]	1.427	1.240	1.108	1.443
North Puget Sound Natural Springs	Nooksack	0.484	NC	0.741	0.330
	Skagit	0.271	NC	NA	0.337

[1] Not available (NA) because of insufficient data (lack of stock-specific tag codes, base period CWT recoveries, etc).
[2] Stock with a CTC-agreed escapement goal.
[3] Not able to calculate (NC) from 2013 Fisheries Regulation Assessment Model harvest projections.

3.2.3.2 *CWT-based Indices in 2011*

Figures 3.11 and 3.12 show the historical ISBM indices based on CWT recoveries from 1999 to 2011. The ISBM fishery restrictions do not apply to stocks meeting CTC-agreed escapement goals. However, should an escapement goal not be met, then the general obligation or the additional obligation (1991–1996 ISBM rate average for the Party in whose waters the stock not meeting escapement goal originates), whichever is lesser (Figure 3.10), needs to be achieved.

Six of the seven Canadian ISBM indices that could be calculated for 2011 from CWT data were reduced more than required under the 2009 Agreement. The WCVI CWT-based ISBM index (0.650) slightly exceeded the general obligation rate (0.635). Since there is no CTC-agreed escapement goal for this stock aggregate, the general obligation applies (Table 3.10). We identified several inconsistencies in the way these indices have been computed in the past, as noted in Table 3.8 footnotes. Most inconsistencies were between model and CWT exploitation rate based methods of calculating ISBM indices. In the case of Lower Strait of Georgia, Nanaimo was dropped from the CWT-based index because of concern about the method for 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.

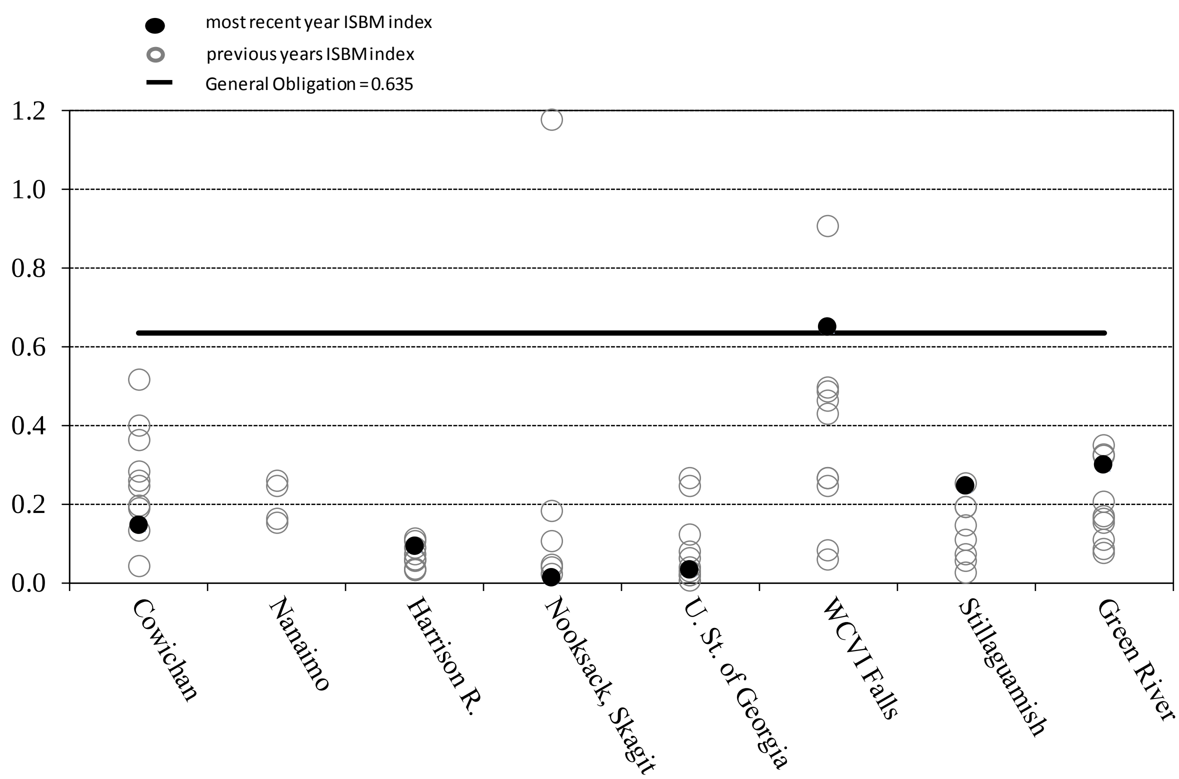


Figure 3.11. CWT-based ISBM indices for B.C. fisheries for 1999–2011. ISBM Index for Nanaimo has not been computed since 2003.

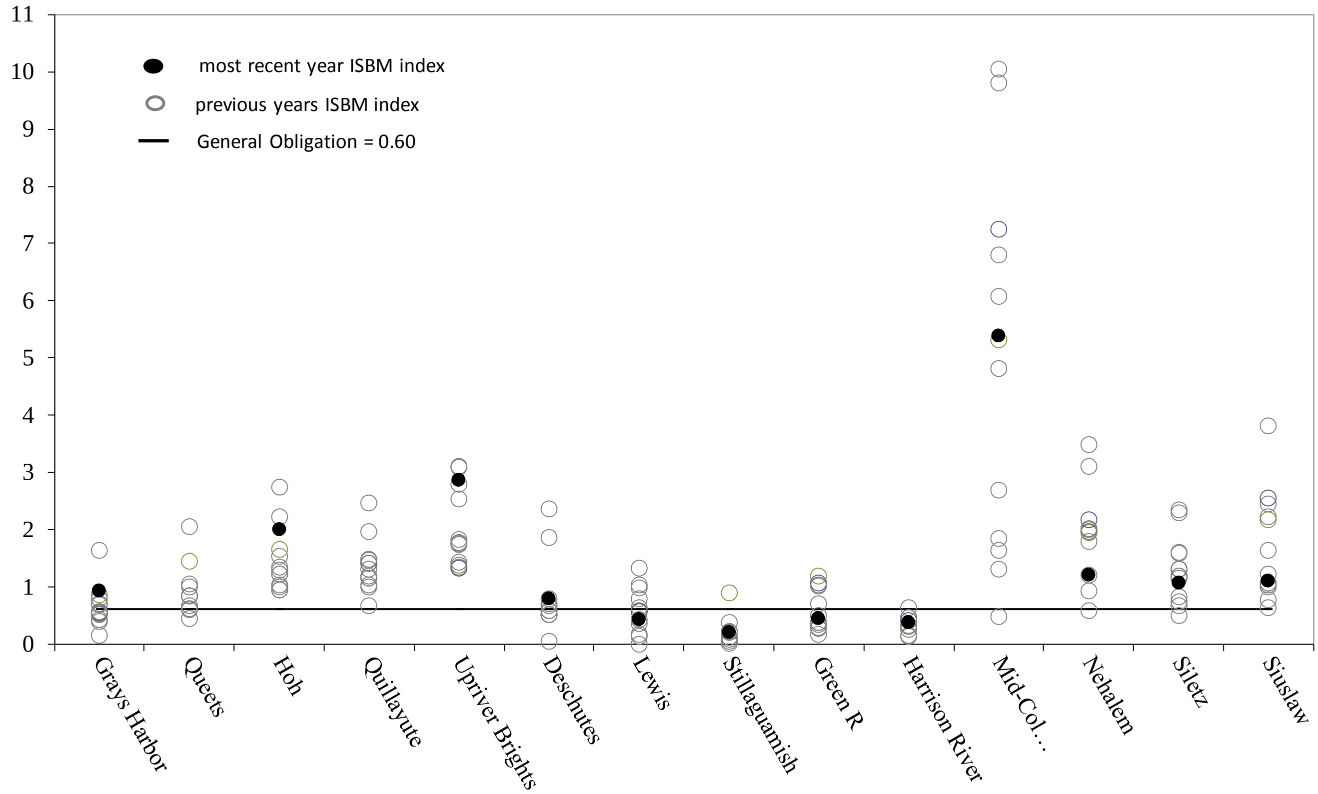


Figure 3.12. CWT-based ISBM indices for Southern U.S. fisheries for 1999–2011. Index for 2011 could not be computed for Queets and Quillayute.

Table 3.10 Review of performance in the Canadian ISBM fishery, 2011.

Stock	CTC Goal	2011 Escapement	Goal met?	Obligation[1]	2011 CWT Index	Compliance under Treaty[2]
Cowichan	6,500	3,492	No	0.621	0.147	Yes
Nanaimo	–	–	–	0.635	NA[3]	NA
Harrison	75,100	123,647	Yes	0.250	0.092	Yes
Nooksack	–	–	–	0.635	0.014	Yes
Skagit	–	–	–	0.635	NA	NA
Klinaklini, Kakweikan, Wakeman, Kingcome, Nimpkish	–	–	–	0.635	0.032	Yes
Upper Fraser, Mid Fraser, Thompson	–	–	–	0.635	NA	NA
Artlish, Burman, Kauok, Tahsis, Tashish, Marble	–	–	–	0.635	0.650	No
Skagit	–	–	–	0.635	NA	NA
Stillaguamish	–	–	–	0.635	0.246	Yes
Snohomish	–	–	–	0.635	NA	NA
Lake Washington	–	–	–	0.635	NA	NA
Green	–	–	–	0.635	0.300	Yes
Yakoun, Nass, Skeena, Area 8	–	–	–	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 = Not available.

Three of the 12 U.S. ISBM indices for the CWT-based estimates for 2011 were reduced more than required under the obligations specified in Paragraph 8 of the Chinook Chapter. The other nine U.S. CWT-based ISBM indices exceeded either the general obligation or the additional obligation (Table 3.11). Seven of these stocks have agreed escapement goals and they all met or exceeded their respective escapement goals, and thus are exempted from the general obligation. Both Nooksack and Grays Harbor ISBM indices also exceeded the general obligation. Since there are no CTC-agreed escapement goals for either of these stocks, the general obligation applies.

Table 3.11 Review of performance in the U.S. ISBM fishery, 2011.

Stock	CTC Goal	2011 Escapement	Goal met?	Obligation[1]	2011 CWT Index	Compliance under Treaty[2]
Hoko	–	–	–	0.600	NA[3]	NA
Grays Harbor	–	–	–	0.600	0.923	No
Queets	2,500	3,928	Yes	0.600	NA	Yes
Hoh	1,200	1,293	Yes	0.600	2.003	Yes
Quillayute	3,000	3,963	Yes	0.600	NA	Yes
Brights	40,000	130,395	Yes	0.600	2.862	Yes
Deschutes	4,532	17,117	Yes	0.431	0.798	Yes
Lewis	5,700	8,009	Yes	0.588	0.432	Yes
Skagit	–	–	–	0.600	NA	NA
Stillaguamish	–	–	–	0.600	0.195	Yes
Snohomish	–	–	–	0.600	NA	NA
Lake Washington	–	–	–	0.600	NA	NA
Green	–	–	–	0.600	0.439	Yes
Harrison	75,100	123,647	Yes	0.600	NA	Yes
Col. R. Summers	12,143	44,432	Yes	0.600	5.376	Yes
Nehalem	6,989	7,665	Yes	0.600	1.210	Yes
Siletz	2,944	3,638	Yes	0.600	1.068	Yes
Siuslaw	12,925	30,713	Yes	0.600	1.108	Yes
Nooksack	–	–	–	0.600	0.741	No
Skagit	–	–	–	0.600	NA	NA

[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 = Not available.

3.2.3.3 *Predicted ISBM Indices for 2013*

Of the 13 ISBM indices for Canada, only the index for Upper Strait of Georgia was predicted to exceed the general obligation of 0.635 for Canadian ISBM fisheries in 2013 based on output from CLB 1308 (Table 3.8). Since there is no CTC-agreed escapement goal for this stock aggregate, the general obligation would apply. Among the stocks with agreed escapement goals, the ISBM index for Harrison was predicted to exceed the additional obligation of 0.250.

Of the 13 ISBM indices for Canada, only the index for Upper Strait of Georgia is predicted to exceed the general obligation of 0.635 for Canadian ISBM fisheries in 2013 based on output from CLB 1308 (Table 3.8). Since there is no CTC- agreed escapement goal for this stock aggregate, the general obligation applies. Among the stocks with agreed escapement goals, the ISBM index for Harrison is predicted to exceed the additional obligation of 0.250.

Eleven of the 20 U.S. ISBM indices are predicted to be above the general obligation of 0.60 or the additional obligation for U.S. ISBM fisheries in 2013 based on CLB 1308 (Table 3.9). Where relevant, all of the corresponding stocks except Fraser Late are expected to meet their CTC-agreed escapement goals.

3.2.3.4 *CWT ISBM Indices for 2012*

One of the limitations of the current ISBM indices relates to delayed data availability (CTC 2011). The data needed to calculate the postseason ISBM CWT-based index for several stocks caught in U.S. ISBM fisheries are not available at the time the index must be computed for reporting. Catch estimates from some U.S. ISBM fisheries may not be available until at least one year after a fishery has occurred, either because the catch data are unavailable or because multiple agencies have not reached timely agreement on the *final* catch estimates needed to generate expansion factors for CWT recoveries. For example, sport harvest estimates for Washington and Oregon are based on punch cards filled in by the fishers and returned by mail more than a year after the fisheries have been completed. Because the sport catch estimates are needed to estimate cohort sizes, the consequence of these delays in some U.S. fisheries is that the ISBM indices for both countries may not be computed within the timeframe needed 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. However, the catch estimates that are necessary to expand the CWT sample data and some of the escapement CWT samples are not available on time for some Washington and Oregon sport and net fisheries.

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 so the CTC can report the ISBM indices in time to use for the preseason management process for the next season (CTC 2011). Reducing the two-year time lag for CWT-based indices is highly desirable and possible for some Canadian stocks with timely available catch and CWT recovery data. The computation of CWT-based ISBM indices for year 2012 was possible for four Canadian stocks; these values are shown in Table 3.12. ISBM indices for stock groups Lower Strait of Georgia, Fraser Late, and Upper Strait of Georgia were below the general obligation. The CWT-based indices for both Lower and Upper Strait of Georgia were within the range observed from 1999 to 2011, and relatively close to the period average whereas the ISBM index for Fraser Late exceeded the previous maximum observed of 0.134 in 2010. The 2011 CWT index value for the WCVI stock group was greater than the general obligation and substantially larger than the index average for 1999–2011. There is a precedent of a higher CWT-based ISBM index value (0.906) for this stock group in 2007.

Fraser Late is the only Canadian stock included in Attachment V in the 2009 Agreement corresponding to U.S. ISBM fisheries. However, the U.S. CWT-based indices for Fraser Late have not been reported from 2005 onward because they do not accurately reflect the impacts on the natural stock. A considerable proportion of the recoveries in U.S. fisheries have occurred in MSFs in which only clipped hatchery-origin fish are retained. The U.S. indices since 2005 indicate greater impacts than would have occurred on the natural stocks and are no longer being reported.

Table 3.12 2012 Canadian CWT-based ISBM indices for Canadian stock groups based on 2013 CWT analysis, their average CWT index values for 1999–2011, model-based ISBM indices for 2012, and the average model values for 1999–2013. Values in parentheses represent standard deviations.

Stock Group	Escapement Indicator Stock	Canadian ISBM CWT Indices 2012	CWT Indices Average (1999–2011)	Model Indices 2012	Model Indices Average (1999–2013)
Lower Strait of Georgia	Cowichan	0.231	0.253 (0.123)	0.443	0.393 (0.133)
Fraser Late	Harrison River	0.183	0.070 (0.034)	0.256	0.292 (0.133)
Upper Strait of Georgia	Klinaklini, Kakweikan, Wakeman, Kingcome, Nimpkish	0.067	0.091 (0.088)	0.596	0.438 (0.269)
West Coast Vancouver Island Falls	WCVI (Artlish, Burman, Kauok, Tahsis, Tashish, Marble)	0.738	0.399 (0.246)	0.636	0.533 (0.400)

3.2.3.5 *Paragraph 13 (d) and (e) analysis*

Paragraph 9 of the 1999 Agreement was rewritten in 2009 as paragraph 13 and now describes a process to implement additional management actions in fisheries if the management as prescribed in paragraphs 8 and 10 fail to meet maximum sustainable yield or other biologically based escapement objectives. Paragraph 13 currently details a process for evaluating stock groups and indicator stocks listed in Attachments I–V to determine if additional management actions should be implemented in relevant AABM and ISBM fisheries. The stock groups and indicator stocks that correspond to the SEAK, NBC and WCVI AABM fisheries are listed in Attachments I (SEAK), II (NBC), and III (WCVI AABM). Additional reductions in the WCVI AABM fishery will only be taken if agreed to by the Commission. If additional management action is required in the SEAK or NBC AABM fisheries, the ISBM fisheries harvesting the stocks listed in Attachments IV and V would commensurably be reduced, thus increasing the escapements of the depressed stocks within the stock groups triggering the additional AABM management actions. A flow diagram depicting the criteria needed to trigger additional management action was reported in the CTC's evaluation of ISBM metrics (CTC 2011). The CTC is to notify the Commission of any required fishery restrictions to be implemented under Paragraph 13 at the February annual meeting.

Additional management actions for SEAK or NBC AABM fisheries would reduce Table 1 catch limits by 10% if a majority of stocks with agreed management objectives in two of the stock groups listed in Attachment I or II of the Chinook Annex met one of the following conditions: at least 15% below their escapement objectives for the past year and forecast to be at least 15% below their escapement goal objectives in the upcoming year, or at least 15% below their escapement objectives for the past two consecutive years (unless a forecast for escapement will exceed the escapement objective in the coming year).

If three or more stock groups in Attachments I or II meet the criteria to trigger additional management action, Table 1 catch limits in the relevant AABM fishery would be reduced by 20%.

Paragraph 13(d) and 13(e) focus on the evaluation of ISBM obligations (see section 3.2.3.1. ISBM Indices by Stock) with respect to AABM management actions. These new components of the 2009 Agreement may trigger additional management action in an AABM fishery when the majority of indicator stocks within a stock group do not achieve their escapement objectives for the past two consecutive years. Paragraph 13(d) and 13(e) call for an evaluation of the effect of interactions between AABM and ISBM fisheries on observed spawning escapements and a determination of whether an indicator stock would have exceeded 85% of its escapement goal if ISBM obligations were met.

Paragraph 13(d) involves an evaluation of whether the indicator stock exceeded 85% of its escapement goal because ISBM fisheries in the jurisdiction that the stock originated were constrained beyond the ISBM obligations. In this case, the indicator stock would not meet its escapement goal, which would be considered in the process for determining if additional management action is required.

Paragraph 13(e) involves an evaluation of whether the indicator stock did not exceed 85% of its escapement goal for two consecutive years as a consequence of an ISBM fishery not meeting the general obligation listed under paragraph 8. In this case, the indicator stock would meet the escapement goal, and the indicator stock would not be involved in triggering additional management actions.

An initial evaluation of ISBM performance under paragraphs 13(d) and 13(e) was undertaken by the CTC in 2011 and reported in CTC (2011). It was demonstrated that paragraphs 13(d) and 13(e) can be quantitatively evaluated. To facilitate timely evaluation and provide efficiency, the CTC developed a computer program (Paragraph13Evaluation.exe) in 2013 to evaluate these provisions of Paragraph 13. The computer program provides detailed quantitative output for each stock and year, and a summary for all stocks with CTC-agreed goals showing whether stocks should be flagged under paragraphs 13(d) or 13(e).

The Paragraph 13(d) and 13(e) evaluation has two main data limitations. First, the computer program can only perform postseason evaluations since it uses CWT data, which are not available until at least the year after a fishery has occurred. Second, only 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; Table 3.13) can be evaluated because management entities have not supplied escapement goals meeting CTC- agreed data standards for the other stock groups (Upper Strait of Georgia, WCVI, NBC, and Fraser Early). For Attachment III, the Columbia River Falls, Columbia River Summers, and Fraser Late stock group can be evaluated; however, the Puget Sound Natural Summer/Falls stock group cannot because none of the five indicator stocks have CTC-agreed escapement goals.

For the purpose of enabling the Paragraph 13 evaluation program, paragraphs 13(c)(i) and

13(c)(ii) were interpreted, within the context of management actions on AABM fisheries, such that a majority is defined as at least half the stocks within a stock group (i.e., one stock within a stock group with two stocks is considered a majority).[2] The appropriate evaluation was possible from 2009 to 2011 for Far North Migrating Oregon Coastal Falls, Columbia River Falls, and Columbia River Summers, from 2009 to 2010 for Washington Coastal Fall Naturals, and from 2010 to 2012 for Fraser Late. The different evaluation timeframes are due to the late reporting of CWT data. Note that ISBM obligations for 2012 cannot be calculated for most Oregon and Washington stocks until 2014 because of the delay in reporting CWT data for some southern U.S. monitoring programs.

The evaluation of paragraphs 13(d) and 13(e) provisions found that none of the indicator stocks or stock groups met the conditions requiring additional management actions. The evaluation for Washington Coastal Falls, Columbia River Falls, and Columbia River Summers showed that annual evaluations were based on 13(d) because escapements exceeded 85% of the corresponding escapement goals. For the North Oregon Coastal Falls stock group the evaluations were mostly based on 13(d) with 13(e) being used for the Nehalem in 2009 and 2010. The evaluation for the Fraser Late stock group was based on paragraph 13(d) in 2011 and 13(e) in 2012.

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[2] It is important to note that this definition of a majority is solely for the purpose of running the computer program; a definition of majority of stocks would require a policy decision. This situation was not encountered for stock groups in Attachments I–III.

Table 3.13 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 whether 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)	2009	2010	2011	AMA (last 2 years)
North Oregon Coastal Falls							No
	Nehalem	Yes	>85% Goal & 13(d)	NA	NA	No	
			<85% Goal & 13(e)	Yes	No	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	No	
			<85% Goal & 13(e)	NA	NA	NA	
Washington Coastal Falls							No
	Hoko	No	-	-	-	-	
	Grays Harbor	No	-	-	-	-	
	Queets	Yes	>85% Goal & 13(d	No	No	-	
			<85% Goal & 13(e)	NA	NA	-	
	Quillayute	Yes	>85% Goal & 13(d	No	No	-	
			<85% Goal & 13(e)	NA	NA	-	
	Hoh	Yes	>85% Goal & 13(d	No	No	-	
			<85% Goal & 13(e)	NA	NA	-	

3.2.4 Model Verification and Improvement

The changes in AIs between 2012 pre- and postseason calibrations noted in Section 3.2.2 were among the greatest observed, equating to a reduction in *ca*. 100,000 allowable catch across the three AABM fisheries (Table 3.5). Model errors of this magnitude underscore the importance of routine model verification, as well as occasional targeted investigations and long-range efforts to improve the PSC Chinook Model. The reliability of Chinook Model outputs, including AI predictions, depends on a number of factors: model parameters (e.g., base period exploitation rates); model structure (e.g., spatiotemporal fishery strata); and/or the annual CWT, catch, and run-size inputs (forecast or postseason estimates) with which it is calibrated. Here, we report on annual comparisons of model and CWT fishery indices and preseason (forecast) versus postseason run sizes, and a more detailed investigation into the general influence of forecast error on AI error for the three AABM fisheries. Lastly, we briefly review ongoing, related model improvement activities.

3.2.4.1 *Evaluation of Fishery Indices*

Fishery mortality indices generated by the model can be compared to values generated from the CWT-based ERA. Model and CWT-based fishery mortality indices use the same equation, but the former are derived from model estimates of catch for all model stocks instead of CWT recovery data from specific exploitation rate indicator stocks. The CWT fishery mortality indices are considered the most accurate. Fishery indices based on reported catch and total mortality are constructed using two methods. The first method is a ratio of means (ROM) and the second is the stratified proportional fishery index (SPFI; CTC 2009a). In general, the model results are closely associated with the CWT-based indices of annual fishery exploitation rates.

3.2.4.1.1 SPFI for the SEAK AABM Fishery

The SEAK fishery mortality index from the model closely follows the trend of the CWT-derived estimate from 1979 through 1989 for both landed catch and total mortality (Figure 3.13; Figure 3.14). Between 1989 and 2000, the model estimates of both the landed catch and total mortality indices are less than the CWT-derived estimate for most years. Contrarily, since 2001, the model estimates have typically been higher. Since 1990, the model estimates also show less variability compared to the CWT-derived indices.

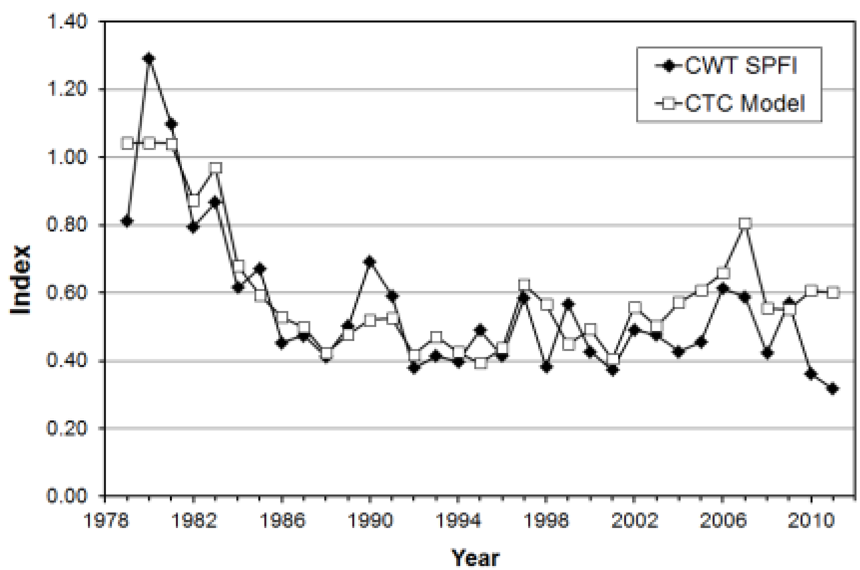

Figure 3.13. Estimated CWT-based SPFI (through 2011) and model landed catch fishery indices (through 2011) for the SEAK troll fishery.

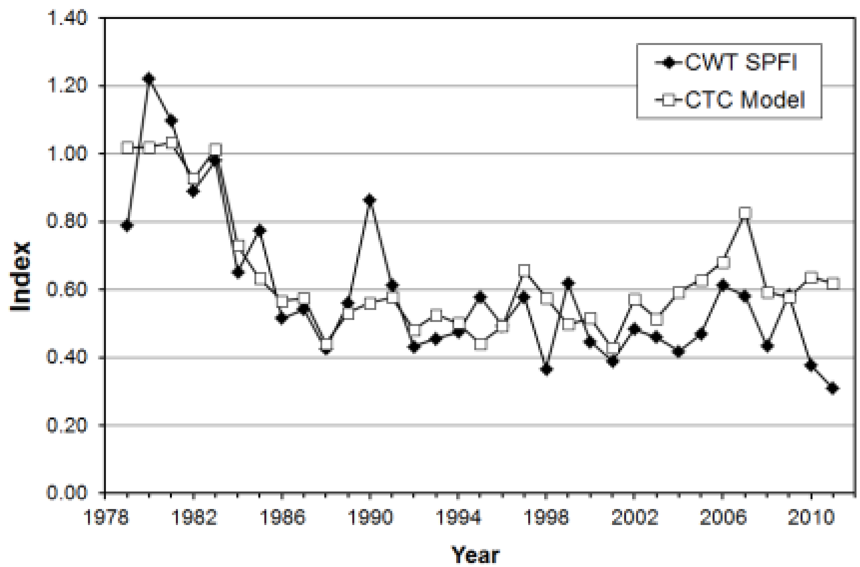

Figure 3.14. Estimated CWT-based SPFI (through 2011) and model total mortality fishery indices (through 2011) for the SEAK troll fishery.

3.2.4.1.2 SPFI developed for NBC and WCVI AABM Fisheries

Based on the results that came out of the Harvest Rate Index Analysis in 2009 (CTC 2009a), a recommendation was made to use the SPFI estimator for the fishery index in all AABM fisheries. As a result, the CTC created the SPFI for WCVI and NBC fisheries and compared them to the model and CWT-based ROM estimator of the fishery index for each of the fisheries analyzed (Figures 3.15–3.18). It should be noted that an assessment of how the SPFI affects results in the calibration procedures was originally intended to be included in this report. This analysis has been deferred until a new base calibration is completed.

The model-derived fishery mortality indices for NBC generally follow the same trend as CWT-derived indices (Figures 3.15–3.16). However, since 1991, the model-based estimates have exceeded the CWT-derived estimates in all but three years for both landed catch and total mortality indices. Since 2001, this difference has been noticeably large.

Since the base period, the model-derived landed catch fishery index estimates and trends for the WCVI troll fishery have been similar to CWT-based ROM FI estimates (Figures 3.17–3.18). Starting in 2000, model and CWT-based ROM estimates have diverged significantly for both landed catch and total mortality, with the CWT indices being consistently higher than model indices. To adjust for this the SPFI was developed that captures temporal and spatial changes in the fishery, and is now reported along with the ROM FI (Figures 3.17–3.18).

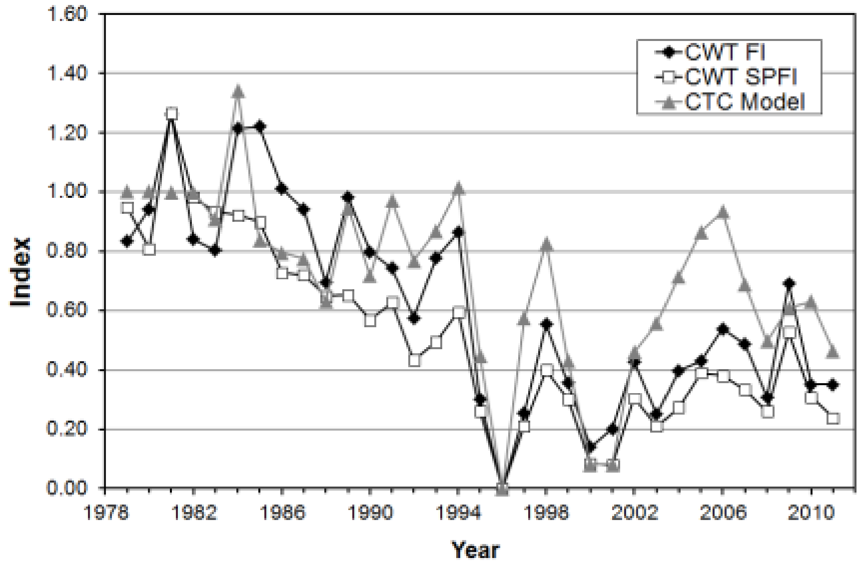

Figure 3.15. Estimated CWT ROM (FI), SPFI (through 2011) and model landed catch fishery indices (through 2011) for the NBC troll fishery.

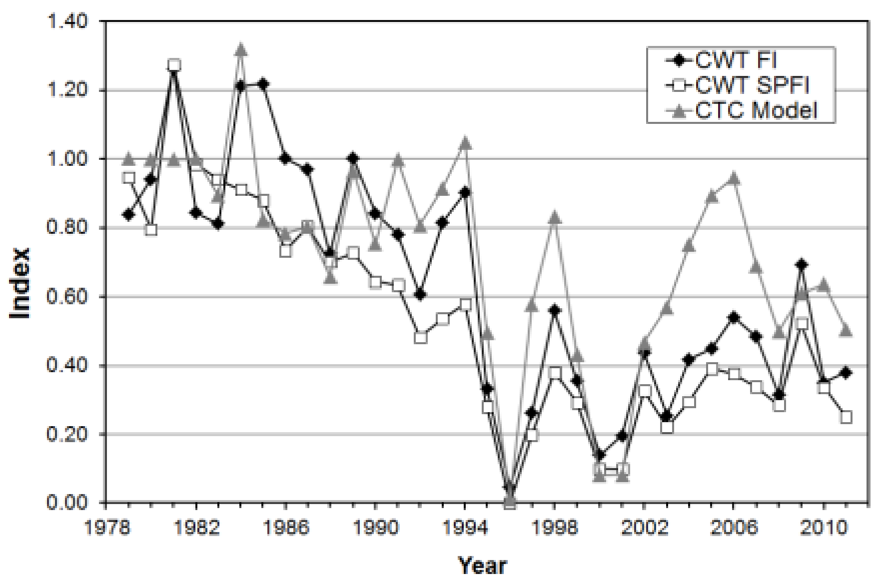

Figure 3.16. Estimated CWT ROM (FI), SPFI (through 2011) and model total mortality fishery indices (through 2011) for the NBC troll fishery.

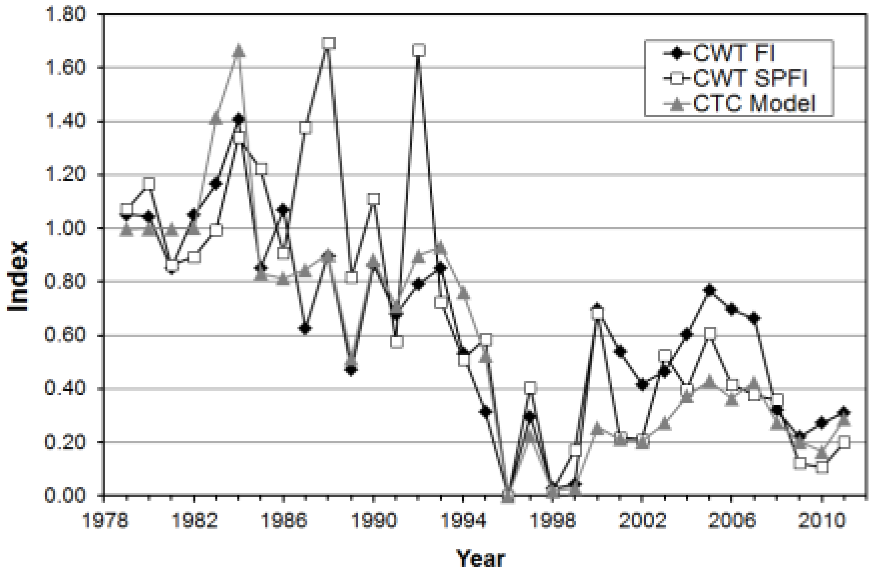

Figure 3.17. Estimated CWT ROM (FI), SPFI (through 2011) and model landed catch fishery indices (through 2011) for the WCVI troll fishery.

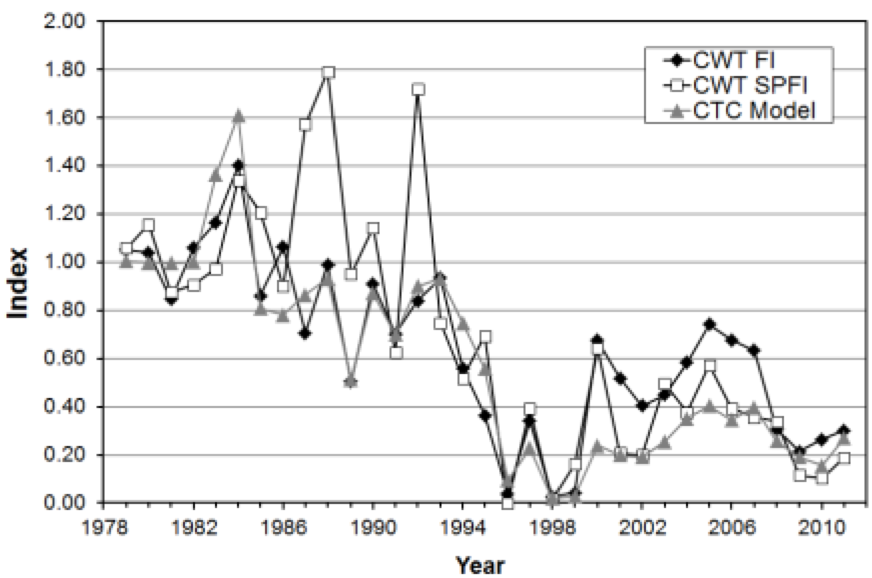

Figure 3.18. Estimated CWT ROM (FI), SPFI (through 2011) and model total mortality fishery indices (through 2011) for the WCVI troll fishery.

3.2.4.2 *Stock Forecasts used in the Model*

A summary of model-produced and agency-produced forecasts during 1999–2013 is shown in Figure 3.19 and Appendix J. The relationship between the model indicator stocks and exploitation rate indicator stocks and PST Annex stocks are shown in Appendix A. 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 for which model forecasts are available. 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. In the Appendix J forecast 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/Postseason* shows the ratio of the agency forecast and the actual return as a percentage. The column labeled *Model Fcst/Postseason* 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.

The model forecasts are similar to the agency forecasts on average. This result is strongly influenced by the incorporation of the agency forecasts into the model calibration procedure. The average percent error of all *Model Fcst/Agency Fcst* is –1.5%. For agency forecasts versus postseason run sizes, the average percent error is –7.6%. The average percent error for model forecasts versus postseason run sizes was –11.0%.

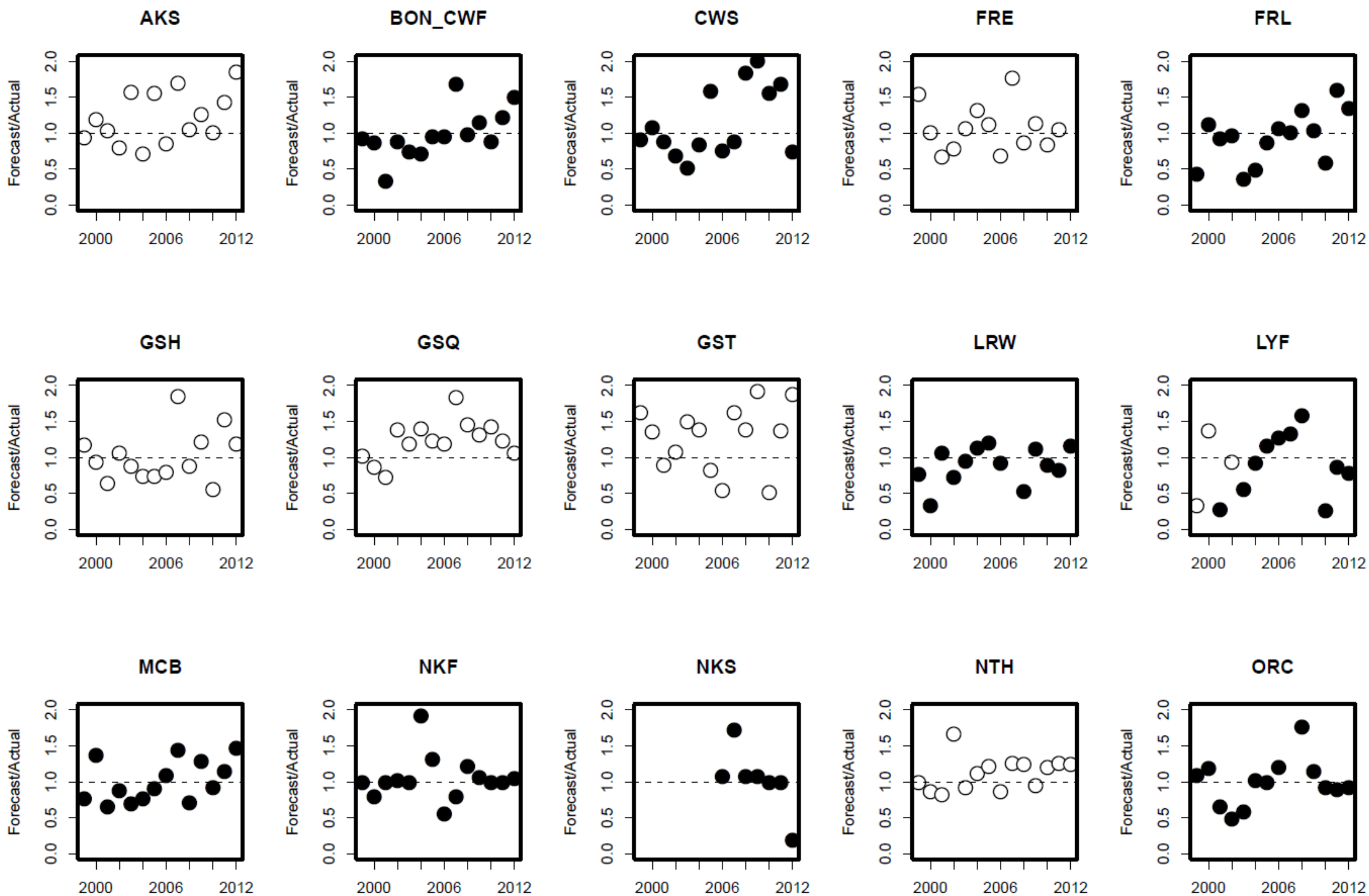

Figure 3.19 Forecast performance (Forecast/Actual) plots for PSC Chinook Model stocks.

Note: Black symbols correspond to years when calibrations were based on agency forecasts, white symbols correspond to years when model-generated forecasts were used. Stock abbreviations follow those defined in Appendix J.

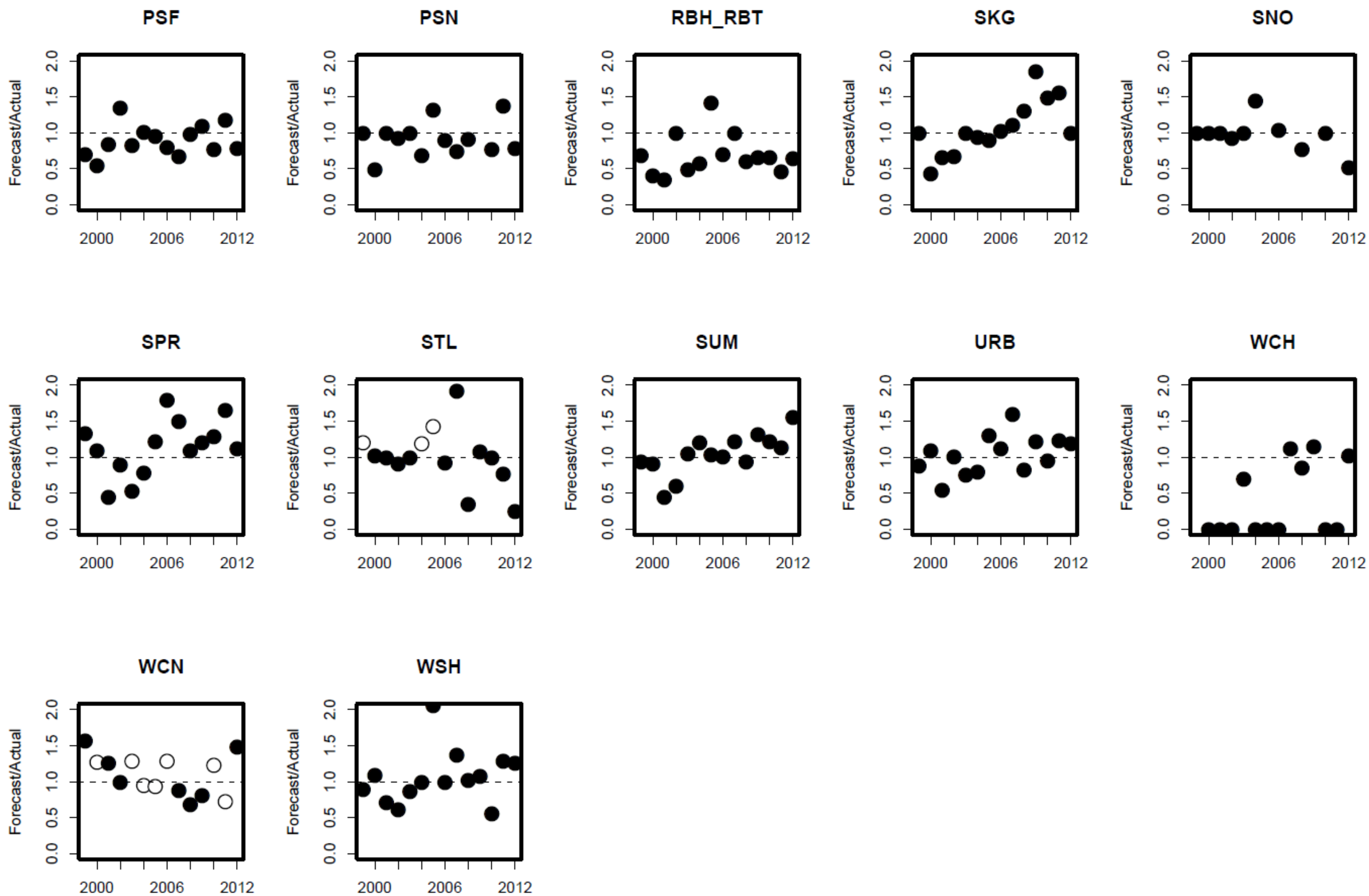

Figure 3.19 Page 2 of 2.

3.2.4.3 *Influence of Forecast Error on Pre- versus Postseason AI changes*

Within the PST Chinook management cycle, AI prediction is the key piece of data used to determine the preseason estimates of the allowable catches for each of the AABM fisheries. The Parties rely upon the CTC Model to generate annual estimates of abundance. Three sources of error in preseason AIs are currently identified as (1) error in agency forecasts of escapement or terminal run supplied for model calibration, (2) assumptions about maturation rates and survival rates used in the model calibration, and (3) model error. Each year, the CTC Model is calibrated, incorporating preseason abundance forecasts with the latest information on catches, exploitation rates, and escapements. For several stocks, escapement or terminal run forecasts provided by agencies represent consistent relationships between siblings of the same brood, implying relatively stable natural survivals after fish reach age 2. For other stocks, forecasts consist of recent year averages or mechanistic models. Previous explorations have shown that forecasting error ([*Forecast-Observed*]/*Observed*) in large stocks can substantially influence aggregate abundance indices, whereas individual stock forecasting errors explain only low proportions of the variability in preseason AI errors. However, the composite error (Equation 3.1) of stocks with the largest contributions to AABM fishery-specific AIs is highly correlated with the corresponding AI error (Figure 3.20), explaining 70% of the variation in the AI error for SEAK, 60% for NBC, and 55% for WCVI. Including all forecasts—generated by the model or provided by agencies used for calibration purposes–does not increase the proportion of the variability in AI errors explained by the composite forecast error for driver stocks; the coefficient of determination actually decreases in NBC and WCVI.

$$Forecast\ Error = \frac{\left(\sum_{stock=1}^{n} Forecast - \sum_{stock=1}^{n} Observed\right)}{\sum_{stock=1}^{n} Observed}$$

Equation 3.1

In spite of the strong correlation between composite forecast error and AI error, the large overprediction observed for SEAK in 2012 was greater than expected given the corresponding composite forecast error. The 2012 AI error is the largest relative AI error for SEAK and the largest absolute error across AABM fisheries since 1999. The 2012 AI error for NBC was also among the largest positive errors ever observed whereas the AI error for WCVI was close to the average for positive errors.

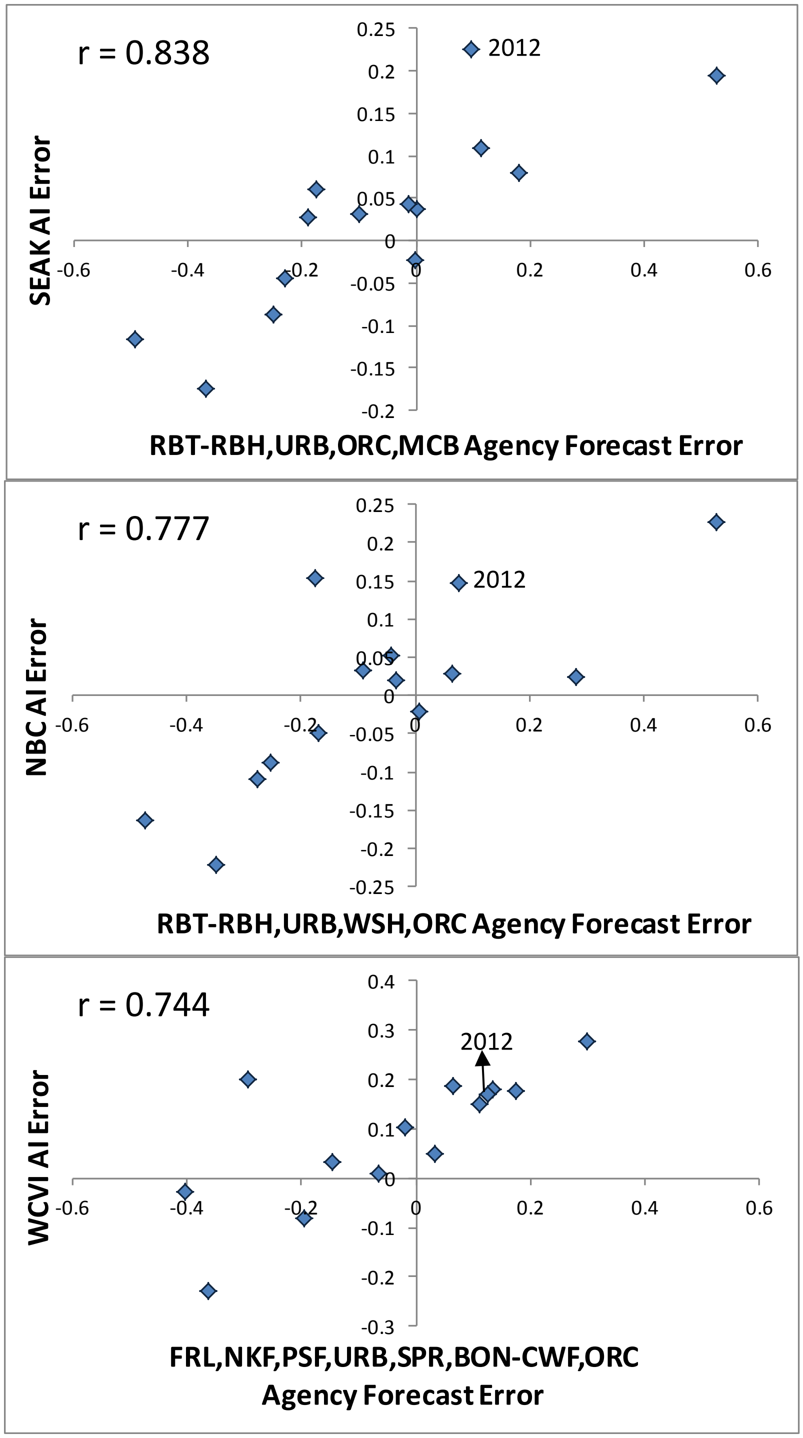

Figure 3.20 Relationship between composite agency forecast error and abundance index error for AABM fisheries SEAK, NBC, and WCVI.

Note: Composite forecast errors (Equation 3.1) are based on pooled abundances of stocks contributing on average more than 5% to AABM-specific abundance indices.

Although model stocks contribute at varying levels to the three AABM fisheries, it is informative to identify stock level variation in forecast performance within the context of the AI shifts noted for 2012. For the 2012 return, positive error (i.e., forecasts in excess of actual returns, forecast/actual >1.0) was evident for 17 stocks (Figure 3.21), half of which were moderate (50–100K) to large (>100K) stocks. Actual returns for the 10 remaining model stocks were at or above forecast levels, although most (7/10) of these stocks were relatively small in size (<10K). Noteworthy positive error was evident for a subset of Columbia River (Bonneville/Cowlitz Fall Hatchery, Mid-Columbia Brights, Summers) and all Fraser River (Earlies, Lates) stocks, as well as for the Southeast Alaska (AKS) stock. The extent of forecast error documented for these stocks in 2012 was among the most extreme since 1999, and the recent track record these and other stocks suggests there are regionally and temporally correlated patterns of positive error (Figure 3.19). Although underforecasting occurred for three large stocks in 2012 (Oregon Coast, Puget Sound Hatchery Fingerling, and WCVI Hatchery+Natural [RBH]), the extent and pattern of error was notable for only one of them (RBH). In particular, the WCVI Hatchery/Natural return was approximately 50% higher than forecast and has erred in this way in nearly all years since 1999 (Figure 3.19). These results in combination with the forecast issues associated with the 2013 preseason calibration (i.e., RBH forecast issues [Appendix K], preliminary indication of underforecasting of record URB/MCB return) suggest that preseason applications of the PSC Chinook model will benefit from efforts aimed at reducing forecast error, especially for driver stocks.

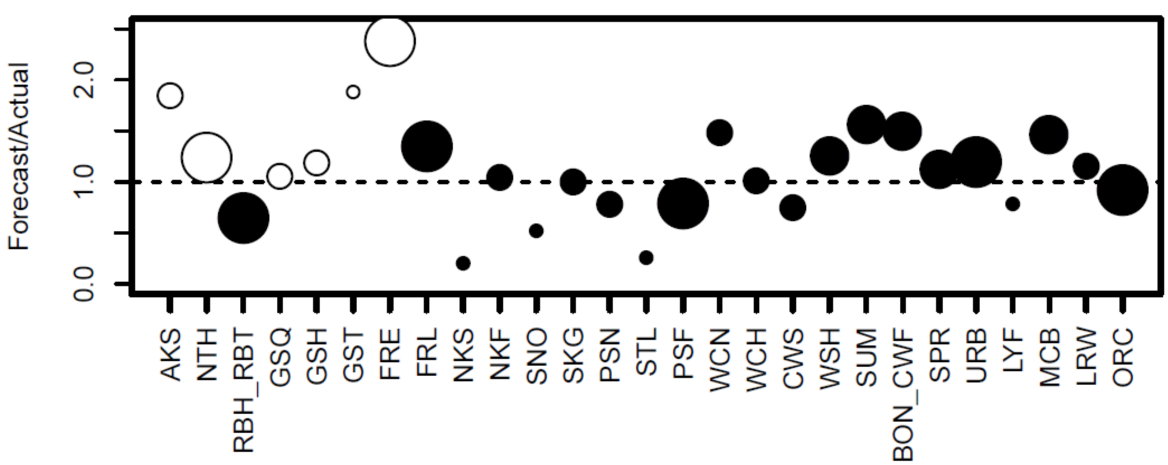

Figure 3.21 Forecast error (forecast/actual) for stocks represented in the Chinook Model for 2012.

Note: Points lying above the dashed horizontal line returned lower than forecast; points lying below the dashed horizontal line returned greater than forecast. Black symbols correspond to stocks with agency-supplied forecasts; white symbols correspond to stocks with forecasts generated by the Chinook Model. The four symbol sizes correspond to categories of increasing relative stock size (based on average terminal run size; <10K, 10–50K, 50–100K, and >100K). Stocks are arranged along the x-axis from north to south, and are defined according to the codes in Table 3.10.

3.2.4.3.1 Potential for preseason AI correction

For stocks without agency forecasts, preseason forecasts are generated automatically by the CTC Model, assuming average survival and maturation rates for the broods contributing to the coming fishing season. In January 2013, the CTC made progress on this regard finding a combination of EVs and maturation-rate averages that minimized AI errors when evaluated retrospectively. These assumptions were applied to the 2013 model calibration to generate the corresponding preseason AIs. It has been shown that agency forecast error is a moderate contributor to preseason AI error and that reducing preseason AI bias through changes in assumptions regarding survival and maturation rates slightly reduces the AI error but do not eliminate it. Hence, it remains a challenge to develop methods that predict the direction and magnitude of error in preseason AIs, which could greatly improve the coastwide management of Chinook stocks. Other analyses conducted by CTC members have demonstrated how indices of coastwide stock performance can predict and reduce model errors in preseason AIs. In particular, a Production Index based on prefishing abundances has proved to be a powerful predictor of relative AI error ([*Preseason-Postseason*]/*Postseason*) across AABM fisheries. These analyses have identified a clear tendency to overpredict AIs when production is low and to underpredict it when production is high. This pattern is consistent across AABM fisheries, thus allowing the development of regression models that can help predict the direction and magnitude of preseason AI errors. The use of Production Index models successfully predicted the direction of errors for all three AABM fisheries for 2012 (Figure 3.22), and if used to adjust first postseason AIs, it would have reduced the error completely for NBC, by 60% for WCVI, and by 23% for SEAK. The ability to predict and reduce AI error is particularly important in the face of the undesirable combination of low abundance and overforecasting evidenced in these analyses. It is important to find appropriate ways to include information generated by these studies in the annual CTC assessments and abundance forecasts.

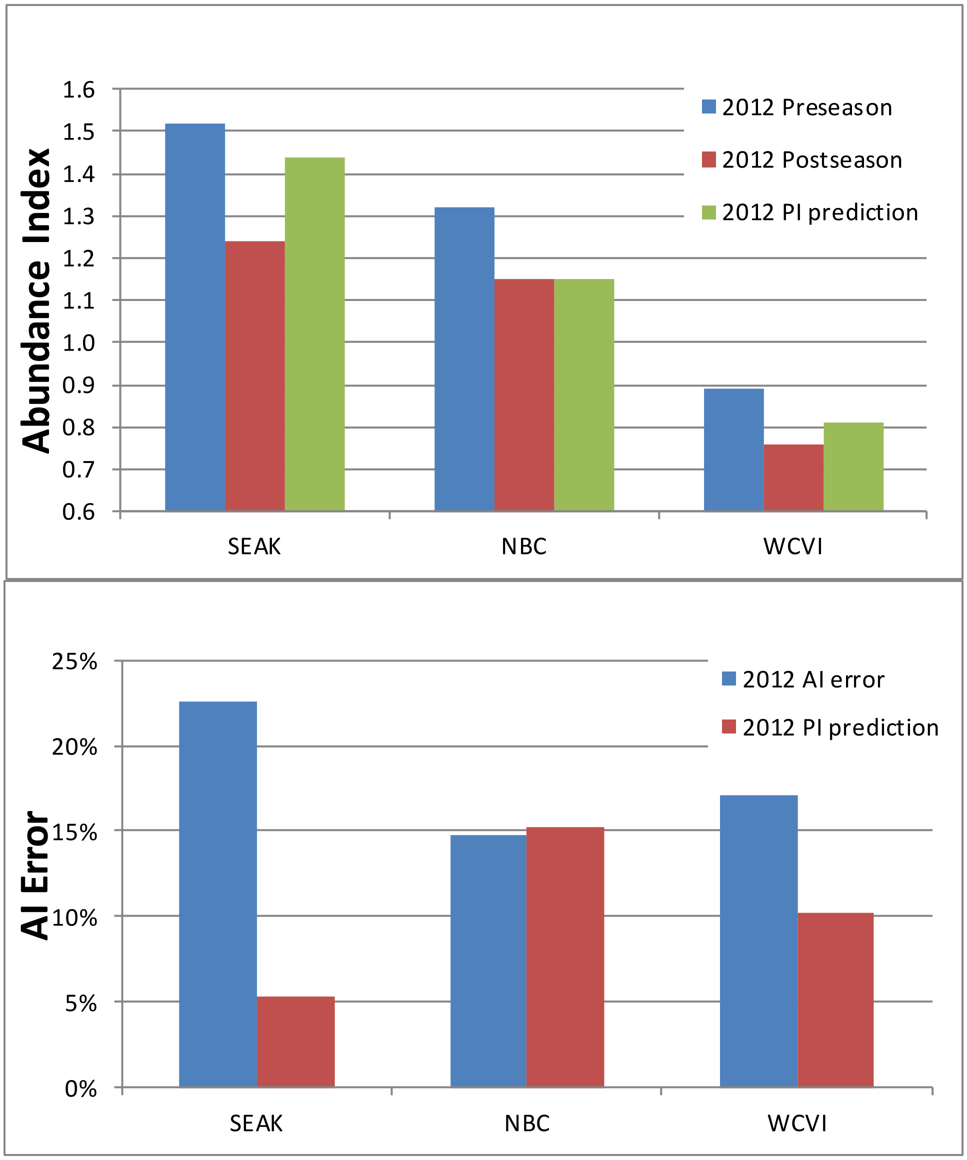

Figure 3.22 Comparing AI errors and AIs generated by the Chinook Model (CLB 1309) with those generated by the Production Index (PI) Model for AABM fisheries in 2012.

3.2.4.4 *Model Improvement Activities*

Improvements to the PSC Chinook model are one of the high priorities identified in the 2009 Agreement that included substantial, dedicated resources ($1 million U.S.). Information and data generated by the Chinook model are used for many purposes, including the management of AABM and ISBM fisheries and the estimation of fishing impacts for model stocks. Knowledge about the model's performance can help direct model improvement resources to where they are needed and beneficial. During 2013, the CTC engaged in the following model improvement activities, which are still ongoing:

1. Data Generation Model: The CTC's stock and fishery assessment methods are largely derived from CWT data. With data collected from the field, it is not feasible to determine the accuracy of statistical estimates derived from the application of methods and algorithms employed by the CTC. A Data Generation Model (DGM) is being developed to evaluate the performance of CWT methods in situations where CWT recoveries and incidental mortalities are known with certainty. The DGM will generate the necessary information to allow for experiments and thorough and systematic evaluations of metrics of interest, including alternative ISBM metrics that were identified for further evaluation in CTC (2011).

2. Revisions to the CTC PSC Chinook Model: Revisions of the Model are being made to incorporate features that have been determined to be feasible and important. For example, modifying the manner in which incidental mortalities are allocated by stock and age, the ability to incorporate observations of encounters of fish that are not retained as landed catch, modifying the stocks and fisheries contained in the Model, and directly incorporating forecasts of ocean abundance instead of relying upon Model calibration algorithms.

3. Chinook Interface System: The CTC is developing an integrated system and platform consisting of a database and associated computer programs to improve the efficiency of the CWT exploitation rate and Model calibration processes.

4. SharePoint: The CTC is supporting the development of SharePoint capabilities to improve the efficiency of CTC analyses and report generation. This SharePoint site will allow the CTC to store information, reports, and analyses. It will also allow for collaboration and the transfer of information that will aid in the preparation and dissemination of the annual CTC reports and assignments.

5. Comparison of CWT and Model-based estimates of stock and fishery impacts: The CTC is undertaking a comparison of statistics derived from CWT recovery data and data generated by the Model, including estimates of stock age and BYER, and maturation rates.

Technical Notes are being developed to memorialize the findings and developments of these investigations and model improvement initiatives.

4 Evaluation of Mark-Selective Fisheries

Chinook salmon released from Puget Sound hatcheries and spring-run hatchery Chinook salmon in the Columbia River have been mass marked 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 (MSFs) 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. Juan de Fuca since 2008 (Table 4.1). Additionally, the first ocean mark-selective Chinook fishery occurred off the Washington Coast (Areas 1–4) in 2010. No new MSFs were introduced during fishing year 2011.

4.1 Catch in MSFs

A mixed-bag, partial MSF has occurred in the B.C. Juan de Fuca sport fishery since 2008 (Table 4.1). The fishery has a minimum size limit of 45 cm, with a daily bag limit of two Chinook salmon; however, wild Chinook salmon exceeding a fork length of 67 cm must be released. The mixed-bag, partial MSF regulation is intended to protect Fraser River Spring-run age-1.2 and age-1.3 stock groups as they returned to the Fraser River.

MSFs have been in place in Puget Sound in Washington Areas 5 and 6, part of Puget Sound North Sport (PSN Sp) during the summer since 2003. In 2005 a winter MSF started in Washington Areas 8-1 and 8-2 (Puget Sound other sport, PSO S). In 2007 additional MSFs were implemented in Washington Areas 9, 10, and 11 (PSO S) in the summer months and in Areas 7 (PSN S), 9, and 10 (PSO S) in the winter months (Table 4.1; Table 4.2). MSFs have continued to expand in Puget Sound marine areas to the extent that in 2010 all marine sport management areas have MSFs for at least some portion of the year. Total landed catch in MSFs in marine sport fisheries remained fairly constant from 2003 to 2005, around 3,000 to 4,000, then increased to approximately 25,000 beginning in 2007. Landed catch in nonselective fisheries has declined from approximately 25,000 to 6,000 over the same period (Figure 4.1). Since 2007, catch in MSF fisheries in northern Puget Sound marine areas has nearly doubled, while MSF catches in other marine areas have remained about the same. MSFs have been implemented in freshwater areas (TERM S) since 2003 (Figure 4.2; Table 4.3), with total estimated MSF catch ranging from 1,000 to 7,000. The percent of total MSF catch in the three PSC sport fisheries in Puget Sound (Figure 4.1) for 2011 is approximately 65% in PSN, 90% in PSO, and approximately 60% in freshwater (TERM S).

Chinook salmon MSFs have been in place in the Columbia and Willamette rivers since 2001 (Table 4.1). Most of the catch from MSFs has been directed on mass marked spring Chinook salmon from the Willamette, Cowlitz, Kalama, Lewis rivers in the lower Columbia, tributaries in the upper Columbia upstream of Bonneville Dam, and in the Snake River (Table 4.1). The first MSF in the mainstem Columbia on summer run Chinook salmon occurred in 2003, and has occurred annually since 2010. MSFs on fall Chinook salmon were first implemented in the Lower Columbia tributaries in 2008 (Grays River only) and have expanded to the other streams with significant numbers of hatchery origin fish (e.g., Elochoman, Cowlitz, Toutle, Lewis, Kalama, Washougal, Wind, and White Salmon rivers, and Drano Lake). Total catch in these MSF fisheries is smaller than the catches from the mainstem Columbia River that has not been under MSF regulations during the fall season (Table 4.1).

Beyond the Columbia River, relatively short Chinook MSF seasons have occurred in both Oregon and Washington coastal waters during recent years (Table 4.1). The May–June MSF catch of Chinook salmon in the Washington-Oregon ocean sport fishery (WDFW Marine Areas 1–4) was approximately 2,400 in 2010 and 5,000 in 2011. There has also been a spring Chinook-directed sport MSF in the Oregon north coast terminal areas since 2008; catch estimates for this fishery are not available at this time.

*Table 4.1 Mark-selective fisheries occurring 2003–2011 (**√**).*

Fishery	Location	Period	2003	2004	2005	2006	2007	2008	2009	2010	2011
Sport	B.C. Strait of Juan de Fuca, selected subareas	Mar–Apr						√	√	√	√
Sport	WA/OR Ocean Area 1-4	June								√	√
Sport	WA PS Area 5	Summer	√	√	√	√	√	√	√	√	√
Sport	WA PS Area 6	Summer	√	√	√	√	√	√	√	√	√
Sport	WA PS Area 7	Winter						√	√	√	√
Sport	WA PS Area 8.1	Winter			√	√	√	√	√	√	√
Sport	WA PS Area 8.2	Winter			√	√	√	√	√	√	√
Sport	WA PS Area 9	Summer					√	√	√	√	√
Sport	WA PS Area 9	Winter						√	√	√	√
Sport	WA PS Area 10	Summer					√	√	√	√	√
Sport	WA PS Area 10	Winter						√	√	√	√
Sport	WA PS Area 11	Summer					√	√	√	√	√
Sport	WA PS Area 11	Winter							√	√	√
Sport	WA PS Area 12	Winter								√	√
Sport	WA PS Area 13	Summer					√	√	√	√	√
Sport	Nooksack	Sep–Dec		√	√	√	√	√	√	√	√
Sport	Skykomish	Jun–July	√	√	√	√	√	√	√	√	√
Sport	Carbon and Puyallup	Aug–Dec	√	√	√	√	√	√	√	√	√
Sport	Upper Skagit	Jun–July			√	√	√	√	√	√	√
Sport	Nisqually	Jul–Jan				√	√	√	√	√	√
Sport	Skokomish	Aug–Dec								√	√
Sport	Quillayute	Feb–Dec	√	√	√	√	√	√	√	√	√
Sport	Hoh	May–Aug						√	√	√	√
Sport	Willapa Bay and tributaries	Jul–Jan								√	√
Commercial	Willapa Bay	Aug–Nov								√	√
Sport	Columbia	Summer	√	√		√		√		√	√
Sport	Lower Columbia	Spring	√	√	√	√	√	√	√	√	√
Sport	Lower Columbia tributaries	Fall									√
Commercial (tangle net)	Lower Columbia	Spring	√	√	√	√	√	√	√	√	√
Commercial, (large net)	Lower Columbia	Spring	√	√	√	√	√	√	√	√	√
Sport	Willamette	Spring	√	√	√	√	√	√	√	√	√
Sport	Yakima	Spring		√				√		√	√
Sport	Lower Snake	Fall						√	√	√	√
Sport	Lower Snake	Spring								√	√
Sport	Oregon terminal	Spring						√	√	√	√

Note: See SFEC (2013) for more detailed information on MSF proposals and fisheries.

Table 4.2 Retained or landed catch and total encounters (landed + released) and total mortalities (landed + release mortalities) by size and mark category in MSFs for Puget Sound and Juan de Fuca marine sport fisheries (PSN, PSO, JDF) for 2003–2011 and the Washington-Oregon ocean sport fishery in 2011.

Fishery	Stat Area	Year	MSF period	Retained Marked Fish	Retained Unmarked fish	Encounters Marked	Encounters Unmarked	% Marked	Legal-sized Marked fish Landed & Release Mortalities	Legal-sized Unmarked fish Landed & Release Mortalities	Sub-Legal-sized Marked fish Landed & Release Mortalities	Sub-Legal-sized Unmarked fish Landed & Release Mortalities
B.C. Juan de Fuca (JDF)	Area 19,20	2008	Apr–May	122	51	122[1]	68[1]	64%	122[2]	64[2]	5[2]	3[2]
	Area 19,20	2009	Mar–May	152	26	152[1]	105[1]	59%	152[2]	41[2]	24[2]	16[2]
	Area 19,20	2010	Mar–May	827	347	827[1]	704[1]	54%	827[2]	135	NA	NA
	Area 19,20	2011	Mar–May	1319	793	1,319[1]	1,231[1]	52%	1,319[2]	236	NA	NA
WA/OR Ocean	Area 1-4	2010	Jun	5,018	19	7,565	3,791	67%	5,123	384	252	164
	Area 1-4	2011	Jun	2,301	35	5,404	2,743	34%	2,439	209	386	205
Puget Sound North (PSN)[3]	Area 5	2003	Jul–Aug	2,476	53	4,469	8,663	34%	2,301	569	556	1,035
	Area 5	2004	Jul–Aug	2,900	0	4,471	6,479	41%	2,766	603	427	492
	Area 5	2005	Jul–Aug	1,620	49	3,058	2,927	51%	1,554	236	342	318
	Area 5	2006	Jul–Aug	3,301	17	4,775	5,354	47%	3,175	479	398	449
	Area 5	2007	Jul–Aug	3,250	117	5,065	3,744	58%	3,036	400	554	317
	Area 5	2008	Jul–Aug	2,819	0	3,298	2,199	60%	2,836	280	58	66
	Area 5	2009	Jul–Aug	5,958	439	16,504	20,958	44%	4,952	1,009	3,079	3,223
	Area 5	2010	Jul–Aug	5,703	14	9,682	9,114	52%	5,583	758	875	828
	Area 5	2011	Jul–Aug	4,535	92	6,764	14,686	32%	4,354	1,461	594	1,085
	Area 6	2003	Jul–Aug	941	22	1,133	1,408	45%	962	215	10	21
	Area 6	2004	Jul–Aug	671	5	813	835	49%	684	128	11	2
	Area 6	2005	Jul–Aug	404	4	534	790	40%	413	118	14	3
	Area 6	2006	Jul–Aug	340	9	388	494	44%	345	74	2	7
	Area 6	2007	Jul–Aug	722	7	838	411	67%	731	68	9	0
	Area 6	2008	Jul–Aug	537				61%				
	Area 6	2009	Jul–Aug	2,293	--	--	--	66%	--	--	--	--
	Area 6	2010	Jul–Aug	1,383	--	--	--	52%	--	--	--	--
	Area 6	2011	Jul–Aug	3,283				66%				
	Area 7	2007–2008	Feb	1,325	2	1,768	1,199	60%	1,331	158	72	31
	Area 7	2008–2009	Feb–Apr	1,420	9	1,768	733	71%	1,437	115	42	3
	Area 7	2009–2010	Dec–Apr	1,418	0	2,341	585	80%	1,431	66	161	29
	Area 7	2010–2011	Dec–Apr	2,378	4	3,253	2,523	56%	2,421	302	114	106
	Area 8-1, 2	2006–2007	Oct–Apr	1,176	33	13,254	6,598	67%	1,067	72	2,517	1,260
	Area 8-1, 2	2007–2008	Nov–Apr	1,543	23	4,040	1,388	74%	1,465	92	568	179
	Area 8-1,2	2009	Jan–Apr	911	27	4,044	1,468	73%	910	24	621	287
	Area 8-1,2	2009–2010	Nov–Apr	1,109	4	3,166	969	77%	1,112	36	400	151
	Area 8-1,2	2010–2011	Nov–Apr	211	0	454	192	70%	202	5	57	31
	Area 9	2007	Jul	5,239	33	7,236	1,461	83%	5,200	180	403	83
	Area 9	2008	Jul–Aug	4,045	3	7,854	5,436	59%	4,124	244	653	765
	Area 9	2009	Jul–Aug	3,229	20	11,946	4,196	74%	3,159	210	1,790	581
	Area 9	2010	Jul–Aug	5,292	39	6,782	2,413	74%	5,393	352	159	55
	Area 9	2011	Jul–Aug	2,363	25	4,852	2,238	68%	2,336	190	508	220
	Area 9	2007–2008	Jan–Apr	1,405	3	2,889	682	81%	1,362	49	330	75
	Area 9	2008–2009	Nov, Jan–Apr	885	14	4,537	3,009	60%	891	37	718	567
	Area 9	2009–2010	Nov–Apr	1,557	27	4,230	1,097	79%	1,483	76	598	146
	Area 9	2010–2011	Nov–Apr	432	0	1,078	539	67%	438	18	120	84
	Area 10	2007	Jul	1,539	38	4,849	1,258	79%	1,501	105	690	152

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Table 4.2 Page 2 of 2.

Fishery	Stat Area	Year	MSF period	Retained Marked Fish	Retained Unmarked fish	Encounters Marked	Encounters Unmarked	% Marked	Legal-sized Marked fish Landed & Release Mortalities	Legal-sized Unmarked fish Landed & Release Mortalities	Sub-Legal-sized Marked fish Landed & Release Mortalities	Sub-Legal-sized Unmarked fish Landed & Release Mortalities
Puget Sound Other	Area 10	2008	Jul–Aug	1,031	3	1,348	898	60%	1,046	79	42	77
	Area 10	2009	Jul–Aug	1,621	22	4,329	1,121	79%	1,538	34	613	203
	Area 10	2010	Jul–Aug	2,988	42	4,444	2,734	62%	3,015	187	242	342
	Area 10	2011	Jul–Aug	2,643	29	3,979	2,595	61%	2,604	295	287	153
	Area 10	2007–2008	Dec–Jan	635	21	2,575	545	83%	551	45	468	72
	Area 10	2008–2009	Dec–Jan	251	0	1,302	498	72%	253	5	207	92
	Area 10	2009–2010	Oct–Jan	395	3	2,979	984	75%	362	15	548	180
	Area 10	2010–2011	Oct–Jan	162	0	998	793	56%	153	8	176	148
	Area 11	2007	Jun–Sep	10,546	95	20,090	5,468	79%	10,419	527	1,960	493
	Area 11	2008	Jun–Sep	7,377	23	10,434	2,270	82%	7,440	318	494	54
	Area 11	2009	Jun–Sep	3,277	37	7,582	4,623	62%	3,230	211	884	680
	Area 11	2010	Jun–Sep	3,910	64	5,390	1,575	77%	3,970	230	207	81
	Area 11	2011	Jun–Sep	2,637	20	4,951	3,719	57%	2,617	327	464	327
	Area 11	2009–2010	Feb–Apr	326	3	487	93	84%	322	15	33	2
	Area 11	2010–2011	Feb–Apr	87	3	421	331	56%	80	16	73	48
	Area 12	2010	Feb–Apr	300	--	--	--	50%	--	--	--	--
	Area 12	2011	Feb–Apr	435	--	--	--	65%	--	--	--	--
	Area 13	2009	May–Sep	1,340	--	--	--	86%	--	--	--	--
	Area 13	2010	May–Sep	668	--	--	--	82%	--	--	--	--
	Area 13	2011	May–Sep	1,001	--	--	--	57%	--	--	--	--

[1] Legal-sized Chinook salmon.

[2] IM and drop-off rates same as used in CTC Catch and Escapement report: drop-off (6.9) and IM release rate (12.3).

[3] Estimates for Puget Sound North and Puget Sound Other fisheries were updated with creel values from the Washington State-Tribal Recreational Angling Impacts Database (Accessed September 2013; url not publicly available), with the exception of Area 6 in 2008–2010 and Areas 12 and 13 in all years (these are based on draft WDFW Catch Record Card system estimates). IM rates used for Puget Sound MSFs are those used by WDFW in MSF impact assessments (legal = 10% release + 5% drop off; sublegal = 20%).

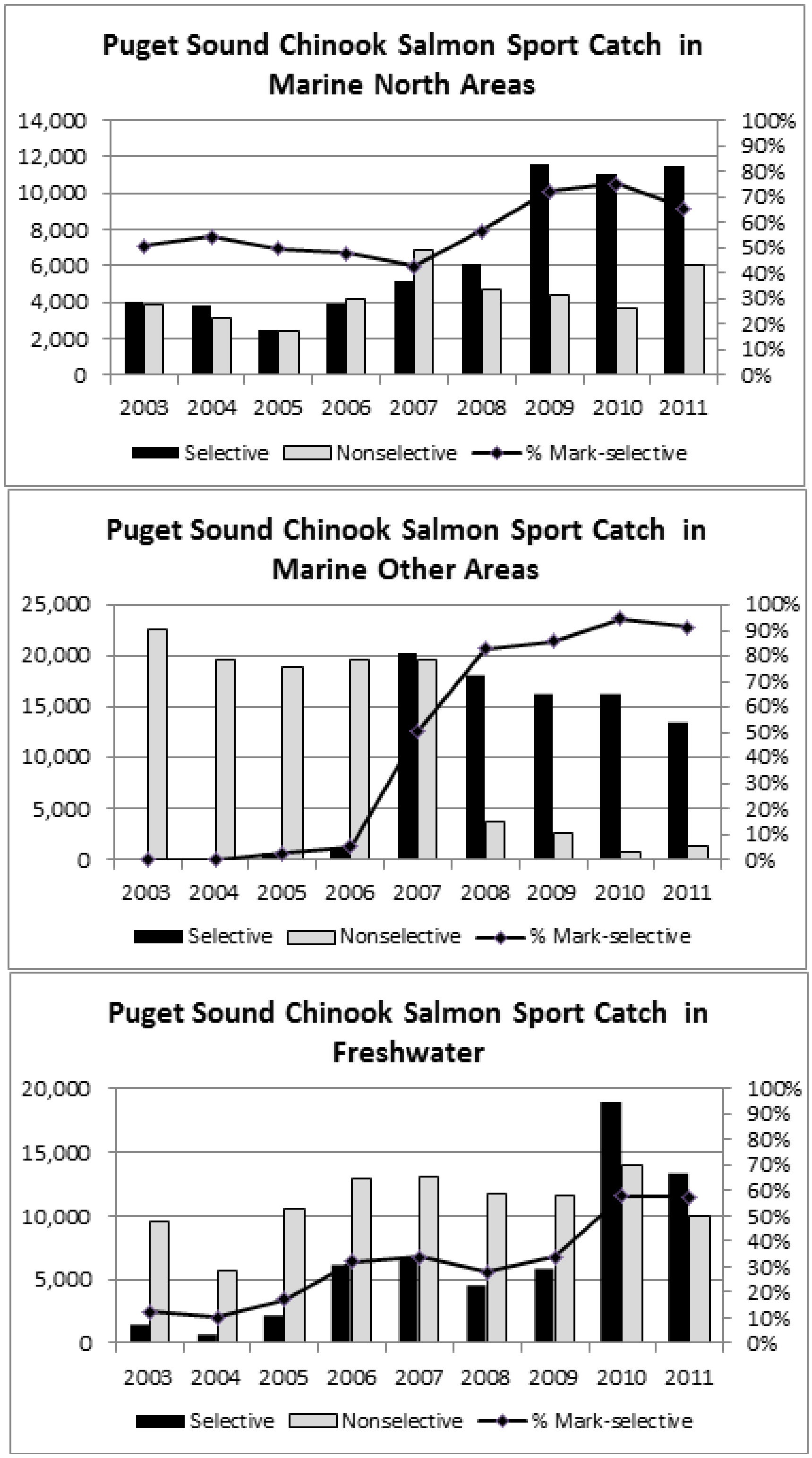

Figure 4.1. Estimated total number of Chinook salmon landed in selective and nonselective fisheries (left y-axis) and % of catch in MSFs (right y-axis) in Puget Sound for catch years 2003–2011.

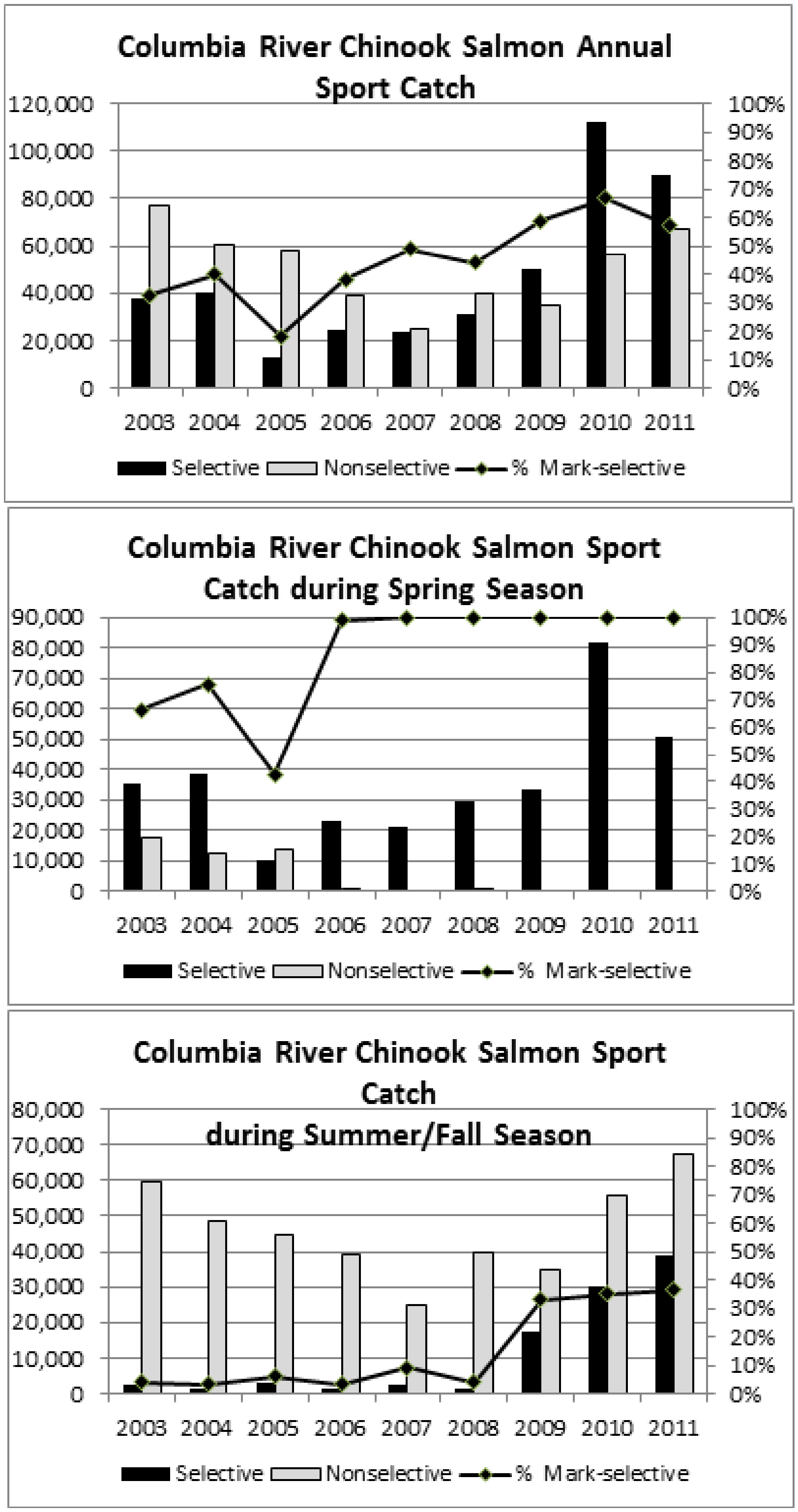

Figure 4.2. Estimated total catch (left y-axis) in Columbia River mark-selective and nonselective sport fisheries and catches during spring (May–June) and summer–fall seasons (Jul–Dec) and % of catch in MSFs (right y-axis) for catch years 2003–2011.

Table 4.3 Total catch (adult salmon) in Puget Sound TERM Sport MSFs for Chinook salmon 2003–2011.

Location	2003	2004	2005	2006	2007	2008	2009	2010	2011
Nooksack River	--	5	168	119	156	14	30	50	72
Skykomish River	127	85	114	145	551	388	131	243[1]	382[1]
Carbon River & Puyallup River	1,292	869	1,879	1,420	2,085	1,534	2,581	466	2,142
Upper Skagit River and Cascade River	--	--	121	590	805	271	96	240[1]	219[1]
Nisqually River	--	--	--	2,209	3,056	1,567	1,174	2,654[1]	2,200[1]
Skokomish River	--	--	--	--	--	--	--	5,631[1]	5,268[1]

Source: Estimates are from the WDFW Catch Record Card system unless noted otherwise.
[1] Estimates are from the WDFW intensive creel study.

4.2 Size of MSFs

The size 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 (Table 4.4). MSFs were first implemented in Puget Sound and on spring stocks in the Columbia River. In Puget Sound a MSF occurred in the summer of 2003 in the Strait of Juan de Fuca and by 2011 had expanded to all areas in Puget Sound (Table 4.2). In 2008, MSFs were implemented in the Columbia River on fall Chinook salmon, in B.C. in the Strait of Juan de Fuca, and in terminal areas of the Oregon coast. The percentage of the total landed, tagged, and marked catch that occurs in MSFs increased over this period for stocks in Puget Sound (Figure 4.3); in 2011 the average was 25.2% and ranged from 3.2–55.1% (Table 4.4).

4.3 Impact of MSFs on unmarked Chinook salmon

PSC indicator stocks that have been double index tagged (DIT) can be used to evaluate the impact of MSFs on the unmarked stocks represented by the unmarked tag group in a DIT pair.[3] The ratio of unmarked to marked fish (λ) for a DIT group provides a relationship between the two tag groups and a measure to evaluate the impact of MSFs on the DIT stock. A comparison of the ratios of unmarked to marked, at release and at escapement, can be used in a test of the null hypothesis of no difference in proportional return of marked and unmarked groups. A positive test statistic occurs when a 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 a 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.

[3] 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.

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.

The ratio of the return proportions between the unmarked and marked tagged groups, or the odds ratio, $\frac{\lambda^{unmarked}}{\lambda^{marked}}$ (Agresti 1984), are methods to statistically compare the DIT groups, where an odds ratio of one indicates that the ratio did not change from release to escapement while an odds ratio larger than one indicates a higher removal of marked fish compared to the DIT unmarked fish, which is assumed to be due to MSFs.

Table 4.4 Estimated landed catch of tagged and marked PSC Chinook Indicator Stocks in B.C., Washington, and Oregon, in all net, troll, and sport fisheries for catch years 2003–2011 and % of total tagged and marked catch landed in MSFs.

REGION	STKNAME	2003		2004		2005		2006		2007		2008		2009		2010		2011	
BRITISH COLUMBIA	Atnarko Spring															1		43	
	Atnarko Summer	149		160		312		299		91		2		329		238		322	
	Big Qualicum	89		114		219		145		214		146	10%	162	2%	155		129	
	Chilliwack (Harrison Fall Stock)	1,258	2%	1,426	1%	1,203	1%	594	1%	379	2%	1,036	4%	699	5%	1,459	6%	994	9%
	Cowichan Fall	218	1%	276	1%	184	2%	174		49		140		280		484	3%	764	7%
	Dome Creek Spring	126		1		161		14		6									
	Nanaimo River Fall	260	3%	254		141	3%	49		441	1%	44		6					
	Nicola River Spring	240		139		101		69		43		68		88	4%	197	4%	97	
	Puntledge Summer	21		26		78		44		57		51		116		123		99	
	Quinsam Fall	202		317		364		282		265		100		141		201		304	
	Robertson Creek	1,161		2,527		2,301		1,749		1,637		831		813		333		1,334	
	Lower Shuswap River Summers	637		607		459		721		127		570		725	0%	858		742	1%
	Chehalis (Harrison Fall Stock)	140	3%	295	3%	262		227		77	2%	509	2%	279	11%	452	7%	586	6%
	Kitsumkalum Summer	182		246		109		108		144		242		168		238		186	
PUGET SOUND	George Adams Fall Fingerling	546	2%	628	6%	910	5%	551	4%	888	10%	468	15%	547	26%	960	18%	1,029	33%
	Green River Fall Fingerling	456	6%	467	3%	305	3%	661	3%	895	6%	721	14%	646	11%	290	19%	473	19%
	Grovers Creek Fall Fingerling	779	7%	747	5%	732	3%	878	6%	814	17%	373	35%	573	24%	591	32%	372	28%
	Nisqually Fall Fingerling	1,149	3%	921	1%	446	2%	1,830	2%	1,891	11%	735	13%	880	14%	1,051	22%	592	26%
	Nooksack Spring Fingerling	215		454		367	2%	326	2%	288	2%	622	6%	311	8%	410	5%	207	5%
	Samish Fall Fingerling	522	0%	354	1%	525	4%	1,307	2%	1,405	3%	1,240	10%	878	11%	1,177	9%	818	4%
	Skagit Spring Fingerling	220	1%	349	1%	401	11%	728	48%	1,221	41%	698	32%	455	33%	705	33%	594	33%
	Skagit Spring Yearling	429	2%	445	2%	470	19%	459	57%	455	54%	352	45%	214	34%	261	55%	337	50%
	Skykomish Fall Fingerling	83	6%	235	6%	202	2%	272	9%	429	4%	143	22%	88	40%	72	27%	189	55%
	South Puget Sound Fall Yearling	5		21		226	7%	208	5%	222	23%	63	42%	114	60%	56	63%	207	51%
	Skagit Summer Fingerling	312	1%	185	2%	311	2%	292	3%	396	1%	453	3%	505	4%	215	1%	285	10%
	Stillaguamish Fall Fingerling	6				120	5%	158	3%	325	0%	376	20%	290	13%	356	13%	426	12%
	White River Spring Fingerling							30	4%	329	23%	52	13%						

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REGION	STKNAME	2003		2004		2005		2006		2007		2008		2009		2010		2011	
WASINGTON COAST	Hoko Fall Fingerling	219		280	2%	239	2%	201	2%	270	2%	127		85	5%	77		210	4%
	Queets Fall Fingerling	935		1,257		1,318		692		488		511		914		1,134		899	
	Sooes Fall Fingerling	356	1%	362	1%	344		161	2%	37		51		159		94	6%	279	2%
COLUMBIA RIVER	Lyons Ferry Yearling	2,834	1%	3,595	2%	3,330	1%	1,723	1%	1,955	2%	1,348	1%	3,203	8%	4,067	3%	3,031	8%
	Cowlitz Fall Tule	301		117	4%	96		54		51		63	5%	129	6%	213	3%	126	2%
	Hanford Wild	643		868		359		325		191		141		201		235		316	
	Columbia Lower River Hatchery	1,063	1%	920	0%	348		45		40		228		335	8%	1,059	4%	445	4%
	Lewis River Wild	204		353		190		352		112		41		81		51		156	5%
	Lyons Ferry	183		78		137	5%	106		101		636	0%	595	1%	1,563	8%	1,133	5%
	Spring Creek Tule	3,259	0%	3,078	0%	1,408		472	1%	572	2%	1,454	2%	1,268	5%	2,604	2%	1,542	3%
	Columbia Summers	4,241	0%	3,882	0%	4,217		2,548	0%	2,672	1%	2,539	0%	2,110	6%	3,333	4%	2,382	20%
	Upriver Brights	1,054		995	0%	1,493		931	0%	334		419		738	1%	662		1,617	2%
	Willamette Spring	1,325	30%	2,051	44%	761	29%	694	42%	423	52%	849	33%	1,403	52%	4,130	62%	3,866	82%
OREGON	Elk River	2,423		2,530		1,257		1,384		1,320		1,425		991	0%	1,225	0%	959	0%
	Salmon River	2,746		2,906		3,144		1,439		516		766		1,407	2%	2,448		2,743	

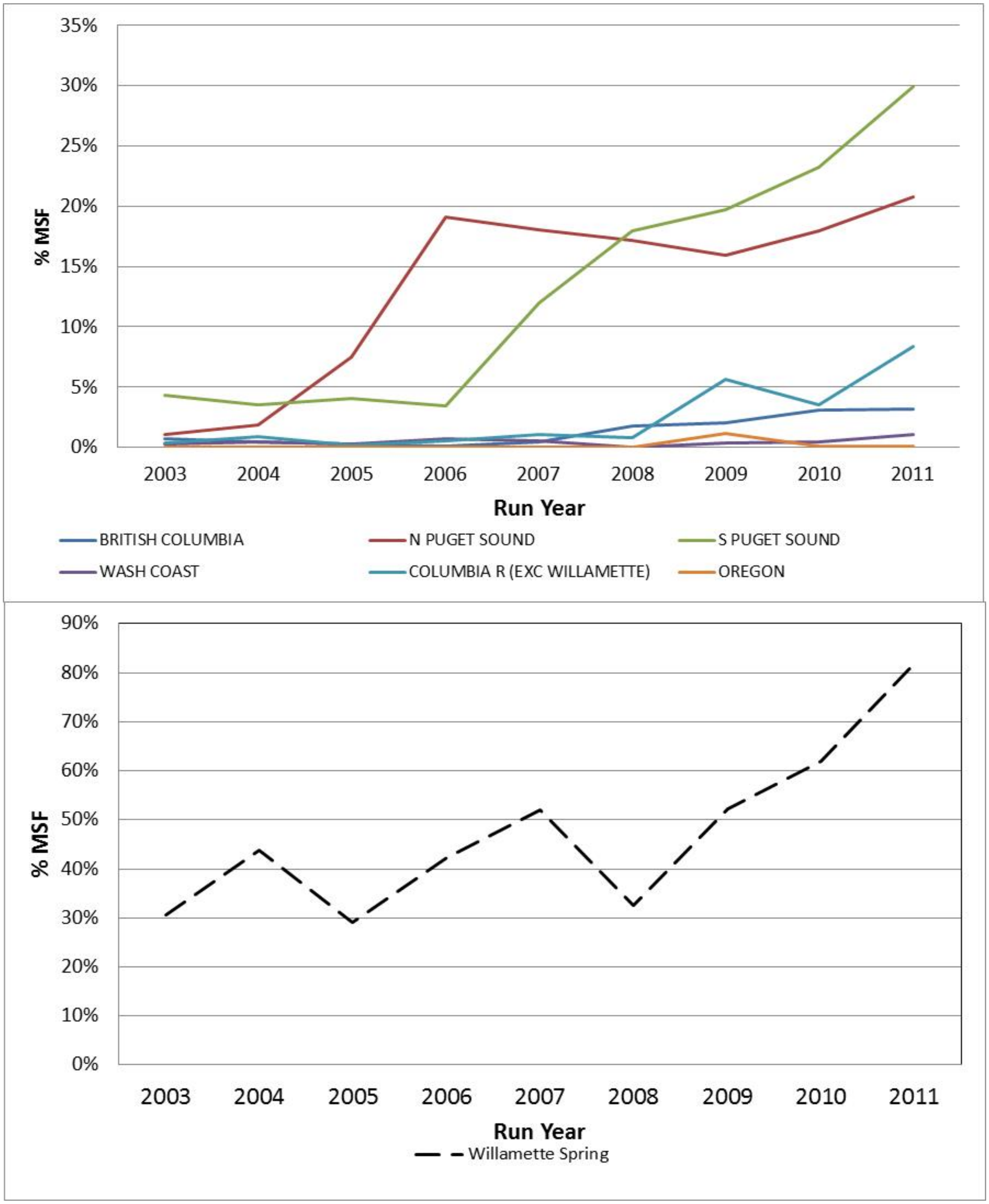

Figure 4.3. Percent of total fishery CWT recoveries in MSFs for run years 2003–2011 for Chinook salmon indicator stocks, by region of origin.

Among the DIT stocks examined in Table 4.5, MSF impacts have been statistically identified more often for recent BYs, except for BY 2009, from which only age-2 fish had matured at the time of analysis (Figure 4.4). There is double index tagging for several Puget Sound indicator stocks, where MSFs have been ongoing since 2003. The comparison of the proportion of marked and unmarked DIT groups returning were not significant for BYs before 2002 for Puget Sound stocks (Table 4.5). For Puget Sound DIT stocks, Skagit Springs (SKS), Skykomish (SKY), Green River (SPS) and Nisqually (NIS) show significant differences in four or more years. All these Puget Sound DIT stocks except the Green River are subject to terminal sport MSFs which target the hatchery production including the DIT returns. When releases and recoveries are summed over North and South Puget Sound DIT stocks the odds ratio is significantly larger than one for BYs 2001–2009 (Figure 4.5) which all have at least 2 ages returning in years with MSFs. The temporal pattern of the odds ratio for the Puget Sound stocks (Figure 4.5) shows that unmarked fish have returned at higher rates than marked fish over the recent time series, presumably due to MSF impacts.

Two Columbia River stocks have DIT: Big Creek for the Lower River Hatchery stock (LRH) and Spring Creek Tule (SPR). The Big Creek stock shows significantly higher return of unmarked fish for 2007 and 2009, but this stock had not been a DIT stock in earlier years. The MSF impacts (Table 4.4) have all occurred in Washington Area 5 and Washington coastal MSFs for this group. The results for the Spring Creek Tules show a negative significant impact indicating fewer unmarked fish returning to the hatchery in two years. This may be due to a problem with the assumptions of the DIT program (e.g., both marked and unmarked tagged groups are identical except for the mark, equal survival) or due to sampling problems in the hatchery.

In British Columbia, the Chilliwack River stock is only subject to preterminal MSFs in U.S. marine areas around Puget Sound and in U.S. and Canadian MSFs in Juan de Fuca Strait. There are no terminal MSFs targeting this stock in Canadian marine or freshwater areas. Four brood have significant results, but two of these had significantly higher returns of unmarked fish, possibly indicating either problems with sampling or assumptions.

Table 4.5 Results for hypothesis test (Ho: No difference in proportion of release of marked and unmarked DIT groups returning to hatchery) by stocks and BYs where DIT data are available.

Stock		Brood Year	Signature?	Unmarked			Marked								
				Ret	Rel	Prop. Ret	Ret	Rel	Prop. Ret	λ rel	λ esc	Odds Ratio	Oldest age in brood	Z-statistic for H(o) of no impact[1]	p(0.05)
COLUMBIA RIVER	LRH	2006		82	221,861	0.00037	92	222,476	0.00041	0.9972	0.8955	0.8979	5	–0.70	0.48
		2007	Y	414	226,752	0.00182	285	227,193	0.00125	0.9981	1.4517	1.4545	4	4.86	0.00
		2009	Y	362	225,203	0.00161	256	225,945	0.00113	0.9967	1.4163	1.4210	2	4.28	0.00
	SPR	2004		95	429,068	0.00022	88	447,881	0.00020	0.9580	1.0849	1.1324	5	0.82	0.41
		2005		1,130	446,416	0.00253	1,210	442,908	0.00273	1.0079	0.9344	0.9270	5	–1.15	0.25
		2006		288	446,241	0.00064	314	446,377	0.00070	0.9997	0.9165	0.9167	5	–0.62	0.53
		2007	Y	755	445,588	0.00552	1,604	445,962	0.01211	2.9970	1.3963	1.3973	4	–4.47	0.00
		2008	Y	495	439,989	0.00227	585	359,893	0.00325	2.4452	1.7073	1.4579	3	–2.30	0.02
BRITISH COLUMBIA	CHI	1998	Y	145	98,926	0.00150	301	98,095	0.00310	1.0080	0.4810	0.4772	5	–7.44	0.00
		1999	Y	403	96,193	0.00420	347	97,903	0.00350	0.9830	1.1610	1.1811	5	2.29	0.02
		2000		170	100,056	0.00170	168	99,766	0.00170	1.0030	1.0110	1.0080	5	0.08	0.94
		2001		230	97,227	0.00240	260	99,171	0.00260	0.9800	0.8850	0.9031	5	–1.13	0.26
		2002	Y	182	99,657	0.00180	232	100,036	0.00230	0.9960	0.7830	0.7861	5	–2.45	0.01
		2003		215	48,344	0.00440	239	48,242	0.00490	1.0020	0.9000	0.8982	5	–1.14	0.25
		2004		126	100,557	0.00130	154	100,023	0.00150	1.0050	0.8230	0.8189	5	–1.67	0.09
		2005	Y	1,116	89,159	0.01250	984	87,801	0.01120	1.0150	1.1350	1.1182	5	2.55	0.01
		2006		109	96,305	0.00110	86	95,382	0.00090	1.0100	1.2670	1.2545	4	1.58	0.11
		2007		866	99,632	0.00870	871	99,465	0.00880	1.0020	0.9940	0.9920	3	–0.15	0.88
		2008		175	99,944	0.00180	168	99,451	0.00170	1.0050	1.0420	1.0368	2	0.33	0.74
N PUGET SOUND	NSF	1998		772	168,574	0.00458	699	167,136	0.00419	1.0086	1.1043	1.0949	5	0.77	0.44
		1999		387	200,294	0.00193	509	198,085	0.00257	1.0112	0.7589	0.7505	5	–1.96	0.05
		2000		213	199,511	0.00107	199	197,364	0.00101	1.0109	1.0728	1.0613	5	0.38	0.71
		2001	Y	336	98,860	0.00339	406	97,528	0.00416	1.0137	0.8268	0.8157	5	–2.68	0.01
		2002		24	206,479	0.00012	27	203,675	0.00013	1.0138	0.8891	0.8770	5	–0.47	0.64
		2003		79	198,270	0.00040	76	202,184	0.00037	0.9806	1.0415	1.0620	5	0.37	0.71
		2004		46	185,400	0.00025	30	179,380	0.00016	1.0336	1.5530	1.5026	5	1.73	0.08
		2005		228	204,021	0.00112	210	203,918	0.00103	1.0005	1.0820	1.0814	5	0.81	0.42
		2006		41	134,773	0.00031	28	143,841	0.00020	0.9370	1.4587	1.5568	5	1.81	0.07
		2007		207	206,670	0.00100	170	206,867	0.00082	0.9990	1.2190	1.2201	4	1.92	0.05
		2008		112	175,656	0.00064	90	171,083	0.00052	1.0267	1.2471	1.2147	3	1.37	0.17
		2009		9	197,619	0.00005	10	195,706	0.00005	1.0098	0.9001	0.8914	2	–0.25	0.80
	SAM	1998		831	198,241	0.00419	953	196,029	0.00486	1.0113	0.8719	0.8622	5	–1.72	0.09

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Table 4.5 *Page 2 of 4.*

Stock		Brood Year	Signature?	Unmarked			Marked			λ rel	λ esc	Odds Ratio	Oldest age in brood	Z–statistic for H(o) of no impact	p(0.05)
				Ret	Rel	Prop. Ret	Ret	Rel	Prop. Ret						
N PUGET SOUND (cont)	SAM (cont)	1999		311	177,940	0.00175	276	168,423	0.00164	1.0565	1.1258	1.0655	5	0.39	0.70
		2000	Y	65	149,187	0.00043	112	146,129	0.00077	1.0209	0.5787	0.5669	5	–2.51	0.01
		2001	Y	176	169,452	0.00104	96	173,971	0.00055	0.9740	1.8385	1.8876	5	2.70	0.01
		2002		137	199,133	0.00069	135	197,111	0.00068	1.0103	1.0139	1.0036	5	0.02	0.98
		2003		330	195,566	0.00169	331	200,153	0.00165	0.9771	0.9973	1.0207	5	0.20	0.84
		2004		189	201,803	0.00094	209	196,576	0.00106	1.0266	0.9039	0.8805	5	–0.94	0.35
		2005		802	182,920	0.00438	778	201,655	0.00386	0.9071	1.0307	1.1362	5	1.65	0.10
		2006		270	205,708	0.00131	223	206,496	0.00108	0.9962	1.2089	1.2135	5	1.37	0.17
		2007		871	216,849	0.00402	741	211,571	0.00350	1.0249	1.1747	1.1462	4	1.27	0.21
		2008		140	201,990	0.00069	133	201,764	0.00066	1.0011	1.0531	1.0519	3	0.42	0.68
		2009	Y	220	203,497	0.00108	170	202,005	0.00084	1.0074	1.2976	1.2881	2	2.47	0.01
	SKS	1998		77	67,098	0.00115	77	65,619	0.00118	1.0225	0.9990	0.9769	5	–0.08	0.94
		1999		857	72,629	0.01180	816	71,246	0.01146	1.0194	1.0500	1.0300	5	0.55	0.59
		2000		780	73,356	0.01063	778	74,091	0.01050	0.9901	1.0026	1.0126	5	0.25	0.80
		2001		649	72,996	0.00890	620	76,520	0.00811	0.9539	1.0471	1.0976	5	1.66	0.10
		2002	Y	561	60,000	0.00935	436	59,777	0.00730	1.0037	1.2866	1.2819	5	3.92	0.00
		2003	Y	340	75,418	0.00451	243	74,590	0.00326	1.0111	1.3971	1.3818	5	3.86	0.00
		2004	Y	720	71,942	0.01001	466	73,668	0.00633	0.9766	1.5431	1.5801	5	7.71	0.00
		2005	Y	121	74,467	0.00163	88	74,633	0.00118	0.9978	1.3767	1.3798	5	2.30	0.02
		2006	Y	216	66,540	0.00325	186	70,079	0.00265	0.9495	1.1631	1.2249	5	2.02	0.04
		2007	Y	247	58,614	0.00422	192	58,502	0.00328	1.0019	1.2897	1.2872	4	2.62	0.01
		2008	Y	161	75,683	0.00212	92	76,752	0.00120	0.9861	1.7473	1.7720	3	4.41	0.00
	SKY	2000		389	209,520	0.00186	358	205,008	0.00175	1.0220	1.0876	1.0642	5	0.78	0.43
		2001		243	197,946	0.00123	245	196,023	0.00125	1.0098	0.9935	0.9839	5	–0.17	0.86
		2002	Y	408	197,105	0.00207	325	195,075	0.00167	1.0104	1.2549	1.2420	5	2.83	0.00
		2003	Y	469	173,116	0.00271	416	176,427	0.00236	0.9812	1.1277	1.1493	5	1.99	0.05
		2004	Y	966	199,529	0.00484	814	200,398	0.00406	0.9957	1.1861	1.1913	5	3.51	0.00
		2005		239	206,091	0.00116	204	204,637	0.00100	1.0071	1.1735	1.1652	5	1.54	0.12
		2006		297	206,362	0.00144	290	205,344	0.00141	1.0050	1.0235	1.0185	5	0.21	0.83
		2007		250	199,678	0.00125	222	199,858	0.00111	0.9991	1.1287	1.1297	4	1.29	0.20
		2008		136	202,000	0.00068	122	201,196	0.00061	1.0040	1.1190	1.1145	3	0.85	0.39
		2009		1	200,265	0.00000	4	201,000	0.00002	0.9963	0.2475	0.2484	2	–1.35	0.18
		2008		136	202,000	0.00068	122	201,196	0.00061	1.0040	1.1190	1.1145	3	0.85	0.39
		2009		1	200,265	0.00000	4	201,000	0.00002	0.9963	0.2475	0.2484	2	–1.35	0.18

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Table 4.5 Page 3 of 4.

Stock		Brood Year	Signature?	Unmarked			Marked			λ rel	λ esc	Odds Ratio	Oldest age in brood	Z–statistic for H(o) of no impact	p(0.05)
				Ret	Rel	Prop. Ret	Ret	Rel	Prop. Ret						
S PUGET SOUND	GAD	1998		700	224,228	0.00312	677	223,343	0.00303	1.0040	1.0338	1.0297	5	0.54	0.59
		1999		501	218,728	0.00229	446	208,330	0.00214	1.0499	1.1234	1.0700	5	1.04	0.30
		2000		508	225,071	0.00226	480	223,009	0.00215	1.0092	1.0586	1.0489	5	0.75	0.45
		2001		493	210,039	0.00235	509	223,933	0.00227	0.9380	0.9683	1.0324	5	0.50	0.62
		2002		912	208,727	0.00437	859	209,531	0.00410	0.9962	1.0618	1.0659	5	1.33	0.18
		2003	Y	601	223,637	0.00269	508	224,905	0.00226	0.9944	1.1815	1.1882	5	2.79	0.01
		2004		307	223,927	0.00137	280	224,882	0.00124	0.9958	1.0993	1.1040	5	1.16	0.25
		2005	Y	1,412	225,257	0.00627	1,224	225,216	0.00543	1.0002	1.1539	1.1537	5	3.54	0.00
		2006		478	225,937	0.00212	418	215,124	0.00194	1.0503	1.1451	1.0903	5	1.26	0.21
		2007	Y	1,912	221,008	0.00865	1,546	219,881	0.00703	1.0051	1.2367	1.2303	4	6.04	0.00
		2008	Y	352	225,942	0.00156	287	226,985	0.00126	0.9954	1.2253	1.2309	3	2.60	0.01
		2009		793	227,548	0.00348	726	227,151	0.00319	1.0017	1.0927	1.0908	2	1.68	0.09
	GRN	1997		124	204,024	0.00061	129	203,028	0.00064	1.0049	0.9597	0.9550	5	–0.37	0.71
		1998		644	197,824	0.00326	592	188,118	0.00315	1.0516	1.0881	1.0348	5	0.60	0.55
		1999		273	197,889	0.00138	264	193,300	0.00137	1.0237	1.0329	1.0090	5	0.10	0.92
		2000		223	202,658	0.00110	197	194,248	0.00101	1.0433	1.1314	1.0844	5	0.82	0.41
		2001	Y	108	162,160	0.00066	88	178,119	0.00049	0.9104	1.2296	1.3506	5	2.08	0.04
		2002	Y	493	198,321	0.00248	550	192,443	0.00286	1.0305	0.8957	0.8692	5	–2.26	0.02
		2003		282	197,541	0.00143	246	197,726	0.00125	0.9991	1.1433	1.1444	5	1.54	0.12
		2004	Y	578	204,269	0.00283	507	204,698	0.00248	0.9979	1.1381	1.1404	5	2.14	0.03
		2005	Y	948	198,542	0.00477	823	196,353	0.00419	1.0111	1.1519	1.1392	5	2.70	0.01
		2006	Y	427	204,385	0.00209	365	204,795	0.00178	0.9980	1.1700	1.1723	5	2.19	0.03
		2007	Y	809	202,635	0.00399	671	202,671	0.00331	0.9998	1.2051	1.2053	4	3.53	0.00
		2008		75	212,303	0.00035	81	201,409	0.00040	1.0541	0.9228	0.8755	3	–0.82	0.41
		2009		37	199,610	0.00018	39	195,191	0.00020	1.0226	0.9460	0.9250	2	–0.34	0.74
	GRO	1999		1,219	180,536	0.00675	1,141	181,132	0.00630	0.9967	1.0686	1.0721	5	1.69	0.09
		2000		693	206,563	0.00336	647	203,754	0.00318	1.0138	1.0703	1.0558	5	0.99	0.32
		2001		532	203,840	0.00261	486	203,509	0.00239	1.0016	1.0943	1.0925	5	1.41	0.16
		2002		875	194,233	0.00451	851	198,987	0.00428	0.9761	1.0291	1.0543	5	1.10	0.27
		2003	Y	1,431	151,492	0.00945	1,348	163,799	0.00823	0.9249	1.0620	1.1483	5	3.65	0.00
		2004	Y	1,133	133,455	0.00849	872	118,197	0.00738	1.1291	1.2987	1.1502	5	3.06	0.00
		2005	Y	1,136	169,954	0.00668	1,084	136,519	0.00794	1.2449	1.0476	0.8415	5	–3.74	0.00
		2006		875	185,397	0.00472	862	185,975	0.00464	0.9969	1.0144	1.0176	5	0.34	0.74

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Table 4.5 Page 4 of 4.

Stock		Brood Year	Signature?	Unmarked			Marked								
				Ret	Rel	Prop. Ret	Ret	Rel	Prop. Ret	λ rel	λ esc	Odds Ratio	Oldest age in brood	Z–statistic for H(o) of no impact	p(0.05)
S PUGET SOUND (cont)	GRO (cont)	2007		1,928	199,622	0.00966	1,955	199,251	0.00981	1.0019	0.9861	0.9843	4	–0.47	0.64
		2008		391	200,006	0.00195	348	186,978	0.00186	1.0697	1.1226	1.0494	3	0.64	0.52
		2009		359	193,417	0.00186	327	200,431	0.00163	0.9650	1.0975	1.1373	2	1.67	0.10
	NIS	1998	Y	668	192,165	0.00348	485	202,103	0.00240	0.9508	1.3766	1.4478	5	6.00	0.00
		1999		508	194,985	0.00260	486	199,030	0.00244	0.9797	1.0449	1.0666	5	1.01	0.31
		2000		590	174,625	0.00678	585	169,143	0.00698	2.0710	2.0127	1.9451	5	–0.69	0.49
		2001		403	214,059	0.00376	368	214,490	0.00343	1.9962	2.1797	2.1859	5	1.71	0.09
		2002	Y	1,071	192,248	0.01113	808	180,294	0.00897	2.1341	2.6494	2.4876	5	6.50	0.00
		2003	Y	1,235	203,624	0.00607	1,096	207,975	0.00527	0.9791	1.1273	1.1513	5	3.30	0.00
		2004	Y	1,102	209,905	0.00525	924	208,724	0.00443	1.0057	1.1931	1.1864	5	3.71	0.00
		2005	Y	675	127,293	0.00530	512	120,154	0.00426	1.0594	1.3194	1.2454	5	3.61	0.00
		2006	Y	445	204,613	0.00217	352	204,221	0.00173	1.0019	1.2630	1.2606	5	2.93	0.00
		2007	Y	1,435	179,625	0.00799	1,229	180,974	0.00679	0.9925	1.1677	1.1765	4	3.88	0.00
		2008	Y	357	206,098	0.00173	291	206,480	0.00141	0.9981	1.2264	1.2287	3	2.49	0.01
		2009		259	201,544	0.00128	244	201,099	0.00121	1.0022	1.0608	1.0585	2	0.62	0.53

[1] A positive Z-statistic indicates that more unmarked fish returned than marked while negative Z-statistics indicate that the return proportion was greater for marked groups than for unmarked groups.

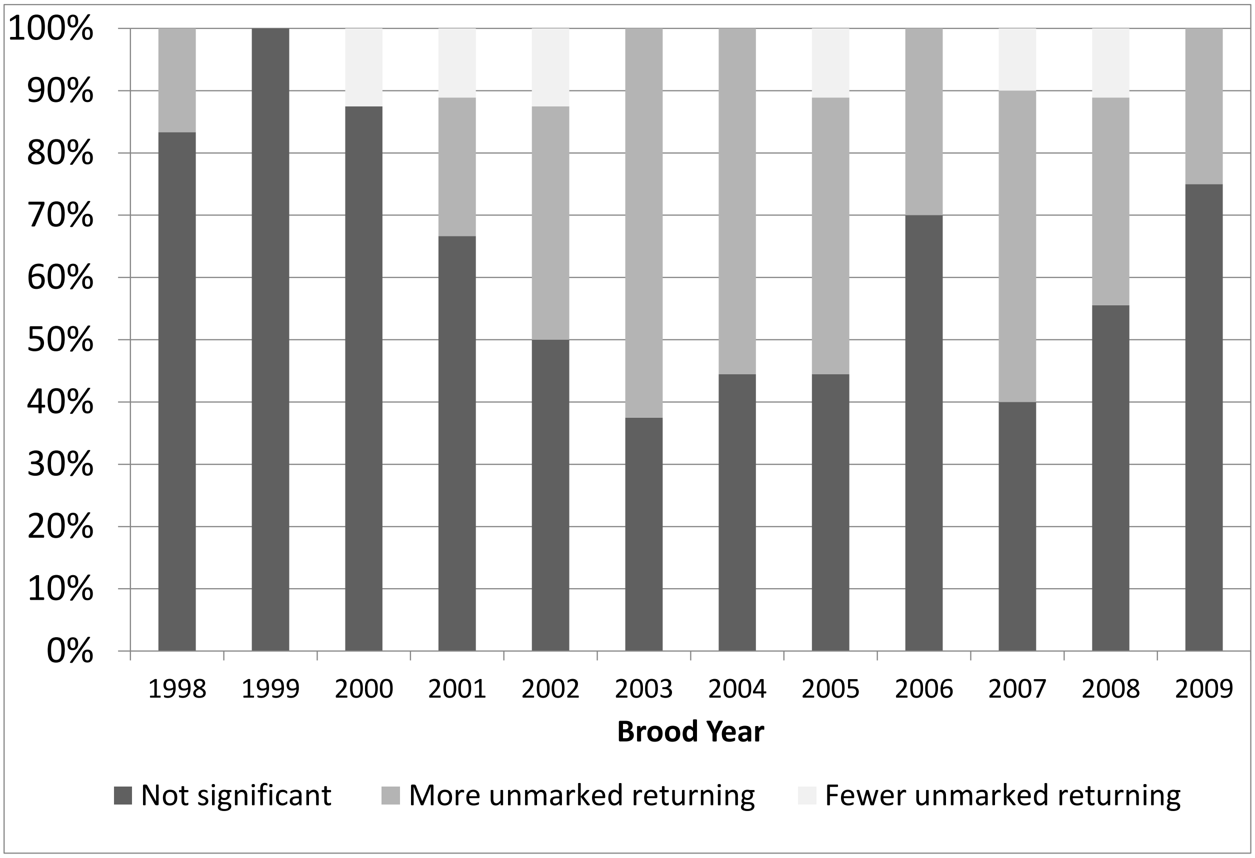

Figure 4.4 The percentage of DIT stock statistical test results reported in Table 4 and Table 5 that compare the lambdas at release and escapement by BY. Test results were grouped as showing no significant difference, significantly fewer marked fish returning, or significantly fewer unmarked fish returning.

Note: 2001 is the first BY for which all ages were exposed to MSFs; recoveries for BY 2009 are for age-2 fish only.

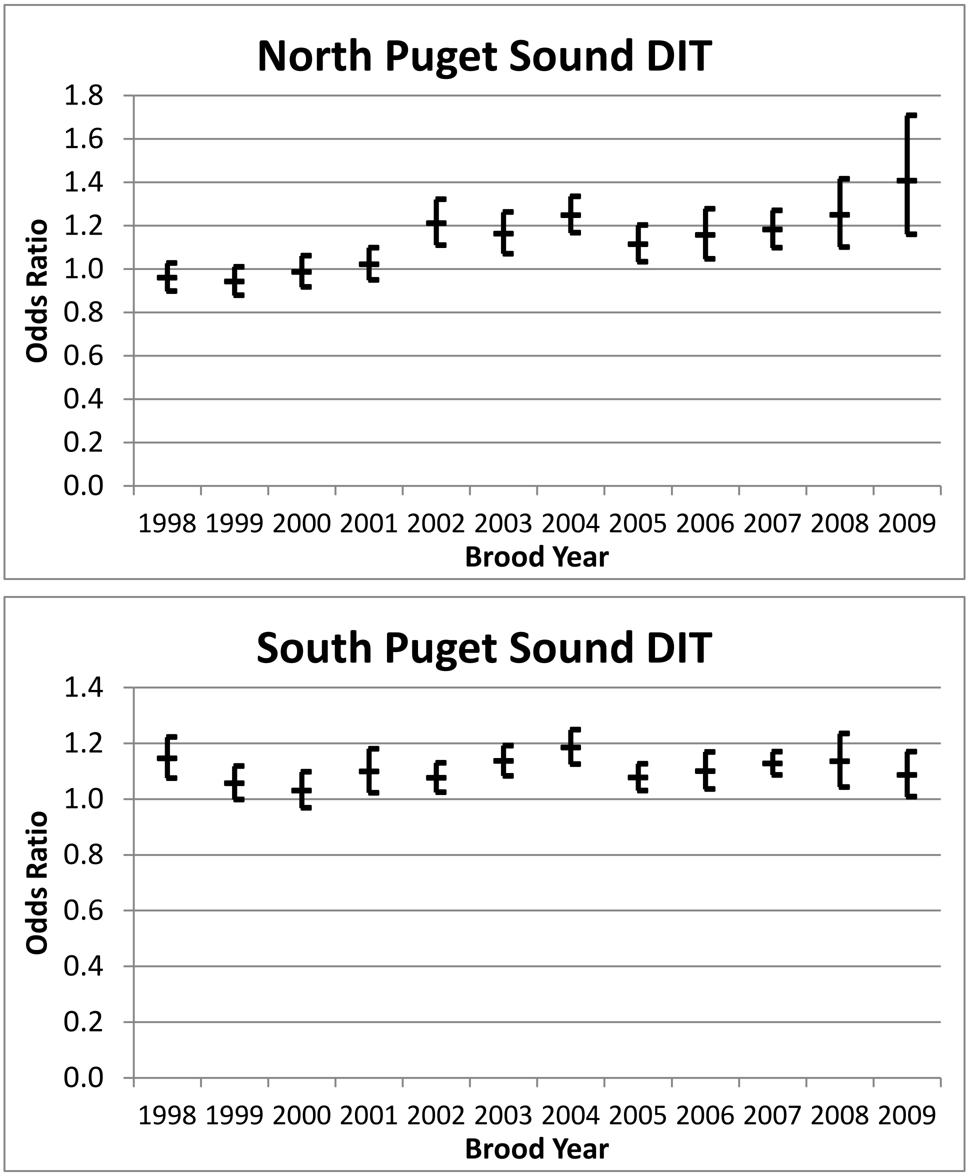

Figure 4.5. Estimated odds ratios (+/–95% confidence interval) for Puget Sound Chinook salmon DIT stocks combined.

Note: 2001 is the first BY for which all ages were exposed to MSFs; recoveries for the most recent BY are for age-2 fish only.

5 PROGRESS REPORT ON IMPROVEMENTS TO THE COASTWIDE CWT PROGRAM

5.1 Background

The Chinook chapter of Annex IV of the 2009 PST Agreement provides a directive for a Coded Wire Tag Improvement Program (CWTIP) in paragraph 3(b) as follows:

> "… to provide $7.5 million each in their respective currencies (subject to the availability of funds) to implement over a five year period beginning no later than 2010 within their respective jurisdictions critical improvements to the coastwide coded wire tagging program operated by their respective management agencies."

The Commission established a bilateral Coded Wire Tag Improvement Team (CWTIT) in November of 2009 to provide annual recommendations to the Commission and the Parties and to implement improvements as identified in the PSC Technical Report Number 25 (PSC 2008). Although Parties prioritize actions based on their specific requirements to improve the precision and accuracy of statistics used by the CTC in support of the Chinook management regime, the CWTIT also performs a coordination role to optimize the benefits of the CWT programs operated in the various jurisdictions through an annual workshop and other coordination activities.

The CWTIT is required to report annually to the Commission each January and to document progress to date in the annual CTC reports. The results for past funding (2009–2011) are reported in CTC (2012a, 2012b, and 2013). The format for reporting has been changed this cycle. A summary of the CWTIP to date is provided here, along with projects that were approved for funding in 2013. Details for individual projects, including description, cost, accomplishments, and benefits, is provided for each project funded in 2012 in Appendix L.

Canada implemented the program in 2009, a year earlier than the U.S., due to differences in the timing of fiscal year cycles. The final year of funding for this initiative in Canada is scheduled for 2013–2014 and in the U.S. through 2014–2015. Total expenditures by the Parties are reported in Table 5.1 according to issues identified in PSC Technical Report 25 (PSC 2008). The projects in Table 5.1 follow general improvements in CWT tagging or sampling and harvest or escapement estimation, and/or improvements in data coordination and reporting.

Canada has invested close to $1.5 million annually on a total of 57 individual projects. The majority of investment has occurred on multiyear projects for improvements to CWT tagging, sampling, harvest and escapement estimation. The U.S. has invested $1.5 million annually on a total of 37 individual projects. Like Canada, the majority has been spent on similar improvements, as well as a portion of funding for major upgrades to the CWT reporting systems in Oregon and Washington, and minor upgrades to the same in Alaska.

In addition to funding provided by the Parties, Northwest Marine Technology, Inc. has worked with agencies to defray costs of increasing tagging levels, and to reduce costs and improve availability of equipment, such as CWT detectors. The objective of these measures is to reduce uncertainties about CWT-derived statistics.

Table 5.1 Regional priority and total investment 2009–2012 in issues identified in PSC Technical Report 25 (PSC 2008).

		Canada			US		
Issue #	**PSC Technical Report 25 Issue**	**Priority TR 25[1]**	**Total Funding**	**% Funding**	**Priority TR 25[1]**	**Total Funding**	**% Funding**
CWT Tagging and Sampling							
1	Representation of Production Regions	H	$623,761	10.5%		$829,217	18.4%
2	Determination of Tagging Levels	M-H	$1,885,099	31.8%		$109,160	2.4%
3	Representation o f Hatchery Production	L	$5,500	0.1%		$124,349	2.8%
4	Low Sampling Rates in Terminal Fisheries	M_H	$482,420	8.1%		$389,313	8.7%
5	Low Sample Rates in Escapements	L-M	$339,390	5.7%		$5,628	0.1%
6	Uncertainty in Estimates of Escapement or Catch	L-H	$359,370	6.1%		$124,992	2.8%
7	Low Sample Rates in Highly Mixed Stock Fisheries	L-M	$324,020	5.5%		$1,219,115	27.1%
8	Uncertainty in Estimates of Catch in Mixed Stock Fisheries	M-H	$286,600	4.8%		$14,843	0.3%
9	Non-representative Sampling	M-H	$267,530	4.5%		$111,604	2.5%
10	Incomplete Coverage of Fisheries or Escapement	L-M	$460,645	7.8%		$111,184	2.5%
11	Voluntary Sport Fishery Sampling Programs	H	$293,860	5.0%		$0	0.0%
12	Sampling to Facilitate MSF Evaluations	L	$73,250	1.2%		$155,792	3.5%
	Subtotal		**$5,401,445**			**$3,195,196**	
Data Coordination and Reporting							
13	Timeliness of Reporting	H	$154,700	2.6%		$433,615	9.6%
14	Incomplete/No Exchange of CWT Data		$122,600	2.1%		$258,165	5.7%
15	Inter/Intra Agency Coordination	M	$104,300	1.8%		$82,775	1.8%
16	Unclear Authority to Enforce/Establish Protocols		$0	0.0%		$0	0.0%
17	Updating CWT Data is Difficult/Cannot Be Tracked		$70,000	1.2%		$124,716	2.8%
18	Validation is Inadequate For Current Uses of CWT Data		$70,000	1.2%		$142,937	3.2%
19	Lack of Formal Designation of RMPC as US Public Database & Lack of Adequate Funding Support		$0	0.0%		$115,444	2.6%
DTT	Funding Guidance		$0	0.0%		$141,586	3.2%
	Subtotal		**$521,600**			**$1,299,237**	
	2009–2012 Total		**$5,923,045**			**$4,494,433**	

[1] The Canadian summary is for four years and the U.S. summary is for three years. Issue priority: L = low, M = medium, H = high.

5.2 Benefits and Performance of CWT Improvements to Date

Some individual projects listed in Table 5.1 may address multiple issues. This is due the relationship of the multiple issues in three general categories identified in PSC Technical Report 25 (PSC 2008). The anticipated results of CWTIT-funded projects can be usefully categorized as legacy, operational, and data improvements.

Legacy projects are those that will provide lasting improvements to ongoing database and reporting issues, reduce costs, or improve efficiencies. Examples of legacy projects include the following.

1. Fisheries and Oceans Canada (DFO) Salmonid Enhancement Program (SEP) database improvements: This project will improve CWT data coordination and reporting procedures, and develop a formal set of Best Practices for the coordination (collection, transfer and management) of CWT Chinook heads and data at all DFO escapement projects. Archived escapement data from DFO enhancement programs are being reviewed to ensure that standardized analytical techniques and data verification procedures have been employed.
2. DFO Mark–Recovery Program (MRP) database and data exchange improvements: DFO has made significant progress in reviewing and converting the legacy FORTRAN system to current technology and improving interfaces within DFO reporting systems (e.g., hatcheries system, catch monitoring system, and escapement systems). The query interface has also been updated for increased speed and end-user versatility. These projects will provide lasting benefits for reconciling timeliness and access to information for data exchange in the Regional Mark Information Centre. Data improvements include clarified techniques for validation and corrections to data and historical algorithms.
3. Improvements to the DFO Fisheries Operating System (FOS) commercial database: This will establish standard protocols for reporting and will improve timeliness of reporting and availability of final commercial catch estimates including test fishing data.
4. Updating and integration of Oregon's computer programs: This will improve the consistency, timeliness, and accuracy of CWT data reporting.
5. Updating several aspects of Washington's CWT reporting system: This will improve the consistency, timeliness, data retrieval and accuracy of CWT data reporting.
6. Development of a Decision-Theoretic Tool: This tool will be used for planning individual or multiple CWT improvement programs (e.g., tagging, sampling, catch/escapement estimation).
7. Equipment such as CWT detectors and microscopes will be purchased new or replaced.
8. Developing indirect methods to estimate CWT recoveries, by age and stock in freshwater sport fisheries from the three-year study in Puget Sound: This will provide the basis to refine past and future estimation.

Operational projects are of three general types: projects to maintain existing capabilities; projects that reduce costs of sampling, processing, or reporting CWT data or improving the timeliness of availability; and projects that evaluate the feasibility of developing and applying new estimation methods. Examples of operational projects include the following.

1. Increasing coverage and sampling of terminal fisheries (e.g., Central Coast marine and fresh water sport, Strait of Georgia marine sport, Chilliwack River sport and Lower Fraser First Nations fisheries) will result in increased accuracy and precision of exploitation rate estimation for CWT indicator stocks.
2. Increased effort in monitoring and sampling indicator escapement programs will result in increased accuracy and precision of indicator cohort abundance, survival rates, and exploitation rates.
3. Mark–Recovery Program (MRP), Fisheries Operating System (FOS), and Salmonid Enhancement Program (SEP) database improvements will provide more timely and accurate reporting of CWT data and access to data required for assessing fishery impacts.
4. Surrogate (indirect) data methods will be used to estimate CWT recoveries in sport fisheries.
5. The use of detection wands in SEAK will reduce freight and CWT lab storage and processing costs by not shipping heads from adipose-clipped salmon without CWTs.

It has been difficult at times to separate improvement projects from programs conducted by agencies using other core funding because of the close association and need of multiple funding sources. For example, in Canada some CWTIT projects were developed to estimate costs and quality of information that would result from the redesign of CWT sampling programs. In the U.S., operational projects have included funding provided to address the loss of funding from *Anadromous Fish Act* grants for CWT sampling in Washington and Oregon. Operational projects have also included projects to evaluate the feasibility of methods to reduce costs or improve the timelines of providing CWT data.

Data Improvement projects involve indicator stock tagging and sampling programs to fill information gaps. The full realization of the improvements resulting from these types of CWT projects depends upon the availability of funding beyond the anticipated end of the CWTIT program. Examples of such projects include increased representation of production regions by indicator systems (e.g., Fraser River, Philips River south coast mainland inlets, Atnarko River central coast B.C., Oregon coastal stocks, and Southeast Alaska stocks). For indicator stock programs, some of the data produced by CWTIP projects will not become available until after the anticipated end of CWTIP funding (Table 5.2). CWTs from augmented CWT releases were encountered in two-year-old Chinook in fishery and escapement sampling programs in 2011, but all possible marine ages will not be represented until at least 2015 or later (Table 5.2). A more detailed analysis of the impacts of the increased CWT releases will be provided in a future year.

Annual program review by CWTIT provides a means to monitor and evaluate the status of the CWT program. The CWTIP has improved communication and collaboration among agencies. CWTIT workshops have provided opportunities for agency staff involved in all aspects of the

CWT program (i.e., tagging, monitoring, analysis, data management, etc.) to share information and expertise to improve the CWT program through the exchange of information, discussion of issues, and experience.

Table 5.2 Year of incremental tag application and anticipated tag recovery by age.

Calendar Year	Tag Application	Tag Recovery by age			
		2	3	4	5
2009	Y[1]				
2010	Y	Y			
2011	Y	Y	Y		
2012	Y	Y	Y	Y	
2013	Planned	NA[1]	NA	NA	NA
2014		NA	NA	NA	NA
2015			NA	NA	NA
2016				NA	NA
2017					NA

[1] Y = Yes; NA = Not Available until future return years.

5.3 Developing Issues

Although the CWTIP has delivered many positive benefits to the CWT system, some issues were identified as the program has proceeded.

Timing and availability of funds has hampered some U.S. projects from beginning at the planned date because of delays in receiving funds due to unanticipated complications in completing the grant process for some agencies/entities and federal appropriations and budgeting processes. In some cases, projects which were approved in February did not begin until 9–10 months after that time.

Inflation has eroded the buying power of the funding available through the CWTIT program due to increases in personnel, transportation, freight, equipment, and other costs.

The initial funding commitment of $15 million over a five-year period was insufficient to make needed, lasting improvements to the CWT program just for Chinook. Improvements are also needed for coho and in systemic programs that affect multiple species (e.g., estimation, sampling, and reporting of catches and escapements, separation of hatchery and wild components, methods to assess impacts of mass marking and mark-selective fisheries).

The potential for future reductions in funding to support CWT programs is a major concern. Management agencies of both Parties are experiencing substantial pressures for fiscal austerity. In the U.S., a means to provide funding to support continuation of base-level ocean sampling in Washington and Oregon to address budgetary pressures from the loss of *Anadromous Fish Act* grants has not been addressed to date. Agencies are evaluating alterations to tagging and sampling programs, and major funding agencies like the Bonneville Power Administration are reviewing future commitments for CWT-related efforts.

5.4 Long-term Issues

CWTs remain the only tool that can provide the information needed for coastwide fishery management and assessment. This is especially true because CWTs provide stock- and age-specific identification without error (i.e., the tag code is from a specific hatchery or wild stock from a specific year class), and CWTs provide the established mechanisms for coastwide data sharing and broadly agreed methods for statistical analysis. Other tools have been used for various management or stock assessment objectives, primarily for region-specific applications, but these other tools do not provide the tools necessary to implement the PST and they are more costly. The CWT program provides the most reliable series of continual data used in estimating stock abundances and fishery impacts.

The CWTIT program is scheduled to sunset in 2013/2014 for Canada and in 2014/2015 for the U.S. A means to continue funding is needed for these improvements to be maintained. Projects such as indicator stock programs, tagging levels, sampling and recovery of tags, and data reporting, require sustained commitment of funding and staff resources. Funding from other sources, such as the Endowment Funds, which could provide funding to support CWT-related improvements is uncertain due to variability in investment performance and the need to provide funding to support other PSC initiatives, like the Sentinel Stocks Program. **Future funding is required to maintain the CWT program, and additional sources of funding to continue to improve it**. Since 2009, when this program was initiated, core agency monitoring and sampling programs have been reduced. In some cases, CWT improvement funds have been used as a temporary solution to cover emerging gaps in agency resources. The consequences of not adequately funding the CWT program in the future are numerous and include (1) not recovering the CWTs already in circulation, (2) reduced sampling rates and coverage coast wide, (3) reduced tagging levels, and (4) loss of a portion of the base agency ocean sampling in Washington and Oregon.

5.5 Canadian CWTIT Projects

5.5.1 Progress on Canadian Projects Undertaken in 2012

A total of 27 Canadian projects in 10 project categories were funded in FY 2012, representing a total expenditure of $1.5 million. These projects are summarized in Appendix L. Each project summary includes a description of the project, the CWT issue(s) listed in the PSC Technical Report 25 (PSC 2008), primary objectives, accomplishments, and benefits to the CWT program.

5.5.2 Canadian Projects Recommended for 2013

The Canadian CWTIT solicited projects to address priority issues identified in PSC Technical Report 25 (PSC 2008; Table 5.3) through an internal process which resulted in 33 projects recommended for funding, totaling $1.5 million. Both projects recommended for funding and contingency projects are listed in Table 5.4. The CWTIT believes that the recommended projects will provide short- and long-term benefits to the CWT program and benefits to abundance-based management of Chinook salmon under jurisdiction of the PST.

Table 5.3 Key to issues in PSC Technical Report 25 (CTC 2008).

CTC 2008 Issue No.	Description
1	Incomplete and inconsistent representation of production regions
2	Determination of tagging levels
3	Representation of hatchery production
4	Low sample rates in terminal fisheries
5	Low sample rates in escapements
6	Uncertainty in estimates of escapement or terminal fisheries
7	Low sample rates in highly mixed stock fisheries
8	Uncertainty in estimates of catch in high mixed stock fisheries
9	Non-representative sampling
10	Incomplete coverage of fisheries or escapement
11	Voluntary sport fishery sampling programs
12	Sampling methods to facilitate sampling of MSFs and CWT processing
13	Timeliness of reporting
14	Incomplete/no exchange of CWT data
15	Inter/intra-agency coordination
16	Unclear authority to establish and enforce standards
17	Updating data is difficult and updates cannot be tracked
18	Validation is inadequate
Chapter 6	Decision Theoretic Tool

Table 5.4 Canadian CWT Improvement Projects approved for FY2013.

Project Category	CTC (2008) Issue	Project Title	Cost ($CDN)
Increased CWT marking of Canadian indicators	2	Incremental tagging of 12 indicator stocks (Robertson Creek, Cowichan, Big Qualicum, Quinsam, Lower Shuswap, Nicola, Chilliwack, Harrison, Taku, Stikine, Kitsumkalum, and Atnarko)[1]	$358,500
Increased deadpitch CWT recovery effort, all indicators	5	Increased effort in CWT recovery in indicator escapement programs (Quinsam, Cowichan, Big Qualicum, Harrison, and Nicola) [1]	$80,500
Uncertainty in estimates of escapement or terminal fishery catch	1, 6	Atnarko Chinook CWT indicator stock[1]	$110,000
Agency staffing (Programmer, Catch QA/QC Analyst, CWT Recovery Coordinator)	4, 6, 7, 8, 9, 10, 11, 14, 15, 17, 18	Regional CWT Data System p\Programming, Regional CWT and Catch Estimation QA/QC, and Regional Sport and First Nations Fishery CWT Recovery Coordination[1]	$250,000
Increased head recovery costs	2, 4, 5, 7	CWT Head Lab Processing and Data Management[1]	$70,000
Low sample rates in terminal fisheries, sport and First Nations CWT recovery improvements	4, 7, 9, 10, 11	Regional Commercial, Sport, and First Nations Fishery CWT Recovery Improvements[1]	$215,000
Low sample rates in terminal fisheries, First Nations fishery CWT recovery improvements	4, 10	Improvements in CWT Recovery in Terminal First Nations Fisheries (Fraser River and Bella Coola) [1]	$80,000
Low sample rates in terminal fisheries, recreational fishery CWT recovery improvements	4, 10	Improvements in Catch Estimates and CWT Recovery in Terminal Recreational Fisheries[1]	$174,000
CWT data reporting system improvement	13, 15, 17	Database Improvements	$162,000
		GRAND TOTAL	$1,500,000

[1] Multiyear projects.

5.6 U.S. CWTIT Projects

5.6.1 Progress on U.S. Projects Undertaken in 2012

A total of 12 U.S. projects were funded in FY 2012, representing a total expenditure of $1,529,685. These projects are presented in summary fashion in Appendix L. Each project summary includes a description of the project, the CWT issue(s) listed in the PSC Technical Report 25 (PSC 2008) and in Table 5.3, primary objectives, accomplishments, and benefits to the CWT program.

5.6.2 U.S. Projects Recommended for 2013

Projects were solicited through a request for proposals released for two months in late 2012. Projects were evaluated by the CWTIT on the basis of those providing the most benefits to the CWT program for the associated cost. Table 5.5 provides a summary of the recommended projects by project category. Project categories are based on the themes specified in PSC Technical Report 25 (PSC 2008). Projects were scored and ranked individually by U.S. CWTIT members and consensus was subsequently reached to develop draft recommendations. These were deliberated by the bilateral CWTIT. The PSC approved the following list of recommendations. The projects recommended by the U.S. represent a complete expenditure of the $1.5 million available under this program for 2013. The CWTIT believes that the recommended projects will provide short- and long-term benefits to the CWT program and benefits to abundance-based management of Chinook salmon under jurisdiction of the PST.

Table 5.5 U.S. CWT Improvement Projects approved for FY2013.

Project Category	TR 25 (PSC 2008) Issue	Project Title	Cost ($USD)
Replace outdated CWT equipment	12, 13	Replace WDFW Outdated Handheld CWT Wand Detectors[1]	$248,543
Low sample rates in mixed-stock fisheries	7	Sampling Washington Ocean Salmon Fisheries[1]	$354,492
Low sample rates in mixed-stock fisheries	7	SEAK Sport Catch Sampling[1]	$57,367
Indicator hatchery stock tagging, terminal fishery and escapement number and sampling	1,3, 4, 6	Mid-Oregon Coast CWT Recovery, and Escapement of Elk River Fall Chinook[1]	$125,195
Replace outdated CWT equipment	13	Purchase of Reading Stations at Alaska CWT Lab	$29,304
Reduce head processing costs & improve sampling efficiency	4, 7, 13	SEAK Commercial Port Sampling of Number Tags[1]	$58,164
Replace outdated CWT equipment	12, 13	Replace 30 Oregon Department of Fish and Wildlife outdated handheld CWT Wand Detectors	$101,063
Purchase new CWT equipment	13, 14, 17, 18	Purchase Data Loggers for 10 Hatcheries for Tag & Release Data Electronically & Train Staff	$99,653
Administrative	19	Partial Funding for Co-Chair	$14,820
Indicator stock tagging of wild stock without hatchery representation	1, 2	Chilkat River Chinook Smolt CWT[1]	$86,801
Indicator stock tagging of wild stock without hatchery representation	1, 2	Stikine River Chinook Smolt CWT–Bilateral[1]	$134,562
Low sample rates in mixed-stock fisheries	7, 8, 12	Improvements to Oregon Ocean CWT Sampling in Columbia River Mnagement Area	$112,597
CWT Lab equipment purchase and sampling	7, 10, 13	Purchase of T-Wands, Reading Station and Fishery Sampling—Makah Tribe	$46,459
CWT Lab and sampling equipment purchase	7, 13	Purchase of T-Wands and Reading Station—Lummi Tribe	$12,607
Administrative—CWT meeting costs	19	PSC—Fund Costs of next 2 CWTIT Workshop	$13,200
Purchase new CWT equipment	7, 13	Purchase of dissection and reading stations—Stillaguamish Tribe	$5,173
		GRAND TOTAL	$1,500,000

[1] Multiyear projects.

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