2024 MARINE SURVIVAL FORECAST OF SOUTHERN BRITISH COLUMBIA COHO

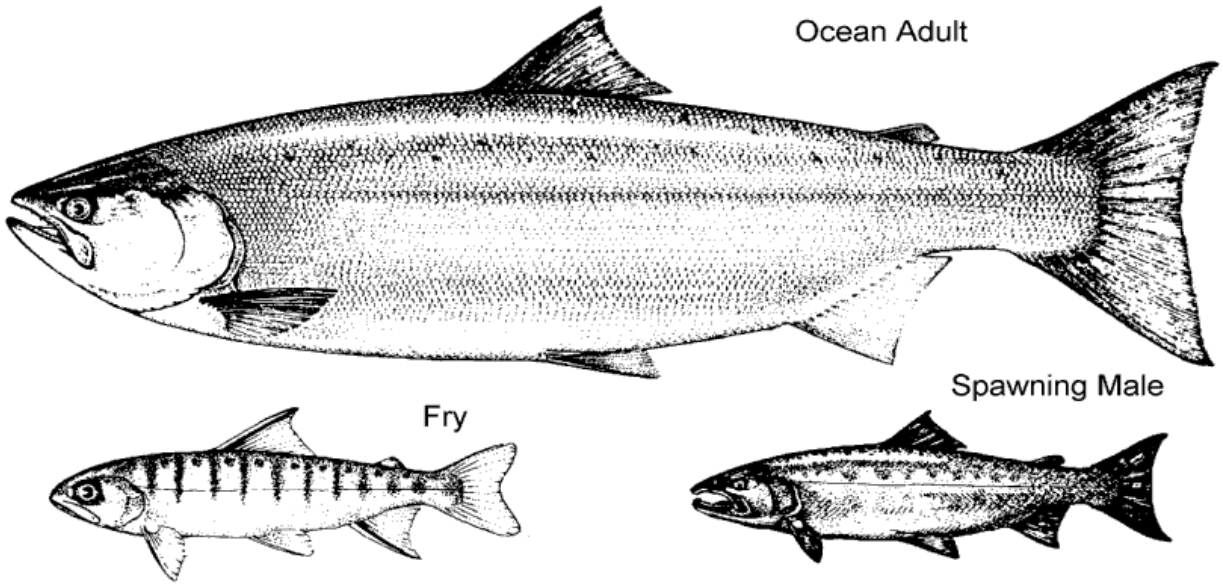

Figure 1: Coho salmon at three life stages: freshwater rearing fry; ocean rearing adult; and returning male. This image has been used on previous Coho Stock Status reports, origin unknown.

SUMMARY

The observed indicator marine survivals and aggregate abundances from 2023 were mixed with four of nine systems slightly lower (-2% to -34%) than the previous year. Area 12 Aggregate, Quinsam, Black Creek, Interior Fraser Aggregate, and Carnation Creek had marine survivals or abundance estimates that were higher in 2023, with increases of 13, 92, 76, 3, and 95 percent, respectively. Six observed indicator survivals were higher than the forecasted levels (+15% to +105%). Big Qualicum, Interior Fraser Aggregate, and Robertson Creek were exceptions with 14, 6, and 33 percent decrease from the 2023 forecast, respectively.

The 2024 forecasts for Coho indicator marine survivals are showing increases from 2023 observed values in five systems (+5% to +22%), with Area 12 and Area 13 Aggregates, Quinsam, and Black Creek showing decreases (-6, -7, -34, and -5%, respectively).The best performing models that were used for the indicators are the Three Year Average (Big Qualicum, Area 12 Aggregate and Area 13 Aggregate), Pacific Decadal Oscillation (Quinsam and Black Creek), Exponential Smoothing with Box-Cox transformation (Inch and Interior Fraser Aggregate), and

Sea Surface Temperature at Amphitrite Point Lighthouse (Quinsam, Robertson & Carnation), and.

The Chrome Island Salinity Distribution Index was not available for 2024 due to malfunctions at the station that prevented data from being recorded.

INTRODUCTION

Coho marine survival and aggregate abundances for Indicator stocks in southern British Columbia and the Fraser River have been forecast annually since 1996. The estimates from these Indicators are used in international stock management processes and domestically for informing fishery management, while the forecasts are used for shaping future fisheries. Indicator stocks are located within five of the Canadian Coho Management Units (MU) in southern British Columbia (Figure 2).

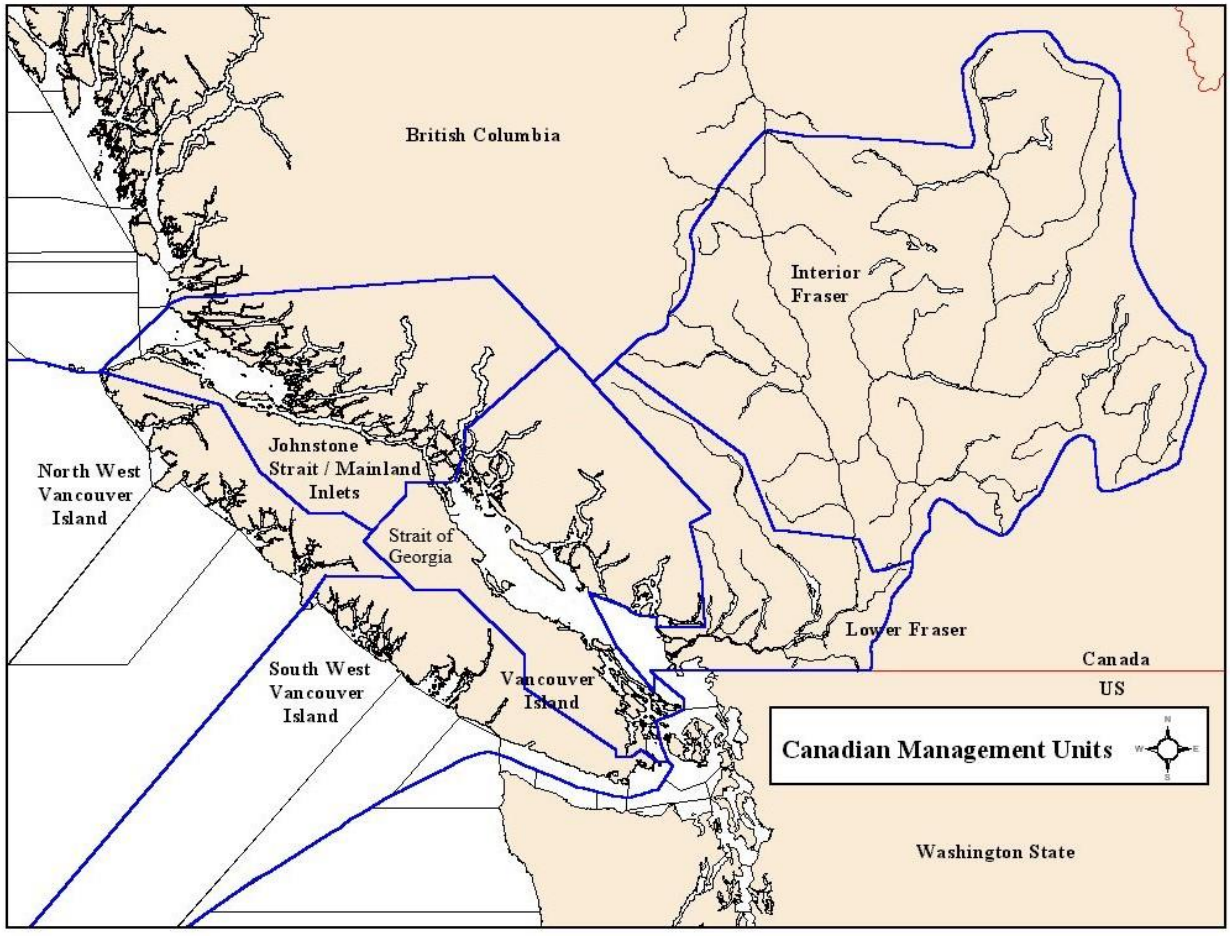

Figure 2: Canadian Coho Management Unit boundaries in Southern British Columbia. Pacific Salmon Treaty Coho MUs are Strait of Georgia, Lower Fraser and Interior Fraser.

Starting with the 2015 forecast, the Ocean Climate Indices were incorporated into the suite of models examined for the two WCVI indicators. In the following year, these indices were

included as possible forecast models for the rest of the marine survival indicators. These models were not considered for the Aggregate Indicators.

Previously, marine survival or aggregate abundance forecasts for southern BC Coho stock groups have been published as Science Advisory Reports. Starting in 2012, this information is set out in an unpublished document for use in domestic and international Coho stock management processes.

Descriptions of the assessment methods, data sets, forecast models and sources of uncertainty have been documented in previous papers and will not be described herein. For more information see Simpson *et al.* (2004), Baillie *et al.* (2005), and annually from DFO (2006) to DFO (2023), which are published on the Fisheries and Oceans Canada Library.

METHODS

Data Sources

The dataset used for the Area 12/13 aggregates is based on a subset of Coho populations from each Area. The forecast is based on the expected total return to the average stream in the area (derived via the P_{max} methodology to standardize escapements in the aggregate area). For the Interior Fraser aggregate, the data represents estimated total abundance for that aggregate. Each datum includes natural spawners, brood stock removals and fishery catches, both recreational and commercial. All other indicators in this forecast use the survival rate between release of smolts and the resulting return of adult Coho, which includes Coho caught in commercial, sport and First Nation fisheries, and entering freshwater to spawn. There are four hatchery stocks used, Robertson Creek Hatchery, Quinsam Hatchery, Big Qualicum Hatchery, and Inch Creek Hatchery. Additionally, there are two wild stocks used, at Black Creek and Carnation Creek.

Exploitation Rate

A change in the methodology used to estimate the exploitation rate for adipose fin clipped Coho indicators was incorporated into the 2015 forecast exercise and has been continued with the current forecast. The Black Creek wild indicator is the exception to this due to the lack of an adipose clip marker. Please see the DFO (2015) for further information.

Directed commercial and recreational fisheries on Coho were severely restricted in the late 1990s in response to decreasing stock abundances. Until recently most exploitation of Coho was incidental catch in commercial fisheries that targeted other species. Non-retention of unmarked Coho is in effect in most areas except for Food, Social and Ceremonial fisheries for First Nations in specific areas where local abundances allow for retention of unmarked Coho (PSC 2013).

Marine Survival

Marine survival is defined as the portion of the coded-wire tagged smolt release that has survived to be either caught in marine fisheries or returned to freshwater as adult Coho, i.e. (Catch + Escapement) / Release. The 2016 brood year progeny from Big Qualicum hatchery were unfortunately lost due to a pump failure, leaving a missing datum from this indicator. In order to include the time series models as part of the forecast, the missing datum was infilled by using a regression of known Big Qualicum marine survivals against the Quinsam River Hatchery marine survivals (R^2 = 0.46) and using the corresponding Quinsam survival for the 2016 brood year to estimate a value for Big Qualicum.

The brood year 2017 escapement of coded-wire tagged adult Coho to the wild indicator, Carnation Creek, was unusually low. Two of 33 adults were found to have a tag, which resulted in a marine survival of 0.1% from a release group of 2106 smolts, a decrease of 94% from the previous year. Marine survivals over the previous 10 years averaged 1.3% (range 0.3% - 2.2%). Also, observed marine survivals from all other indicators increased an average of 69% from the previous year (range -2% to +243%: see Appendix 2). In addition, nearly all smolts had a coded-wire tag applied and although a similar ratio is not expected, the observed very low return suggests an issue with either smolt tag application or adult tag detection. Therefore, for the purposes of the forecast models, a marine survival was estimated using a regression of known marine survivals with the results from Robertson Creek Hatchery Coho.

Similar to the BY 2016 Big Qualicum infill, a regression with Robertson Creek Hatchery marine survival (R^2 = 0.52) was used to estimate the BY 2017 Carnation Creek marine survival for the purposes of running the forecast models.

Forecast Models

The forecast is chosen from a variety of both time-series and biologically based methods which are evaluated and selected based on performance criteria. See Simpson *et al.* (2004) for a description of the times series models.

The 2024 Interior Fraser Aggregate and Inch Hatchery forecasts use an Exponential Smoothing model with Box-Cox transformation which the retrospective analysis showed had the best predictive capability relative to the other time series models and models with climate indicators.

Climate Indicators

Large scale climate indicators have been shown to be correlated to biological processes, including marine survival of Pacific salmon (Trudel *et al*., 2015). In addition, the odd/even year has been shown be a co-variable in association with the climate indicators. This was used in developing the forecast model regressions.

The marine survival forecast models in this report use direct data input from the specific populations and a marine survival forecast is generated in a naïve manner with respect to climate trends. Specifically, marine climate indicators such as the Pacific Decadal Oscillation (PDO), North Pacific Gyre Oscillation (NPGO), El Nino Southern Oscillation (ENSO), and Sea Surface Temperature (SST) will be included. The marine climate indices are included in the forecast model comparison for all the marine survival indicators. The data for the climate indicators was obtained from: PDO, NPGO, ENSO, and Amphitrite SST.

Passive Integrated Transponder (PIT) Tags

PIT tags are small (9-12 mm) inert devices that are inserted into the abdominal cavity of juvenile salmonids. These tags utilize Radio Frequency Identification (RFID) technology that is read when a tag passes over an antenna at short distances. The antenna records the date, time, and unique ID from each tag. When the unique ID is linked to a tagging database the origin, time of tagging and age can be determined.

This method is currently being used to estimate survival at different life stages. The ability to link the unique ID back to the tagging database allows for calculations of survival through various life stages. Marine survival can be calculated by comparing the detections from adult returns to the number of smolts that were initially tagged. PIT systems can also be used to estimate escapement through expansion factors determined from the proportion of PIT tags in a population that passes through a counting fence. After a fence has been removed, the expansion factor can then be applied to the PIT detections from permanent antennas to calculate the total escapement.

Appendix 3 shows Coho marine survival estimates using Passive Integrated Transponder (PIT) from the Cowichan, Black, Quinsam, Big Qualicum, Englishman, Puntledge, Nanaimo and Sakinaw systems.

RESULTS

Graphical depictions of the observed marine survival or aggregate abundance for all Coho indicators used in this forecast are shown in Appendix 1, while Appendix 2 is a table that shows the observed 2021 and 2023 values, and the forecast for 2024 returns.

Johnstone Strait/Mainland Inlets

In 2023 the observed return in Area 12 was 19% higher than forecast and the Area 13 return was about 15% higher than forecast. Compared to the brood year (2020), returns to Area 12 were roughly equal, but escapement to Area 13 was 2.17 times greater. Our indicators at the Keogh River and Black Creek provide smolt abundance information; in 2022, we saw above average smolt production at the Keogh River (75,174) and at Black Creek (58,527). Based on the observed returns to these indicators in 2023, marine survival improvements appear to have stabilized, although marine survival continues to be low for both Area 12 and Area 13 Coho stocks.

The Area 12 forecast for 2024 is 948, which is 6% lower than the returns in 2023. The Area 13 forecast is 330, which is 7% lower than the 2023 observed indices. Coho abundance in this region can be characterized as 'well below average' for both Area 12 stocks and for Area 13 stocks. See Simpson et al., 2004 for description of characterizations. Smolt production in 2023 was above average for both Black Creek (>80,166 smolts) and the Keogh River (92,907). Please keep in mind that these more recent year returns do not have the high levels of exploitation as in the past and these forecasts are highly uncertain. These forecasts should be viewed with caution due to the continued decline of contributing index streams, further exacerbating the uncertainty in the expectations.

Georgia Basin – West

The observed 2023 marine survival rates of Quinsam and Big Qualicum Hatcheries were 2.7% and 2.3%, respectively, and the marine survival at the wild indicator at Black Creek was 3.7%. For Quinsam Hatchery, this marine survival is 92% higher than the previous year and 105% higher than the 2023 forecast. For Big Qualicum, the marine survival is slightly lower than the previous year by 2% and lower than the forecast by 14%. The wild indicator at Black Creek was higher than the previous year by 76% and higher than the forecast by 36%.

After a retrospective analysis with the addition of the 2023 return, the best performing forecast model for the Quinsam River Hatchery Indicator changed to the PDO index. The best performing model for Big Qualicum was again the 3-year average. The best performing model for the Black Creek Indicator was PDO.

The 2024 forecast for the three indicators is for a continuation of the low marine survival levels seen in recent years although the figure in Appendix 1 suggests a slow increase since the low levels in the early 2000s. The model forecasts a marine survival of 1.8%, 2.6% and 3.5% for Quinsam Hatchery, Big Qualicum Hatchery and Black Creek (changes of -34%, +13% and -30% from 2023 observed levels), respectively.

Lower Fraser

The preliminary observed 2023 marine survival from the Inch Creek Hatchery indicator was 7.2% which was lower than the previous year (-26%), but higher than the forecast value (+31%). The retrospective analysis showed that the best performing model was Exponential Smoothing with Box-Cox transformation. The 2024 forecast for marine survival for this indicator is 8.3%, an increase (+15%) from the preliminary observed survival in 2023.

Interior Fraser

The preliminary estimate of the 2023 pre-fishery abundance for the Interior Fraser Aggregate was 81,592, 6% lower than the 2023 forecast and 3% higher than the 2022 abundance of 79,451.

The forecast model selected for the 2024 return is an Exponential Smoothing with Box-Cox transformation. The 2024 forecast of pre-fishery abundance for the Interior Fraser Aggregate is 85,813 Coho with an 80% forecast range of 76,573 – 128,544. This forecast is 5% higher than the preliminary estimate of recruitment in 2023.

Southwest Vancouver Island

The two indicators in this Management Unit are Robertson Creek Hatchery and Carnation Creek, both located in Barkley Sound. For the Robertson indicator the estimate of Coho escapement is based on the estimated abundance from the Stamp Falls fishway project.

The observed 2023 marine survival of 6.7% for Robertson (Stamp) Indicator was lower than the previous year (-10%), the SST forecast (-33%), and the NPGO forecast (-6%). The marine survival of the wild indicator at Carnation Creek was 2.0% which was higher than the 2023 forecast (+35%) and lower than the 2022 observed value (+95%).

For the 2024 forecast, two models (SST and NPGO) that provided similar performance have been identified in the forecast table below for the Robertson (Stamp) Indicator. In evaluating those two models the SST model forecast of 7.0% is a 5% increase in marine survival relative to what was observed in 2023 and the NPGO based forecast of 4.0% is a 40% decrease relative to 2023 observed survival.

The best performing model for the Carnation Wild Indicator has remained the Sea Surface Temperature index. The marine survival for the wild indicator at Carnation Creek is forecast to be 2.4%, a 22% increase from the 2023 observed marine survival.

Distribution

The distribution Index is a metric that uses salinity in the Strait of Georgia to forecast whether Coho will be present in the Strait during their final summer (“inside”) or wait until fall to re-enter the Strait (“outside”). In Figure 3, the central red line indicates the base period average distribution of Coho catches between Strait of Georgia and WCVI fisheries. Deviations from this line suggest a greater ‘Inside’ or ‘Outside’ catches of Coho if the same fisheries regimes were in place.

This model is based on the relationship between salinity and the relative quantity of Coho that were harvested, using data from a base period (1975-1997). As fisheries have been restricted since the late 1990’s the relationship is fixed and cannot be updated or have a retrospective analysis.

The average salinity as measured at Chrome Island lighthouse was not available again for 2024 due to malfunctions in recording data at the station. Alternate locations were considered for this forecast, however, the relationship between salinity and distribution were not similar to what is observed at Chrome Island.

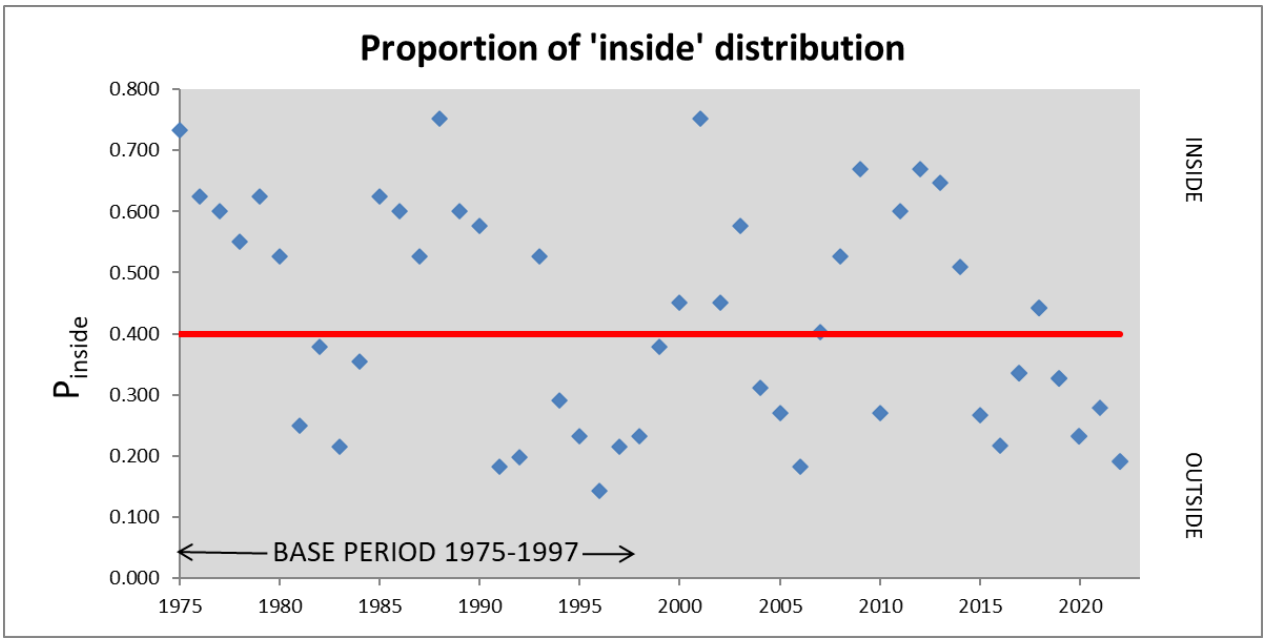

Figure 3. Distributional index for Strait of Georgia Coho, with observed data from 1975-1997, and results from the salinity-based model for 1998-2022. The red line indicates the division between an 'inside' year and an 'outside' year.

ACKNOWLEDGEMENTS

The Coho forecast for southern British Columbia requires data from many sources and is very much a collaborative document. All sources are DFO staff except where noted. Data analyses of the Interior Fraser Management Unit and Inch Creek were completed by Michael Arbeider, and the Johnstone Strait Aggregates by Matt Clarke. Karalea Filipovic (author) completed analysis of WCVI and Strait of Georgia indicators.

Freshwater creel survey data were provided by Théa Rachinski. Coho data from the WCVI indicators was collated by Nick Brown and Pat Vek. Brock Ramshaw provided escapement data from the hatcheries. Wild Coho data were provided by Andrew Pereboom (Black Creek) and, Dr. Peter Tschaplinski and Steve Voller (BC Ministry of Environment - Carnation Creek). Commercial catch data was provided by Karin Mathias and Christie Morrison. PIT tag data was provided by Kevin Pellett, Andrew Pereboom and Jamieson Atkinson. Steve Baillie graciously offered assistance and answered many questions. Ocean Climate indices were obtained from various internet sources noted in the text.

REFERENCES AND PREVIOUS FORECAST DOCUMENTS

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FOR MORE INFORMATION

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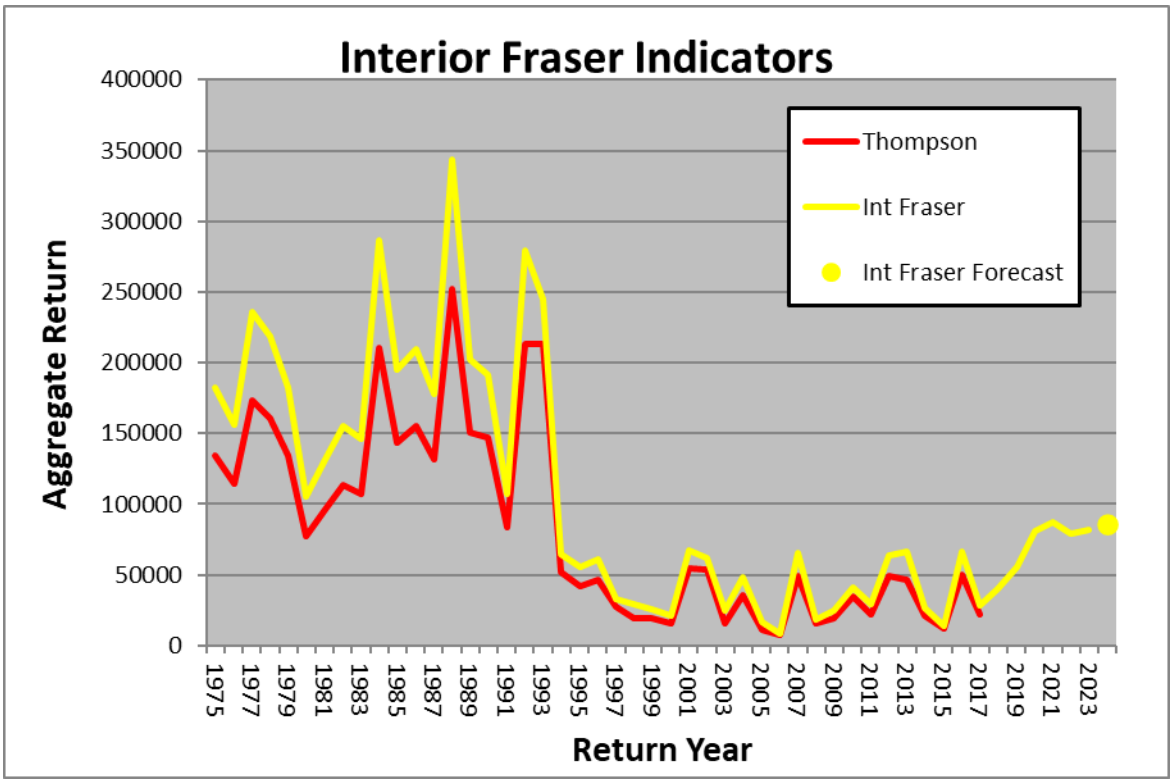
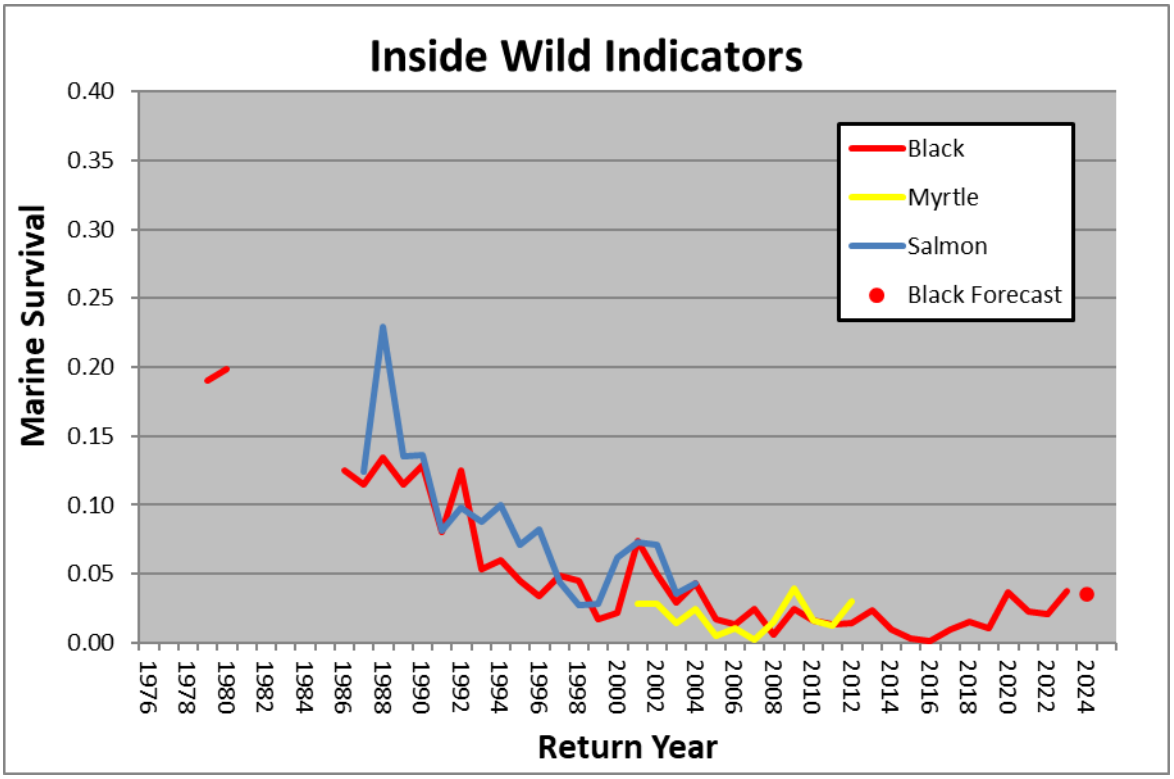
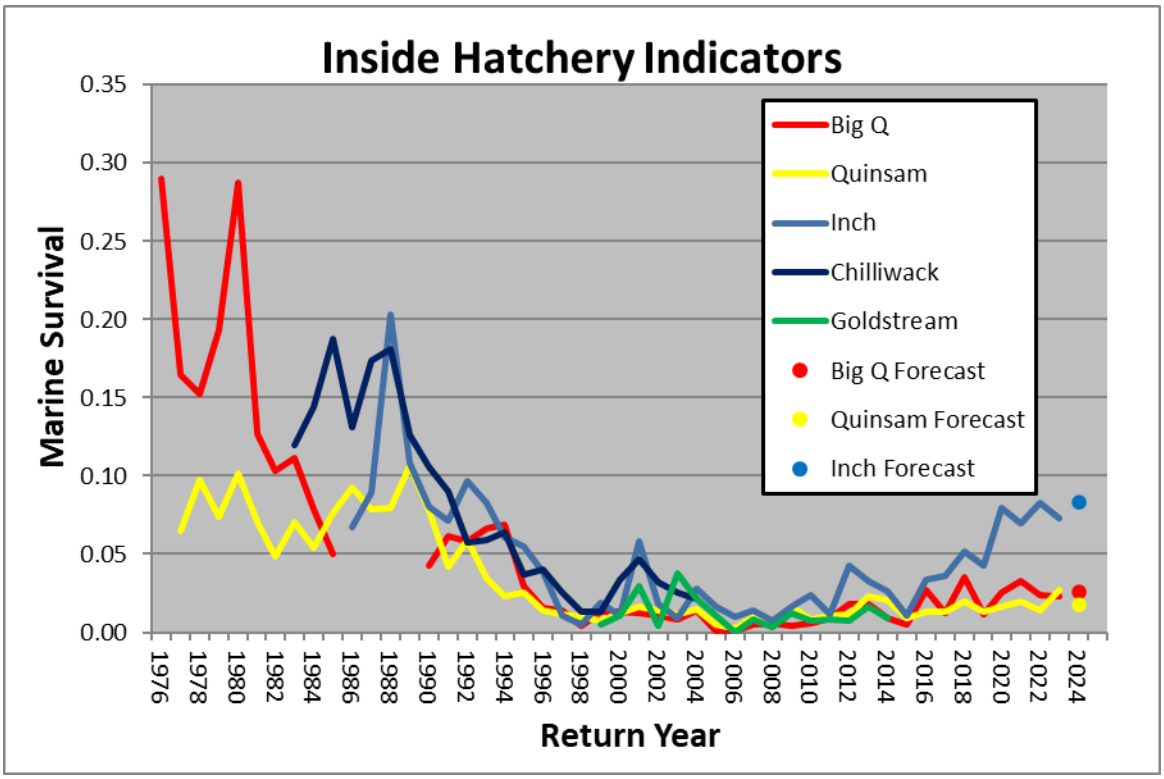
APPENDIX

Appendix 1. Marine survival or aggregate abundances for southern BC Coho indicators, including the 2024 forecast.




Inside Wild Indicators
Marine Survival
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
1976 1978 1980 1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018 2020 2022 2024
Return Year
Black
Myrtle
Salmon
Black Forecast


Inside Hatchery Indicators
Marine Survival
0.35
0.30
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0.15
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0.05
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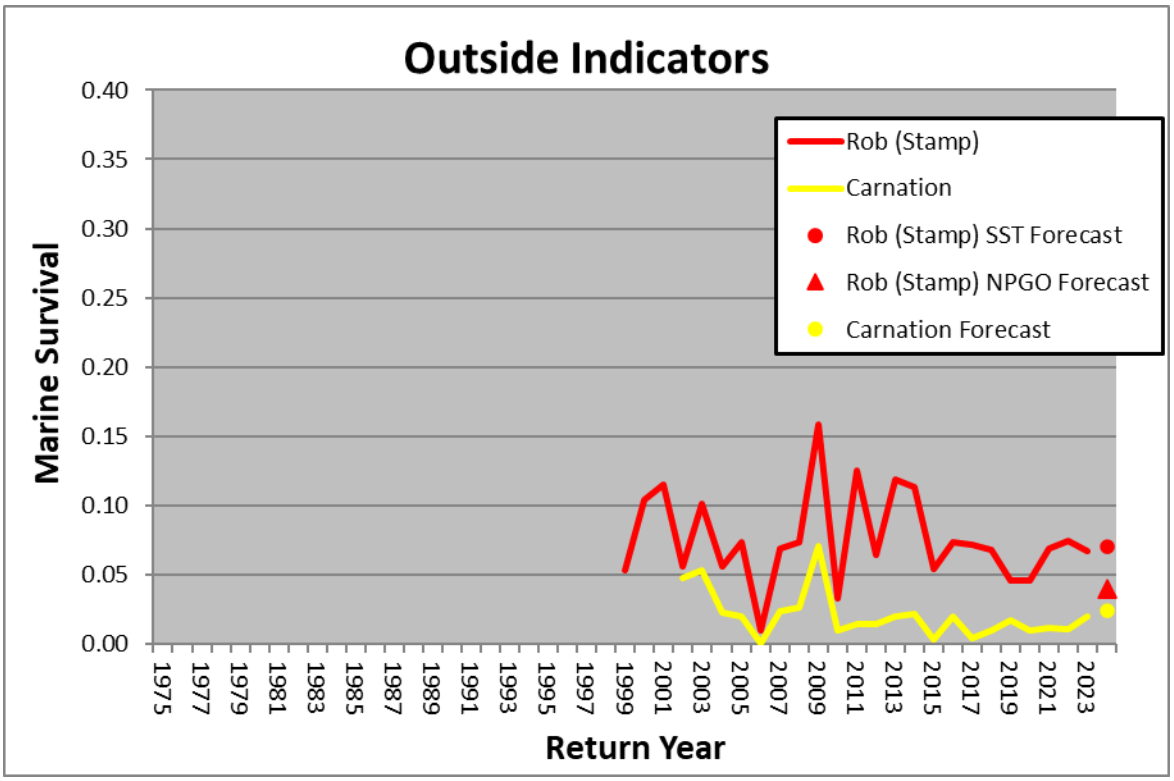
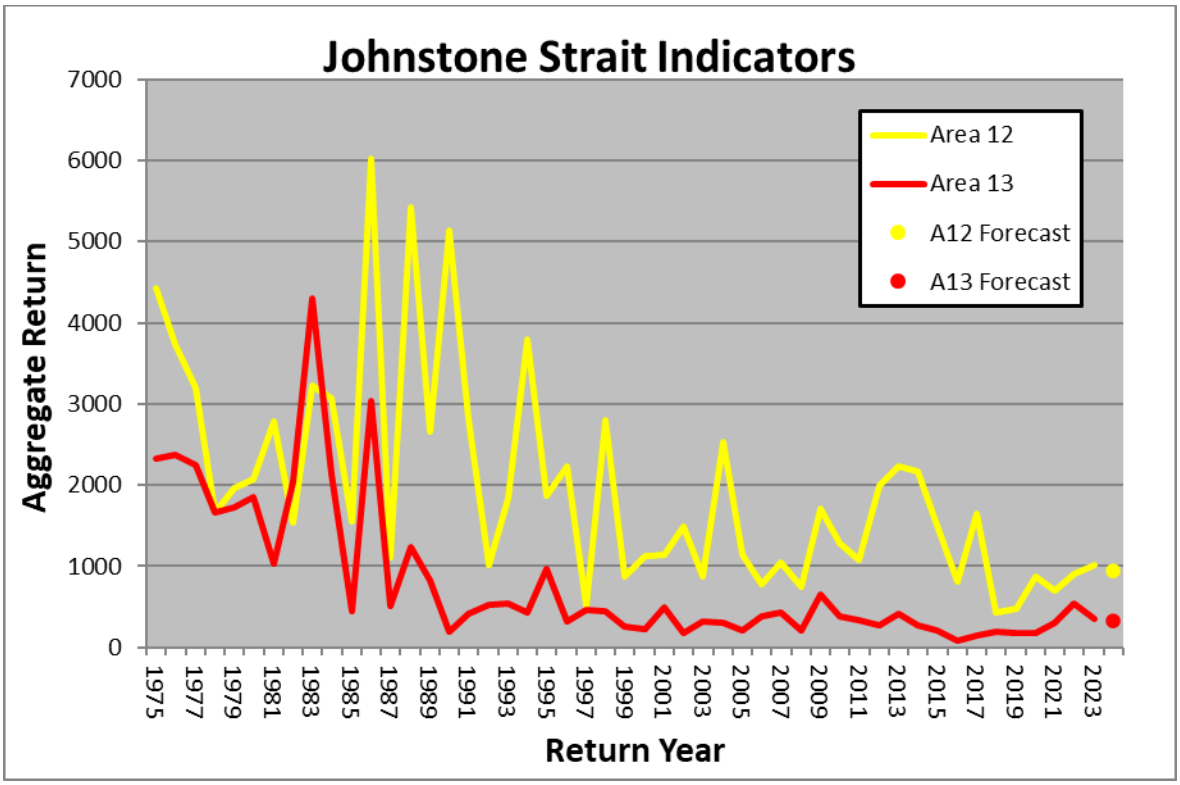
1976 1978 1980 1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018 2020 2022 2024
Return Year
Big Q
Quinsam
Inch
Chilliwack
Goldstream
Big Q Forecast
Quinsam Forecast
Inch Forecast


Outside Indicators
Marine Survival
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Rob (Stamp)
Carnation
Rob (Stamp) SST Forecast
Rob (Stamp) NPGO Forecast
Carnation Forecast
1975 1977 1979 1981 1983 1985 1987 1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011 2013 2015 2017 2019 2021 2023
Return Year


Johnstone Strait Indicators
Aggregate Return
7000
6000
5000
4000
3000
2000
1000
0
Area 12
Area 13
A12 Forecast
A13 Forecast
1975 1977 1979 1981 1983 1985 1987 1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011 2013 2015 2017 2019 2021 2023
Return Year

Appendix 2. Observed and forecast marine survival and aggregate abundance indicators from southern BC Coho indicator stocks.

Column Headings

Stock: The name of the Management Unit in **Bold**, followed by the individual indicator or stock grouping within that Management Unit.

2022 Observed: The values in this column represent either the aggregate value (whole numbers) or the estimated marine survival (decimal numbers), from the 2022 return year.

2023 Forecast, 50% CI, and Model refer to the forecast for the 2023 return year. The actual forecasted value is given first, followed by the 50% confidence interval, then the forecasting model used.

2023 Observed, Change from forecast and Change from 2022 refer to the estimated values for each indicator, then the % change from the forecasted value and from the observed value in the previous year. The % change is in relation to the base value so a marine survival of 1.5% in year one increasing to 2.0% in the next year is expressed as a plus 33% change and is highlighted in green. A decrease of 2.0% to 1.5% is expressed as a minus 25% change and is highlighted in pink.

2024 Forecast, 50% CI and Model refer to the forecast for the current year.

Change from 2023 is the change in value from the observed 2023 value to the 2024 forecast. Each change is highlighted in green or pink, depending on whether the change is up, or down.

Distribution Index (P_{inside}) does not have an annual inside/outside measure so there are no Observed data to report or compare to.

Table 1: Observed and forecast marine survival and aggregate abundance indicators from southern BC Coho indicator stocks.

Stock	2022	2023						2024			
	Observed	Forecast	50% CI	Model	Observed	Change from Forecast	Change from 2022	Forecast	50% CI	Model	Change from 2023
Johnstone Strait/Mainland Inlets											
Area 12 Aggregate	896	852	593 - 1,223	3YRA	1,012	**19%**	**13%**	948	595 - 1378	3YRA	**-6%**
Area 13 Aggregate	539	309	103 - 450	3YRA	356	**15%**	**-34%**	330	230 - 453	3YRA	**-7%**
Strait of Georgia											
Quinsam Hatchery	0.014	0.013	0.009 - 0.019	SST	0.027	**105%**	**92%**	0.018	0.012 - 0.026	PDO	**-34%**
Big Qualicum Hatchery	0.024	0.027	0.015 - 0.048	3YRA	0.023	**-14%**	**-2%**	0.026	0.015 - 0.046	3YRA	**13%**
Black Creek (wild)	0.021	0.028	0.016 - 0.048	PDO	0.037	**36%**	**76%**	0.035	0.019 - 0.064	PDO	**-5%**
Lower Fraser											
Inch Hatchery*	0.097	0.055	0.030 - 0.098	ENSO	0.072	**31%**	**-26%**	0.083	0.065 - 0.099	ExpSmBC	**15%**
Interior Fraser											
Interior Fraser Aggregate*	79,451	87,079	74,538 - 130,525	ARIMA with Box-Cox	81,592	**-6%**	**3%**	85,813	76,573 - 128,544	ExpSmBC	**5%**
South West Vancouver Island											
Robertson (Stamp Falls) Hatchery**	0.074	0.099	0.072- 0.135	SST	0.067	**-33%**	**-10%**	0.070	0.051 - 0.097	SST	**5%**
		0.071	*0.051 - 0.098*	*NPGO*		**-6%**		*0.040*	*0.029 - 0.056*	*NPGO*	**-40%**
Carnation Creek (wild)	0.010	0.015	0.009 - 0.025	SST	0.020	**35%**	**95%**	0.024	0.014 - 0.041	SST	**22%**
Distribution Index (P_{inside})			No Value in 2023						No Value in 2024		

* Inch Hatchery and Interior Fraser Aggregate uses an 80% CI for forecast uncertainty. Observed 2023 values are preliminary.
**WCVI Stock Assessment recommended the NPGO model in 2023.

Appendix 3. Coho PIT tags in Southern BC Systems.

Table 2: PIT tag application on hatchery and wild Coho smolts, and the associated jack and adult escapement. Survival estimates in this table do not include any exploitation data or corrections for detection efficiency (av. 90%).

Watershed	Brood Year	Release Year	# Tags Released	Jack Return	Adult Return	Smolt to Jack Survival	Smolt to Adult Survival
Cowichan (Wild)	2016	2018	534	0	15	0.00%	2.81%
	2017	2019	4821	19	219	0.44%	4.54%
	2018	2020	1642	1	100	0.06%	6.09%
	2019	2021	5416	5	292	0.09%	5.39%
	2020	2022	2410	6	121	0.25%	5.02%
	2021	2023	2112	2		0.09%	
Black Creek (Wild)	2016	2018	4000	92	26	2.30%	0.65%
	2017	2019	4300	183	81	4.26%	1.88%
	2018	2020	8337	121	167	1.45%	2.00%
	2019	2021	9192	217	123	2.36%	1.34%
	2020	2022	6734	64	223	0.95%	3.24%
	2021	2023	7969	189		2.37%	
Quinsam (Hatchery)	2019	2021	4904	29	79	0.59%	1.61%
	2020	2022	4949	15	56	0.31%	1.13%
	2021	2023	7977	20		0.25%	
Big Qualicum (Hatchery)	2019	2021	4885	20	60	0.41%	1.23%
	2020	2022	4886	4	76	0.08%	1.56%
	2021	2023	0	0			
Englishman (Wild)	2019	2021	3641	14	46	0.38%	1.26%
	2020	2022	2885	10	28	0.35%	0.97%
	2021	2023	2622	15		0.57%	

Puntledge (Hatchery)	2019	2021	4911	108	188	2.20%	3.83%
	2020	2022	4924	49	219	1.00%	4.45%
	2021	2023	2500	92		3.68%	
Nanaimo (Hatchery)	2019	2021	5000	20	115	0.40%	2.30%
	2020	2022	4978	1	5	0.02%	0.10%
	2021	2023	5337	9		0.17%	
Sakinaw (Wild)	2018	2020	1094	16	9	1.46%	0.82%
	2019	2021	3154	22	6	0.70%	0.19%
	2020	2022	937	4	3	0.43%	0.32%
	2021	2023	1555	13		0.84%	

Table 3: Comparison of proportional CWT Marine Survival (MS) and adult PIT Tag based MS. CWT MS uses CWT for escapement with CWT and ER-Effort Model for exploitation. PIT Marine Survival uses adult PIT tags for escapement with CWT and ER-Effort Model for exploitation.

Watershed	**Brood Year**	**CWT Marine Survival**	**PIT Marine Survival**
Black Creek	2016	0.011	0.008
	2017	0.037	0.020
	2018		0.023
	2019	0.021	0.014
	2020	0.037	0.033
Quinsam	2019	0.014	0.032
	2020	0.027	0.017
Big Qualicum	2019	0.024	0.017
	2020	0.023	0.022