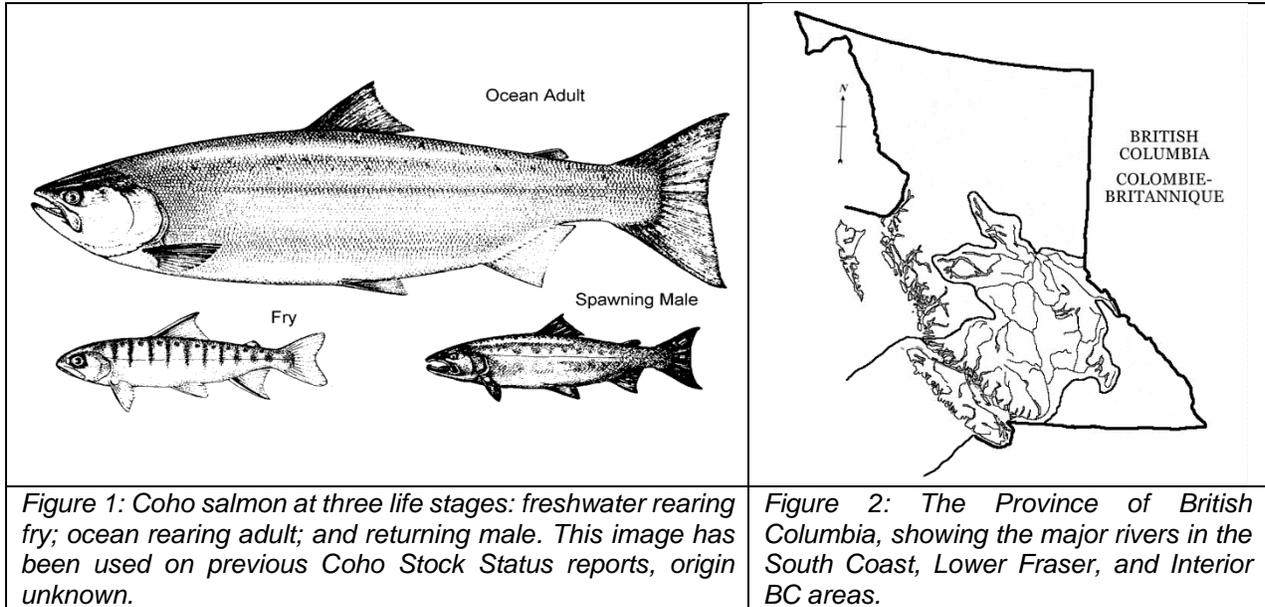




2023 MARINE SURVIVAL FORECAST OF SOUTHERN BRITISH COLUMBIA COHO



SUMMARY

The observed indicator marine survivals and aggregate abundances from 2022 were mixed with five of nine systems lower (-7% to -30%) than the previous year. Area 12 and 13 Aggregates, Robertson, and Inch Creek had marine survivals that were higher in 2022, with increases of 29%, 78%, 8% and 18%, respectively. Seven observed indicator survivals were higher than the forecasted levels (+13% to +206%), with Carnation Creek wild indicator and the Interior Fraser Aggregate as exceptions with a 31% and 4% decrease from the 2022 forecast, respectively.

The 2023 forecasts for Coho indicator marine survivals are showing increases from 2022 observed values in five systems (+14% to +44%), with Inch Creek, Quinsam, Area 12 and Area 13 Aggregates showing decreases (-34%, -6%, -5%, and -43% 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), the Sea Surface Temperature at Amphitrite Point Lighthouse (Quinsam, Robertson & Carnation), the Pacific Decadal Oscillation (Black Creek), the El Nino-Southern Oscillation (Inch Creek), and the ARIMA with Box-Cox transformation (Interior Fraser Aggregate).

The Chrome Island Salinity Distribution Index was not available for 2023 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.

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), DFO (2006), DFO (2008), DFO (2009) and DFO (2012). Baillie *et al.* (2005), DFO (2010), DFO (2011), DFO (2013), DFO (2014), DFO (2015), DFO (2016), DFO (2017), DFO (2018), DFO (2019), DFO (2020), DFO (2021), and DFO (2022) are similar reports that are published on the [Fisheries and Oceans Canada Library](#).

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 the 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 2015 forecast 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 2023 Interior Fraser Aggregate forecast is based on using an ARIMA (0,1,1) with Box-Cox transformation model which the retrospective analysis showed had the best predictive capability relative to the other time series models.

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 to 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 Niño 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 2022 values, and the forecast for 2023 returns.

Johnstone Strait/Mainland Inlets

In 2022 the observed return to the average stream in Area 12 was 896, 28% higher than forecast, and the Area 13 return was 539, 148% higher than forecast. Compared to the brood year (2019), returns to Area 12 were 1.89 times greater, while escapement to Area 13 was 3.02 times greater. Indicators at the Keogh River and Black Creek provide smolt abundance information; in 2021, the highest ever smolt production was seen at the Keogh River (129,200) and Black Creek saw well above average production (86,118). Based on the observed returns to these indicators in 2022, 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 2023 is 852, which is 5% lower than the returns in 2022. The Area 13 forecast is 309, which is 43% lower than the 2022 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 2022 was above average for both Black Creek (58,527 smolts) and the Keogh River (75,174). 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 2022 marine survival rates of Quinsam and Big Qualicum Hatcheries were 1.4% and 2.4%, respectively, and the marine survival at the wild indicator at Black Creek was 2.1%. For Quinsam Hatchery, this marine survival is 30% lower than the previous year and 23% higher than the 2022 forecast. For Big Qualicum, the marine survival is lower than the previous year by 28% and higher than the forecast by 13%. The wild indicator at Black Creek was lower than the previous year by 7% but higher than the forecast by 71%.

After a retrospective analysis with the addition of the 2022 return, the best performing forecast model for the Quinsam River Hatchery Indicator changed to the SST index. The best performing model for Big Qualicum was again the 3-year average. The best performing model for the Black Creek Indicator was the PDO.

The 2023 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 1.3%, 2.7% and 2.8% for Quinsam Hatchery, Big Qualicum Hatchery and Black Creek (changes of -6%, +14% and +30% from 2022 observed levels), respectively.

Lower Fraser

The estimated 2022 marine survival from the Inch Creek Hatchery indicator was 8.3% which was higher than the previous year (+18%), and much higher than the forecast level (+206%). The retrospective analysis showed that the best performing model switched to the ENSO climate index. The 2023 forecast for marine survival for this indicator is 5.5%, a decrease (-34%) from the observed level in 2022.

Interior Fraser

The preliminary estimate of the 2022 pre-fishery abundance for the Interior Fraser Aggregate was 80,235, 4% lower than the 2022 forecast and 8% lower than the 2021 abundance of 87,096.

The forecast model selected for the 2023 return is an ARIMA (0,1,1) with Box-Cox transformation, which was also used in 2022. The 2023 forecast of pre-fishery abundance for the Interior Fraser Aggregate is 87,079 Coho with an 80% forecast range of 74,538-130,525. This forecast is 9% higher than the preliminary estimate of recruitment in 2022.

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 2022 marine survival of 7.4% for Robertson (Stamp) Indicator was higher than the previous year (+8%) and the NPGO forecast (+63%), but lower than the PDO forecast (-1%). The marine survival of the wild indicator at Carnation Creek was 1.0% which was lower than the forecast (-31%) and lower than 2021 (-14%).

For the 2023 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 9.9% is a 34% increase in marine survival relative to what was observed in 2022 and the NPGO based forecast of 7.1% is a 4% decrease relative to 2022. WCVI Stock assessment is recommending the NPGO based forecast as it aligns with other marine indicators.

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 1.5%, a 44% increase from the 2022 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 for 2023 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.

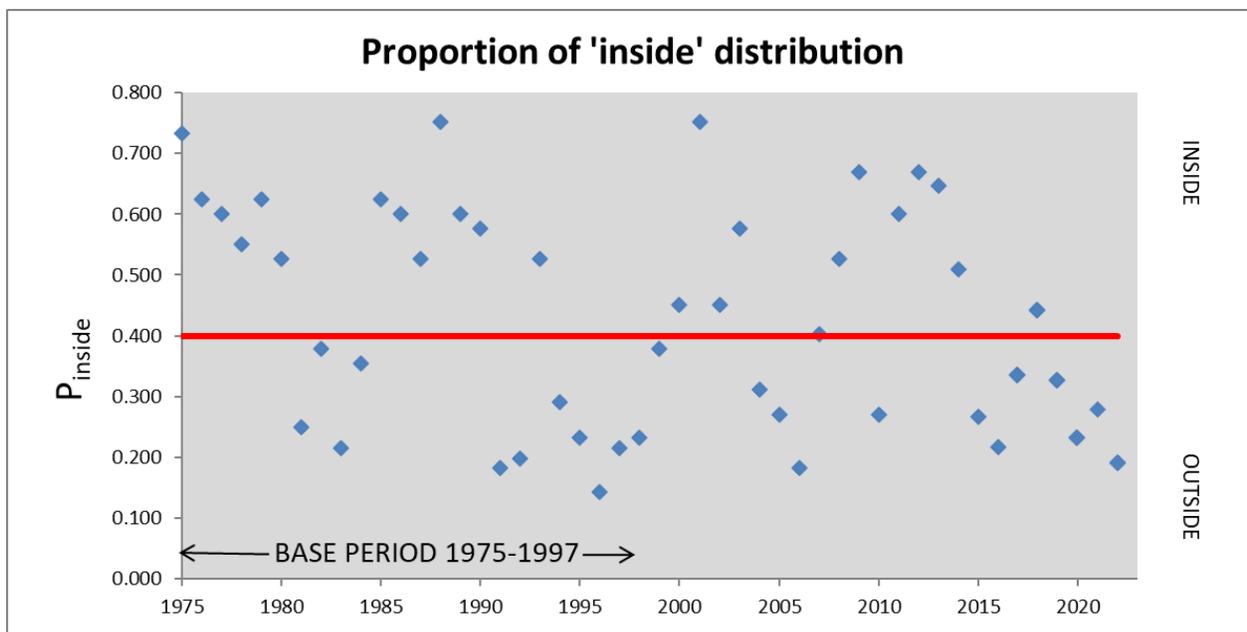


Figure 3. Distributional index for Strait of Georgia Coho, with observed data from 1975-1997, and results from the salinity-based model for 1998-2022. The red line indicates the division between an ‘inside’ year and an ‘outside’ year.

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 analysis of the Interior Fraser Management Unit was completed by Michael Arbeider, and the Johnstone Strait Aggregates by Matt Clarke. Karalea Cantera (author) completed analysis of WCVI and Strait of Georgia indicators.

Freshwater creel survey data were provided by Théa Rachinski (Strait of Georgia). Coho data from the WCVI indicators was collated by Pieter Van Will and Pat Vek. Brock Ramshaw and Joe Tadey 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 Lee Kearey 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

Ocean Climate index sources were accessed in February 2023.

Baillie, S., Simpson, K., Chamberlain, M., Van Will, P., Tanacetum, R., Dobson, D., and Sweeting, R. 2005. Forecast for Southern British Columbia Coho Salmon in 2005. Unpublished report.

DFO, 2006. 2006 Marine Survival Forecast of Southern British Columbia coho. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2006/037.

DFO, 2008. 2007 Marine Survival Forecast of Southern British Columbia coho. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2008/032.

DFO, 2009. 2008 Marine Survival Forecast of Southern British Columbia coho. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2008/053.

DFO, 2010. 2009 Marine Survival Forecast of Southern British Columbia coho. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2009/073.

DFO, 2011. 2010 Marine Survival Forecast of Southern British Columbia coho. DFO unpublished document.

DFO, 2012. 2011 Marine Survival Forecast of Southern British Columbia coho. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2012/037.

DFO, 2013. 2013 Marine Survival Forecast of Southern British Columbia coho. DFO unpublished document.

DFO, 2014. 2014 Marine Survival Forecast of Southern British Columbia coho. DFO unpublished document.

DFO, 2015. 2015 Marine Survival Forecast of Southern British Columbia coho. DFO unpublished document.

DFO, 2016. 2016 Marine Survival Forecast of Southern British Columbia coho. DFO unpublished document.

DFO, 2017. 2017 Marine Survival Forecast of Southern British Columbia coho. DFO unpublished document.

DFO, 2018. 2018 Marine Survival Forecast of Southern British Columbia coho. DFO unpublished document.

DFO, 2019. 2019 Marine Survival Forecast of Southern British Columbia coho. DFO unpublished document.

DFO, 2020. 2020 Marine Survival Forecast of Southern British Columbia coho. DFO unpublished document.

DFO, 2021. 2021 Marine Survival Forecast of Southern British Columbia coho. DFO unpublished document.

DFO, 2022. 2022 Marine Survival Forecast of Southern British Columbia coho. DFO unpublished document.

Pacific Salmon Commission Joint Coho Technical Committee. 2013. 1986-2009 Periodic Report (Revised). Report TCCOHO (13)-1. 174 p.

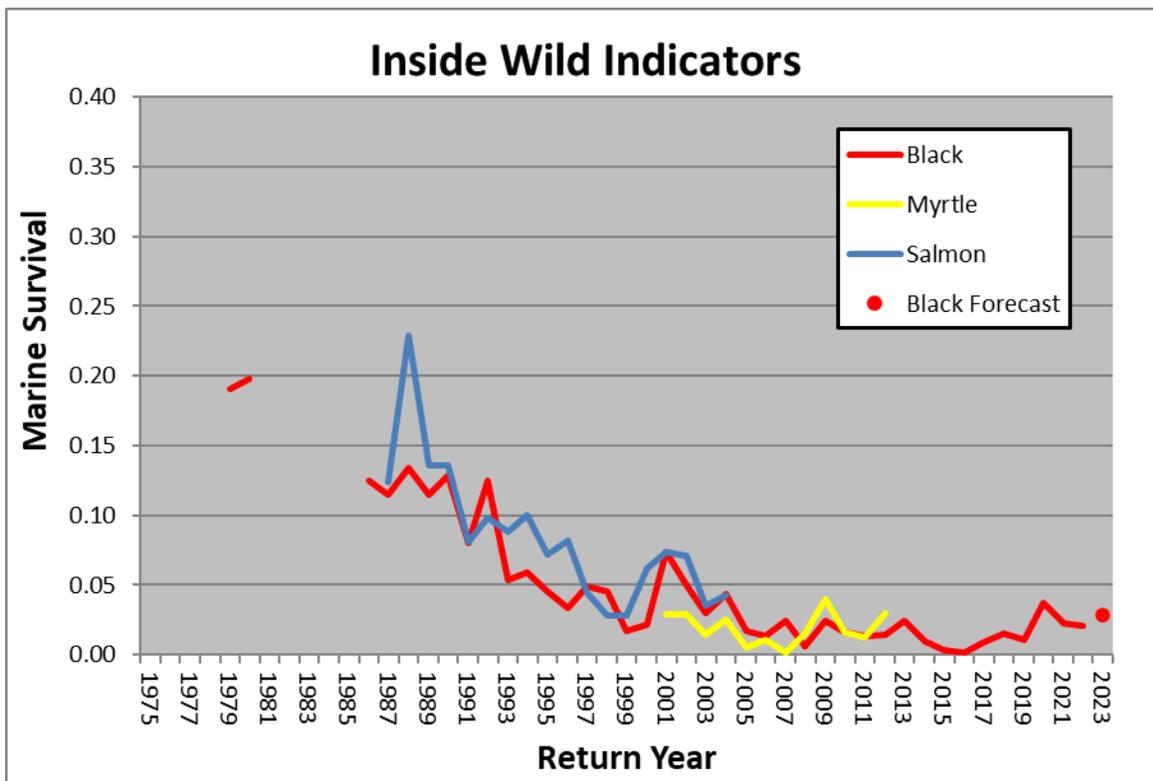
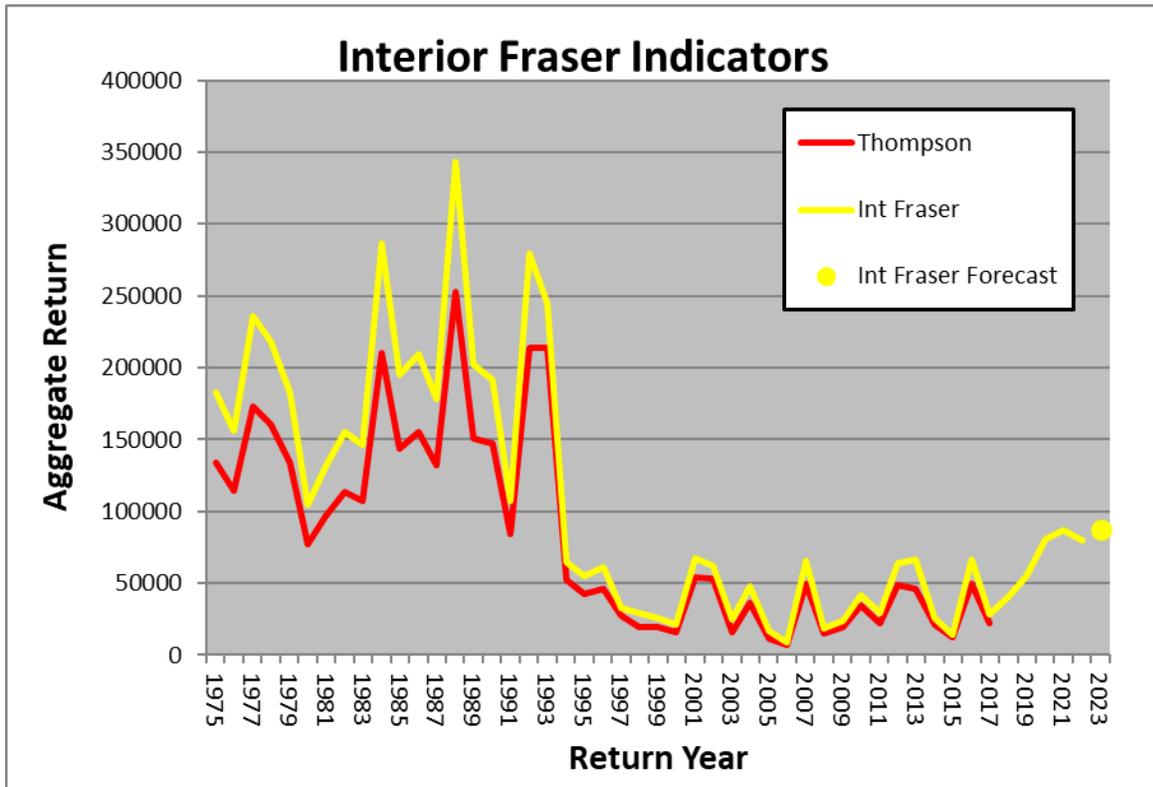
Simpson, K., Chamberlain, M., Fagan, J., Tanasichuk, R., and Dobson, D. 2004. Forecast for southern and central British Columbia coho salmon in 2004. Can. Sci. Advis. Sec. Res. Doc. 2004/135.

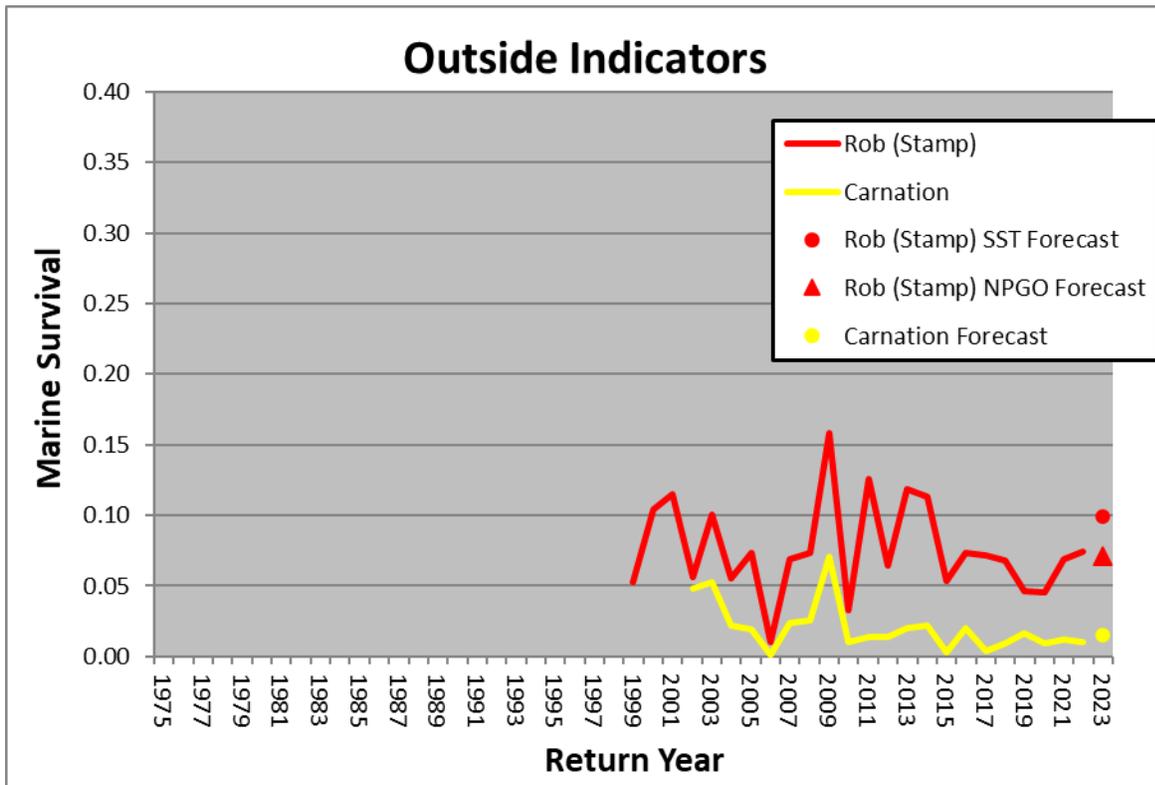
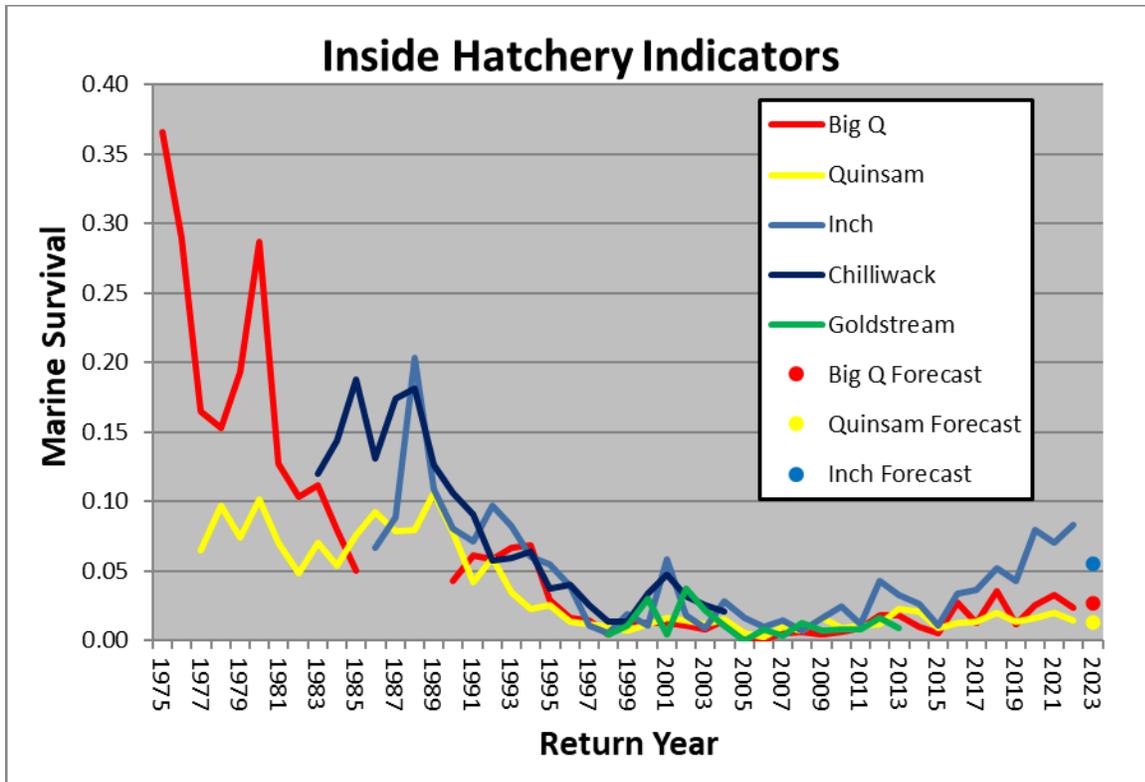
Trudel, M., Thiess, M., Morris, J., Tucker, S., Zubkowski, T., Jung, Y., and Baillie, S. 2015. Growth of juvenile Coho Salmon of WCVI: The highest on record in 2014 since 1988, *in* State of the Ocean, 2015.

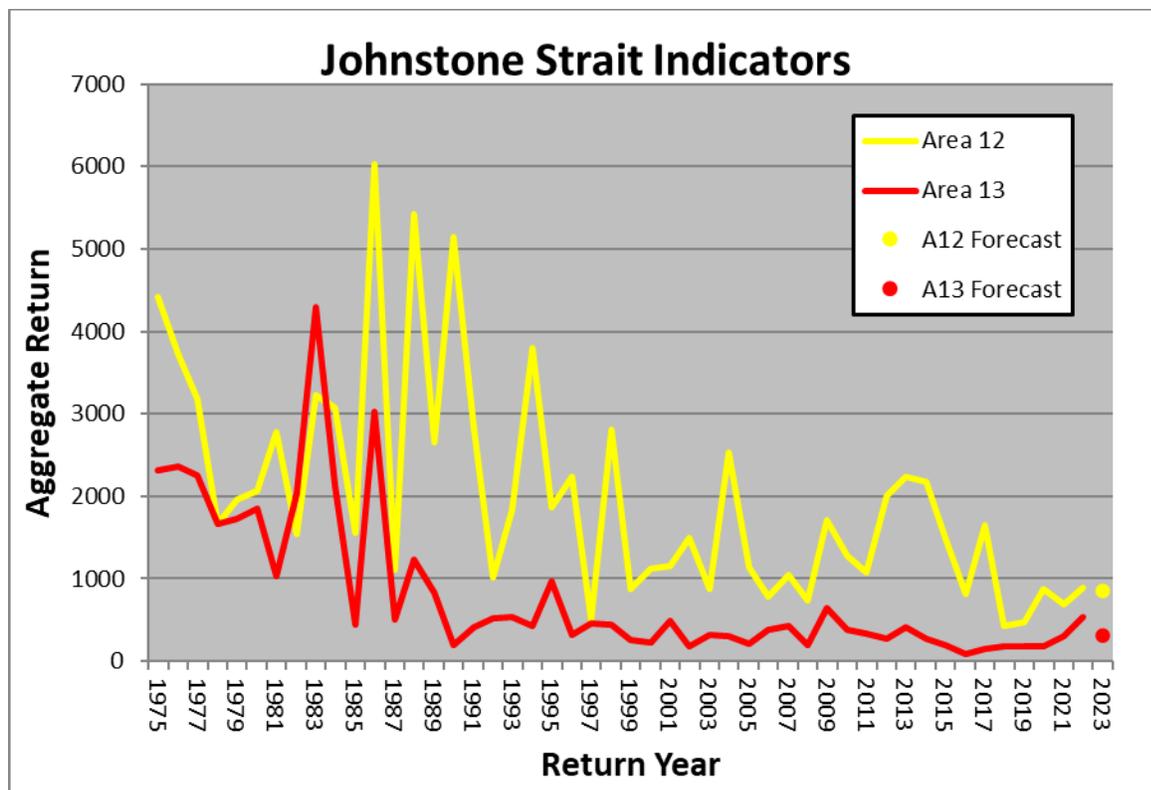
FOR MORE INFORMATION

Contact:	Karalea Cantera South Coast Area, Fisheries and Oceans Canada 3225 Stephenson Point Road Nanaimo, BC V9T 1K3
Tel:	(778) 268-2847
E-Mail:	karalea.cantera@dfo-mpo.gc.ca

Appendix 1. Marine survival or aggregate abundances for southern BC Coho indicators, including the 2023 forecast.







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.

2021 Observed: The values in this column represent either the aggregate value (whole numbers) or the estimated marine survival (decimal numbers), from the 2021 return year.

2022 Forecast, 50% CI, and Model refer to the forecast for the 2022 return year. The actual forecasted value is given first, followed by the 50% confidence interval, then the forecasting model used.

2022 Observed, Change from forecast and Change from 2021 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.

2023 Forecast, 50% CI and Model refer to the forecast for the current year.

Change from 2022 is the change in value from the observed 2022 value to the 2023 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.

Stock	2021	2022			2022 Observed	Change from forecast	Change from 2021	2023			Change from 2022
	Observed	Forecast	50% CI	Model				Forecast	50% CI	Model	
Johnstone Strait/Mainland Inlets											
Area 12 Aggregate	696	702	488-1,009	3YRA	896	28%	29%	852	593 - 1,223	3YRA	-5%
Area 13 Aggregate	303	217	150-315	3YRA	539	148%	78%	309	103 - 450	3YRA	-43%
Georgia Basin - West											
Quinsam Hatchery	0.020	0.011	0.008 - 0.016	PDO	0.014	23%	-30%	0.013	0.009 - 0.019	SST	-6%
Big Qualicum Hatchery	0.033	0.021	0.011 - 0.038	3YRA	0.024	13%	-28%	0.027	0.015 - 0.048	3YRA	14%
Black Creek (wild)	0.023	0.012	0.007 - 0.022	NPGO	0.021	71%	-7%	0.028	0.016 - 0.048	PDO	30%
Lower Fraser											
Inch Hatchery	0.070	0.027	0.017 - 0.043	NPGO	0.083	206%	18%	0.055	0.030 - 0.098	ENSO	-34%
Interior Fraser											
Interior Fraser Aggregate*	87,096	83,613	25,542-173,248	ARIMA with Box-Cox	80,235	-4%	-8%	87,079	74,538 - 130,525	ARIMA with Box-Cox	9%
South-west Vancouver Island											
Robertson (Stamp Falls) Hatchery**	0.069	0.045	0.033- 0.062	NPGO	0.074	63%	8%	0.099	0.072- 0.135	SST	34%
		0.075	0.054 - 0.103	PDO		-1%		0.071	0.051 - 0.098	NPGO	-4%
Carnation Creek (wild)	0.012	0.015	0.009 - 0.025	SST	0.010	-31%	-14%	0.015	0.009 - 0.025	SST	44%
Distribution Index (P_{inside})											
		0.190	0.134-0.263	Salinity				No value for 2023			

* Interior Fraser Aggregate uses an 80% CI for forecast uncertainty

**WCVI Stock Assessment chose to use the PDO model in 2022 and NPGO in 2023. See text for rationale.

Appendix 3. PIT tag application on 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	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		0.25%	
Black Creek	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		0.95%	
Quinsam	2019	2021	4904	29	79	0.59%	1.61%
	2020	2022	4911	15		0.31%	
Big Qualicum	2019	2021	4885	20	60	0.41%	1.23%
	2020	2022	4886	4		0.08%	
Englishman	2019	2021	3641	14	46	0.38%	1.26%
	2020	2022	2883	10		0.35%	
Puntledge	2019	2021	4911	108	188	2.20%	3.83%
	2020	2022	4915	49		1.00%	
Nanaimo	2019	2021	5000	20	115	0.40%	2.30%
	2020	2022	4976	1		0.02%	
Sakinaw	2018	2020	1094	16	9	1.46%	0.82%
	2019	2021	3154	22	6	0.70%	0.19%
	2020	2022	937	4		0.43%	

The only comparison that can be made at this time is the Black Creek indicator, Brood years 2016, 2017 & 2019. For 2018, marine survival was calculated only from PIT tags due to issues with CWT tagging during the COVID-19 pandemic in 2020. With a sample size of three, data suggest that a PIT based marine survival is lower than the corresponding CWT based marine survival. Over the ensuing years additional observations will increase the size of this dataset to allow for a more significant comparison.

Watershed, Brood Year	CWT Marine Survival	PIT Marine Survival
Black, BY 2016	0.011	0.007
Black, BY 2017	0.037	0.019
Black, BY 2018		0.020
Black, BY 2019	0.021	0.013

CWT Marine Survival uses CWT for escapement, CWT and ER-Effort Model for exploitation. PIT Marine Survival uses PIT tags for escapement, CWT and ER-Effort Model for exploitation.