2020 MARINE SURVIVAL FORECAST OF SOUTHERN BRITISH COLUMBIA COHO

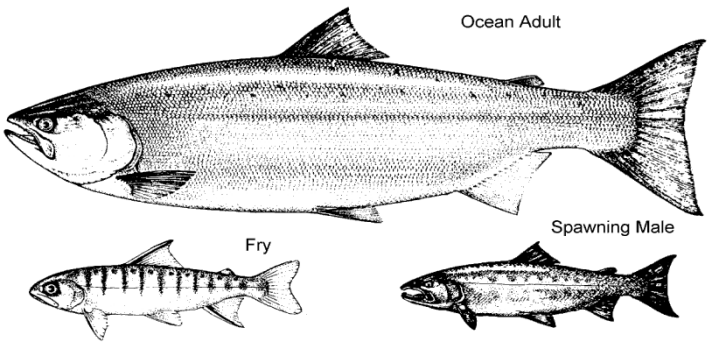

Figure 1: Coho salmon at three life stages: freshwater rearing fry; ocean rearing adult; and returning male. This image has been used on previous coho Stock Status reports, origin unknown.

Figure 2: The Province of British Columbia, showing the major rivers in the South Coast, Lower Fraser and Interior BC areas.

SUMMARY

The observed indicator marine survivals and aggregate abundances from 2019 were generally similar to the previous year with some (Area 12, Interior Fraser Aggregates, Carnation Wild) slightly higher and some (Area 13 Aggregate, Quinsam, Big Qualicum, Inch and Robertson Hatcheries, Black Wild) lower. All but Area 12 Aggregate and Robertson Hatchery were higher than the forecasted levels. The two wild indicators at Carnation and Black Creek were both much higher than the forecast level.

The 2020 forecast for coho indicator marine survivals is showing a decrease from 2019 levels (minus 3% - 63%) for all indicators except for Area 12 Aggregate. The best performing models that were used for the indicators that have a decrease forecast are both time-series models and climate index models. This suggests that both types of models are forecasting a decrease in marine survivals.

The Chrome Island salinity Distribution Index suggests a high outside distribution for coho suggesting a late summer return of coho adults to the Strait of Georgia.

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.

The changes in indicator marine survivals from 2018 to 2019 were mixed, with Area 12 and Upper Fraser Aggregates and Carnation Wild higher than both the previous year, and Area 13 Aggregate, Quinsam, Inch and Robertson (Stamp) Hatcheries and Black Wild lower than the previous year. All were higher than the forecast, except for Area 12 Aggregate and Robertson Hatchery.

Starting with the 2015 forecast, the Ocean Climate Indices was 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) and DFO (2019) are similar reports that are unpublished but are available from Wilf Luedke, StAD Chief, South Coast Area, DFO.

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. Generally, 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).

For the 2020 forecast, the non-clipped coded-wire tagged coho released from Black Creek were detected in the Northern Troll fishery. 20 CWT only coho were observed, with an estimated catch of 52 coho. This information was incorporated in the exploitation rate estimate for this Indicator.

Data Sources

The data set 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, Broodstock 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.

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 2020 Interior Fraser Aggregate forecast is based on using the Ricker model which the retrospective analysis showed to be a better fit than other time series models. This model uses the Ricker formulae parameters from the population to forecast the recruitment for this stock.

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. In this year's annual report the marine climate indices will be included in the forecast model comparison for all the marine survival indicators.

The data for the climate indicators was obtained from:
PDO: https://www.ncdc.noaa.gov/teleconnections/pdo/data.csv
NPGO: http://www.o3d.org/npgo/data/NPGO.txt
ENSO: http://www.esrl.noaa.gov/psd/enso/mei/
Amphitrite SST: http://www.pac.dfo-mpo.gc.ca/science/oceans/data-donnees/lighthouses-phares/data/AmphitriteMonthlyTemp.txt

The previous data file for PDO (http://research.jisao.washington.edu/pdo/PDO.latest.txt) has not been updated since Sept 2018 so a 2020 marine survival forecast based on the early ocean period of May-September 2019 is not possible from this dataset. Instead, a different data set has been substituted as noted above. A comparison of the average observations from the May-September period was made for the years 1998-2018, resulting in an R^2 of 0.956.

The original source for the NPGO data file has not been updated since July 2019. Since this model index uses an average of the monthly observations from May-Sept the averages for the

May-July and May-Sept periods were compared and showed a very close R^2 of 0.986, so the shorter period was used for the 2020 forecast.

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 2018 and 2019 values, and the forecast for 2020 returns.

Johnstone Strait/Mainland Inlets

In 2019 the observed return in Area 12 was 33% lower than forecast and the Area 13 return was about 27% higher than forecast. The Area 12 return saw 58% of the 2016 brood return and about 110% of what was estimated for the previous year return (2018). The Area 13 return demonstrated an almost doubling of abundance relative to the brood year (2016) and a similar abundance as the previous year's return (2018). For the indicator systems at Keogh and Black Creek, smolt production in 2018 was below average for both at 65,000 and 34,000 smolts respectively. Based on the observed 2019 returns at those and other system in the area, marine survival continue to be low for both Area 12 and Area 13. This reduction in marine survival in Area 12 and 13 was also observed in many of the local pink salmon stocks that out-migrated in 2018 similar to the coho salmon.

The Area 12 forecast for 2020 is 60% lower than the brood returns in 2017. The Area 13 forecast is 17% higher than the 2017 observed indices. Coho abundance in this region is varied and 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 2019 was average for Keogh River (72,000). 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 (Figure 5) further exacerbating the uncertainty in the expectations.

Georgia Basin – West

The Big Qualicum Hatchery experienced a technical malfunction while rearing the progeny from the 2016 brood and subsequently lost most of the production. The surviving few smolts were released in 2018 but were not coded-wire tagged or adipose clipped. As a result there is no observed marine survival metric for this Indicator for the 2019 return, and the model regressions could not be updated. The forecast models for this Indicator used the previous regressions from 2018.

The observed 2019 marine survival rate of Quinsam Hatchery was 1.3%, and the marine survival at the wild indicator at Black Creek was 1.1%. Both Indicators had observed marine survival levels that were lower than the previous year (-33% and -40%), but higher than the forecast (+49% and +114%).

After a retrospective analysis with the addition of the 2019 return, the best performing forecast model for the Quinsam River Hatchery Indicator has changed to the Sea Surface Temperature index. The best performing model for Big Qualicum switched from the NPGO to the ENSO despite the regression not updated. The change is due to revision of the index figures from

preliminary to final. The best performing model for the Black Creek Indicator was still the NPGO.

The 2020 forecast for the three indicators is for a continuation of the low marine survival levels seen in recent years. The model forecasts a marine survival of 1.0%, 0.6% and 0.4% for Quinsam Hatchery, Big Qualicum Hatchery and Black Creek (changes of -25%, n/a, and -63% from 2019 observed levels), respectively. Smolt production in 2019 (46,000) was below average for Black Creek.

Lower Fraser

The observed 2019 marine survival from the Inch Creek Hatchery indicator was 2.8% which was lower than the previous year (-44%) and was higher than the forecast level (+47%).

The retrospective analysis showed that the best performing model has switched from the ENSO to NPGO climate index. The 2020 forecast for marine survival for this indicator is 2.0%, a decrease (-28%) from the observed level in 2019.

Interior Fraser

The observed 2019 abundance for the Interior Fraser Aggregate was 55,133, 36% higher than the previous year and the 2019 forecast.

The forecast model selected for the 2020 return is the Ricker stock-recruit relationship, which is a change from last year when the Like Last Year model was used. The 2020 forecast of abundance for the Interior Fraser Aggregate is 39,223 coho with an 80% forecast range of 31493 to 48,849. Please note that the confidence interval was changed from 50% to 80%. This forecast is 29% less than the observed recruitment in 2019.

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 2019 marine survival of 4.6% for Robertson (Stamp) Indicator was lower from the previous year (-32%) and lower than the forecast (-21%). The marine survival of 1.7% for Carnation Creek (Wild) was higher (+69%) than the previous year and much higher than the forecast (+181%).

For the 2020 forecast, the best performing model for the Robertson (Stamp) Indicator remained as the NPGO while the best performing model for the Carnation Wild Indicator was the 3 Year Average time series model. The 2020 marine survivals are forecast to decrease to 2.7% (Robertson), and decrease to 1.3% (Carnation) from the 2019 observed values. This is a decrease of 42% and 23%, respectively.

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 4, 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 27.60 ppt, which results in a P_{inside} statistic of 0.232, suggesting a high outside distribution of coho.

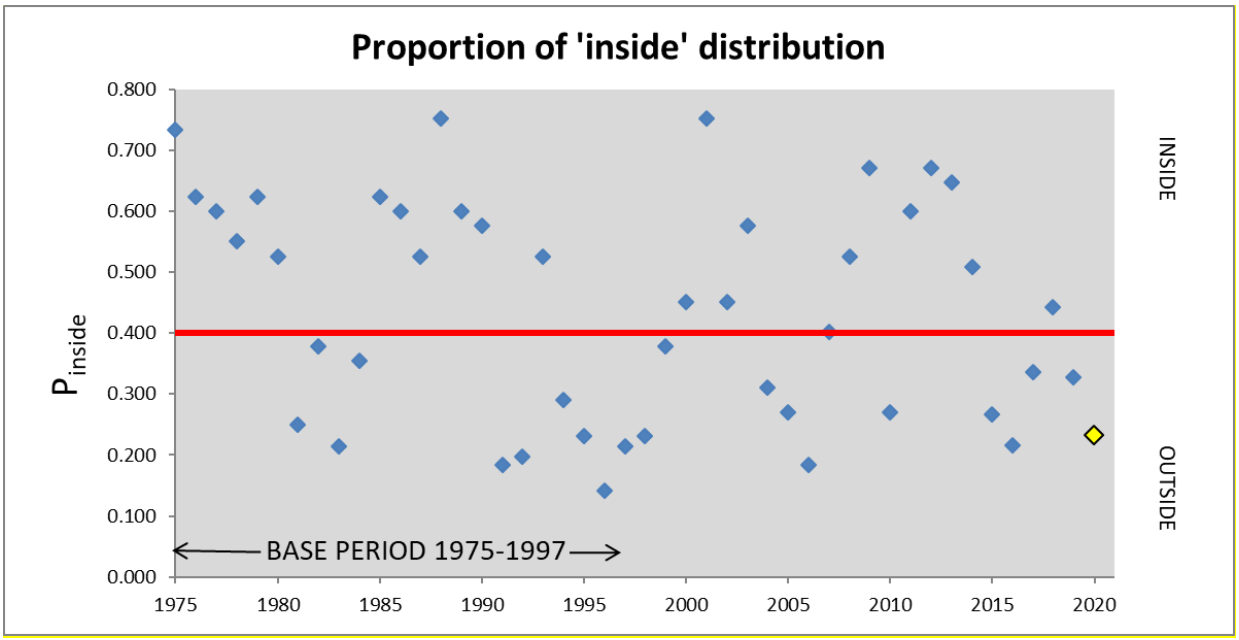

Figure 4. Distributional index for Strait of Georgia Coho, with observed data from 1975-1997, and results from the salinity based model for 1998-2020. The red line indicates the division between an 'inside' year and an 'outside' year. The yellow datum represents the current year.

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. Steve Baillie (ret., DFO) completed analysis of WCVI and Strait of Georgia indicators. Data analysis of the Interior Fraser Management Unit was completed by Lynda Ritchie, and the Johnstone Strait Aggregates by Pieter Van Will.

Fresh water creel survey data were provided by Joan Bennett (Strait of Georgia) and Joe Tadey (Lower Fraser). Coho data from the WCVI indicators was collated by Erin Porszt and Mike Spence. Cheryl Lynch provided escapement data from the hatcheries. Wild coho data were

provided by Andrew Pereboom - Black Creek) and Dr. Peter Tschaplinski (BC Ministry of Environment - Carnation Creek). Chrome Island salinities were collected by the lighthouse keeper and provided by Peter Chandler, Institute of Ocean Sciences.

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 2020.

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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

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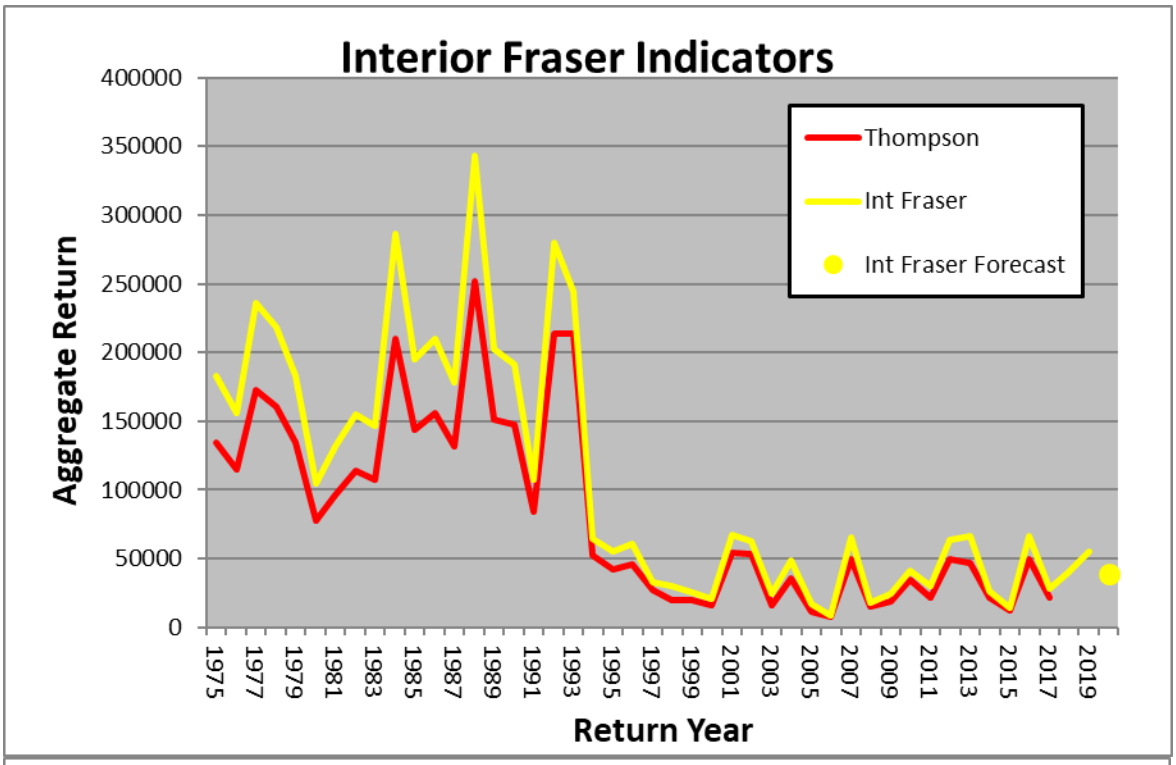
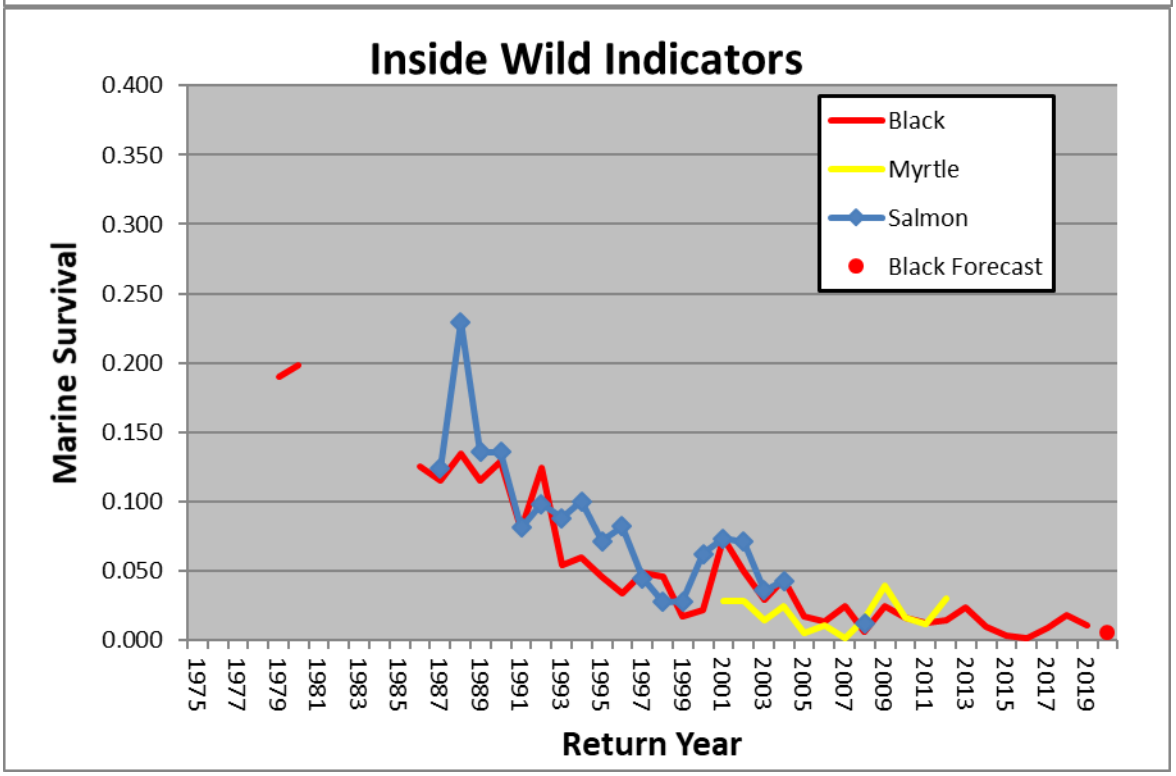
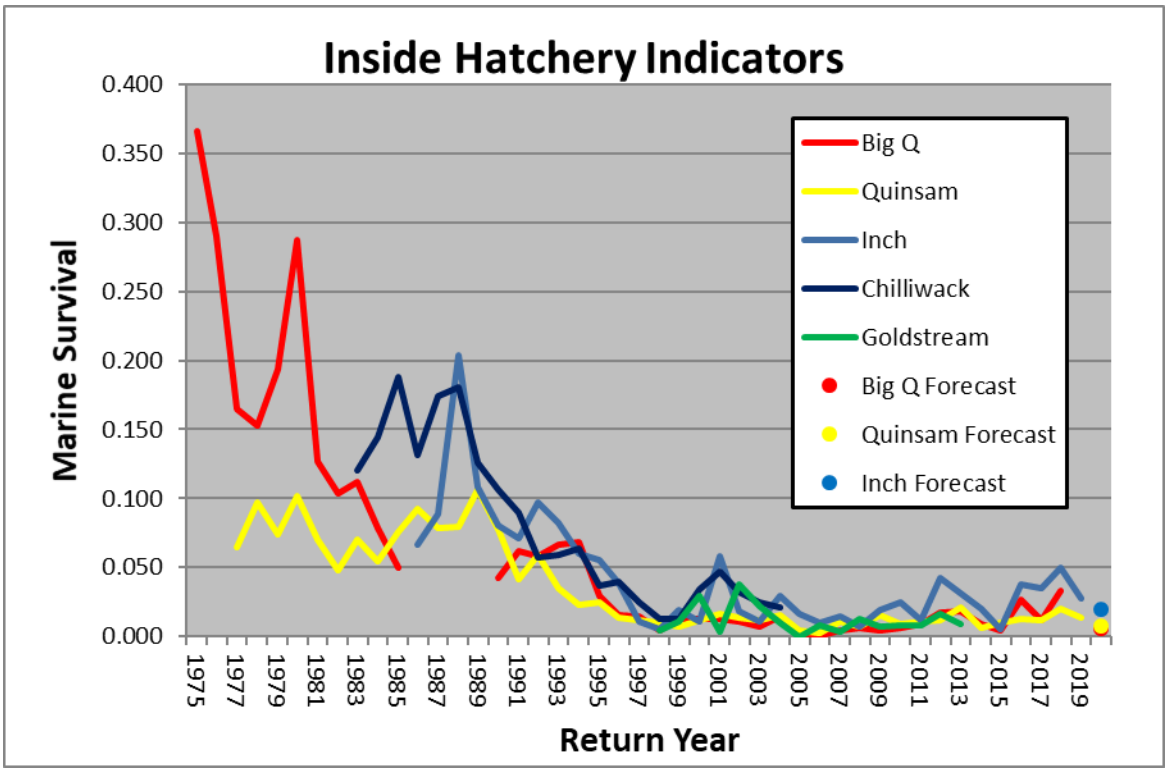
Appendix 1. Marine survival or aggregate abundances for southern BC coho indicators, including the 2020 forecast.






Inside Hatchery Indicators
Marine Survival
0.400
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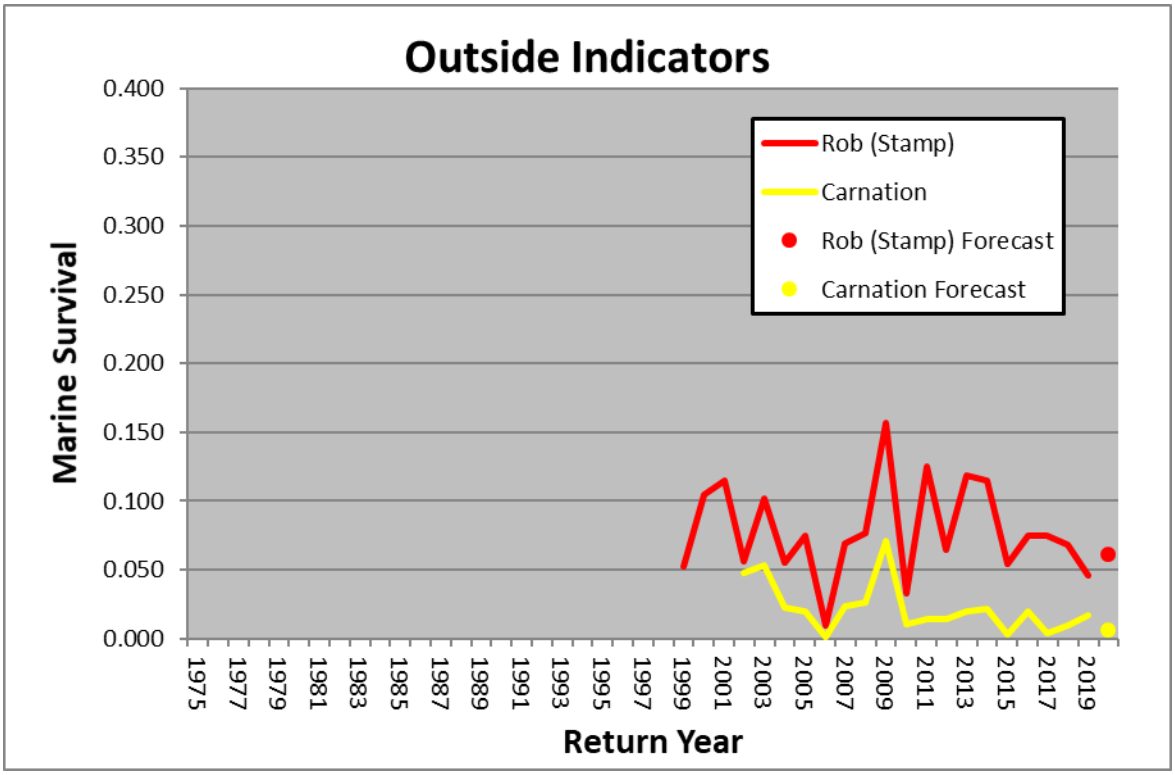
Inch Forecast


Outside Indicators
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Return Year
Rob (Stamp)
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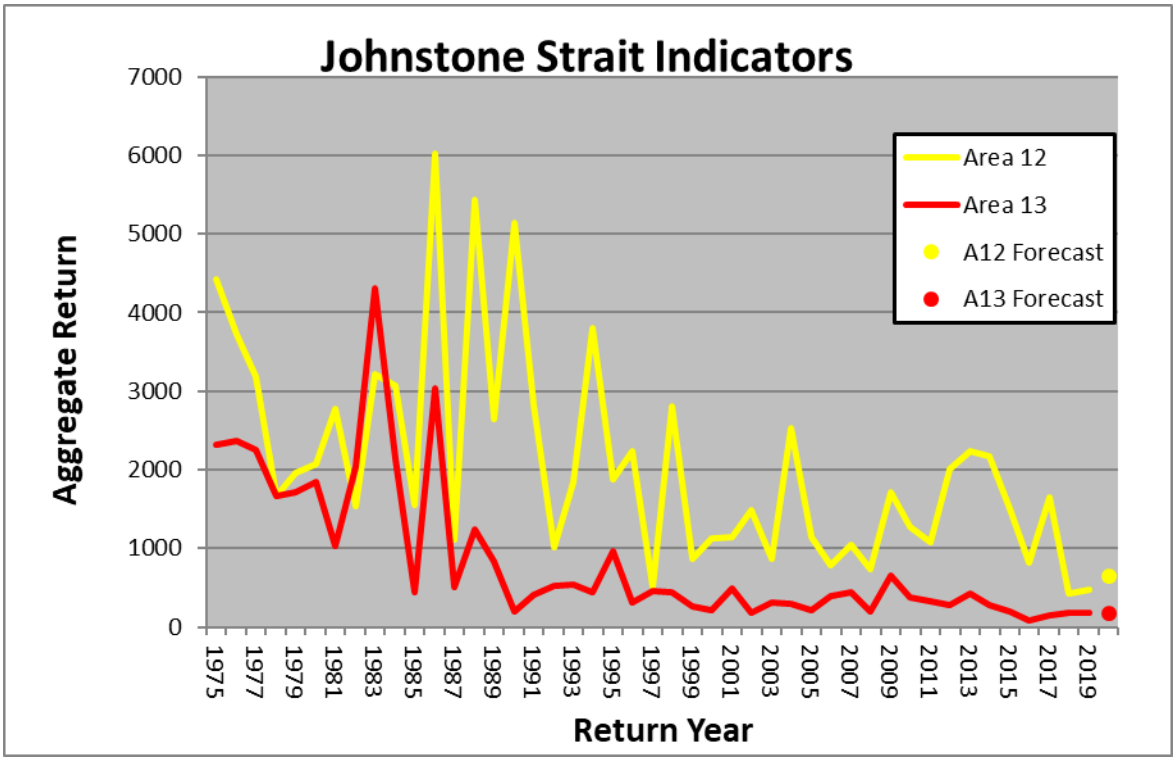
Rob (Stamp) Forecast
Carnation Forecast


Johnstone Strait Indicators
Aggregate Return
Return Year
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Area 13
A12 Forecast
A13 Forecast
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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.

2018 Observed: The values in this column represent either the aggregate value (whole numbers) or the estimated marine survival (decimal numbers), from the 2018 return year.

2019 Forecast, 50% CI, and Model refer to the forecast for the 2019 return year. The actual forecasted value is given first, followed by the 50% confidence interval, then the forecasting model used.

2019 Observed, Change from forecast and Change from 2018 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.

2020 Forecast, 50% CI and Model refer to the forecast for the current year.

Change from 2019 is the change in value from the observed 2019 value to the 2020 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	2018	2019			2019	Change from forecast	Change from 2018	2020			Change from 2019
	Observed	Forecast	50% CI	Model	Observed			Forecast	50% CI	Model	
Johnstone Strait/Mainland Inlets											
Area 12 Aggregate	427	712	494 - 1047	3YRA	474	**-33%**	**11%**	649	451 - 935	3YRA	**39%**
Area 13 Aggregate	185	140	95 - 204	3YRA	178	**27%**	**-4%**	172	118 - 251	3YRA	**-3%**
Georgia Basin - West											
Quinsam Hatchery	0.020	0.009	0.006 - 0.012	NPGO	0.013	**49%**	**-33%**	0.010	0.007 - 0.013	SST	**-25%**
Big Qualicum Hatchery	0.033	0.006	0.003 - 0.010	NPGO	N/A			0.006	0.003 - 0.010	ENSO	
Black Creek (wild)	0.018	0.005	0.003 - 0.008	NPGO	0.011	**114%**	**-40%**	0.004	0.003 - 0.007	NPGO	**-63%**
Lower Fraser											
Inch Hatchery	0.050	0.019	0.012 - 0.029	ENSO	0.028	**47%**	**-44%**	0.020	0.013 - 0.030	NPGO	**-28%**
Interior Fraser											
Interior Fraser Aggregate*	40,533	40,533	28422 - 58342	LLY	55,133	**36%**	**36%**	39,223	31,493 - 48,849	Ricker	**-29%**
South-west Vancouver Island											
Robertson (Stamp Falls) Hatchery	0.068	0.059	0.043 - 0.081	NPGO	0.046	**-21%**	**-32%**	0.027	0.020 - 0.037	NPGO	**-42%**
Carnation Creek (wild)	0.010	0.006	0.003 - 0.011	3YRA	0.017	**181%**	**69%**	0.013	0.007 - 0.023	3YRA	**-23%**
Distribution Index (P_{inside})		0.326	0.244 - 0.420	Salinity				0.232	0.167 - 0.313	Salinity	

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