2017 MARINE SURVIVAL FORECAST OF SOUTHERN BRITISH COLUMBIA COHO

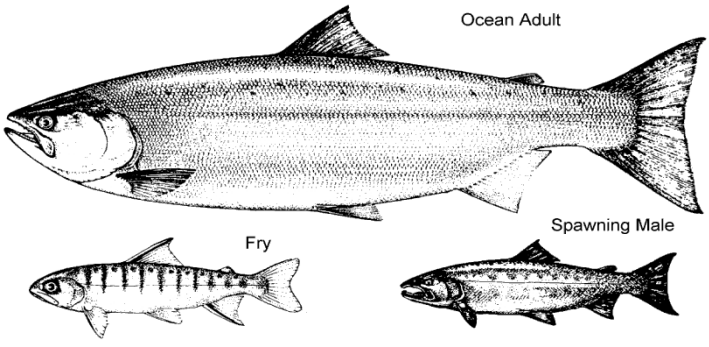


Figure 1: Coho salmon at three life stages: freshwater rearing fry; ocean rearing adult; and returning male. This image has been used on previous coho Stock Status reports, origin unknown.

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

SUMMARY

Many of the indicator marine survivals and aggregate abundances from 2016 were much higher (37% - 575%) than the previous year; the exceptions were the indicators in Johnston Strait (46% - 60% lower). This increase is deceptive. The actual observed marine survivals and aggregate abundances are still within the range that has been in place since the mid-1990's.

The 2017 forecast for coho indicators are showing a return to the low marine survivals that have been observed over the last few years. The indicators that experienced higher survivals in 2016 are forecast to have a decrease in marine survival or aggregate abundance of 19% to 85% from the 2016 observations. The two Johnstone Strait aggregate indicators, which decreased in abundance in 2016, are forecast to increase in abundance by 71% - 103% in 2017.

The Distribution Index forecast for 2017 indicated a slightly moderate 'outside' distribution of coho in the Strait of Georgia. This forecast is based on marine salinity measurements from February and March of the returning year.

INTRODUCTION

Most of the indicators of marine survivals and returns in 2016 showed a reversal from the downward trend from the last few years. Many indicators showed 2016 observations that were multiple times higher than the previous year however all were still within the low range that has occurred since the mid-1990s. The exceptions to this general description

are the Quinsam Hatchery and Robertson (Stamp) Hatchery Indicators that had increased slightly from 2015, and the Johnstone Strait Aggregate indicators that decreased from 2015.

Previously, in the 2015 forecast, the Ocean Climate Indices and the Growth model were incorporated into the suite of models examined for the two WCVI indicators. For the current forecast, these indices were included with the rest of the marine survival indicators. These models were not considered for the Aggregate Indicators in this forecast.

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 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 (2007), DFO (2008), DFO (2009) and DFO (2012). Baillie et al. (2005), DFO (2011), DFO (2013), DFO (2014), DFO (2015) and DFO (2016) are similar reports that are unpublished but are available from the lead author.

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. 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).

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 aggregates, the data represents the estimated total abundance for those areas. 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.

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 Growth model is described in Trudel *et al.* (2008).

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: http://jisao.washington.edu/pdo/PDO.latest
NPGO: http://www.o3d.org/npgo/data/NPGO.txt
ENSO: http://www.esrl.noaa.gov/psd/enso/mei/table.html
Amphitrite SST: http://www.pac.dfo-mpo.gc.ca/science/oceans/data-donnees/lighthouses-phares/data/amphitrt.txt

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 2015 and 2016 values, and the forecast for 2017 returns.

Johnstone Strait/Mainland Inlets

In 2016 the observed return in Area 12 was 58% lower than forecast and the Area 13 return was about 72% lower than forecast. The Area 12 return saw only 36% of the 2013 brood return and only 54% of what was estimated for the previous year return (2015). The Area 13 return demonstrated a 19% decrease in abundance relative to the brood year (2013) and 39% lower than the previous year's return (2015). For the indicator systems at Keogh, smolt production in 2015 was just well above average (112,000). Based on the observed 2016 returns at this and other systems in the area, marine survival had declined in both Area 12 and Area 13 relative to the 2015 return. This reduction in marine survival was also observed in many of the Area 12 and 13 pink salmon stocks that out-migrated in 2015 similar to the coho salmon.

The 2017 Area 12 and 13 forecasts are lower than the brood returns in 2014. The Area 12 and 13 forecasts are respectively 37% and 40% lower than the 2014 observed indices.

Coho abundance in this region is varied and can be characterized as 'average' for Area 12 stocks and 'below average' for Area 13 stocks. See Simpson et al., 2004 for description of characterizations. Smolt production in 2016 was well above average for Keogh River (92,000). 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.

Georgia Basin – West

The Hatchery indicators for this Management Unit are Quinsam and Big Qualicum Hatcheries and the Wild indicator is Black Creek. In 2015 the smolt production at Black Creek (24,000) was well below average. In 2016 the reported proportion of coded-wire tagged coho adults from Black Creek was extremely low, much lower than expected, suggesting that there was a technical or operational problem with detecting tags. As a result, the time series of the Black Creek Indicator could not be updated and the performance of the forecast model could not be run. For the 2017 forecast for this Indicator, the model used for the 2016 forecast (3 Year Average) will be used. The LLY model (Like Last Year) was not considered due to the absent data for 2016.

The observed 2016 marine survival rate of Quinsam Hatchery did not show a substantial increase from the observed 2015 level and the 2016 forecast. The Big Qualicum Hatchery, similar to other indicators in the Strait of Georgia, Fraser River, and the west coast of Vancouver Island, has shown a substantial increase over the observed 2015 level, reversing a trend over the last two years. Smolt production for Black Creek (25,000) was well below average.

The best performing model for the Big Qualicum Hatchery indicator is the Growth Model. For the Quinsam Hatchery and the Black Creek Wild indicator the North Pacific Gyre Oscillation index was used as the preferred model from the 2016 forecast. The 2017 forecast for the Quinsam and Big Qualicum Hatchery indicators is for a decrease from the 2016 levels, to 0.8% and 0.4% marine survival, respectively. The Black Creek wild indicator forecast is 0.7% marine survival.

Lower Fraser

The Hatchery indicator for this Management Unit is Inch Creek Hatchery. Previously Chilliwack Hatchery and Salmon River (wild) were used as indicators but are no longer in use.

The observed 2016 marine survival from Inch Creek hatchery increased 533% from the 2015 level, similar to most of the other indicators. Under the retrospective analysis the climatic index Pacific Decadal Oscillation has performed better than the other forecast models and the 2017 forecast is 1.2% marine survival.

Interior Fraser

The observed 2016 abundances for both the Thompson River and Interior Fraser Aggregates were substantially higher than the observed 2015 abundance and 2016 forecast by 303% and 379%, respectively.

The forecast model selected for the 2017 return is the 3 Year Average model, which is a return back from last year when the Like Last Year model was used. This change was based on the retrospective performance analysis of each model which showed the 3YRA model as having the lowest Mean Annual Percent Error (MAPE).

The 2017 forecast of abundance for the Interior Fraser Aggregate is 31,212 coho with a 50% forecast range: 19,309 to 50,453. Similarly, the 2017 forecast for Upper Thompson Aggregate is 24,752 with a range of 15,119 to 40,525.

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 2016 marine survival for both hatchery and wild indicators were substantially higher than the previous year. The Robertson Indicator marine survival was 41% higher while the Carnation Indicator was 557% higher than the very low levels observed in the previous year. Both values were also substantially higher than the 2016 forecast.

In developing the 2017 forecast for the Robertson (Stamp) Indicator, the North Pacific Gyre Oscillation index was found to have superior predictive power over the other models and indices. For the Carnation Wild Indicator, the 3 Year Average was found to have the best predictive power. The 2017 marine survivals are forecast to decrease to 6.2% (Robertson) and 0.8% (Carnation) from the 2016 observed values.

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 2017 forecast of P_{inside} is 0.335, indicating a slightly outside distribution of coho. This suggests that coho abundance in the Strait of Georgia will be a more of an inside

year compared to the last two years. Figure 4 shows the time series of data used for the Salinity/distribution relationship (1975-1997) and the result of the model (1998-present).

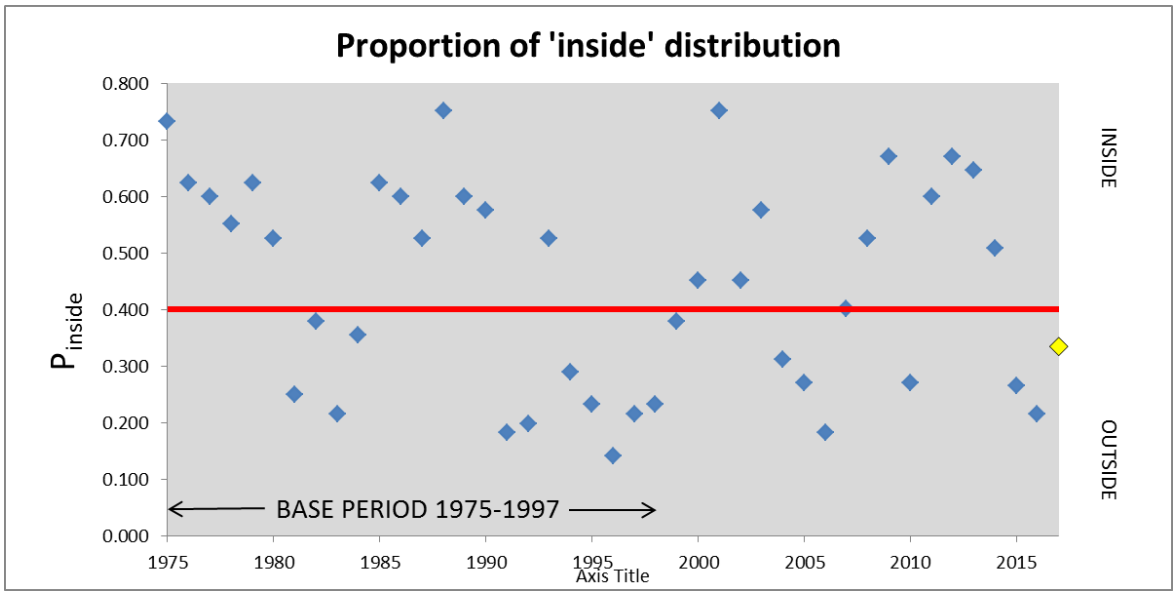


Figure 4. Distributional index for Strait of Georgia Coho, with observed data from 1975-1997, and results from the salinity based model for 1998-2017. The yellow datum represents the current year.

ACKNOWLEDGEMENTS

The coho forecast for southern British Columbia requires data from many sources and is very much a collaborative document. Steve Baillie completed analysis of Strait of Georgia and WCVI indicators. Data analysis of the Interior Fraser Management Units was completed by Lynda Ritchie and Johnstone Strait by Pieter Van Will.

Fresh water creel survey data were provided by Joan Bennett (Strait of Georgia), and Joe Tadey (Lower Fraser). The marked coho escapement for Robertson Creek Hatchery was supplied by Erin Porszt. Cheryl Lynch provided escapement data from the hatcheries. Wild coho data were provided by Jim Meldrum (A'tlegay First Nation - Black Creek) and Dr. Peter Tschaplinski (BC Ministry of Environment - Carnation Creek). Thanks to Dr. Jackie King for contributing data for the Growth Model for forecasting marine survivals of WCVI salmon stocks. Ocean Climate indices were obtained from various internet sources noted in the text. Salinity data was provided by Peter Chandler (IOS).

REFERENCE CITED

Ocean Climate index sources were accessed in February 2017.

Baillie, S., Simpson, K., Chamberlain, M., Van Will, P., Tanasichuk, 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.

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

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.

Kuhn, B.R., Lapi, L., and Hamer, J.M. 1988. An Introduction to the Canadian Database on Marked Pacific Salmonids. Can. Tech. Rep. Fish. Aquat. Sci. 1649: viii + 56 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.

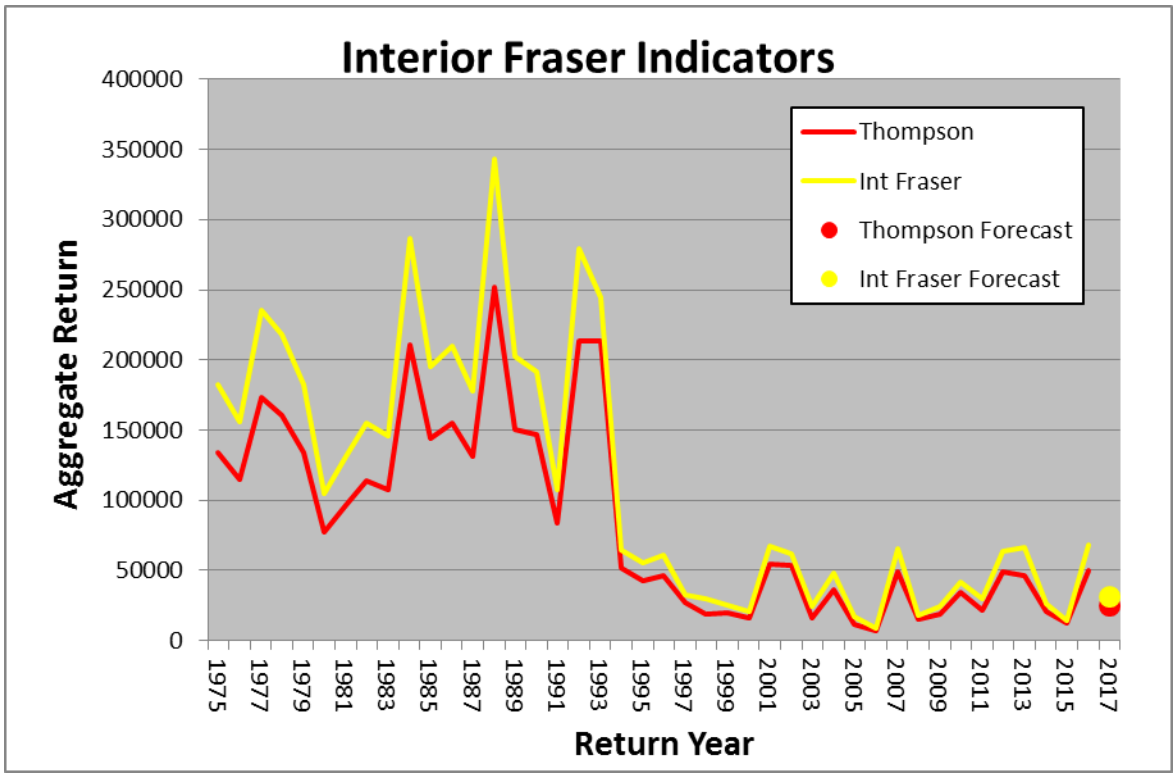
Trudel, M., Baillie, S., Parken, C., and O'Brien, D. 2008. Average Growth for Coho Salmon in Southern BC, *in* State of physical, biological, and selected fishery resources of Pacific Canadian marine ecosystems. Irvine, J., and Crawford, B. editors. Can. Sci. Ad. Sec. Res. Doc. 2008/013. 113 pp.

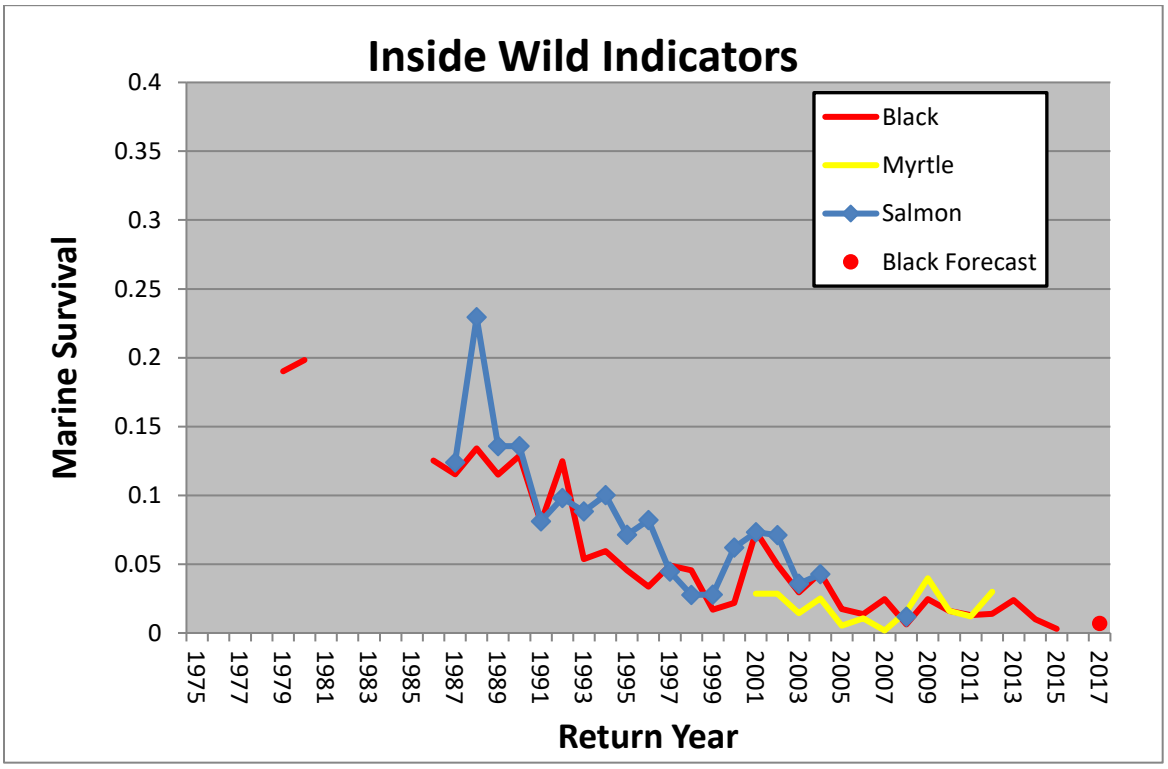
Trudel, M., Thiess, M., Morris, J., Tucker, S., Zubkowski, T., Jung, Y., and Baillie, S. 2015. Growth of juvenile Coho Salmon of WCVI: The highest on record in 2014 since 1988, *in* State of the Ocean, 2015.

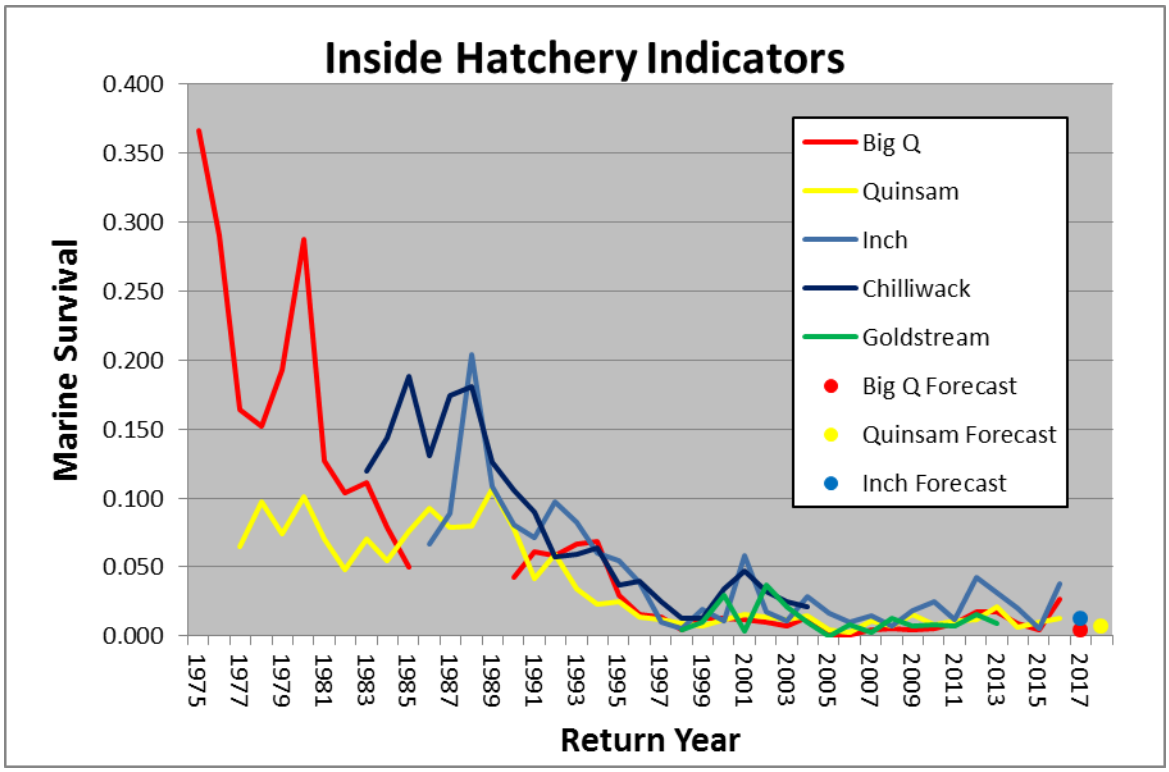
FOR MORE INFORMATION

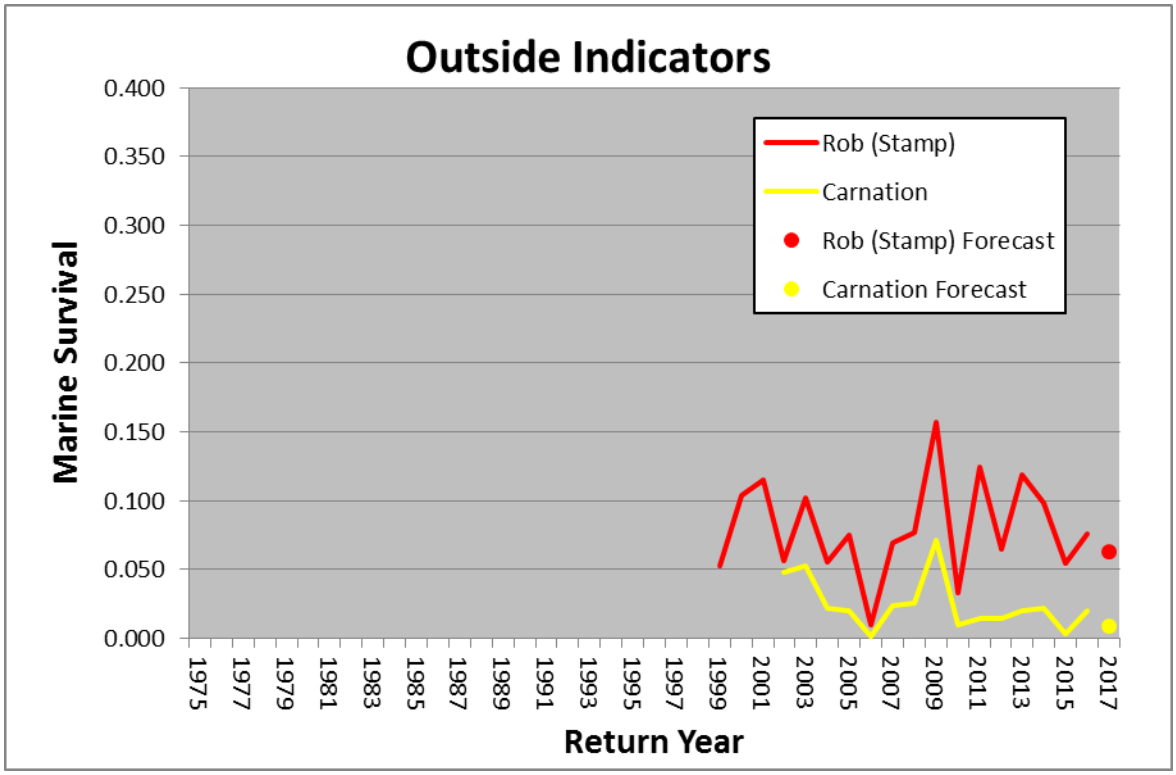
Contact:	Steve Baillie South Coast Area, Fisheries and Oceans Canada 3225 Stephenson Point Road Nanaimo, BC V9T 1K3
Tel:	(250) 756-7227
Fax:	(250) 756-7020
E-Mail:	steve.baillie@dfo-mpo.gc.ca

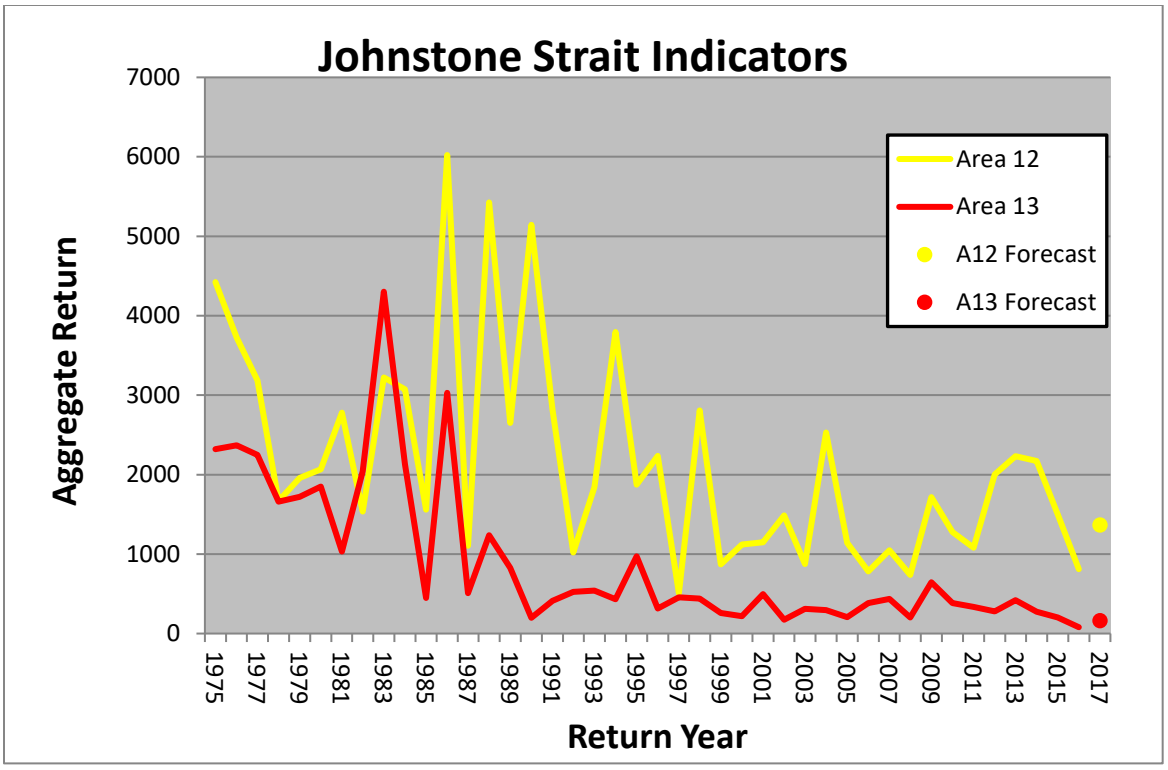
Appendix 1. Marine survival or aggregate abundances for southern BC coho indicators, including the 2017 forecast. The Quinsam forecast datum is offset for clarity.






Inside Hatchery Indicators
Marine Survival
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015
2017
Return Year
Big Q
Quinsam
Inch
Chilliwack
Goldstream
Big Q Forecast
Quinsam Forecast
Inch Forecast


Outside Indicators
Marine Survival
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015
2017
Return Year
Rob (Stamp)
Carnation
Rob (Stamp) Forecast
Carnation Forecast


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

2015 Observed: The values in this column represent either the aggregate value (whole numbers) or the estimated marine survival (decimal numbers), from the 2015 return year.

2016 Forecast, 50% CI, and Model refer to the forecast for the 2016 return year. The actual forecasted value is given first, followed by the 50% confidence interval, then the forecasting model used.

2016 Observed, Change from forecast and Change from 2015 refer to the estimated values for each indicator, then the % change from the forecasted value and 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 33% change and is highlighted in green. A decrease of 2.0% to 1.5% is expressed as a – 25% change and is highlighted in pink.

2017 Forecast, 50% CI and Model refer to the forecast for the current year.

Change from 2016 is the change in value from the observed 2016 to the 2017 forecast. Each changed is highlight 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	2015	2016			2016	Change from forecast	Change from 2015	2017			Change from 2016
	Observed	Forecast	50% CI	Model	Observed			Forecast	50% CI	Model	
Johnstone Strait/Mainland Inlets											
Area 12 Aggregate	1,500	1,909	1,322 - 2,757	3YRA	811	**-58%**	**-46%**	1,367	944 - 1981	3YRA	**71%**
Area 13 Aggregate	202	286	196 - 416	3YRA	80	**-72%**	**-60%**	162	110 - 239	3YRA	**103%**
Georgia Basin - West											
Quinsam Hatchery	0.010	0.016	0.011 - 0.022	3YRA	0.013	**-19%**	**37%**	0.008	0.006 - 0.010	NPGO	**-38%**
Big Qualicum Hatchery	0.004	0.004	0.002 - 0.007	LLY	0.027	**575%**	**575%**	0.004	0.003 - 0.007	Growth	**-85%**
Black Creek (wild)	0.003	0.009	0.006 - 0.013	3YRA	N/A			0.007	.0.005 - 0.012	NPGO	
Lower Fraser											
Inch Hatchery	0.006	0.006	0.003 - 0.010	LLY	0.038	**533%**	**533%**	0.012	0.008 - 0.018	PDO	**-68%**
Interior Fraser											
Interior Fraser Aggregate	14,260	14,260	8,556 - 23,767	LLY	68,292	**379%**	**379%**	31,212	19,309 - 50,453	3YRA	**-54%**
Thompson River Aggregate	12,374	12,374	7,419 - 20,638	LLY	49,904	**303%**	**303%**	24,752	15,119 - 40,525	3YRA	**-50%**
South-west Vancouver Island											
Robertson (Stamp Falls) Hatchery	0.054	0.016	0.013 - 0.021	NPGO	0.076	**376%**	**41%**	0.062	0.048 - 0.079	NPGO	**-19%**
Carnation Creek (wild)	0.003	0.003	0.002 - 0.004	NPGO	0.020	**557%**	**516%**	0.008	0.004 - 0.015	3YRA	**-59%**
Distribution Index (P_{inside})		0.216	0.155 - 0.294	Salinity				0.335	0.430 - 0.252	Salinity	