2016 MARINE SURVIVAL FORECAST OF SOUTHERN BRITISH COLUMBIA COHO

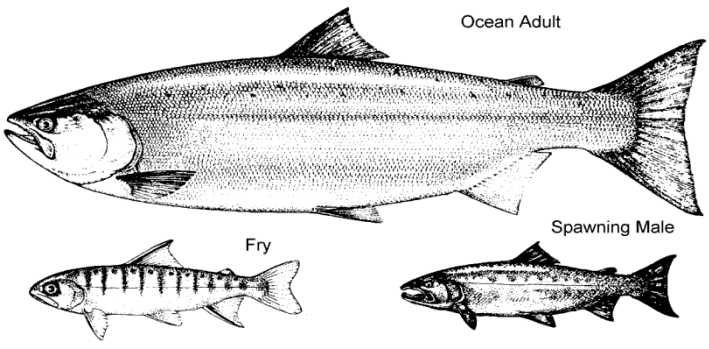

Figure 1: Coho salmon at three life stages: freshwater rearing fry; ocean rearing adult; and returning male. This image has been used on previous coho Stock Status reports, origin unknown.

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

SUMMARY

Indicator marine survivals and aggregate abundances from 2015 were universally much lower than the previous year (decreases of 26% – 85%), and less than the lower 50% confidence interval bound. In particular, the marine survival of the two wild indicators at Black Creek and Carnation Creek, and the Inch Creek Hatchery indicator saw the largest decreases of 71%, 85%, and 73%, respectively.

This complete failure of existing forecast models, coupled with the oceanic climate indices that indicated poor survival conditions for the 2015 returns, suggests that these factors have a more significant effect on the productivity of coho salmon than in previous years. The predictive power of these indices were compared to existing models and found to have superior results so the best performing model (NPGO) was used for Robertson River Hatchery and Carnation Creek. Other indicators were not included in this comparison for 2016.

The 2016 forecast for coho indicators are showing a continuation of the low marine survivals seen in 2015. The indicators of the stock groupings Johnstone Strait and Georgia Basin – West are forecast to remain at the same level or increase moderately, Lower and Interior Fraser are forecast to remain at the same level, and WCVI are forecast to decrease from last year.

Ocean climate indices are all consistent with a low marine survival of coho returning to the west coast of Vancouver Island in 2016. Although these indices were not used for the other indicators, the existing forecast models are also suggesting very low marine survivals and aggregates.

The Distribution Index is forecasting a moderate 'outside' distribution of coho in the Strait of Georgia, similar to 2015. This suggests that inside coho will be re-entering the Strait of Georgia later in the summer of 2016 than an 'inside' distribution year.

INTRODUCTION

The coho marine survivals and returns in 2015 showed a large downward deviation from forecast models. Not only were all the metrics lower than their corresponding point forecast, but they were all lower than the lower 50% confidence interval limit.

As noted in the 2015 coho forecast document:

> *The global climate indicators in the Pacific Ocean (PDO, NPGO, ENSO, SST) for the 2014 ocean entry year for the 2015 returning coho salmon, were ranked 17, 15, 15, and 14 out of 17 annual data points, thus are collectively suggesting a marine survival at the lowest range of observations (0.7% - 1.7% for Carnation Creek Wild; 3.3% - 5.3% for Robertson (Stamp). As noted above under the Results for Southwest Vancouver Island, the Marine Growth model is showing a marine growth at the highest range of observations. As a result of these contra-indicators, caution must be exercised when using the forecasted Marine Survival.*

This complete failure of the existing time series models and early marine growth models suggest that the factors that affect the marine productivity of coho salmon were dominated by the marine oceanic conditions displayed by the 2014 ocean entry year climate indices. For the two WCVI indicators, Robertson Creek Hatchery and Carnation Creek, the four climate indices were included in the suite of forecast models and, using retrospective analysis to test for forecasting strength, were found to have a better performing predictive value. Consequently, the best performing model used the North Pacific Gyre Oscillation (NPGO) so this was used as a forecast model for these two indicators.

This process was not extended to the other indicators for the 2016 forecast but will be for next year.

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) and DFO (2015) 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, and the CPUE and sibling regression 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 the two WCVI indicators.

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 2014 and 2015 values, and the forecast for 2016 returns.

Johnstone Strait/Mainland Inlets

In 2015 the observed return in Area 12 was 27% lower than forecast and the Area 13 return was about 38% lower than forecast. The Area 12 return saw only 79% of the 2012 brood return and only 70% of what was estimated for the previous year return (2014). The Area 13 return demonstrated a 33% decrease in abundance relative to the brood year (2012) and 26% lower than the previous year's return (2014). For the indicator systems at Keogh and Black Creek, smolt production in 2014 was just above average (67,000) and average (56,000) respectively. Based on the observed 2015 returns at those and other system in the area, marine survival had declined in both Area 12 and Area 13 relative to the 2014 return.

The Area 12 and 13 2016 forecasts are lower than the brood returns in 2013. The Area 12 and 13 forecasts are respectively 14% and 32% lower than the 2013 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 2015 was well below average (23,600) for Black Creek and well above average for Keogh River (112,000). 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. Goldstream Hatchery was not included this year due to a discontinuation of a coded-wire tag release. The Wild indicator is Black Creek.

The observed 2015 marine survival rates of hatchery indicators decreased from 2014 levels by 53% and 56% for Quinsam and Big Qualicum, respectively. This is the second consecutive year of decreases of this magnitude, reversing a trend of slowly increasing marine survivals since the mid-2000s.

For the wild indicator system at Black Creek, 2015 marine survival decreased from 1.0% in 2014 down to 0.3%. In 2013 the marine survival was 1.7%

The best performing models for the Big Qualicum Hatchery indicator is the "Like Last Year", and for the other two hatcheries and Black Creek the "Three Year Average" is the preferred model. The 2016 forecast for the hatchery indicators is for a slight decrease from the 2014 levels, to 0.4% to 1.0%. The Black Creek wild indicator is forecast to improve to 0.9% 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 2015 marine survival from Inch Creek hatchery decreased 73% from the 2014 level, similar to the other Georgia Basin West Hatchery indicators. Under the retrospective analysis the time series model "Like Last Year" has performed better than the other forecast models therefore the 2016 forecast will be similar to the observed survival of 2015.

Interior Fraser
The observed 2015 abundances for both the Thompson River and Interior Fraser Aggregates were substantially less than the observed 2014 abundance by 68% and 71% for the Thompson Aggregate and Upper Fraser Aggregate, respectively, and both were lower than the forecast and below the lower 50% confidence interval bound.

The forecast model selected for the 2016 return is the "Like Last Year" model, which is a change from previous years in which the "3 Year Average" model had been used. This change was based on the retrospective performance analysis of each model which showed the LLY model as having the lowest Mean Annual Percent Error (MAPE).

The 2016 forecast of abundance for the Interior Fraser Aggregate is 14,260 coho with a 50% forecast range: 8,556 to 23,767 based the LLY forecast model. However, forecast results have considerable uncertainty and high prediction error. Given current ocean conditions, there is a high likelihood that returns and escapement in 2016 will fall below brood-year levels. As a comparison, the 3YRA model forecasts the 2016 escapements (50% CI) for Thompson River and Interior Fraser Aggregates of 24,154 (15,282 – 38,175) and 30,890 (19,566 – 48,768), respectively.

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 count at the Stamp Falls fishway.

The observed 2015 marine survival for both hatchery and wild indicators were substantially lower than the previous year. The Robertson Indicator marine survival was 45% lower while the Carnation Indicator was 85% lower than the previous year. Both values were also substantially lower than the forecast and less than the lower 50% CI. This result was suggested as a possible outcome due to the marine climate indicators which contradicted the 'best' performing model of marine growth.

In developing the 2016 forecast, the oceanic climate indices were compared to the standard models and found to have superior predictive power, specifically the North Pacific Gyre Oscillation (NPGO). The 2016 marine survival, based on this index, is forecast to decrease to 1.6% (Robertson) and continue at 0.3% (Carnation).

Marine climate indicators

Figure 3 shows correlations for four ocean climate indicators, regressed against the observed marine survivals for coho salmon from Robertson Creek Hatchery. The climate data is matched to the year of ocean entry of the coho salmon. The red squares represent the 2015 data, for salmon returning in 2016. This figure shows the consistency of the PDO, NPGO, ENSO, and SST climate indicators in suggesting a low marine survival.

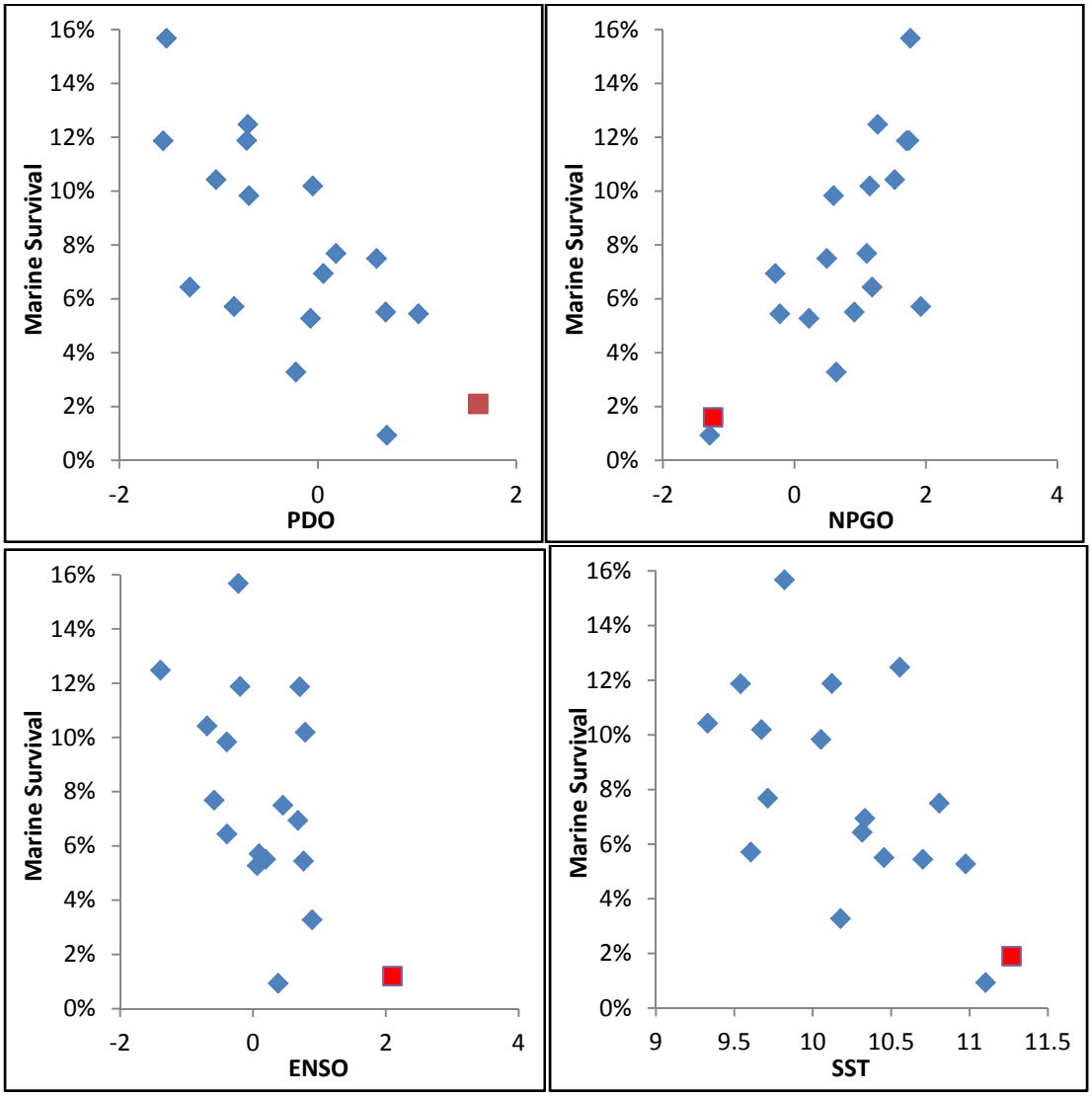

Figure 3. Regressions of the four Marine Climate data sets against observed marine survival of coho as represented by the hatchery stock Robertson (Stamp) Creek. The red square represents the forecasted marine survival for the 2016 return.

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 2016 forecast of P_{inside} is 0.296, indicating a moderate outside distribution of coho. This suggests that coho abundance in the Strait of Georgia will be much lower than the levels observed in 2011-2014. Figure 4 shows the time series of data used for the Salinity/distribution relationship (1975-1997) and the result of the model (1998-present).

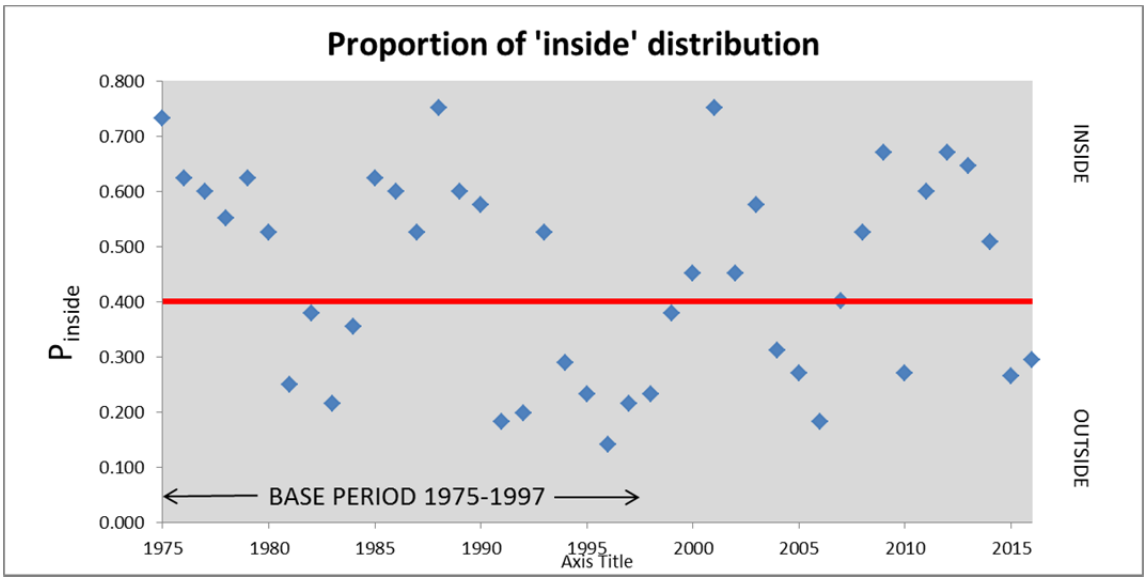

Figure 4. Distributional index for Strait of Georgia Coho, with observed data from 1975-1997, and results from the salinity based model for 1998-2016.

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 Lower Fraser and 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 Chuck Parken and Joe Tadey (Lower Fraser). The marked coho escapement for Robertson Creek Hatchery was supplied by Jeff Till. 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. Marc Trudel for contributing the Growth Model for forecasting marine survivals of WCVI salmon stocks and information on Ocean Climate indicators. Salinity data was provided by Peter Chandler (IOS).

REFERENCE CITED

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.

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 (in preparation).

FOR MORE INFORMATION

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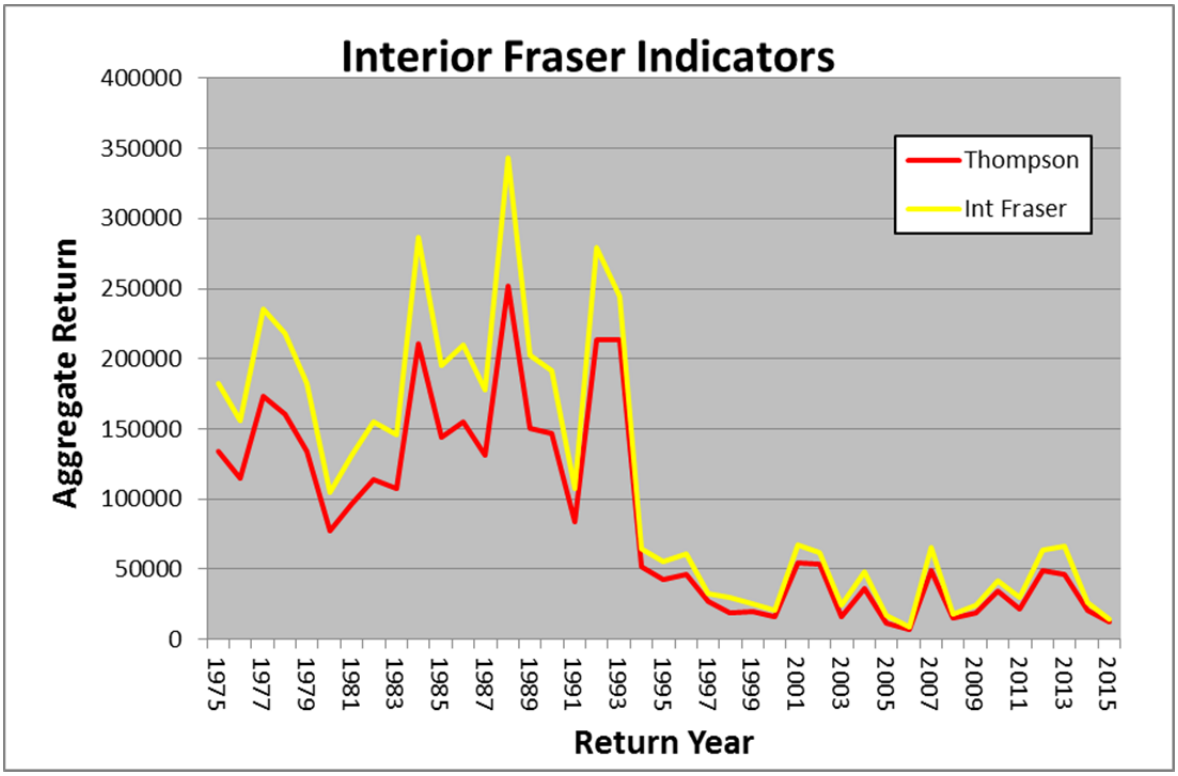
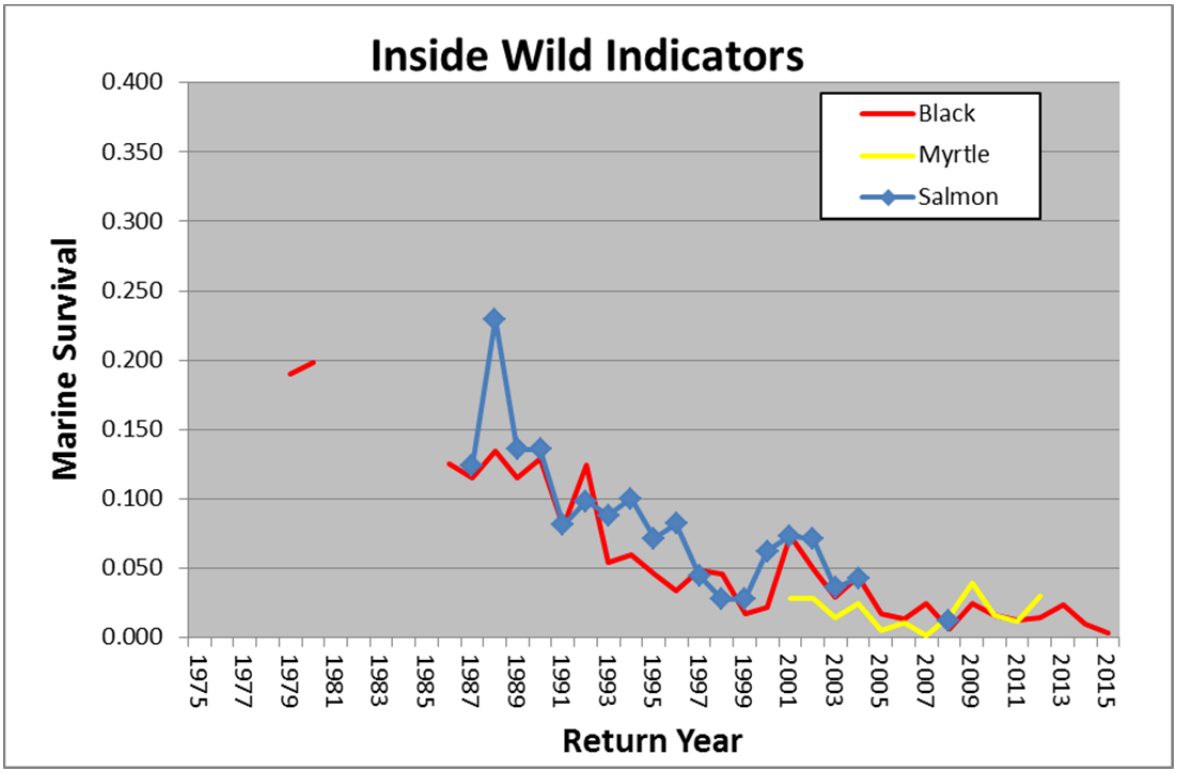
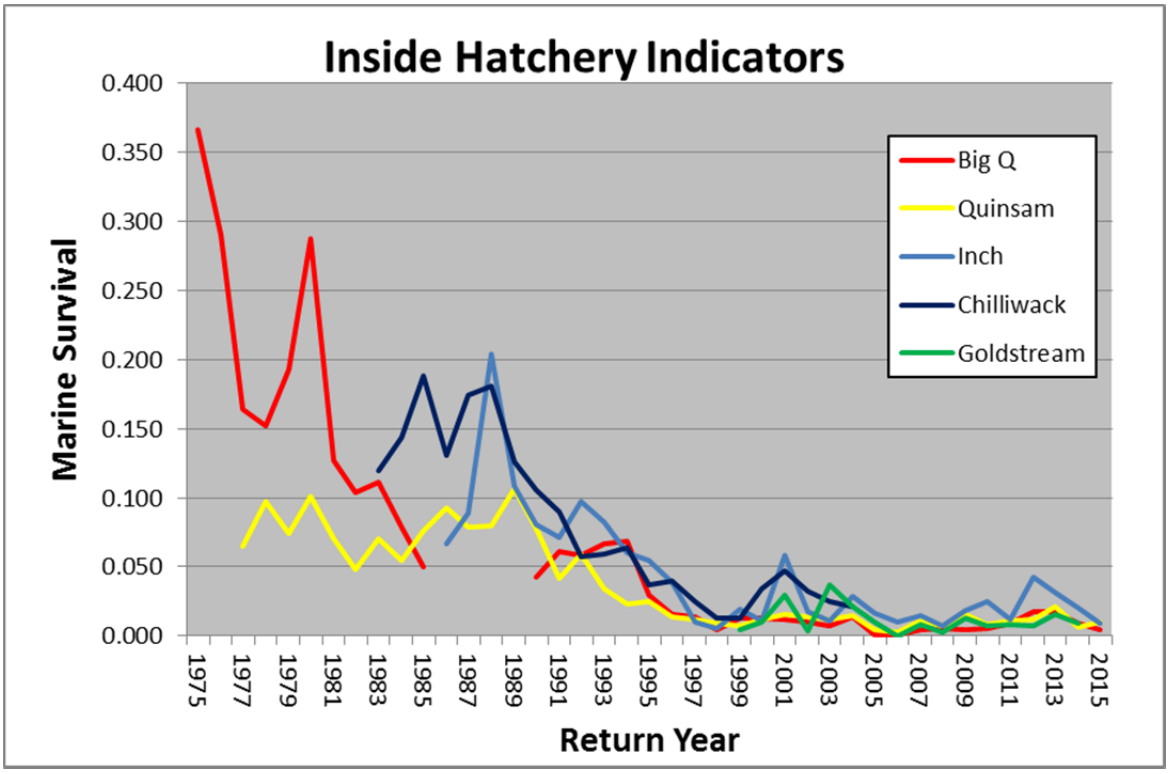
Appendix 1. Marine survival or aggregate abundances for southern BC coho indicators.






Inside Hatchery Indicators
Marine Survival
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
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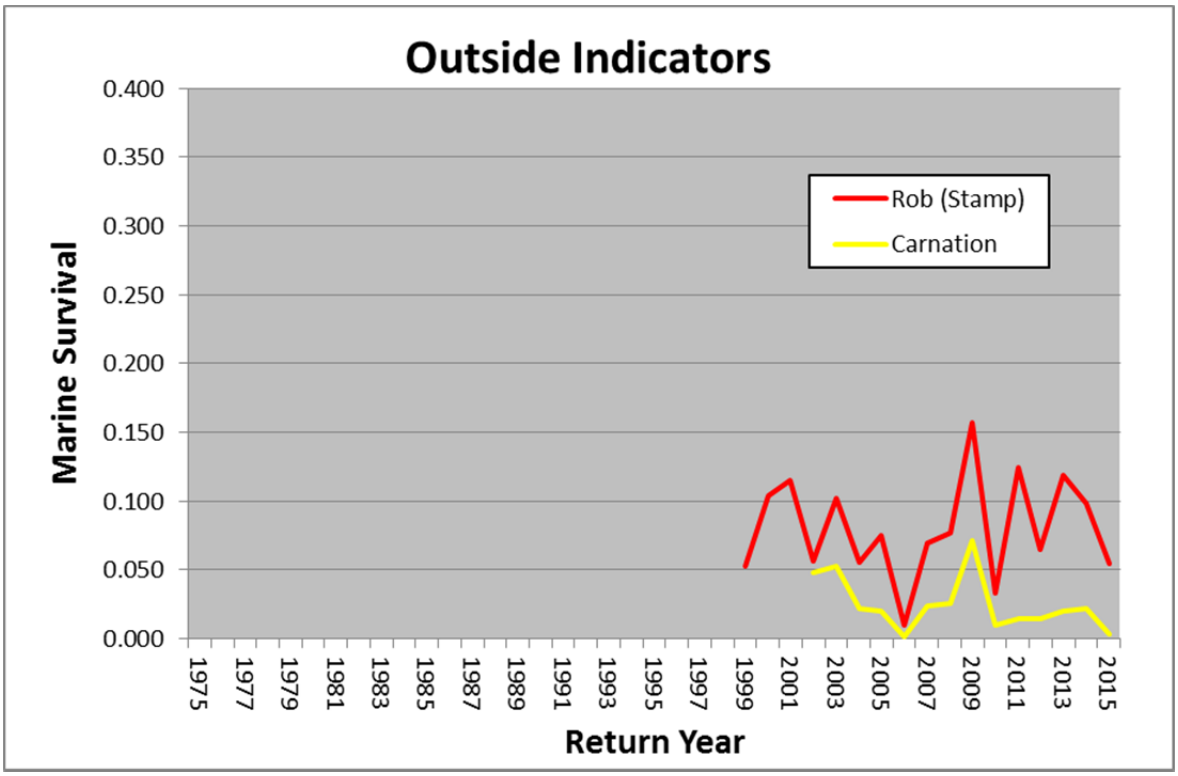
2015
Return Year
Big Q
Quinsam
Inch
Chilliwack
Goldstream


Outside Indicators
Marine Survival
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0.350
0.300
0.250
0.200
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0.100
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1975
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1983
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1999
2001
2003
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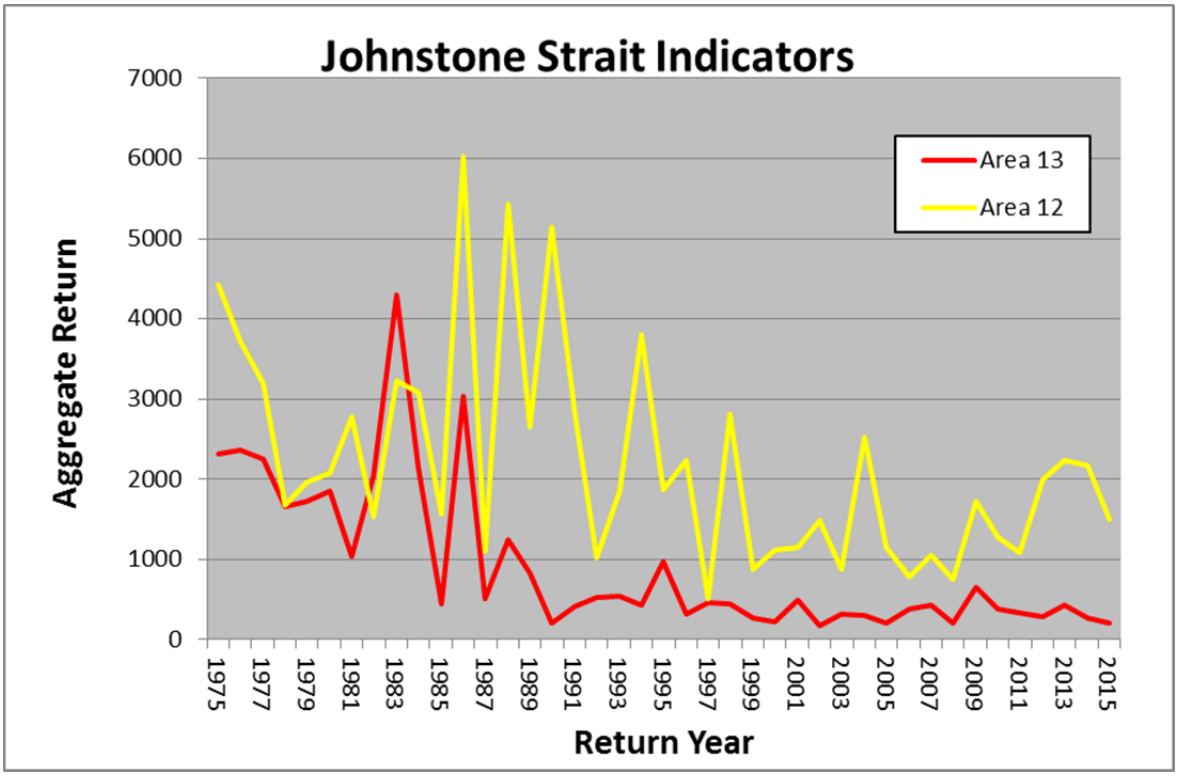
2013
2015
Return Year
Rob (Stamp)
Carnation


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

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.

2014 Observed: The values in this column represent either the aggregate value (whole numbers) or the estimated marine survival (decimal numbers), from the 2013 return year.

2015 Forecast, 50% CI, and Model refer to the forecast for the 2014 return year. The actual forecasted value is given first, followed by the 50% confidence interval, then the forecasting model used.

2015 Observed, Change from forecast and Change from 2014 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.

2016 Forecast, 50% CI and Model refer to the forecast for the current year.

Change from 2015 is the change in value from the observed 2015 to the 2016 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	2014	2015			2015	Change from forecast	Change from 2014	2016			Change from 2015
	Observed	Forecast	50% CI	Model	Observed			Forecast	50% CI	Model	
Johnstone Strait/Mainland Inlets											
Area 12	2,170	2,068	1428 - 2994	3YRA	1,500	**-27%**	**-31%**	1,909	1,322 - 2,757	3YRA	**29%**
Area 13	274	327	224 - 476	3YRA	202	**-38%**	**-26%**	286	196 - 416	3YRA	**42%**
Georgia Basin - West											
Big Qualicum Hatchery	0.009	0.009	0.005 - 0.016	LLY	0.004	**-56%**	**-56%**	0.004	0.002 - 0.007	LLY	**0%**
Quinsam Hatchery	0.020	0.017	0.012 - 0.024	3YRA	0.010	**-44%**	**-53%**	0.016	0.011 - 0.022	3YRA	**68%**
Black Creek (wild)	0.010	0.015	0.010 - 0.021	3YRA	0.003	**-81%**	**-71%**	0.009	0.006 - 0.013	3YRA	**210%**
Lower Fraser											
Inch Hatchery	0.022	0.022	0.013 - 0.037	LLY	0.006	**-73%**	**-73%**	0.006	0.003 - 0.010	LLY	**0%**
Interior Fraser											
Interior Fraser watershed	26,114	49,554	31,872 - 77,047	3YRA	14,260	**-71%**	**-45%**	14,260	8,556 - 23,767	LLY	**0%**
Thompson River aggregate	21,178	38,206	24,531 - 59,505	3YRA	12,374	**-68%**	**-42%**	12,374	7,419 - 20,638	LLY	**0%**
South-west Vancouver Island											
Robertson (Stamp Falls) Hatchery	0.098	0.145	0.118 - 0.179	Growth	0.054	**-63%**	**-45%**	0.016	0.013 - 0.021	NPGO	**-70%**
Carnation Creek (wild)	0.022	0.066	0.044 - 0.086	Growth	0.003	**-95%**	**-85%**	0.003	0.002 - 0.004	NPGO	**-6%**
Distribution Index (P_{inside})		0.266	0.194 - 0.352	Salinity				0.294	0.161 - 0.384	Salinity	