2010 MARINE SURVIVAL FORECAST OF SOUTHERN BRITISH COLUMBIA COHO

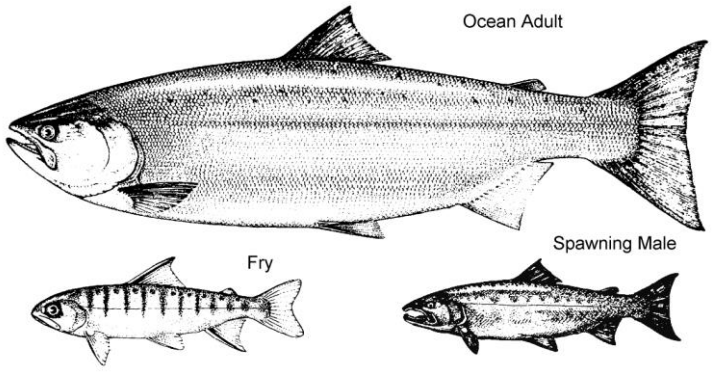


Figure 1: Coho salmon at three life stages: freshwater rearing fry; ocean rearing adult; and returning male in spawning colours. This image has been used on previous coho Stock Status reports, origin unknown.

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

Context

This report presents a forecast for southern British Columbia coho returning in 2010. Stock assessment and forecast documents on southern BC coho have been submitted to the Pacific Scientific Advice Review Committee (PSARC) since 1995. Simpson et al. (2004) represents the most recent full treatment of the forecast process and should be referred to for more the detailed description of the data sources, their assumptions and uncertainties, and the models. This forecast report relies on identical methods reviewed by PSARC on this subject. Since 2005 the forecast report has been published as a Science Advisory Report.

SUMMARY

- 2009 marine survival and abundance observations were much higher than 2008 in southern British Columbia.
- Marine survivals have decreased from the 10% to 20% range in the early 1970s to less than 2% in recent years.
- Forecast models predict low marine survivals and abundances for 2010, similar to the last four years. Interior Fraser, Georgia Basin East and Georgia Basin West Management Units in particular are coho stocks of concern.
- The distributional forecast is for a moderate outside distribution than the long term average.
- Monitoring programs for coded-wire tagged, adipose fin clipped coho must be maintained or strengthened to continue to monitor southern British Columbia coho populations.

INTRODUCTION

During the 1990s DFO Fisheries Management and Stock Assessment divisions observed an unprecedented decrease in the marine survival of southern British Columbia coho populations. Hatchery indicator stocks decreased from a mean survival of 6.6% (Brood Year (BY) 1983-1992) to 2.5% (BY 1993-2001) and wild indicator stocks from 10.2% to 4.4% during the same time period. In response, all directed coho fisheries were curtailed to protect weaker stocks such as Thompson River and Strait of Georgia coho. This management action resulted in a decrease of the total exploitation rate (all sectors) from a mean of 67% (BY 1983-1994) down to 17% (adipose fin clip (AFC) coho, BY 1995-2001) and 4% (non-AFC coho).

These measures allowed more coho salmon to return to natal creeks. Bradford et al. (2000) found that a minimum rate of 3% marine survival is required for a wild, coastal population to sustain itself. Hatchery indicators can withstand lower levels of marine survival because of the higher egg to fry survival rates of these stocks.

The scope for this forecast is southern British Columbia (sBC), which comprises seven Management Units (MU):

Johnstone Strait/Mainland Inlets (JST): Johnstone Str., Queen Charlotte Str., and adjacent inlets (Areas 11, 12 and the northern portion of Area 13). The indicator data consists of the return (catch plus escapement) of a group of monitored streams.

North-west Vancouver Island (NWVI): Estevan Pt. to Cape Scott (Areas 25-27). There are no indicators in this MU.

South-west Vancouver Island (SWVI): Victoria to Estevan Pt. (part of Area 19 (sub-areas 1 to 4) and Areas 20-24). There is one wild indicator (Carnation Creek) and one hatchery indicator (Robertson Hatchery).

Georgia Basin – East (GBE): east side of the Str. of Georgia excluding the Fraser R. system (Areas 15, 16, 28 and the coastal foreshore streams in Area 29). Myrtle Creek, a wild indicator has been operating since 2000 and will be used for the 2010 Forecast. Currently there is no hatchery indicator available however Lang Creek Hatchery has started releasing coded-wire tagged coho smolts in 2009 and will be available after several years of returns.

Georgia Basin – West (GBW): west side of the Str. of Georgia (Areas 13 (southern portion), 14, 17, 18 and the Str. of Georgia portion of Area 19 (sub-areas 5 to 12)). There is one wild indicator (Black Creek) and three hatchery indicators (Quinsam, Big Qualicum and Goldstream Hatcheries).

Lower Fraser (LowFr): Lower Fraser R. system as far upstream as Hell's Gate (Area 29). There is one hatchery indicator (Inch Hatchery) and one wild indicator (Salmon River), which discontinued operations after spring 2005 and restarted in fall 2006. Operations were discontinued again in 2009.

Interior Fraser (IntFr): upstream from Hell's Gate, including the Thompson R. system (Area 29). The indicator data used for this MU is the estimated total escapement into the MU, including North Thompson, South Thompson, Lower Thompson and non-Thompson Fraser coho.

ASSESSMENT

For the hatchery indicators, a cohort of smolts is coded-wire tagged, adipose fin clipped and released. This group of tagged coho is followed through the fisheries (where possible) and is enumerated when they return to their natal creeks. Any freshwater fisheries are monitored and included as escapement so that the calculated marine survival can be applied to the entire MU.

For the wild indicators, the smolts are coded-wire tagged only. The escapement is monitored at enumeration weirs and the coho are tested with a CWT Wand Detector to establish the presence or absence of a coded-wire tag. The marine exploitation is estimated by comparing the 2009 fishing effort with a base period (1987-1997) when coho by-catch was monitored in non-target fisheries.

The process of developing the sBC coho forecast is as follows:

1. Gather data on coded-wire tagged / adipose fin clipped (CWT/AFC) coho from marine and freshwater fishing mortality and escapement from the previous forecast year for indicator stocks. For Interior Fraser River (Thompson) and Area 12/13 coho populations escapement and exploitation information is modeled. For the Goldstream Hatchery indicator there are no coded-wire tag catch data from this stock available for the baseline period so exploitation information must be based on tag recoveries. Finally, salinities from February and March of the current year from Chrome and Sisters Islets are collected.
2. Add the data to the forecast models' data sets.
3. Examine the predictive power of each model and select the one that best fits the past data to use for the next forecast year.

Forecast models

1. Time Series Models.

The following four models were applied in all abundance and survival forecasts:

- '**Like last year' (LLY):** the forecasted survival or abundance will remain the same as that observed in the previous year;
- **Three year average (3YRA):** the forecasted survival or abundance will equal the mean of the previous three years of observed values;
- **One year trend (RAT1):** the change in survival or abundance from last years observed to this years forecast will equal the previous change (from that observed two years ago to that observed last year); and,
- **Average three year trend (RAT3):** the change in survival or abundance from last years observed value to this years forecast will equal the mean of the previous three changes.

2. Biological Models

- **Sibling Model:** This forecasts the adult return to an indicator using a regression that relates past adult returns to the escapement of jacks one year prior. Forecast returns to hatcheries are converted to forecasts of survival by dividing returns by the smolt releases.
- **Euphausiid Model:** This model forecasts the return to Carnation Creek using a regression that relates past adult returns to the abundance of a euphausiid species in Barkley Sound one year prior. This species is an important prey for coho in Barkley Sound.
- **CPUE Model:** This is a forecast of the total return of CWT/AFC coho for the three hatchery indicators in the Georgia Basin: Quinsam, Big Qualicum and Inch. A research vessel is used to sample juvenile coho in July of their first year in the Strait of Georgia. The catch of AFC coho is related in a regression to the CWT/AFC return to these hatcheries the following year. The catches are from a standard trawl survey conducted annually. The return forecast is then divided by the total CWT/AFC release from the hatcheries to provide a marine survival forecast. There are other sources of AFC coho that can be found in the Strait including Puget Sound however the releases from the hatcheries are used as an index of the AFC coho population in the Strait of Georgia.

- **Stock-Recruit Model:** The time series of standardized escapements and returns to Area 12 and Area 13 streams were used as inputs to Ricker stock-recruitment analyses, which were then used to forecast recruitment and returns using observed spawner indices in the brood year.
- **Growth Model:** This model was recently proposed by Dr. Marc Trudel (Pacific Biological Station, Nanaimo, BC). (Trudel et al. 2008). It is based on the hypothesis that larger and faster growing fish have higher marine survival either because they are more successful at escaping predators or accumulate enough energy to survive winter starvation (Beamish and Mahnken 2001). Growth is estimated for juvenile coho salmon caught in a trawl survey off the west coast of Vancouver Island during fall (October-November) as the difference between size at capture and size at ocean entry divided by the time spent at sea (Trudel et al. 2007).
- **Distribution Forecast:** Young coho originating in the Georgia Basin are thought to rear in the Strait of Georgia until the fall, when they primarily migrate to the west coast of Vancouver Island. A varying proportion return to the Strait soon after, in late winter, and are available to 'inside' fisheries in their last year at sea. This proportion has been related to salinity in the strait in this late winter period: low salinities are associated with few coho returning early. The salinity model predicts the proportion of catch taken in the strait if pre-1997 fishing regimes were in place and this proportion, P_{inside}, is now used as an index of inside distribution. P_{inside} should not be interpreted as the proportion that is occupying the strait in their last year.

A retrospective analysis is done for each model to choose the one with the best fit to the observed data using common time periods. The model that best fits the past data was used to forecast the following year return either as marine survival or adult return.

Changes from previous reports

Salmon River (LowFr) escapement was not monitored in 2009 so this system was dropped as a wild indicator.

Myrtle Creek (GBE) has been included as a wild indicator. This project was initiated in 2000 and the smolt and adult enumeration has been conducted annually at an enumeration weir. The exploitation rate is assumed to be the same as Black Creek. Myrtle Creek is located immediately east of the community of Powell River and flows due south to the estuary in Malaspina Strait.

Previous Carnation Creek (SWVI) forecasts are for the adult return (catch + escapement) because there was no direct measure of marine survival using coded-wire tags. The use of tags was started with the 1999 brood year and this forecast incorporates the marine survival based on a coded-wire tagged cohort, similar to the other indicators.

Recent work on the first summer marine stage of coho has developed a promising predictive model based on marine growth. The model results are presented in a separate table for the Carnation Wild indicator and the Robertson Hatchery indicator.

Sources of uncertainty

Commercial by-catch of coho

Exploitation rates are estimated by using the by-catch of coho in non-targeted commercial fisheries from a base period of return years 1987 – 1997 and comparing the effort from this base period to the effort in 2009 to estimate the exploitation rate of coho.

Sport catch

CWT-based estimates of sport fishing mortality have become less certain due to decreased participation by sport fishers in submitting adipose clipped head samples. Freshwater creel

surveys were limited to Quinsam River, Nicomen Slough (Inch Creek Hatchery) and the Fraser River.

Predictive power of the time series models

The time series models used in this forecast can only forecast continuing trends therefore they have no predictive power for changes to that trend.

Spawning Escapement and Abundance Estimates (Interior Fraser)

Annually spawning escapements within the Interior Fraser River (Thompson) are calculated through the summation of extensive (low/unknown precision) and intensive (known precision) enumeration methods on approximately 100 streams within the interior watershed. Surveys are designed to reduce the amount of variability in the escapement estimates within and between systems, but the total precision of the aggregate estimate for Interior Fraser Coho is unknown.

Stock trends

Table 1. Forecasted 2009 coho marine survival and abundance values with 50% confidence intervals and values observed in 2008 and 2009.

	2008	2009			2009	Change	Change
	Observed	Forecast	50% CI	Model	Observed	from forecast	from 2008
Area 12	829	975	650 - 1459	3YRA	1,904	95%	130%
Area 13	221	349	231 - 529	3YRA	581	66%	163%
Georgia Basin - West							
Big Qualicum Hatchery	0.005	0.005	0.003 - 0.009	LLY	0.004	-30%	-29%
Quinsam Hatchery	0.007	0.004	0.003 - 0.006	3YRA	0.013	208%	95%
Goldstream Hatchery	0.004	0.002	0.001 - 0.006	3YRA	0.010	304%	173%
Black Creek (wild)	0.007	0.014	0.009 - 0.020	3YRA	0.0280	106%	331%
Georgia Basin - East							
Myrtle Creek (wild)	0.016				0.038		145%
Lower Fraser							
Inch Hatchery	0.006	0.007	0.004 - 0.013	LLY	0.018	147%	184%
Str. Of Geo. Hatcheries	0.007	0.007	0.004 - 0.010	CPUE	0.012	69%	82%
Interior Fraser							
Thompson aggregate	15,289	17,405	10,743 - 28,200	3YRA	19,310	11%	26%
South-west Vancouver Island							
Robertson (Stamp Falls) Hatchery	0.086	0.050	0.035 - 0.073	Sibling	0.146	192%	70%
Carnation Creek (wild) adult return	163	18	9 - 35	Euphausiid	256	1325%	57%
Carnation Creek (wild)	0.026				0.071		
Distribution Index (P_{inside})		0.667	0.568 - 0.753	Salinity			

Since the early 1970's, marine survival of coho salmon has decreased from a range of 10% - 20% down to less than 2%. The majority of the observed marine survival estimates for the 2008 return continued to be at the bottom of this range. Returns of coho in 2009 in all areas were above the observed 2008 values and above the forecasted values. The exception was Big Qualicum Hatchery which was below both the observed and forecasted levels.

Johnstone Strait/Mainland Inlets

In 2009 the observed return in Area 12 was 95% greater than forecast and the Area 13 return was about 66% higher than forecast. The Area 12 return was 2.3 times greater than the 2006 brood return and approximately 2.4 times greater than what was estimated for the previous year's return (2008). The Area 13 return also demonstrated a 1.5 times improvement over the brood year (2006) and significantly higher than the previous year's return (approx. 3 times 2008 return abundance). Above average smolt production was encountered in 2008 in the Keogh River coho indicator. This production and an improvement in marine survival (3-5% at Keogh and ~3% at Black Creek) during the 2008 juvenile out-migration resulted in the much higher than expected returns to the Johnstone Strait areas in 2009.

North-west and South-west Vancouver Island

Returns of wild coho to the west coast of Vancouver Island increased substantially from the previous year for the second consecutive year. The 2009 Carnation Creek return (256) was 1325% above the forecast of 18 and 57% higher than the 2008 observed return of 163. This was supported by observations of higher numbers of coho spawners in other monitored rivers. Similarly, the Robertson Hatchery coho survival was 192% above the forecast level and 70% above the 2008 return.

Figure 3. Coho marine survivals for South West Vancouver Island indicators. Note that the Hatchery trend is the upper line and the Hatchery forecast is the lower point, similarly the Wild trend is the lower line and the Wild forecast is the upper point.

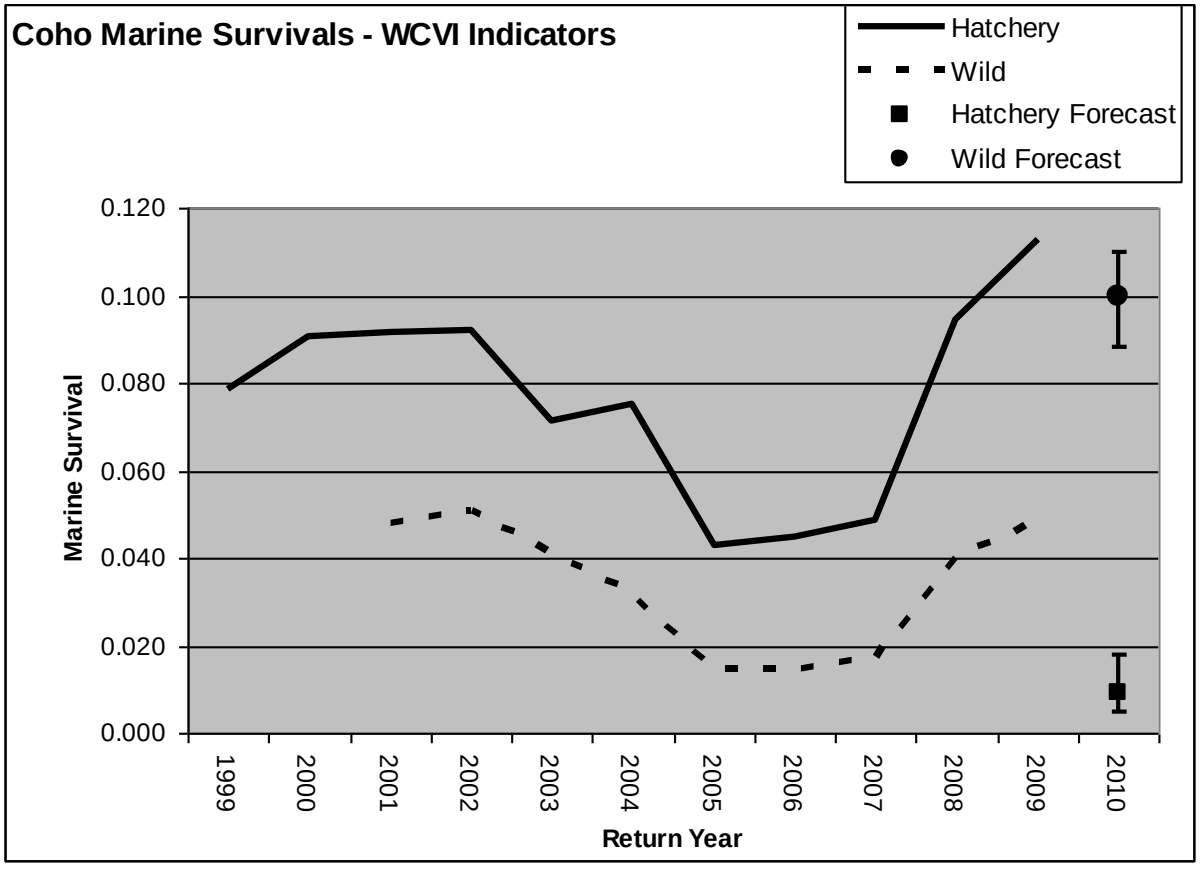


Figure 3 shows the marine survival for wild (Carnation Creek) and hatchery (Robertson Hatchery) indicators, and the 2010 marine survival forecast including 50% confidence intervals. The data has been smoothed by plotting a running three year average. In previous years the Carnation

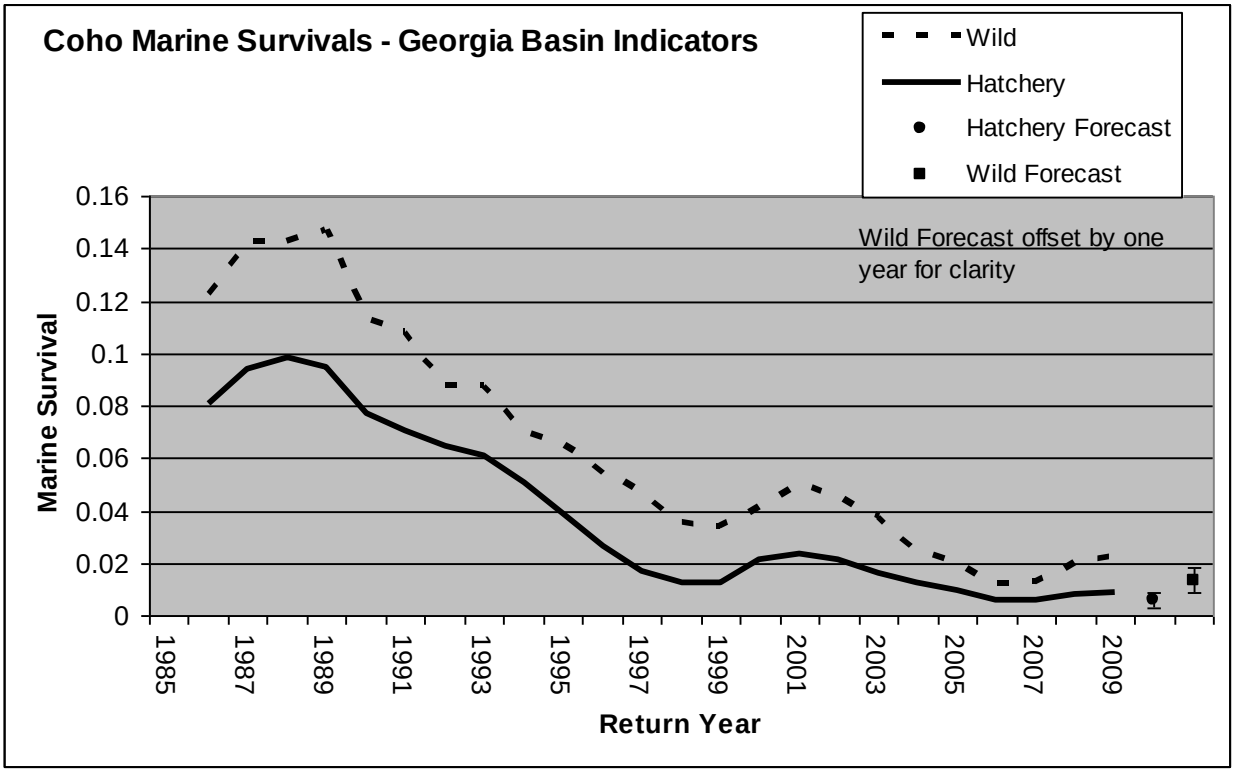
marine survival was based on 'smolts out / adults back' which does not take into account returning adults that originate from stages other than a spring smolt. This year we have started using a coded-wire tagged cohort to estimate marine survival, similar to the other indicators so the data presented is based on the coded-wire tagged time series and is much shorter. The Robertson Hatchery is based on the coded-wire tagged escapement estimates at Stamp Falls, not the return to the hatchery.

Georgia Basin West and Georgia Basin East

Coho returns to the Georgia Basin in 2009 were generally higher than the previous year and higher than the forecast's upper 50% confidence limit. The exception was the Big Qualicum Hatchery indicator which was lower than forecast but within the lower 50% confidence limits. The combined hatchery marine survival was also higher than the biologically based CPUE model forecast 50% CI.

The wild indicator, Black Creek was higher than forecast and above the upper 50% CI. The new wild indicator, Myrtle Creek did not have a 2008 forecast however the observed 2009 marine survival was higher than the previous year which is consistent with the other indicators in this area.

Figure 4. Coho marine survivals for Georgia Basin indicators (GBE, GBW and LowFr).



Lower Fraser

The 2009 observed marine survival of Inch Creek hatchery coho was higher than the previous year and higher than the forecast upper 50% CI, similar to the Georgia Basin indicators.

The wild indicator for the Lower Fraser is the Salmon River (Langley, B.C.). This project was not operated in the fall of 2009 so no forecast is available.

Figure 4 shows the marine survival for wild (Black Creek, Salmon River and Myrtle Creek) and hatchery (Quinsam, Big Qualicum, Inch, Chilliwack and Goldstream Hatcheries) indicators, and the 2010 marine survival forecast including 50% confidence intervals. The data has been smoothed by plotting a running three year average of the annual means.

Interior Fraser (Thompson)

The total abundance of Thompson River watershed coho in 2009 was approximately 19,310 animals which was well within the 50% CI of the forecasted abundance of 17,405 animals. The abundance in 2009 was higher than the abundance observed in 2008 (15,289), and 158% higher than the brood year abundance of 7,181.

Exploitation rates on Interior Fraser River coho from Canadian fisheries were derived from the post-season estimates generated from the CDFO coho fisheries effort model and the post-season Fraser River fisheries ER rate calculation. United States impacts are delayed by one year due to data availability. For the forecasting exercise, U.S. impacts were estimated to be the maximum allowed under the Pacific Salmon Treaty given the low status designation of the Interior Fraser MU (10%). The estimated exploitation rate for IFR coho in 2009 was approximately 12.4%. Total Canadian exploitation was estimated at 2.4%.

2010 Forecasts

Table 2. Observed 2008 and 2009 coho marine survival and abundance values and 2010 forecasts with 50% confidence intervals.

	2008	2009	2010			Change (2010 forecast minus
	Observed	Observed	Forecast	50% CI	Model	2009 observed)
Area 12	829	1,904	1,193	790 - 1904	3YRA	-37%
Area 13	221	581	374	247 - 567	3YRA	-36%
Georgia Basin - West						
Big Qualicum Hatchery	0.005	0.004	0.004	0.002 - 0.006	LLY	0%
Quinsam Hatchery	0.007	0.013	0.008	0.006 - 0.012	3YRA	-40%
Goldstream Hatchery	0.004	0.010	0.005	0.002 - 0.015	3YRA	-45%
Black Creek (wild)	0.007	0.0280	0.017	0.011 - 0.025	3YRA	71%
Georgia Basin - East						
Myrtle Creek (wild)	0.016	0.038	0.048	0.010 - 0.203	RAT3	26%
Lower Fraser						
Inch Hatchery	0.006	0.018	0.018	0.011 - 0.031	LLY	0%
Str. Of Geo. Hatcheries	0.007	0.012	0.010	0.007 - 0.013	CPUE	-15%
Interior Fraser						
Thompson aggregate	15,289	19,310	24,442	15,235 - 39,215	3YRA	27%
South-west Vancouver Island						
Robertson (Stamp Falls) Hatchery	0.086	0.146	0.009	0.005 - 0.018	Sibling	-94%
Carnation Creek (wild) adult return	163	256				
Carnation Creek (wild)	0.026	0.071	0.100	0.088 - 0.110	Euphausiid	41%
Distribution Index (P_{inside})			0.264	0.0193 - 0.0350	Salinity	

Johnstone Strait/Mainland Inlets

The Area 12 and 13 2010 forecasts are approximately similar to the brood and greater than the brood returns, respectively (parental brood year is 2007). The Area 12 and 13 forecasts are respectively 63% and 64% lower than the 2009 observed indices. Coho abundance in this region remains low and can be characterized as 'below average' for both Area 12 and 13 stocks. See Simpson et al., 2004 for description of characterizations. Smolt production in 2009 was just above average (69,000 vs. 63,000) for Black Creek and well above average for Keogh River (77,000 vs. 55,000). The best performing model (3 year average) was not able to detect the significant change in marine survival that occurred in 2009. If marine conditions were similar for the smolts in 2009 as in 2008, the expectations, based on the above average smolt production from indicators, could be for a continued improving trend in 2010 return abundance. 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.

North-west and South-west Vancouver Island

The euphausiid model predicts a marine survival of 10.0% coho to Carnation Creek. This will be a substantial increase over the last five year where the average marine survival was 1.8% The Robertson Hatchery stock is forecast to survive at 0.9%, based on the sibling model, a very large decrease from the observed 2009 marine survival of 14.6%.

Recent work on the first summer marine stage of coho has developed a promising predictive model based on marine growth (Trudel et al. 2008). The model results are presented in a separate table for the Carnation Wild indicator and the Robertson Hatchery indicator.

The Marine Growth model describes a much different picture (see Table 3). It shows an optimistic marine survival of 3.2% for the hatchery indicator and a pessimistic forecast of 0.7% for the wild indicator. Comparing the forecast performance of the Marine Growth model to the standard models shows that for the same time period the Marine Growth model has a superior statistical relationship.

Just a cautionary note: a strong to moderate El Niño developed at the end of 2009 and is expected to persist until the summer of 2010. It is unclear how this will affect the marine survival of coho salmon at this point, though the strong 1982-1983 El Niño resulted in lower returns that were predicted from sibling models.

Table 3. 2010 forecast of WCVI Indicators using the Marine Growth Model.

	2008	2009	2010			Change (2010 forecast minus
	Observed	Observed	Forecast	50% CI	Model	2009 observed)
Marine Growth model						
Robertson (Stamp Falls) Hatchery	0.086	0.146	0.032	0.024 - 0.041	Growth	-78%
Carnation Creek (wild)	0.026	0.071	0.007	0.005 - 0.011	Growth	-90%

Georgia Basin West

The wild indicator, Myrtle Creek, has been in operation since 2000 and is used as a forecast indicator for the first time in this report. The marine survival forecast is 4.8%, an increase of 26% over the observed 2009 marine survival of 3.8%, using the RAT3 time series model.

Georgia Basin East

The marine survival forecast for hatchery stocks, using the LLY and 3YRA models, is similar to levels observed in the previous years and is continuing to be extremely low at 0.4% - 0.8%. The wild indicator at Black Creek is forecast to decrease to 1.7% using the 3YRA model.

The CPUE model forecasts a marine survival of 1.0%, which is higher than the forecasts for the Big Qualicum and Quinsam Hatcheries and lower than the forecast for Inch Creek Hatchery.

Lower Fraser

The forecast model used for 2010 is the LLY model for the hatchery indicator. The forecast is for 1.8% marine survival. This will be a continuation of the low survivals that have been observed over the last 10 years.

Interior Fraser

Based on the 3YRA abundance model, the forecast of total abundance of Thompson River coho for 2010 is estimated to be 24,442. The forecasted return to the Thompson River watershed is approximately 50% of the mean abundance of the time series, and would represent an decrease from the brood abundance of 49,461 animals.

2009 was the third year in a row in which Thompson River coho abundances met and exceeded the brood year abundances. The 2010 forecasted abundance is still below the lower threshold escapement suggested in the IFR Coho Recovery Strategy required to ensure that genetic integrity and demographic concerns are maintained in the entire Management Unit. The 2007 brood year from which the 2010 adults are produced was the highest observed since 2002.

Distribution

The P_{inside} statistic for 2010 is 0.264, indicating a moderate 'outside' distribution of coho, similar to the 1994 – 1997 period. This indicates that coho should return to the Strait of George later than average.

CONCLUSIONS

The 2009 returns of coho to southern British Columbia improved in all areas and exceeded both the forecasted marine survival and the upper 50% confidence interval. The exception was the Big Qualicum Hatchery indicator which declined slightly from the forecast.

The 2010 forecasts show mixed marine survivals relative to 2009 in southern BC. There is no consistent pattern between inside and outside indicators, or between time series and biological based forecast models.

In light of the abundance trend, coupled with the continuing low marine survival rates of southern B.C. coho stocks, the forecast of marine survival and abundance should be characterized as extremely low and caution should be exercised when planning fisheries or activities which may exploit these stocks.

Monitoring of CWT/AFC coho catch in all sources of mortality should be maintained or improved and be responsive to shifting fishing pressures, particularly recreational fishing. Coho by-catch in commercial fisheries should be monitored as exploitation rate estimation models are no longer reliable.

SOURCES OF INFORMATION

The data, models and treatments that were used in this report are fully documented in Simpson et al. (2004). Refer to that document for descriptions and background information.

The coho forecast for southern British Columbia requires data from many sources and is very much a collaborative document. Data analysis of Thompson River and Johnstone Strait coho was completed by Michael Chamberlain and Pieter Van Will, respectively. Ron Tanasichuk provided euphausiid data and analysis. The CPUE data were collected Ruston Sweeting. Fresh water creel survey data were provided by Jason Mahoney (Lower Fraser), and Joan Bennett (Strait of Georgia). Roberta Cook provided escapement data from the hatcheries. Wild coho data were provided by Pieter Van Will (Black Creek), Ian Matthews (Myrtle Creek) and Dr. Peter Tschaplinski (BC Ministry of Forests - Carnation Creek). Thanks to Dr. Marc Trudel for contributing the Growth Model for forecasting marine survivals of WCVI salmon stocks.

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