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WCVI Salmon Bulletin
2017 WCVI Chinook Terminal Forecast
April 3, 2017

SUMMARY

- The estimated terminal return of WCVI index stocks (i.e. excluding catch in pre-terminal Canadian fisheries) was 167,000 adults. The terminal return of the Stamp River/RCH CWT Indicator Stock was 72,000 adults and 1,900 jacks (age-2 males).
- In 2016, the estimated pre-terminal exploitation rates for age 3, 4 and 5 year old fish were 6%, 41% and 74%, respectively.
- After ocean fisheries, the 2017 forecast return of Stamp/RCH adult chinook to the terminal area of Barkley Sound and Alberni Inlet is about 79,000 (range 58,000 to 100,000).
- Terminal returns of other WCVI stocks are also forecast to be moderately abundant in 2017. The forecast of aggregate terminal abundance (sum of all hatchery and wild indicator stocks) is 157,000, near the long term average of 152,000 (1980 to 2016). The overall expected age composition of the WCVI aggregate terminal run is 41% age-3, 40% age-4, and 19% age-5, with an expected sex ratio of 45% female.
- Some modest increase in the escapement of wild populations has been observed over the last 3 years and this improvement is expected to be maintained in 2017. However, spawner levels in the SWVI CU remain below upper biological benchmarks with fewer than 100 spawners observed in some rivers in recent years. Therefore, wild WCVI chinook remains a stock of concern.

BACKGROUND

- Chinook salmon spawn in over 100 WCVI rivers of the medium and large rivers along the west coast of the island (WCVI), with 60 systems having escapement records of at least 100 spawners. For implementation of Canada's Wild Salmon Policy (WSP), stock status is evaluated for a set of wild indicator populations within conservation units, or "CUs". CUs are groups of biologically and genetically similar populations. There are three chinook CUs defined within the WCVI area; including south-west Vancouver Island (populations within DFO Statistical Areas 20 to 24, or from San Juan to Clayoquot Sound); Nootka-Kyoquot (populations within DFO Statistical Areas 25 and 26) and North Vancouver Island (populations within DFO Statistical Area 27, or Quatsino Sound).
- The average aggregate terminal return (catch and escapement) of WCVI chinook is about 150,000; ranging from about 40,000 to 300,000 over the period from 1980 to 2015. However, a large portion of the terminal return and spawning escapement is hatchery origin fish. About twenty WCVI populations receive some form of stock enhancement to supplement natural spawning. Annual releases of chinook smolts from WCVI enhancement facilities total about 21 million per year. The majority (17M) is released directly from three major hatcheries located on the Stamp, Nitinat, and Conuma rivers, but there is also additional enhancement of chinook populations in nearby systems either directly or through straying. About 3 million chinook smolts are released annually from smaller facilities, including volunteer public involvement projects and community development projects.
- The Stamp River/Robertson Creek Hatchery (RCH) chinook salmon stock is the coded-wire-tag (CWT) indicator stock for survival, exploitation rate and marine distribution patterns of WCVI

chinook populations. Detailed assessments and forecasts of the Stamp/RCH indicator stock are required annually for management and as an indicator of the status and expected returns for other WCVI populations. Management actions taken to achieve goals for this stock in pre-terminal fisheries are assumed to have similar effects on other WCVI stocks. Forecasts developed for other WCVI chinook stocks to determine the expected aggregate abundance of WCVI chinook and to inform terminal fishery management are based on trends in marine survival and exploitation rate of the RCH indicator stock.

FORECAST METHODOLOGY

Stamp River / Robertson Creek Hatchery (RCH)

Riddell et al. (PSARC 96-01) outlined the analytical framework for forecasting returns of Stamp River / RCH chinook. This forecast follows the same procedures.

Cohort analysis is conducted using 'estimated' CWT recoveries to estimate production of RCH chinook. The cohort model used is documented in Appendix 2 of Starr and Argue (1991) and was modified by the CTC to account for the chinook non-retention fisheries implemented in Canada (TCCHINOOK (99)-2). For each brood year, information generated from the cohort analyses and used in forecast models includes: i) survival to age 2 recruitment; ii) ocean exploitation rates by fishery and age; and iii) total estimated production. Total production is estimated by multiplying the brood releases (for the selected tag codes) by the estimated total fishing mortality exploitation rates.

To forecast production of RCH chinook, or "pre-fishery abundance", two sibling regression models are applied that use information from younger age classes to predict the production of older age classes:

- Model 1 uses total terminal return at a younger age class (independent variable) to predict total production (the surviving cohort in the ocean) of a subsequent age or ages from the same brood year. The dependent variable is the total (total ocean fishing mortality plus terminal run) production at a subsequent age or ages. All regressions are forced through the origin.
- Model 2 model uses estimated total production (total fishing mortality plus escapement) of an age class(es) to predict total production of subsequent ages (i.e., the surviving cohort, dependent from the same brood year. All regressions are forced through the origin.

Relationships between all possible age class combinations were examined using these two models. The actual models used for the forecast were based on the highest r^2 values. In the case where more than one age class is used, such as the total terminal run of age 2+3, the total terminal runs at age 2 and age 3 were summed. Estimates of surviving cohort include natural mortality factors and are estimated as the pre-fishery abundance of the youngest age being predicted. Assuming recent average maturation rates, the remaining cohort was assigned either to the expected terminal run or to the surviving cohort remaining at sea. The terminal return to the Barkley Sound/Alberni Inlet is forecast after accounting for expected impacts in pre-terminal ocean fisheries. A forecast range is generated from the distribution of the deviations between the observed and forecast run size.

Note for 2017 forecasts the following adjustments were made to the models based on recommendations made by Peterman et al. (2016): all sibling regressions were based on log-transformed data and only recent year average maturation rates were applied. Age-specific pre-terminal exploitation rates were assumed similar to the recent 3-year average (Table 5).

Other WCVI Populations

Overall, the data available for other WCVI populations are less rigorous than that available for the Stamp/RCH stock. However, trends in brood year survival and ocean fishery impacts for other WCVI chinook populations are assumed similar to the RCH Indicator Stock. Therefore, it is possible to use brood survival and age specific exploitation rate information from the RCH cohort analysis to forecast returns for other WCVI terminal areas or populations.

In past years, the terminal return of the WCVI chinook aggregate was forecast by expanding the expected return of the Stamp/RCH stock by the brood year average ratio of the return Stamp/RCH to the total of

other WCVI index stocks. In more recent years, when detailed age data are available from other stocks (i.e. sibling performance of earlier age classes that have already returned for the contributing brood years), this information is used to adjust expectations and develop more specific forecasts for hatchery stocks, such as Conuma or Nitinat, and the remaining index stocks (as a whole). These models were initially developed to inform domestic management of Canadian fisheries, but have recently been applied to forecast the aggregate WCVI terminal abundance as the stock specific forecasts are generally more accurate than the simple ratio method of expansion described above. The contribution of Stamp/RCH stock to the aggregate WCVI abundance has been variable due to apparent differences in marine survival rate among WCVI hatchery stocks and from changes in hatchery release strategies.

2016 RETURN, COHORT ANALYSIS RESULTS, AND FORECAST PERFORMANCE

The estimated terminal return of WCVI index stocks (i.e. excluding catch in pre-terminal Canadian fisheries) was 167,000 (Table 1, Figure 1). More specifically, the terminal return of adult WCVI chinook included returns of 72,000, 45,000, 21,000 and 29,000 to Stamp/RCH, Conuma Hatchery, Nitinat Hatchery and other extensive indicator stocks, respectively. The estimated age at return of the WCVI aggregate as whole was 27.7%, 67.6% and 4.6% age 3, 4 and 5 year old chinook, respectively.

Overall, the observed terminal return of WCVI chinook was about 57% lower than expected (Table 2). The estimated survival rate of 4.4% for 2012 brood year (2013 sea entry year) decreased significantly from the preliminary estimate of 10.4% generated by the 2016 cohort analysis. A data error was discovered that explains the change – i.e. escapement data were duplicated in the CTC cohort database. Correcting for the error and generating the 2016 forecasts retrospectively, results in a lower deviation so that the observed return was only 21% lower than expected (Table 2).

Trends in marine survival rate to age 2 estimated through cohort analysis using RCH CWT recoveries are plotted in Figure 2. For the 2011, 2012, 2013 and 2014 brood years (returned as age 5, 4, 3, 2 year old fish in 2016), the estimated survival rates to age 2 were 0.2%, 4.4%, 3.2% and 6.1%, respectively. Estimates for the 2012 to 2014 brood years are based on incomplete brood returns and therefore preliminary.

Age specific pre-terminal exploitation rates estimated from the cohort analysis using RCH CWT recovery data are summarized in Table 3 and Figure 2. The estimated pre-terminal exploitation rates for age 3, 4 and 5 year old fish in 2016 were 6%, 41% and 74%, respectively. In the last 3 years, the estimated pre-terminal exploitation rates of 4 and 5 year old WCVI chinook have averaged about 40% and 55%, respectively. There has been a general trend of increasing pre-terminal exploitation of 4 and 5 year old fish since about the 1999 brood year, roughly coinciding with the start of AABM management (Figure 2).

2017 FORECAST

Terminal return Stamp River / Robertson Creek Hatchery (RCH) chinook

The forecast terminal return of adult Stamp/RCH chinook to Barkley Sound and Alberni Inlet in 2017 is approximately 79,000 (range 58,000 to 100,000). This is about an average return and similar last year (Table 7, Table 2). The predicted adult age composition is 57%, 29% and 14% of 3, 4 and 5-year old fish, respectively.

With an expected return of 74,000 adults, directed chinook fisheries are expected in the terminal Alberni Inlet area for all sectors.

Terminal return of other WCVI chinook populations

Marine survival rates for the other major hatcheries and some other WCVI stocks appeared to be significantly higher than the survival estimated for the Robertson Creek Hatchery (RCH) CWT Indicator Stock for the 2009 through 2011 brood years. Therefore in recent years, returns to some of the WCVI other hatchery stocks were relatively abundant compared to Area 23. However, for the three most recent brood years (2012 to 2014) survival rate estimates from the RCH CWT Indicator Stock appear to be more representative of WCVI chinook as a whole. Therefore, general expectations are for a moderately abundant, or average, return of adult chinook to the WCVI area (Table 4). Similar to Area 23, directed fishery opportunities are expected in WCVI terminal areas dominated by hatchery stock.

Conuma Hatchery: The expected terminal return of Conuma Hatchery chinook to Area 25 is 36,000 (range 22,000 to 50,000) with an age composition of 20%, 64% and 16% age 3, 4 and 5-year old fish, respectively.

Nitinat Hatchery: The expected terminal return of Nititat Hatchery chinook to Area 22 is 19,000 (range 13,000 to 25,000) with an age composition of 37%, 48% and 15% age 3, 4 and 5-year old fish, respectively.

Other WCVI Stocks: The expected terminal return of other WCVI index stocks is 23,000 (15,000 to 31,000) with an age composition of 24%, 35% and 42% age 3, 4 and 5-year old fish, respectively. This forecast abundance results largely from index stocks that are enhanced. However, in most recent years, spawner abundances of wild indicator stocks within WCVI Conservation Units have been below provisional upper biological benchmarks and, in the case of the SWVI Conservation Unit, often below the lower biological benchmark in many years (Figure 4). Therefore, fisheries within Canada are managed to limit mortality on wild WCVI chinook.

SOURCES OF UNCERTAINTY

The mean absolute percentage error (MAPE) for the forecast models used to predict terminal returns of Stamp/RCH chinook is 26% for the years when the models have been applied (1988 to 2015, Figure 5). That is, on average, the observed return is about 26% higher or lower than the predicted return. In 2 of the last 3 years, the forecast has under-estimated the actual return. Factors that contribute to uncertainty in the forecast include, but are not limited to: model structure, uncertainty associated with cohort analysis CWT data and results which form the model inputs, etc.

For other WCVI chinook stock forecasts, there is higher uncertainty due to the general lower quality assessment data relative to the Stamp/RCH indicator stock. There are less complete age data, relatively high uncertainty in the estimates of spawner abundance (for extensive indicator stocks in particular), and also higher uncertainty in catch estimates. In addition, survival, exploitation and maturation rates of other WCVI stocks may vary from the Stamp/RCH indicator stock. The MAPE of forecasts for other WCVI stocks ranges from about 30% to 37% when a retrospective analysis is applied for the 1995 to 2015 return years.

For all the WCVI terminal forecasts, two key sources of uncertainty are the maturation rate and pre-terminal exploitation rate assumptions applied to generate run size estimates.

There is some evidence that maturation rates of WCVI chinook have declined in recent years so that fish are maturing and returning to the terminal area at a younger age. Declines in maturation rate will affect the expected return of older age classes relative to average. This source of uncertainty is a larger factor in 2016 given that over 80% of the abundant return is expected from only one older age class.

The reliability of the terminal forecasts is also dependent on the accuracy of the prediction of the age-specific pre-terminal exploitation rates, which vary considerably from year to year. Variability in fishery exploitation patterns are caused by a number of factors including regulatory changes to fisheries, relative stock abundance in mixed stock fisheries, changes in the marine distribution of the WCVI stock, changes in the maturation rate of the WCVI stock (such as described above), etc.

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Table 1. 2016 return of WCVI chinook index stocks to the terminal WCVI area (i.e. after pre-terminal Canadian fisheries). "APE" is the annual percent error in the forecast.

Stock(s)	Average (1995-2016)	2016 Observed	2016 Forecast Range	2016 Predicted (midpoint)	APE
Escapement:					
WCVI Index Stocks*	17,000	**29,000**	(25,000 - 47,000)	36,000	-24%
Terminal Run (Major Hatchery):					
Conuma	38,000	**45,000**	(50,000 - 110,000)	80,000	-78%
Nitinat	25,000	**21,000**	(19,000 - 37,000)	28,000	-33%
Somass/RCH	64,000	**72,000**	(24,000 - 41,000)	118,000	-64%
Total WCVI	**144,000**	**167,000**	(80,000 - 151,000)	**262,000**	-57%

* Sum of all indexed populations, including those that are enhanced outside major production facillities.

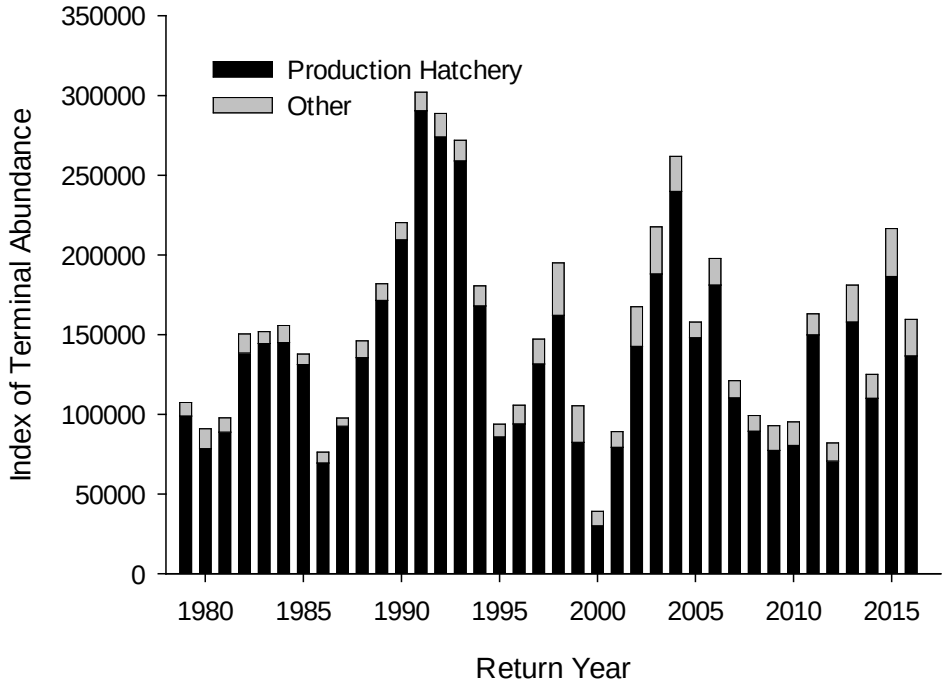

Figure 1. Aggregate terminal return of WCVI indicator stocks, including major hatchery facilities (Robertson, Conuma and Nitinat) and all other indicator stocks, many of which are also supplemented with hatchery production.

Table 2. The performance of 2016 WCVI forecast assessed retrospectively after correcting errors in the 2015 cohort analysis and re-evaluating 2016 forecasts.

Stock (s)	2016 Observed	2016 Predicted (midpoint)	APE
Escapement:			
WCVI Index Stocks*	**29,000**	29,000	0%
Terminal Run (Major Hatchery):			
Conuma	**45,000**	69,000	-53%
Nitinat	**21,000**	19,000	10%
Somass/RCH	**72,000**	90,304	-25%
Total WCVI	**167,000**	**207,304**	-24%

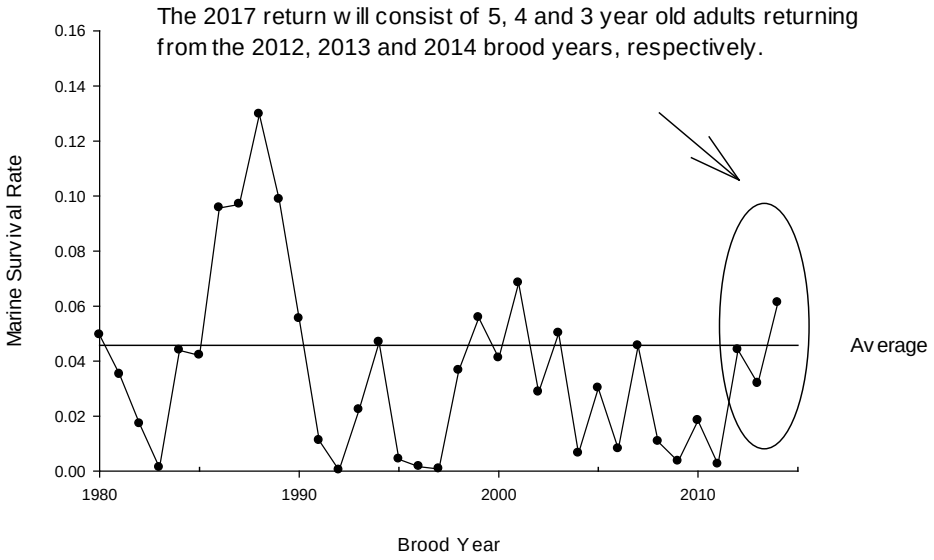

Figure 2. Estimated survival to age 2 of WCVI chinook (estimated by cohort analysis using RCH Indicator Stock CWT recoveries). Note that estimates for the last 3 sea-entry years are preliminary as they are based on incomplete brood years.

Table 3. Age-specific exploitation rates of WCVI chinook in pre-terminal fisheries, 2016 (estimated by cohort analysis using RCH Indicator Stock CWT recoveries). Age 3, 4 and 5 year old fish were from the 2013, 2012 and 2011 brood years, respectively.

Age	Alaska			NBC	CBC	WCVI	NBC	NCBC	WCVI	OTHER	Total
	Troll	Net	Sport	Troll	Troll	Troll	Net	Sport	Sport	Ocean	Pre-Terminal
3	2.0%	1.0%	0.3%	0.5%	0.0%	0.0%	0.0%	1.0%	0.5%	0.5%	**5.9%**
4	14.4%	4.1%	4.1%	1.7%	0.0%	1.0%	0.0%	7.4%	2.4%	5.5%	**40.7%**
5	16.4%	25.7%	0.0%	0.0%	0.0%	0.0%	0.0%	3.5%	28.6%	0.0%	**74.3%**

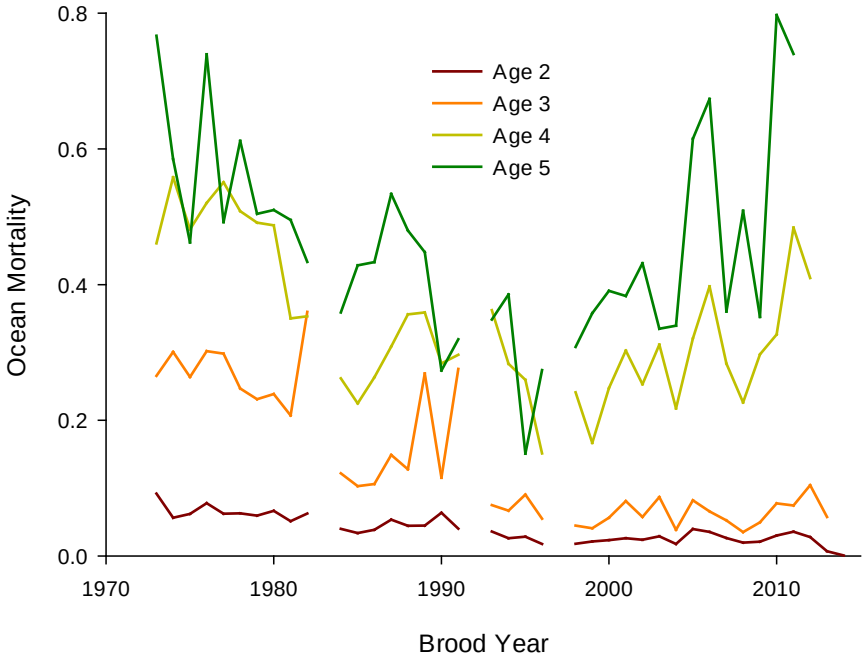

Figure 3. Age-specific exploitation rates of WCVI chinook in pre-terminal fisheries, brood years 1973 to 2014 (estimated by cohort analysis using RCH Indicator Stock CWT recoveries).

Table 4. Age specific pre-terminal exploitation rates of Stamp/RBT chinook for the last 3 brood years. For forecasting, the 2017 pre-terminal exploitation rates were assumed similar to the recent 3-year average.

Return Year	Age 2	Age 3	Age 4	Age 5
2014	3%	7%	33%	35%
2015	1%	10%	48%	80%
2016	0%	6%	41%	74%
Average	1%	8%	41%	63%

Table 5. Summary of the 2017 forecast abundance and terminal run size of adult Stamp River / Robertson Creek Hatchery chinook salmon.

Model	Pre-Fishery Abundance[1]	Somass/RCH Terminal Return[2]	
1. Terminal return versus Total Production			
2014 brood	273,648	45,351	
2013 brood	77,178	29,040	
2012 brood	28,378	9,500	
Total	379,204	84,544	
2. Total Production versus Total Production			
2014 brood	205,614	34,076	
2013 brood	45,309	17,049	
2012 brood	34,555	11,568	
Total	285,478	65,346	
Average of both models (2010 brood based on Model 2 only)			
2014 brood	273,648	45,351	57%
2013 brood	61,243	23,044	29%
2012 brood	31,466	10,534	13%
Total	366,358	78,929	

1. Forecast total production from the respective brood years.
2. Forecast return to Barkley Sound/Alberni Inlet, assuming recent 3-year average pre-terminal fishery mortality.

Table 6. 2017 pre-season terminal run size expectations for indexed WCVI chinook populations in addition to Stamp/Robertson Creek Hatchery. The total is the terminal run prediction for the WCVI aggregate (i.e. summed index stocks).

Age	Stock				Total	Age Comp
	RCH	CON	NIT	OTHER		
3	45,000	7,000	7,000	5,000	**64,000**	41%
4	23,000	23,000	9,000	8,000	**63,000**	40%
5	11,000	6,000	3,000	10,000	**30,000**	19%
Forecast	**79,000**	**36,000**	**19,000**	**23,000**	**157,000**	
Range	**(58,000 - 100,000)**	**(22,000 - 50,000)**	**(13,000 - 25,000)**	**(15,000 - 31,000)**	**(108,000 - 205,000)**	

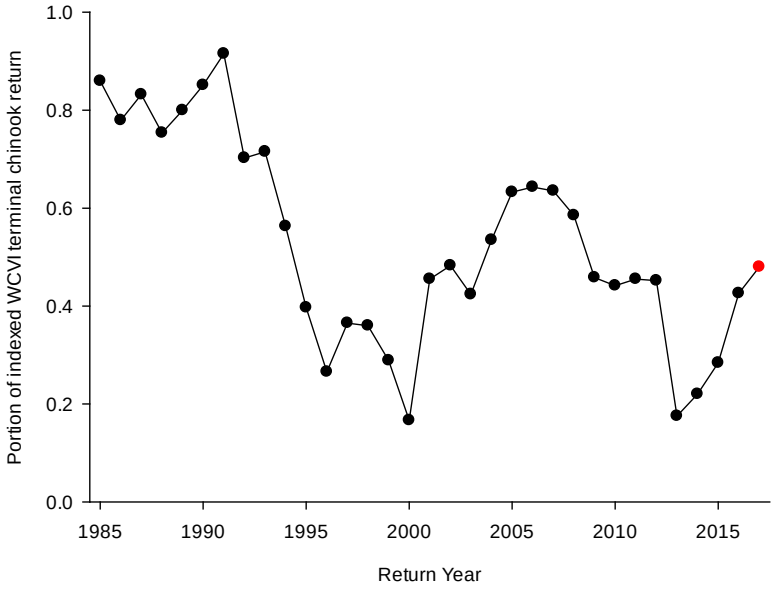

Figure 4. Estimated contribution of Stamp/RCH chinook to the total return of WCVI indexed stocks, 1986-2016. The forecast contribution for 2017 is also plotted (48%).

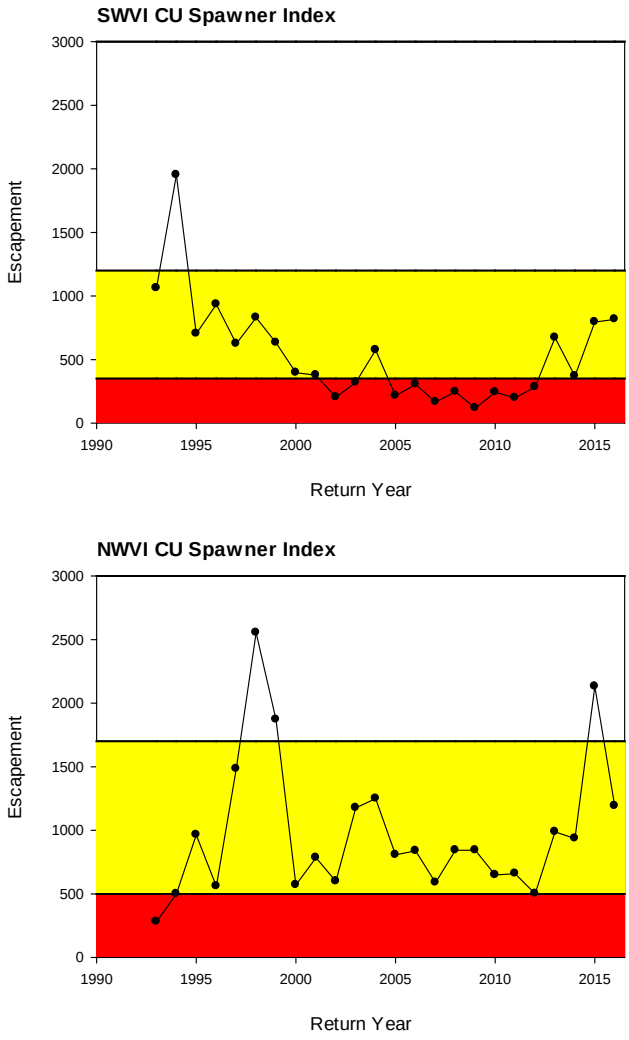

Figure 5. Spawner abundances of SWVI and NWVI Conservation Units relative to provisional lower and upper biological benchmarks (.4 and .85 $S_{MSY,}$ respectively; S_{MSY} for index stocks is estimated by the habitat model described in Parken et al. 2006). For each CU, spawner abundances are the summed estimates for wild index stocks that receive little or no enhancement. Similarly, for each CU, the upper and lower biological benchmarks are summed across wild index stocks.

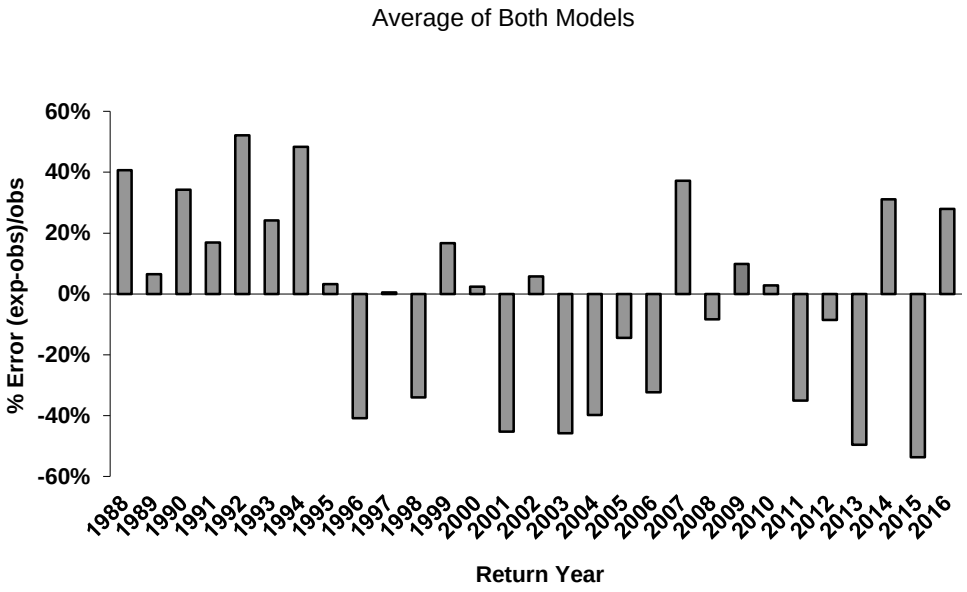

Figure 6. Average annual percentage error of the Somass/RCH terminal run forecast (both sibling models averaged), 1988 to 2015. The mean absolute percentage error (MAPE) in the forecast terminal run size versus observed is 26% since 1988.