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West Coast of Vancouver Island Chinook Terminal Return Forecast for 2024

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SUMMARY

- After deducting expected catch in pre-terminal ocean fisheries, the 2024 forecast return of Stamp River/Robertson Creek Hatchery (RCH) Chinook to the terminal area of Barkley Sound and Alberni Inlet is 107000 adults (range: 50000–165000). The Area 23 Harvest Committee will manage early season Chinook fisheries to a forecast of 125000 to account for a likely bias in the model prediction.
- Terminal Chinook returns of Conuma, Nitinat, and smaller WCVI indicator stocks are forecast to be above average in 2024. The forecast of aggregate terminal abundance (sum of all hatchery and wild indicator stocks, including RCH) is 244000 adults (range: 141000–345000), significantly higher than the long-term average of 160000 (1980–2022). The overall expected adult age composition of the WCVI aggregate terminal run is 23% age-3, 62% age-4, and 16% age-5, with an expected sex ratio of 44% female.
- The 2023 terminal return of the Stamp River/RCH coded-wire tag (CWT) Indicator Stock was approximately 197000 adults and 4000 jacks (age-2 males), 84% higher than the pre-season prediction. The 2023 aggregate terminal return (*i.e*. excluding catch in pre-terminal fisheries) of West Coast of Vancouver Island (WCVI) Chinook index stocks—including RCH—was estimated at 329000 adults, 35% higher than the pre-season forecast prediction.
- In 2023, the total estimated pre-terminal exploitation rate on WCVI Chinook was 20%; estimates were 3%, 19% and 34% for ages 3, 4 and 5 fish, respectively.
- Spawner levels in natural indicator streams in the Southwest Vancouver Island (SWVI) Conservation Unit (CU) remain below upper biological benchmarks with fewer than 100 spawners observed in some rivers in recent years. WCVI natural-origin Chinook therefore remains a stock of concern.

BACKGROUND

Chinook salmon spawn in over 100 medium and large rivers along the WCVI, with 60 systems having escapement records of at least 100 spawners. For implementation of Canada's Wild Salmon Policy, stock status is evaluated for a set of wild indicator populations within CUs, which are groups of biologically and genetically similar populations. There are three Chinook CUs defined within the WCVI; including SWVI (populations within DFO Statistical Areas 20–24, or from San Juan to Clayoquot Sound); Nootka-Kyuquot (populations within DFO Statistical Areas 25 and 26) and Northwest Vancouver Island (NWVI; populations within DFO Statistical Area 27, or Quatsino Sound).

The average aggregate terminal return (catch and escapement) of WCVI Chinook is approximately 160000; ranging from about 40000–330000 over the period from 1980–2023. However, a large portion of the terminal return and spawning escapement is hatchery-origin fish. About 20 WCVI populations receive some form of hatchery enhancement to supplement natural spawning. Annual releases of Chinook smolts from WCVI enhancement facilities total about 15 million. The majority (*c.* 13 million) are 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 2 million Chinook smolts are released annually from smaller facilities, including volunteer public involvement projects and community development projects. Natural-origin Chinook returning to rivers in the SWVI and Nootka-Kyuquot CUs are designated as "Threatened" by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC, 2020).

The Stamp River/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 undertaken annually to support stock assessments for WCVI Chinook as a whole. 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 rates of the RCH indicator stock.

FORECAST METHODOLOGY

Stamp River / Robertson Creek Hatchery (RCH)

Riddell *et al.* (1996) 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 (for select tag codes representing normal releases) 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 Pacific Salmon Commission's (PSC) Chinook Technical Committee (CTC) to account for the Chinook non-retention fisheries implemented in Canada (Pacific Salmon Commission, 1999). For each brood year, information generated from the cohort analysis and used in forecast models includes: 1) survival to age-2 recruitment; 2) ocean exploitation rates by fishery and age; 3) age-specific maturation rates; and 4) total estimated production. The cohort analysis produces estimates of CWT recoveries in all Canadian and USA fisheries, as well as in natal and stray escapement. Total production is then determined by expanding all estimated CWTs by the total release/CWT ratios for the selected tag codes and then correcting this using recent average observed total returns/CWT-based estimates.

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.
- Model 2 uses estimated total production (fishing mortality plus escapement) of particular age classes to predict total production of subsequent ages (*i.e.*, the surviving cohort from the same brood year).

Relationships between all possible age class combinations were examined using these two models. The actual models used for the forecast were based on the strongest correlations (highest R^2 values). In the case where more than one age class is used as a predictor (*e.g.* ages 2 & 3 fish) the total terminal runs at those ages 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 (10-year) 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 Barkley Sound/Alberni Inlet is forecast after accounting for expected removals in pre-terminal ocean fisheries. A forecast range is generated from the historical distribution of the deviations between the observed and forecast run size.

Beginning for the 2019 forecast and continuing through 2024, three adjustments were implemented based on recommendations from PSC (2016): 1) all sibling regressions are based on log-transformed data; 2) only recent average maturation rates are applied (Figure 6); and 3) age-specific pre-terminal exploitation rates are assumed similar to the recent 3-year average (Figure 2, Table 3).

Other WCVI Populations

Other WCVI populations lack precise data to estimate specific survival and exploitation rates. However, trends in brood year survival and ocean fishery impacts for other WCVI Chinook populations are assumed similar to the RCH Indicator Stock. These survival and exploitation rate data from the RCH cohort analysis are used to inform forecasts for returns to other WCVI terminal areas and 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. With increasingly detailed age data being collected from other stocks (*i.e.* sibling performance of earlier age classes that have already returned for the contributing brood years), specific forecasts have been developed for the Conuma and Nitinat hatchery returns, and for the remaining index stocks as a whole (see list in Table 2). These models were initially developed to inform domestic management of Canadian fisheries, but have recently been applied to forecast the aggregate WCVI terminal abundance because the stock-specific forecasts are generally more accurate than the

simple ratio method described above (see Figure 5). The contribution of Stamp/RCH stock to the aggregate WCVI abundance has been variable due to apparent differences in marine survival rates among WCVI hatchery stocks and from changes in hatchery release strategies (Figure 5).

COHORT ANALYSIS AND FORECAST PERFORMANCE FOR THE 2023 RETURN

The estimated 2023 terminal adult return of WCVI index stocks (*i.e.* excluding catch in pre-terminal fisheries) was 329000, with estimated adult returns of 197000, 42500, 34500 and 55000 to Stamp/RCH, Conuma Hatchery, Nitinat Hatchery and other extensive indicator stocks, respectively (Table 1). The estimated age composition of the WCVI aggregate return was 31%, 67% and 4% for 3-, 4- and 5-year-old Chinook, respectively.

The observed terminal returns of WCVI Chinook were higher than forecast for all stocks (Table 2). Overall, the total observed WCVI return was 39% higher than forecast (Table 2). The trend in marine survival rate to age-2, as estimated through cohort analysis using RCH CWT recoveries, is plotted in Figure 3. The long-term average marine survival rate is about 4.7%. For the 2018, 2019, 2020 and 2021 brood years (returned as 5-, 4-, 3-, and 2-year-old fish in 2023), the estimated survival rates to age-2 were 5.4%, 3.4%, 7.4% and 6.4%, respectively. Estimates for the 2019–2021 brood years are based on incomplete brood returns and are 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 total estimated pre-terminal exploitation rate was 39%. Estimated pre-terminal exploitation rates on 3-, 4- and 5-year-old fish in 2023 were 3%, 19% and 34%, respectively. In the last 3 years, the estimated pre-terminal exploitation rates of 4- and 5-year-old WCVI Chinook have averaged about 27% and 42%, 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). The management objective is to limit fishery exploitation in Canadian AABM fisheries to 10%, within which the Northern Troll fishery is limited to 3.2%. In 2023, the exploitation rate in Canadian AABM fisheries was estimated at 11.3% with the Northern Troll at 1.6%.

2024 FORECAST

Terminal return of Stamp River / Robertson Creek Hatchery (RCH) Chinook

The forecast terminal return of adult Stamp/RCH Chinook to Barkley Sound and Alberni Inlet in 2024 is approximately 107000 (range: 50000–165000). This is an above average return and suggests a continuation to the trend of strong returns that began *c.* 2018. The predicted adult age composition is 17%, 68%, and 15% of 3, 4 and 5-year old fish, respectively (Table 4). As the predicted return falls within the “abundant” category, directed Chinook fisheries are expected in the terminal Alberni Inlet area for all sectors.

Management forecast for Stamp River / Robertson Creek Hatchery (RCH) Chinook

There is higher uncertainty in the 2024 forecast relative to previous years due to missing CWT data from the 2019 brood year (see Sources of Uncertainty, below). The 2023 pre-season forecast was subject to the same uncertainty and underpredicted the observed return by 42%, the highest percentage error of all 2023 WCVI Chinook forecasts (Table 2). This is unusual because the RCH/Stamp forecast historically performs best among all the WCVI Chinook forecasts. In addition, the 2024 forecast return of RCH/Stamp Chinook relative to forecasts for other WCVI stocks (see below) is unusually low compared to recent observations (Figure 6). Considering these factors, on 30 May 2024, the Area 23 Harvest Committee agreed that the 2024 forecast of 107000 terminal return of RCH/Stamp River Chinook is likely an underestimate. The Harvest Committee reached a consensus decision to adopt a pre-season management forecast of **125000** terminal return.

Terminal return of other WCVI Chinook populations

Marine survivals of WCVI Chinook have been increasing since the 2012 brood year (Figure 3). Estimated

survival rates from the 2020–2021 ocean-entry years (4- and 5-year-old Chinook returning in 2024) are well above the recent 10-year and long-term (1984–2021) averages. Expectations in 2024 are for an above-average return with a strong component of ages 4–5 fish. Similar to Alberni Inlet, directed fishery opportunities are expected in WCVI terminal areas dominated by hatchery stocks.

Conuma Hatchery: The predicted terminal return of Conuma Hatchery Chinook to Area 25 is 48000 (range 31000–64000) with an age composition of 38%, 56% and 6% for 3-, 4- and 5-year-old fish, respectively.

Nitinat Hatchery: The predicted terminal return of Nitinat Hatchery Chinook to Area 22 is 35000 (range 24000–45000) with an age composition of 26%, 70% and 4% for 3-, 4- and 5-year-old fish, respectively.

Other WCVI Stocks: The predicted terminal return of other WCVI index stocks (see list in Table 2) is 54000 (37000–71000) with an age composition of 18%, 50% and 32% for 3-, 4- and 5-year-old fish, respectively. This forecast return results largely from index stocks that are enhanced. 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 CU, below the lower biological benchmark in many recent years (Figure 8).

ESCAPEMENT TARGET FOR STAMP/RCH CHINOOK

The Chinook escapement target for the Somass River is adjusted annually based on the 7.1-million-egg target for RCH broodstock, and a goal of allowing a healthy natural-spawning biomass into the Stamp River habitat. In 2023, the Area 23 Harvest Committee reached a consensus to adopt a spawner escapement target to the Stamp River of 14600 adult spawners. An egg target for RCH of 9M was agreed to be appropriate because it includes a 2-M-egg buffer above the hatchery's 7-M-egg target to account for uncertainty in the forecast sex ratio. Thus, the adult escapement target for Somass Chinook is calculated annually as 14600 + the expected number of spawners to attain 9M eggs for RCH. Accordingly, the target for 2024 is 21000 adult spawners.

SOURCES OF UNCERTAINTY

In 2020, no CWTs were applied at RCH to Chinook from the 2019 brood year due to COVID-19 lockdown restrictions. Consequently, no recoveries were available to run the sibling model predicting total production of age-5 fish. The age-4 CWT recovery data in 2023 were imputed by applying the recent 5-year ratio of age-3 to age-4 fish, a methodology that was developed by the CTC and endorsed by the Pacific Salmon Commission (2023). However, Chinook from the 2019 brood year have dominated total abundance in the 2022 and 2023 return years, suggesting higher than average survival for this cohort. Imputed CWT recoveries of age-4 fish in 2023 made up 43% of the total estimated CWT recoveries. In contrast, age-4 fish estimated from scale sampling in the 2023 terminal run reconstruction made up 61% of the total return. The prediction for the age-5 return in 2024 is therefore much more uncertain than in previous years, and likely biased low by a skewed CWT age composition resulting from imputation of age-4 recoveries. Re-running the forecast model with CWT recoveries adjusted to match the age composition in the terminal run reconstruction increased the predicted return from 107000 to ≈124000.

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 (1988–2023, Figure 4). That is, on average, the observed return is about 26% higher or lower than the predicted return. Factors that contribute to uncertainty in the forecast include, but are not limited to: changing maturation rates, uncertainty associated with cohort analysis CWT data, changing exploitation patterns in pre-terminal fisheries, and the changing ocean environment under climate change.

For other WCVI Chinook forecasts, there is higher uncertainty due to the general lower quality assessment data relative to the Stamp/RCH indicator stock. There are incomplete age data, relatively high uncertainty in spawner abundance estimates (for extensive indicator stocks in particular), and also higher uncertainty in pre-terminal catch estimates. In addition, survival, exploitation, and maturation rates of other WCVI stocks could vary significantly from the Stamp/RCH indicator stock. The MAPE of forecasts

for other WCVI stocks ranges from 31–36% when a retrospective analysis is applied for the 1996–2023 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 has been a trend in recent decades toward increased maturation rates in WCVI Chinook; fish are generally maturing quicker and returning to the terminal area at younger ages (Figure 6). Increases in maturation rate will affect the expected return of older age classes relative to average rates (Lewis *et al*., 2015). The reliability of the terminal forecasts also depends on the accuracy of age-specific pre-terminal exploitation rate predictions, which can vary considerably from year to year. Variability in fishery exploitation patterns is caused by a number of factors including regulatory changes to fisheries, relative stock abundances in mixed-stock fisheries, changes in the marine distribution of the WCVI stock, and changes in the maturation rate of the WCVI stock (such as described above).

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APPENDIX—FIGURES AND TABLES

Table 1. Estimated 2023 returns of Chinook index stocks to the terminal WCVI area (*i.e.* after pre-terminal Canadian fisheries).

Stock	Age				Adult Total
	2	3	4	5	
Area 23	4000	68000	123000	6000	197000
Area 25	1000	16000	24500	2000	42500
Area 21/22	500	3500	29500	1500	34500
Other WCVI	1000	12000	39000	4000	55000
Total	6500	99500	216000	13500	**329000**

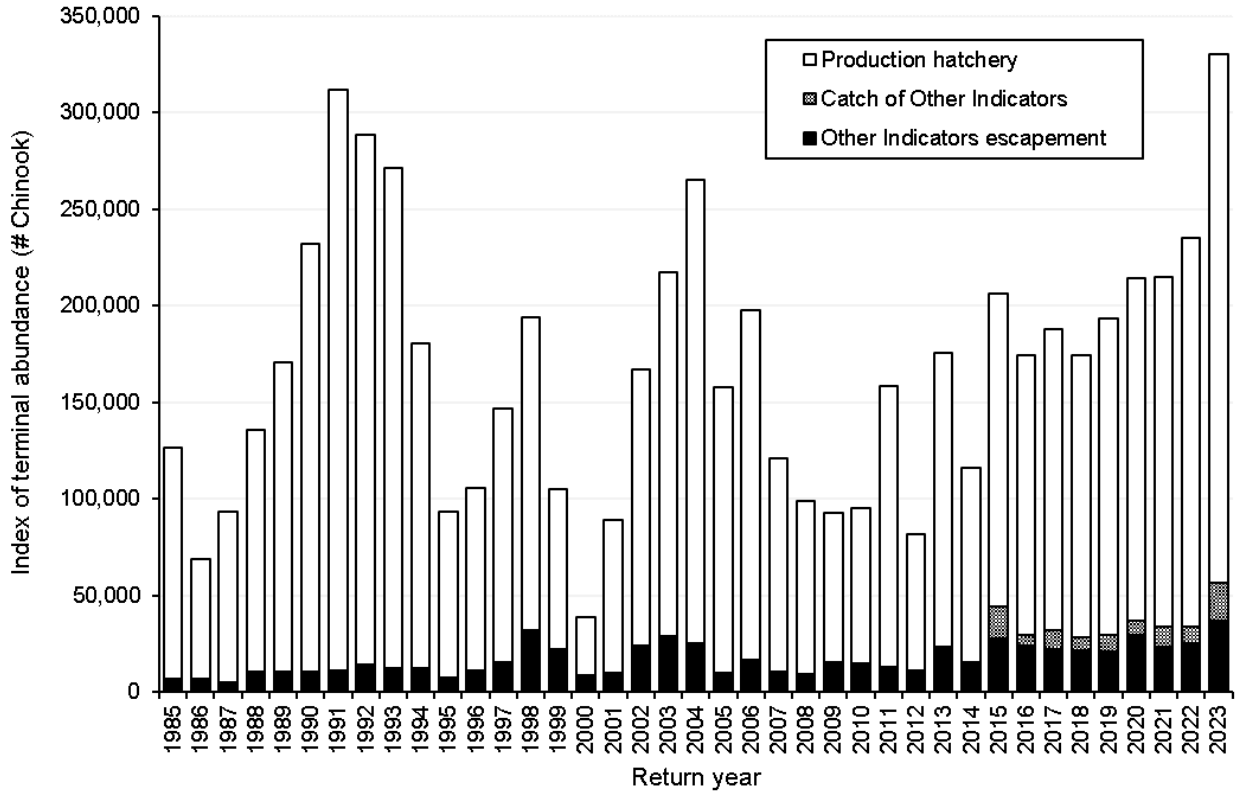

Figure 1. Aggregate terminal Chinook return of WCVI indicator stocks, including major production hatcheries (Robertson Creek, Conuma and Nitinat) and all other indicator stocks—many of which are also supplemented with smaller-scale hatchery production.

Table 2. The performance of 2023 WCVI Chinook adult (age ≥ 3 years) terminal return forecasts. "PE" is the percentage error of the forecast, *i.e.* the discrepancy between predicted and observed returns.

Stock(s)	Average (1996–2022)	2023 Observed	2023 Forecast Range	2023 Forecast Prediction	PE
*WCVI Index Stocks	†34000	55000	26000–51000	38000	−31%
Conuma	37000	42500	22000–49000	35000	−18%
Nitinat	26000	34500	18000–34000	26000	−25%
Somass/RCH	78000	197000	85000–144000	114000	−42%
Total	**175000**	**329000**	**151000–278000**	**213000**	**−35%**

*****An aggregate of the PSC indicators (Artlish, Burnam, Gold, Kaouk, Marble, Tahsis, & Tashish rivers) and "extensive" indicators (Bedwell, Colonial, Cypre, Leiner, Megin, Moyeha, Nahmint, San Juan, Sarita, Tranquil, & Zeballos rivers).
†Average from 2015–2022. Prior to 2015, catch was not included—only escapement estimates for the systems were available.

Table 3. Age-specific exploitation rates of WCVI Chinook in pre-terminal fisheries, 2023 (estimated by cohort analysis using RCH Indicator Stock CWT recoveries).

Age	Alaska			NBC Troll	CBC Troll	WCVI Troll	NBC Net	NCBC* Sport	WCVI Sport	OTHER Ocean	Total Pre-terminal
	Troll	Net	Sport								
3	0.1%	0.2%	0.0%	0.4%	0.0%	0.3%	0.0%	0.3%	0.6%	0.7%	2.6%
4	2.4%	0.9%	1.6%	2.0%	0.0%	0.7%	0.0%	4.1%	3.3%	3.8%	18.9%
5	10.5%	2.6%	7.3%	1.5%	0.0%	0.0%	0.0%	9.2%	2.6%	0.0%	33.7%

*Northern and Central BC

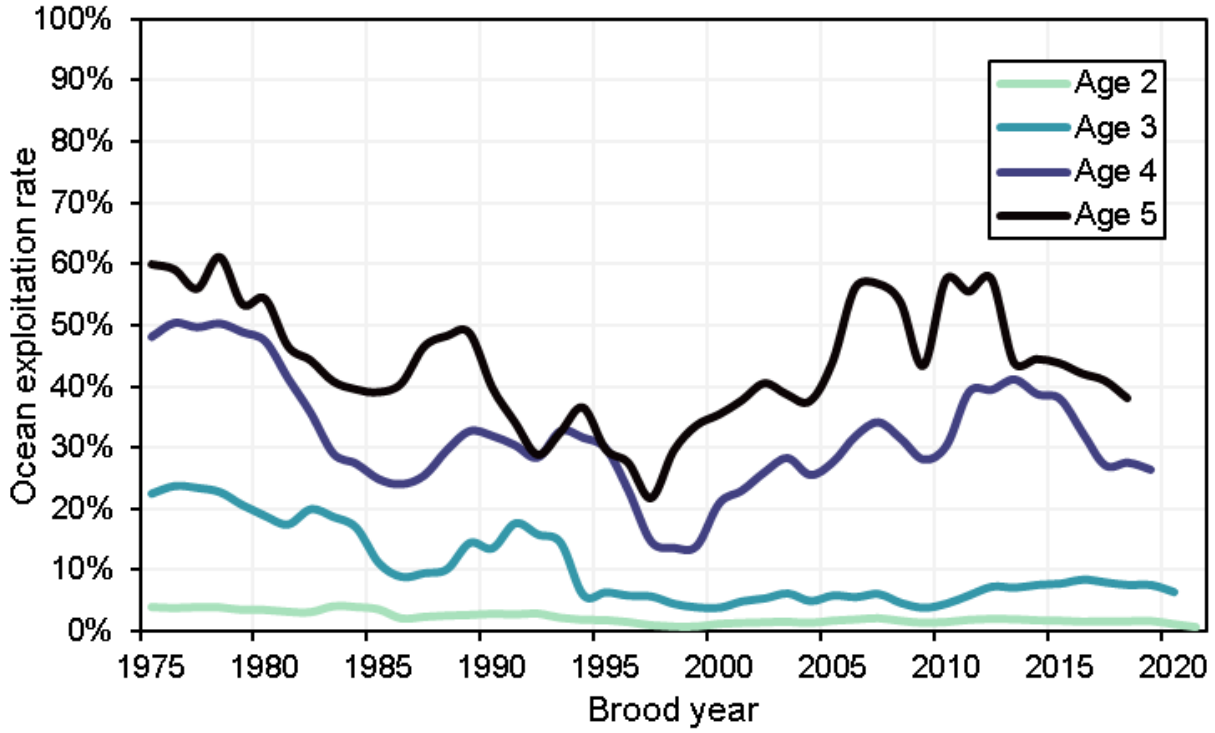

Figure 2. Three-year-rolling-average age-specific exploitation rates of WCVI Chinook in pre-terminal fisheries, brood years 1973–2021. Exploitation rates are estimated by cohort analysis using RCH Indicator Stock CWT recoveries. Data from 1983, 1992, and 1997 were excluded because too few CWT recoveries were observed to yield accurate estimates.

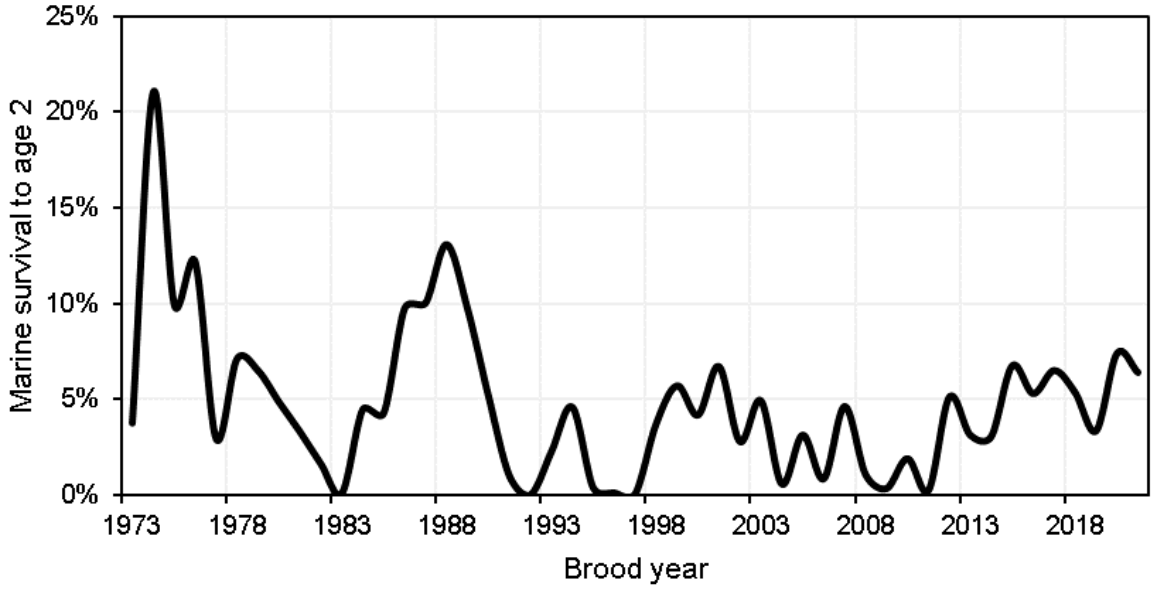

Figure 3. Estimated survival by age of WCVI Chinook (estimated by cohort analysis using RCH Indicator Stock CWT recoveries). The thick black line shows the survival rates from smolt to age 2.

Table 4. Summary of the 2024 Stamp River/Robertson Creek Hatchery forecast pre-fishery abundance and return of mature fish to Canada and the terminal WCVI area.

Model	Pre-Fishery Abundance[1]	Return to Canada[2]	Terminal Return[3]	Terminal Age Comp
1. Terminal return versus Total Production				
2021 brood	40869	10585	9709	8%
2020 brood	164334	108962	85783	73%
2019 brood	41023	29610	21535	18%
Total	246226	149157	117027	
2. Total Production versus Total Production				
2021 brood	110915	28726	26350	27%
2020 brood	114941	76212	59999	62%
2019 brood	20307	14657	10660	11%
Total	246163	119595	97009	
Average of both models				
2021 brood	75892	19655	**18029**	**17%**
2020 brood	139638	92587	**72891**	**68%**
2019 brood	30665	22133	**16097**	**15%**
Total	246194	134376	**107018**	

1. Forecast total production from the respective brood years.
2. Forecast mature return to Canada prior to Canadian fisheries.
3. Forecast mature return to Barkley Sound/Alberni Inlet.

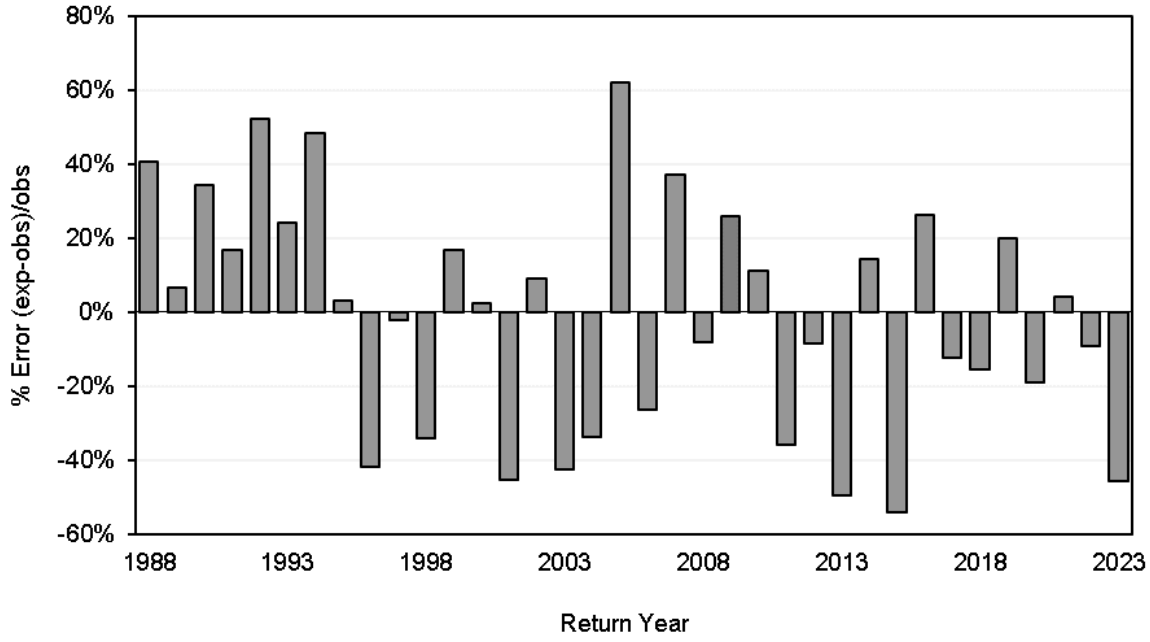

Figure 4. Annual percentage errors of the Somass/RCH terminal run forecast (both sibling models averaged), 1988–2022. The mean absolute percentage error (MAPE) in the forecast terminal run size versus observed return is 26% since 1988.

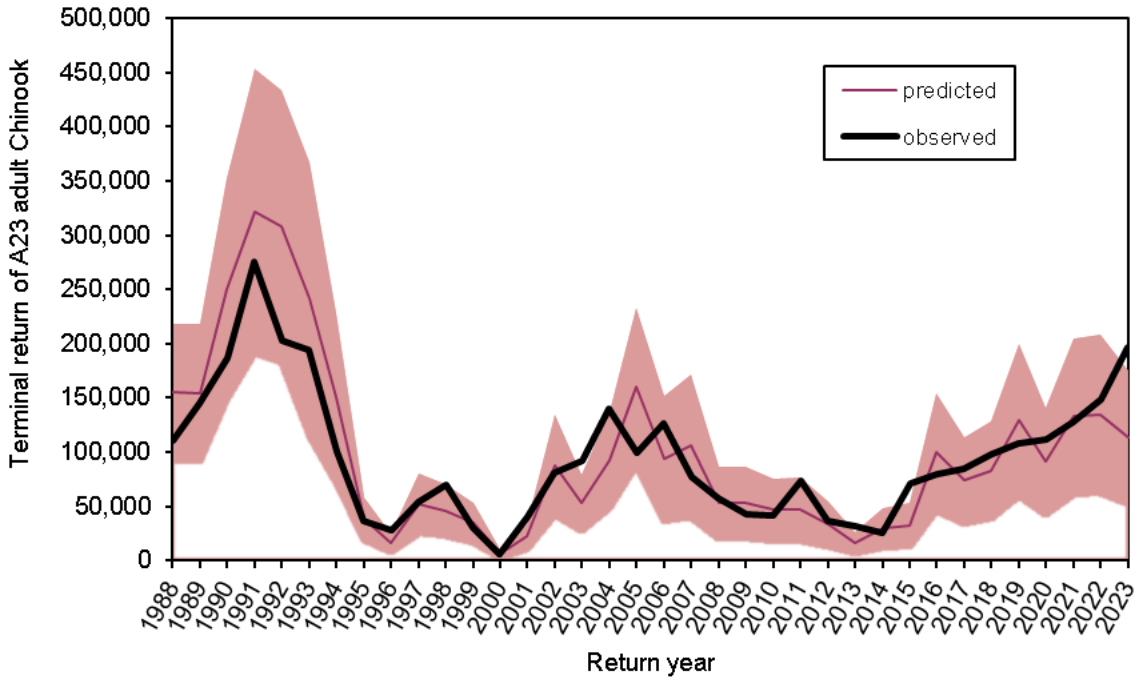

Figure 5. Forecast model predictions and range (in red) versus observed returns (in black) from 1988–2023. The running 10-year maximum absolute percentage error between predicted and observed returns is used to suggest the prediction range (shaded red area).

Table 5. 2024 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).

Stock	Age						Total	Range
	3	%	4	%	5	%		
RCH	18000	17%	73000	68%	16000	15%	107000	49000–165000
CON	18000	38%	27000	56%	3000	6%	48000	31000–64000
NIT	9000	26%	24000	69%	2000	6%	35000	24000–45000
OTHER	10000	19%	27000	50%	17000	31%	54000	37000–71000
Total	55000	23%	151000	62%	38000	16%	**244000**	**141000–345000**

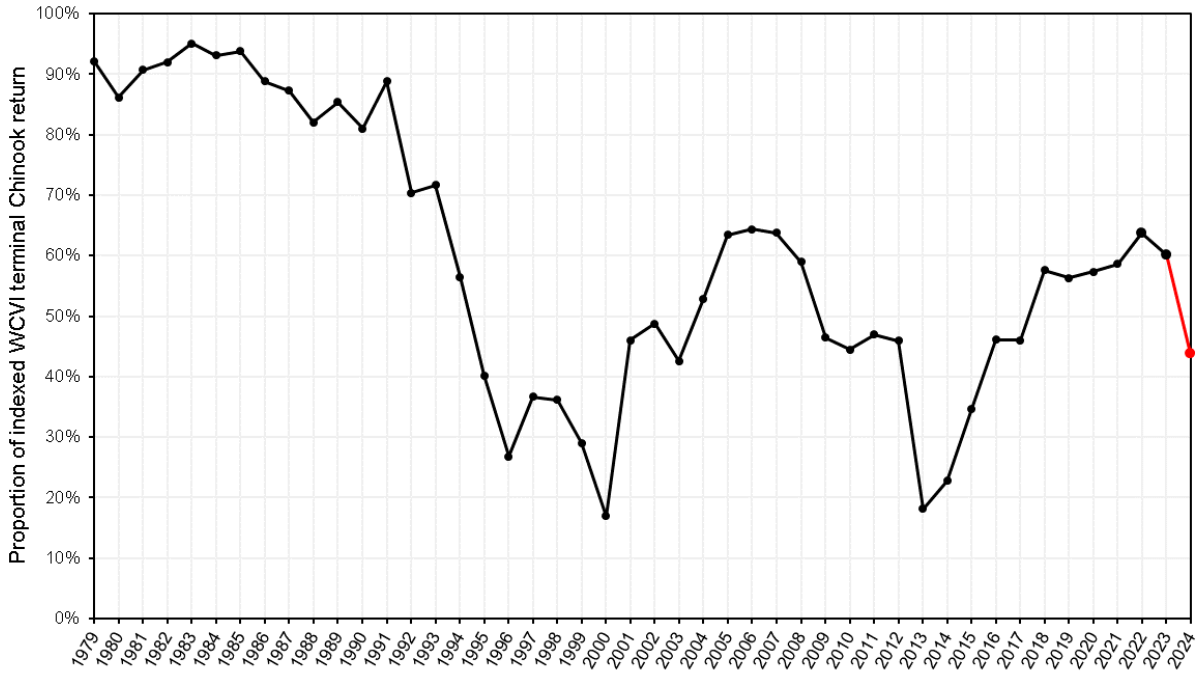

Figure 6. Estimated contribution of Stamp/RCH Chinook to the total return of WCVI indexed stocks, 1979–2023. The predicted contribution for 2024 (44%) is plotted in red.

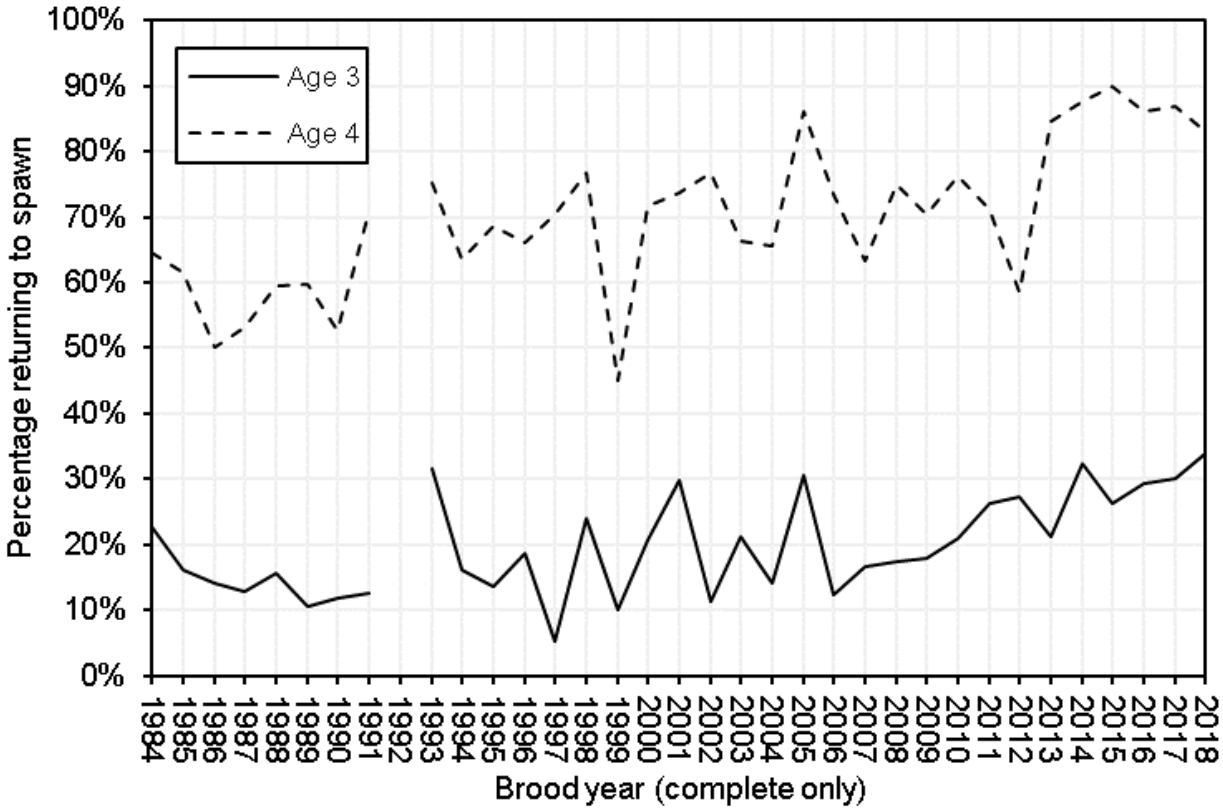

Figure 7. Maturation rates for Stamp/RCH Chinook estimated from the CTC's CWT-based cohort analysis. Data from 1992 were excluded because too few CWT recoveries were observed to yield accurate estimates. All age 5 fish are assumed to be mature, and <2% of fish mature at age 2.

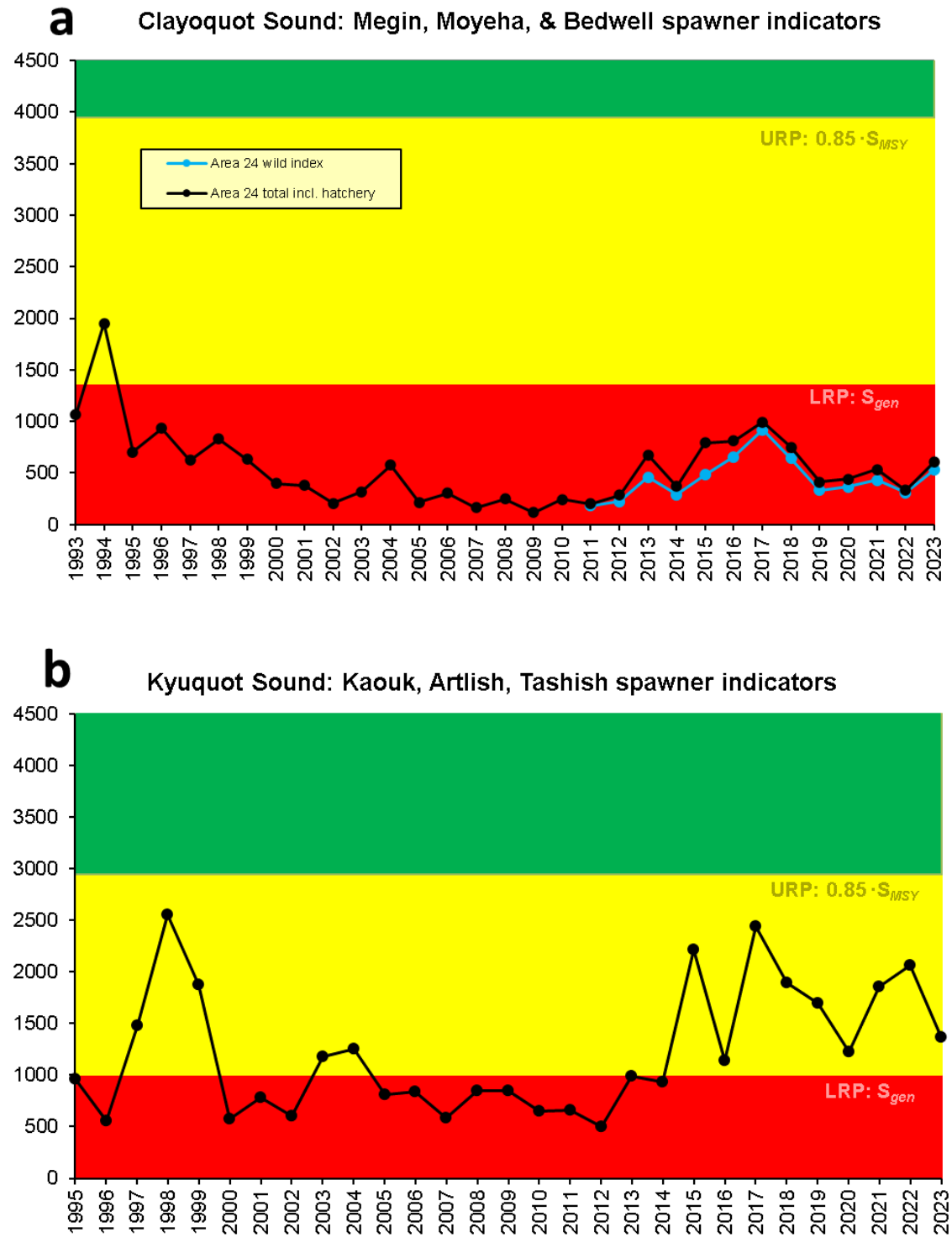

Figure 8. Spawner abundances of a) SWVI and b) NWVI CUs relative to provisional lower and upper biological benchmarks (S_{gen} and 85% S_{MSY}, respectively; Holt et al. 2023). For each CU, spawner abundances are the summed estimates for wild index stocks that receive little or no enhancement. The upper and lower biological benchmarks are summed across the same wild index stocks.