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West Coast of Vancouver Island Chinook Terminal Return Forecast for 2023

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Nicholas A. W. Brown
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SUMMARY

- After deducting expected catch in ocean fisheries, the 2023 forecast return of Stamp River/Robertson Creek Hatchery (RCH) Chinook to the terminal area of Barkley Sound and Alberni Inlet is **114000** adults (range: **85000**–**144000**).
- Terminal Chinook returns of Conuma, Nitinat, and smaller WCVI indicator stocks are forecast to be average in 2023. The forecast of aggregate terminal abundance (sum of all hatchery and wild indicator stocks, including RCH) is 214000 adults (range: 151000–278000), significantly higher than the long-term average of 160000 (1980–2021). The overall expected adult age composition of the WCVI aggregate terminal run is 16% age-3, 68% age-4, and 16% age-5, with an expected sex ratio of 47% female.
- The 2022 terminal return of the Stamp River/RCH coded-wire tag (CWT) Indicator Stock was approximately 149000 adults and 6000 jacks (age-2 males), 13% higher than the pre-season prediction. The 2022 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 232000 adults, 3% lower than the pre-season forecast prediction.
- In 2022, the total estimated pre-terminal exploitation rate on WCVI Chinook was 39%; estimates were 12%, 36% and 42% for ages 3, 4 and 5 fish, respectively.
- After a period of modest increase in wild populations, escapements have been decreasing over the last five years for many wild stocks. Spawner levels in the South West Vancouver Island (SWVI) Conservation Unit (CU) remain below upper biological benchmarks with fewer than 100 spawners observed in some rivers in recent years. Wild WCVI 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 40000–300000 over the period from 1980–2022. 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 21 million. The majority (*c.* 17 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 4 million Chinook smolts are released annually from smaller facilities, including volunteer public involvement projects and community development projects. Wild 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 rate 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 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; and 3) 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 impacts in pre-terminal ocean fisheries. A forecast range is generated from the distribution of the deviations between the observed and forecast run size.

Beginning for the 2019 forecast and continuing through 2023, three adjustments were implemented based on recommendations from Peterman et al. (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 rate among WCVI hatchery stocks and from changes in hatchery release strategies (Figure 5).

COHORT ANALYSIS AND FORECAST PERFORMANCE FOR THE 2022 RETURN

The estimated 2022 terminal adult return of WCVI index stocks (*i.e.* excluding catch in pre-terminal fisheries) was 232000, with estimated adult returns of 149000, 24000, 27000 and 32000 to Stamp/RCH, Conuma Hatchery, Nitinat Hatchery and other extensive indicator stocks, respectively (Table 1). The estimated age composition at return of the WCVI aggregate was 48%, 47% and 5% for 3-, 4- and 5-year-old Chinook, respectively.

The observed terminal returns of WCVI Chinook were lower than expected for all stocks other than Stamp/RCH (Table 2). Overall, the total observed WCVI return was 3% lower than forecast (Table 2). Trends in marine survival rate to age-2 estimated through cohort analysis using RCH CWT recoveries are plotted in Figure 3. The long-term average marine survival rate is about 4.7%. For the 2017, 2018, 2019 and 2020 brood years (returned as 5-, 4-, 3-, and 2-year-old fish in 2022), the estimated survival rates to age-2 were 6.3%, 5.2%, 3.0% and 2.2%, respectively (Figure 3). Estimates for the 2018–2020 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 2021 were 12%, 36% and 42%, respectively. In the last 3 years, the estimated pre-terminal exploitation rates of 4- and 5-year-old WCVI Chinook have averaged about 30% and 41%, 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 2022, the exploitation rate in Canadian AABM fisheries was estimated at 14.8% with the Northern Troll at 1.5%.

2023 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 2022 is approximately 114000 (range: 85000–144000). 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 13%, 77% and 11% 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.

Terminal return of other WCVI Chinook populations

While estimated marine survival rates for Nitinat, Conuma, and some other WCVI stocks from the 2009–2011 brood years exceeded estimates for the RCH Indicator Stock, the trend appears to have reversed in the most recent complete brood years (2014–2017). However, given that returns observed for Nitinat, Conuma, and the other extensive indicators in 2022 were close to average (Table 2), general expectations are for roughly average returns of adult Chinook in 2023 (Table 5). Similar to Area 23, 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 35000 (range 22000–49000) with an age composition of 36%, 50% and 14% for 3-, 4- and 5-year-old fish, respectively.

Nitinat Hatchery: The predicted terminal return of Nititat Hatchery Chinook to Area 22 is 26000 (range 18000–34000) with an age composition of 12%, 67% and 20% 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 38000 (26000–51000) with an age composition of 11%, 60% and 29% 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 7).

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 naturally spawning biomass into the Stamp River habitat. However, the target for a healthy spawning biomass in the Stamp River has been under discussion in recent years. Prior to 2021, the Somass Chinook escapement target was based on a total egg deposition goal of 39 million, which included 9 million eggs for RCH broodstock (the 7.1-million target plus a 2-million buffer) and 30 million eggs for the river. This egg target was converted to a spawner target based on forecast age compositions, and biostandards for sex ratios and fecundity at age. However, declining trends in Chinook fecundity, maturation rates, and size at age warrant ongoing discussion of appropriate assumptions for calculating spawner targets (Lewis et al., 2015; Ohlberger et al., 2018, 2020; Figure 6). A study carried out at Robertson Creek Hatchery in 2021 provided updated fecundity biostandards with median fecundities of 2900, 3500, and 4500 for 3-, 4-, and 5-year-old females, respectively. These results shed light on appropriate values for egg target calculations, but did not address concerns around an appropriate escapement target for Stamp river spawners.

Prior to 2023, the escapement target for the Stamp River was derived from a habitat-based model that was parameterized for the Stamp River in 2006 (Parken et al., 2006). The S_{MSY}—the predicted spawning population required for maximum sustainable yield—was 5000 spawners. However, verification of the habitat-based models showed predicted S_{MSY} could differ from stock-recruit derived S_{MSY} by up to 221% (Parken et al., 2006). Therefore, a conservative buffer of 200% was applied on the original S_{MSY} of 5000, yielding a Stamp River escapement target of 15000 spawners, which was converted into an 30-million-egg target based on the average age and sex compositions and historic fecundity biostandards for the population. In 2022, Holt et al. (in prep) updated the model using revised watershed-area estimates of higher precision, resulting in an S_{MSY} of 7300 spawners.

Managing the Stamp/RCH Chinook return to an egg-based escapement target is advantageous in that it allows flexibility in years when the age composition and sex composition deviate extremely from historical norms. In 2015, for example, the estimated age composition of returning Stamp/RCH Chinook was 90%, 9%, and 2% for ages 3-, 4-, and 5- Chinook, respectively. However, the pre-season forecast is considerably less accurate at predicting the age composition in the return than it is at predicting the total number of returning Chinook, and changing the full Somass escapement target annually increases uncertainty for harvesters planning fisheries. Because Robertson Creek Hatchery Chinook operations are based on a fixed broodstock target and produce Chinook primarily for harvest, an egg-based escapement target for the hatchery is appropriate. However, the habitat-based productivity estimates are subject to a moderate degree of uncertainty and have not been validated using data from the Stamp River population. Therefore, an escapement target that combines the RCH broodstock egg target with a spawner target for the Stamp River would allow a compromise that decreases uncertainty in the escapement target for harvesters but increases the chances of RCH attaining its broodstock target in extreme years.

Considering the information laid out above, the Area 23 Harvest Committee reached a consensus on 19 May 2023 to adopt a spawner escapement target to the Stamp River of 14600 adult spawners, which is the revised S_{MSY} + a 100% buffer against model uncertainty. Much of the uncertainty in the habitat-based productivity estimates is associated with uncertainty in watershed area calculations (Parken et al., 2006); thus, the revised target is assumed to be more precise, and a 100% buffer rather than a 200% buffer is appropriate. An egg target for RCH of 9M was agreed to be the most appropriate buffer against variability in sex ratios between years. Thus, the adult escapement target for Somass Chinook will be calculated annually as 14600 + the expected number of spawners to attain 9M eggs for RCH. Accordingly, the target for 2023 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-4 fish. The prediction for the age-4 return in 2023 is therefore much more uncertain than in previous years. The two models (see Forecast Methodology section, above) that are averaged to yield the final prediction differ by more than 53000 Chinook or 36% (Table 5), which is a greater than usual discrepancy. The predictions are based on CWT recoveries imputed via methodologies developed by the CTC and endorsed by the Pacific Salmon Commission (2023). Overall, the estimated contribution of imputed 3-year-old recoveries to the total terminal return (Model 1) was much greater than to the total production (Model 2). The number of 3-year-old Somass Chinook observed in the 2022 terminal return (≈84490) was the highest since the time series began in 1985, which suggests production from the 2019 brood will continue to be strong in 2023.

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 (1988–2022, 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 31–38% when a retrospective analysis is applied for the 1996–2022 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). Declines 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 are 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).

Information prepared by:

Nick Brown
Salmon Stock Assessment Biologist
Fisheries & Oceans Canada
Nicholas.Brown@dfo-mpo.gc.ca

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APPENDIX—FIGURES AND TABLES

Table 1. Estimated 2022 returns of WCVI 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	6000	84500	59000	5500	149000
Area 25	1500	7500	14500	2000	24000
Area 21/22	100	9500	16000	1500	27000
Other WCVI	500	10000	19000	3000	32500
Total	8100	111500	108500	12000	**232500**

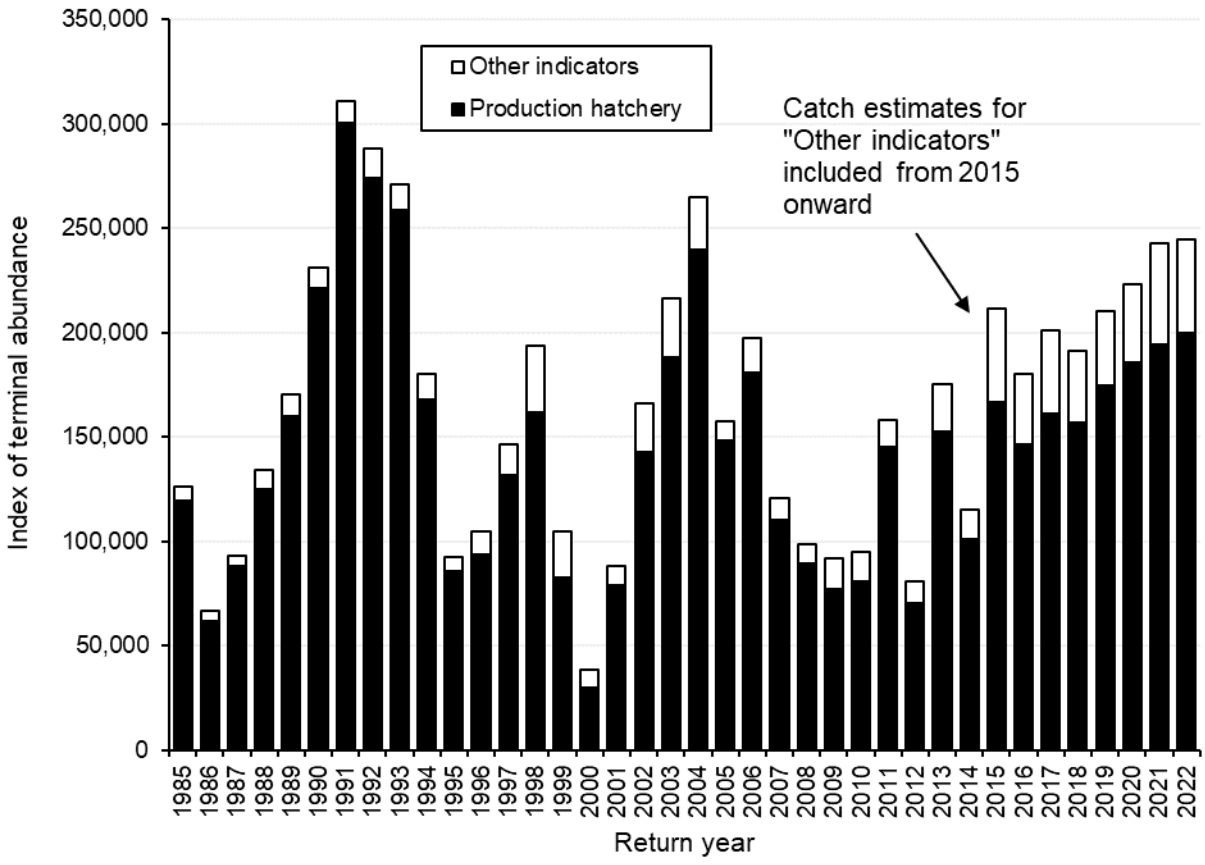

Figure 1. Aggregate terminal Chinook return of WCVI indicator stocks, including major production hatcheries (Robertson Creek, Conuma and Nitinat) and all other indicator stocks—many of which are also supplemented with smaller hatchery production.

Table 2. The performance of 2022 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 (1996–2020)	2022 Observed	2022 Forecast Range	2022 Forecast Prediction	PE
*WCVI Index Stocks	†32000	32500	23000–45000	37 000	16%
Conuma	37000	24000	28000–63000	40 000	67%
Nitinat	26000	27000	17000–32000	28 000	4%
Somass/RCH	74000	149000	100000–170000	135 000	−9%
Total	**168000**	**232500**	**168000–310000**	**240000**	**3%**

*****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 2015–2020. 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, 2022 (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	1.6%	2.5%	0.4%	1.0%	0.0%	0.3%	0.0%	1.3%	1.2%	0.5%	8.8%
4	8.5%	3.4%	2.0%	2.1%	0.0%	0.4%	0.0%	5.1%	6.2%	1.9%	29.6%
5	13.9%	4.6%	2.5%	3.1%	0.0%	0.6%	0.0%	5.4%	7.9%	2.9%	40.9%

*Northern and Central BC

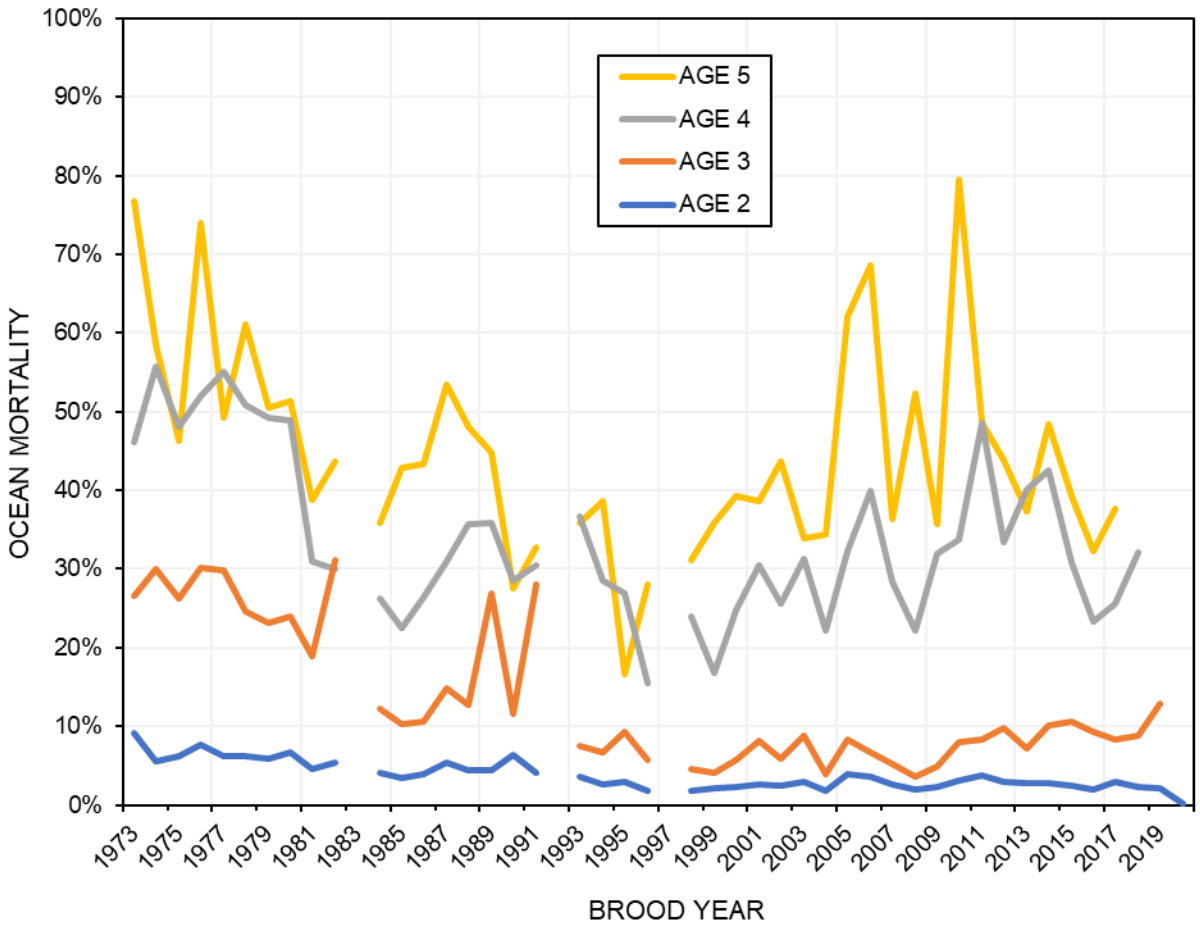

Figure 2. Age-specific exploitation rates of WCVI Chinook in pre-terminal fisheries, brood years 1973–2019. Exploitation rates are estimated by cohort analysis using RCH Indicator Stock CWT recoveries. Data from some years (*e.g.* 1992, 1997) were excluded because very low numbers of CWT recoveries were producing anomalous estimates.

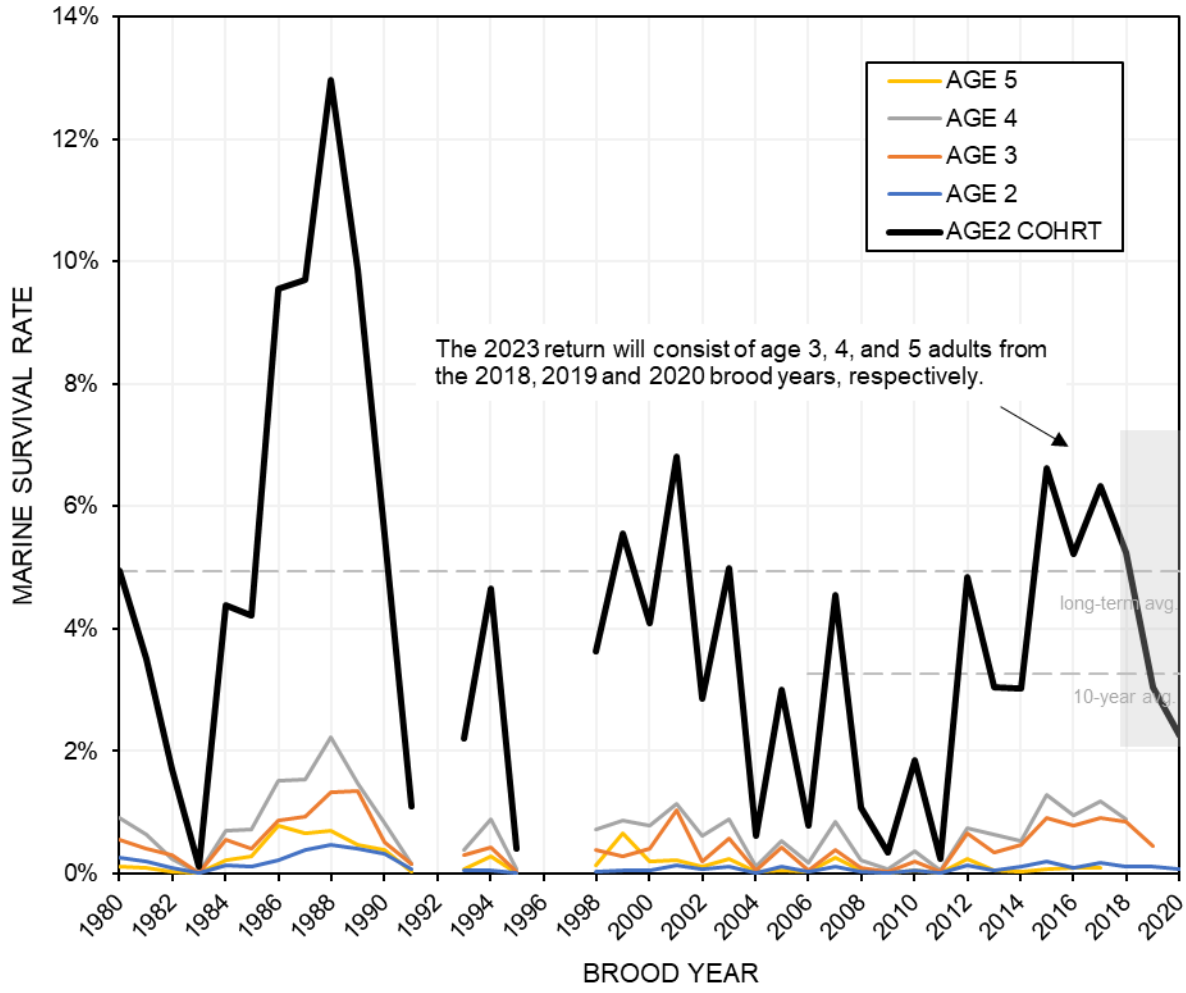

Figure 3. Estimated survival by age of WCVI Chinook (estimated by cohort analysis using RCH Indicator Stock CWT recoveries). The thick black line shows the survival rates from smolt to age 2, whereas the thin coloured lines show survival-at-age. *Note.*—estimates for the last 3 sea-entry years are based on incomplete brood years. Data from 1992 & 1997 were excluded because very low numbers of CWT recoveries were producing anomalous estimates. The grey dashed lines show the long-term average marine survival rate, and the 10-year recent average marine survival rate (which is based on the complete brood years 2007–2017, but extended for visual comparison to subsequent years).

Table 4. Summary of the 2023 Stamp River/Robertson Creek Hatchery forecast pre-fishery abundance and return of mature fish to Canada and the terminal run WCVI area.

Model	Pre-Fishery Abundance[1]	Return to Canada[2]	Terminal Return[3]	Terminal Age Comp
1. Terminal return versus Total Production				
2019 brood	65897	16215	14683	10%
2018 brood	217819	146099	116251	80%
2017 brood	23758	18214	13554	9%
Total	307474	180528	144488	
2. Total Production versus Total Production				
2019 brood	97898	24089	21813	24%
2018 brood	110628	74202	59042	64%
2017 brood	18831	14437	10743	12%
Total	227356	112728	91599	
Average of both models				
2019 brood	81897	20152	**14683**	**13%**
2018 brood	164223	110150	**87647**	**77%**
2017 brood	21294	16326	**12149**	**11%**
Total	267415	146628	**114478**	

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.

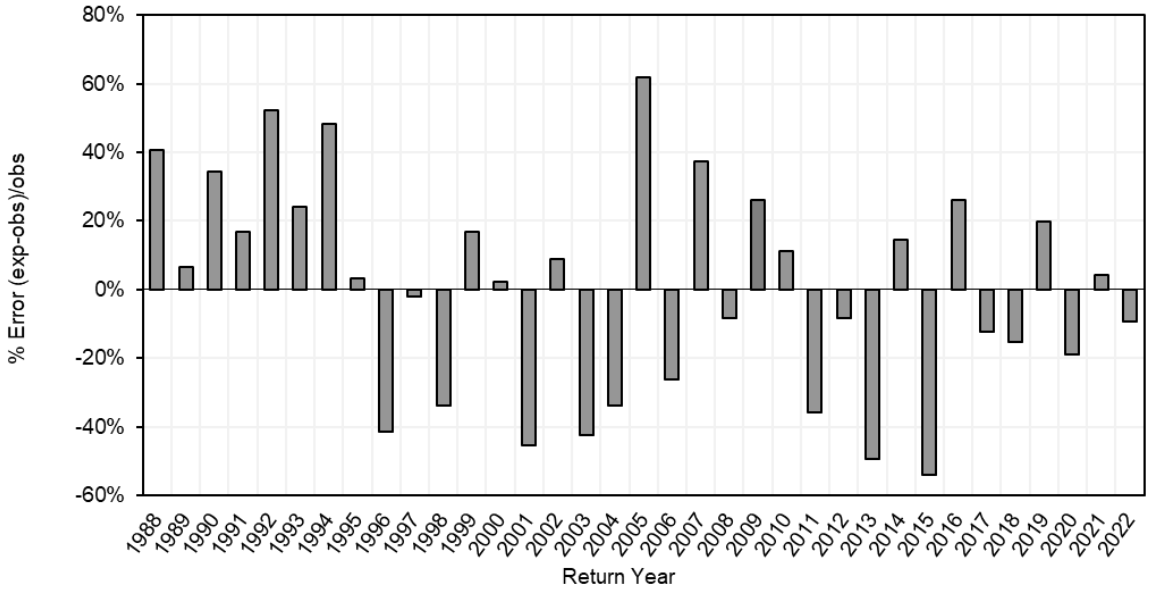

Figure 4. Average annual percentage error of the Somass/RCH terminal run forecast (both sibling models averaged), 1988–2022. The mean absolute percentage error (MAPE) in the forecast terminal run size versus observed is 26% since 1988.

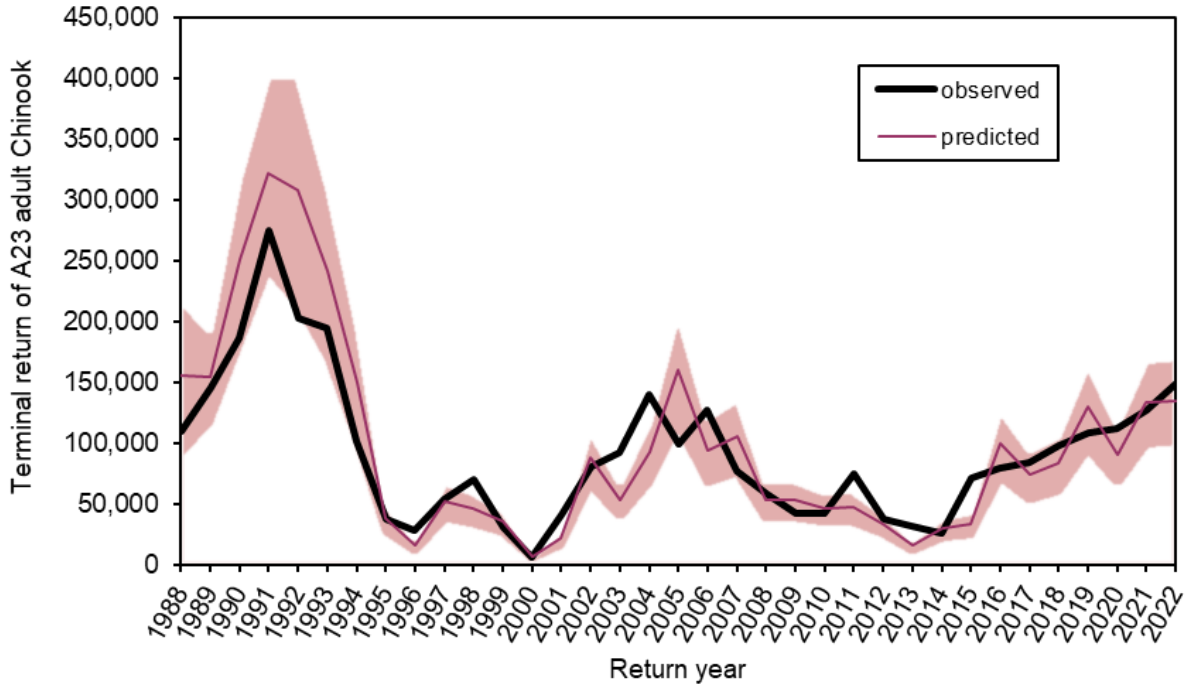

Figure 5. Forecast model predictions and range (in red) versus observed returns (in black) from 1988–2022. The mean absolute percentage error (MAPE) between predicted and observed returns throughout the time series is 26%.

Table 5. 2023 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	15000	13%	88000	77%	12000	10%	115000	144000–85000
CON	13000	36%	18000	50%	5000	14%	36000	49000–22000
NIT	3000	12%	17000	68%	5000	20%	25000	34000–18000
OTHER	4000	11%	23000	61%	11000	29%	38000	51000–26000
Total	35000	16%	146000	68%	33000	15%	**214000**	**278000–151000**

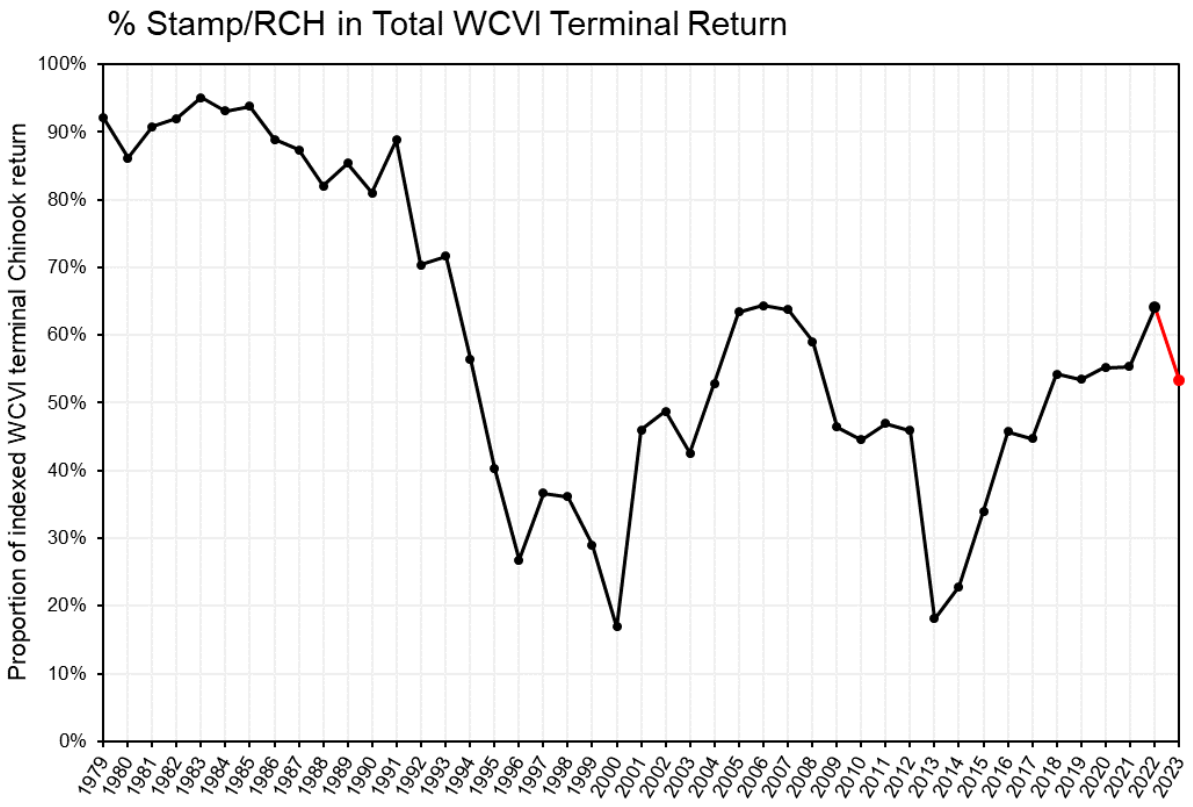

Figure 5. Estimated contribution of Stamp/RCH Chinook to the total return of WCVI indexed stocks, 1979–2022. The predicted contribution for 2023 (53%) is plotted in red.

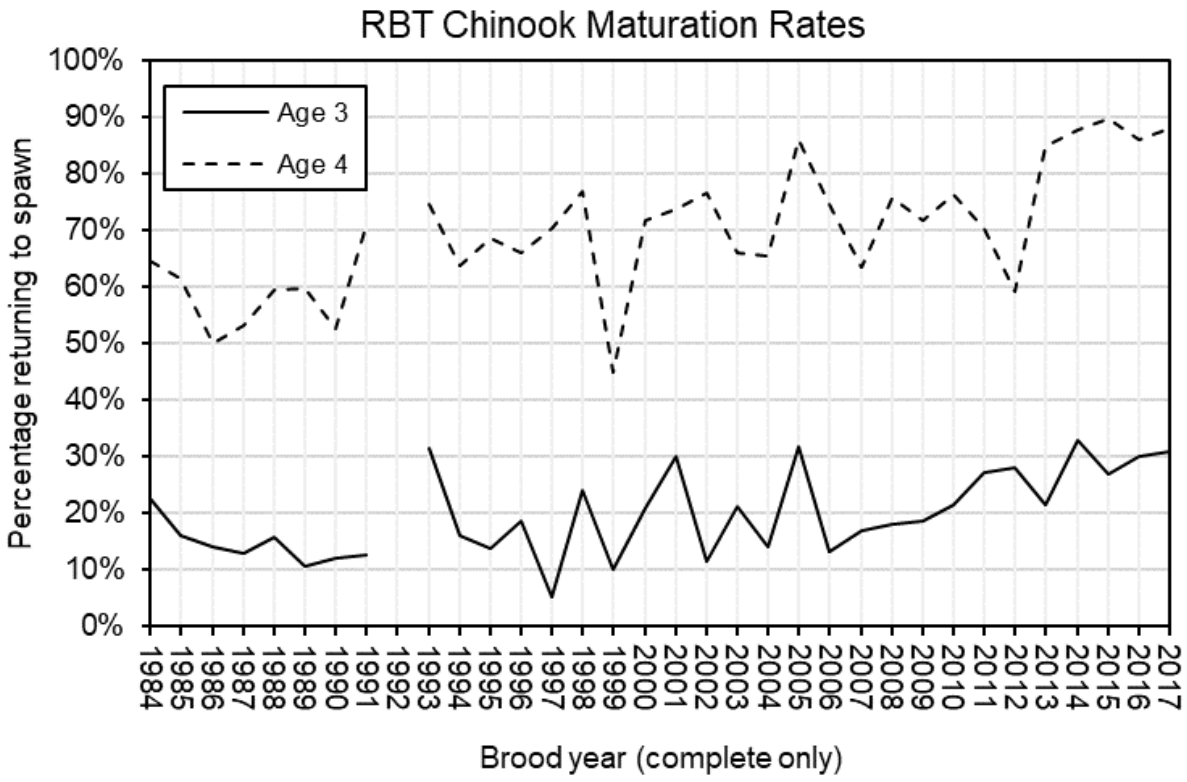

Figure 6. Maturation rates for Stamp/RCH Chinook estimated from the CTC's CWT-based cohort analysis. Data from 1992 were removed because very low recoveries of CWTs were yielding anomalous estimates.

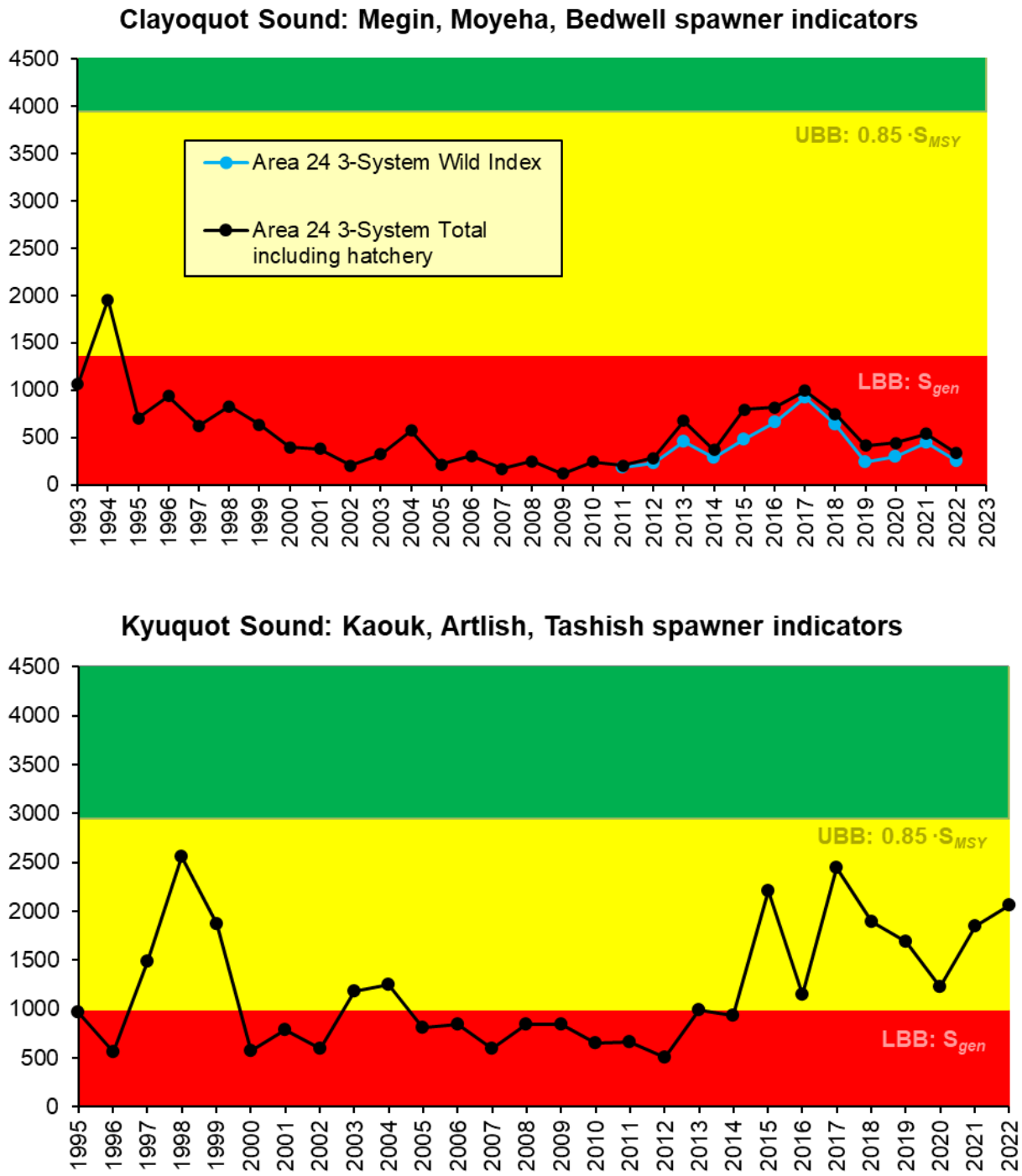

Figure 7. Spawner abundances of SWVI (top) and NWVI (bottom) CUs relative to provisional lower (red) and upper (green) biological benchmarks (S_{gen} and $0.85 \cdot S_{MSY}$, respectively; S_{MSY} for index stocks is estimated by the habitat model described in Parken et al. 2006 and updated by Holt et al. [*in prep*] in 2022). 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.