

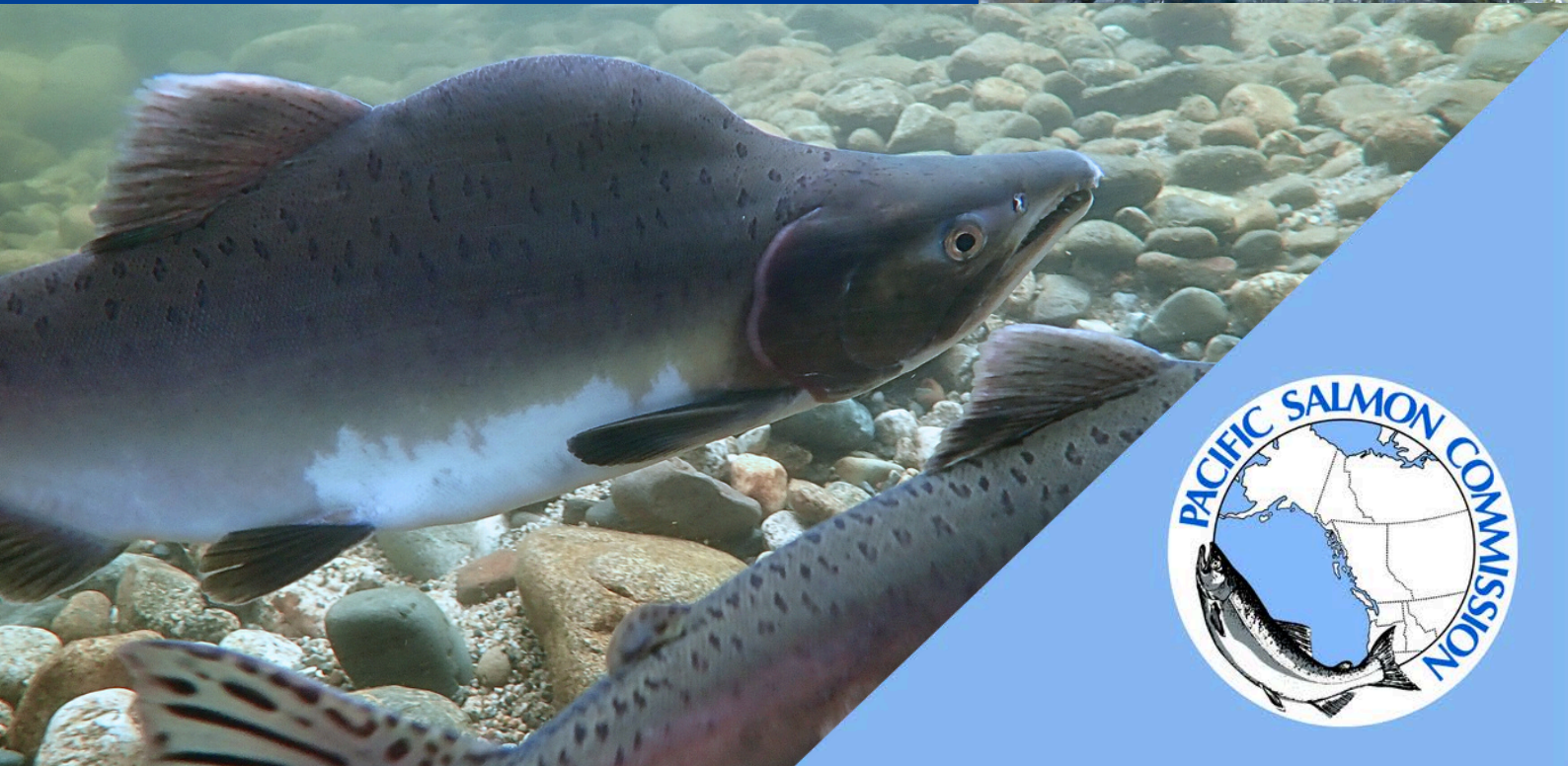
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OVERVIEW OF PRE-SEASON AND IN-SEASON ASSESSMENT METHODS FOR FRASER RIVER PINK SALMON

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Introduction

Fraser River sockeye and pink salmon are managed according to Chapter 4 of the Pacific Salmon Treaty which has been in effect since 1985. Ensuring Treaty obligations are met and implementation is followed correctly entails gathering data and information for assessment purposes. This is done in support of Fraser River Panel management actions aimed at meeting objectives pertaining to (1) achieving spawning escapement targets, (2) meeting international catch allocation goals and (3) meeting domestic catch allocation objectives. As a result, data and information are collected throughout the year and analyzed from the perspective of pre-season planning, in-season management and post-season review. This technical report serves to document the pre-season and in-season assessment methods supporting Fraser River Panel management of Fraser River pink salmon.

This technical report is a compilation of short chapters that document different data collection and assessment methods for Fraser River pink salmon. Each chapter can potentially be used as a separate, stand-alone document or sub-report when wanting to provide others with information on the topic. Each chapter/sub-report contains all the technical details required to understand, critique and replicate the methods. This includes among others an overview of the data and the methods used and planned changes or areas for improvement. To ensure the accessibility of the individual chapters and prevent readers from being overwhelmed by details, the individual chapters are restricted to about five pages. If the information on a topic is too lengthy, it is spread over several chapters, either by providing first a more general overview followed by one or more chapters that go into further detail (e.g., a chapter discussing the overall hydroacoustic program at Mission followed by several chapters of the different components of the hydroacoustic program), or by spreading one topic over several chapters (e.g., separate discussion of marine versus in-river test fisheries). The use of individual chapters as sub-reports allows more flexibility in terms of adding additional documentation for new methods.

This technical report aims to inform members of the Fraser River Panel and technical committee, academia and the general public about the different data collection and assessment methods for Fraser River pink salmon. This report does not aim to provide the results of these assessments, which can be found in the Fraser River Panel annual reports available on the PSC website (www.psc.org). Further questions regarding this technical report and its content can be directed to info@psc.org.

Assessment overview of Fraser River pink salmon

Annual pre-season planning of the fisheries management season for Fraser River pink salmon starts by gathering the necessary inputs for the PSC Planning Model, a simulation tool used by the Fraser River Panel to assess the ability of different fisheries plans to reach management targets given the information and forecasts available preseason for both Fraser River sockeye and pink salmon ([Chapter A3](#)). Fisheries and Oceans (DFO) provides the following model inputs: a run size forecast ([Chapter A1](#)), marine timing and northern diversion rate forecasts ([Chapter A1](#)), and the spawning escapement plan ([Chapter A2](#)). The Planning Model relies on a forward reconstruction with assumptions on fish movement and migration behaviour as well as assumptions about the vulnerability of pink salmon to different fisheries operations ([Chapter A3](#)). The Planning Model helps create pre-season fisheries schedules ([Chapter A4](#)) and assesses the sensitivity of fishery plans and the achievement of management targets to alternative biological and management scenarios. This helps guide pre-season planning for stakeholders and informs early in-season management prior to the availability of updated in-season information.

In-season fisheries management relies on real time data of returning pink salmon to adjust and refine preseason fisheries plans and helps guide fisheries management decisions. One of the key data sources in-season are the test fisheries ([Chapter B1](#)) that provide information on abundance, timing, and diversion rates as well as species and stock composition information for use in stock assessments. Test fishing occurs in marine approaches to the Fraser River (Johnstone Strait and Juan de Fuca Strait, [Chapter B2](#)) and within the Fraser River ([Chapter B3](#)). Purse seine and gillnets form the main gear types used for quantitative pink salmon assessments. One key data set collected by these test fisheries is the catch-per-unit-effort (CPUE, [Chapter B4](#)), which is used to estimate daily pink salmon abundances in the test fishing area. For marine purse seine test fisheries in Johnstone Strait and Juan de Fuca Strait, the CPUE data along with an annual historical expansion line estimate (the inverse of the catchability coefficient) are used to derive daily abundances ([Chapter B14](#)). Unlike for Fraser sockeye salmon, it is not possible to update expansion lines for pink salmon in-season because pink salmon migrate more slowly through marine approach areas and redistribute prior to migrating upstream making it impossible to reconstruct marine daily abundances based on hydroacoustic estimates and seaward catch.

Fish caught by the test fisheries, and by commercial fisheries when they occur, are sampled on a regular basis to collect a range of biological information used for in-season assessments ([Chapter B5](#)). Biological information includes length, weight and sex information ([Chapter B6](#)). Length measurements are used as inputs into hydroacoustic models to differentiate fish species. Weights are important for understanding fish condition and provide the fishing industry with information on the potential value of fishing opportunities. Pink salmon within marine catch samples are classified to three regional stock groups for in-season management: Fraser, B.C. South Coast, and Washington. Since 2007, genetic analyses have been performed using microsatellites ([Chapter B7](#)). Biological DNA samples are collected in a procedural manner to ensure up-to-date stock identification data are available for each Panel meeting. DNA analyses use genetic profiles from fishery catches of unknown stock composition and compares this to a genetic baseline with known stock origin using a Bayesian statistical framework. The genetic identification of pink salmon is essential for marine test fishing catches to assess the total run size and timing for Fraser River pink salmon. In-season logistics associated with the collection and analyses of samples taken from test fisheries hamper the timeliness of GSI estimates, as it may take between four to five days before results from collected DNA samples are available. As a result, a Bayesian model has been developed that incorporates historical information while updating predictions with new GSI data ([Chapter B7](#)).

Another in-season assessment program operated by the PSC is the Mission hydroacoustic program which provides daily estimates of salmon passage in the Fraser River throughout the summer ([Chapter B8](#)). As the river width is 400 m, several hydroacoustic systems are deployed to adequately monitor the salmon migration past the Mission area. The first 40 meters closest to the left and right bank are monitored by stationary ARIS imaging sonars ([Chapter B9](#)). The remaining offshore region is monitored by a mobile, downward-looking ARIS system deployed from a sampling vessel that transects the river ([Chapter B10](#)). The cross-river location of each sonar and its observed fish targets are determined based on GPS coordinates and then input into a salmon density model to determine the total daily salmon passage. Each estimate of daily salmon passage is based on 24 hours of monitoring data. Respecting Semá:th inherent fishing rights in the area, any Food, Social, and Ceremonial (FSC) driftnet fishing activity within site boundaries results in the temporary cessation of offshore data collection due to safety concerns and may introduce bias in the hydroacoustic estimates by impacting fish behaviour. Depending on the length of the fishery, either linear or non-linear hourly data imputations are used to fill in the missing data ([Chapter B11](#)). These hourly imputation methods on average reduce the percent error of the daily salmon abundance at Mission to less than half of the error associated with simpler interpolations, such as use of daily averages or assuming the previous day's abundance. In addition to abundance information, the ARIS systems on both the left and right bank also provide estimates of salmon species composition using a mixture model based on acoustically observed fish lengths ([Chapter B12](#)). The total salmon estimates when combined with species composition estimates ([Chapter B13](#)) provide daily pink salmon abundance estimates at Mission.

Unlike sockeye salmon, in-season estimates of daily pink salmon abundance plus seaward catch are not used for in-season reconstructions because pink salmon have a slower migration speed and experience variable amounts of delay on route to the Mission hydroacoustic site. Annual totals of Mission abundance plus seaward catch are however used post-season to generate the post-season run size estimates and to generate historical annual catchability estimates. In-season reconstructed daily marine abundances estimates along the Johnstone Strait and Juan de Fuca routes ([Chapter B14](#)) are derived from catch-per-unit-effort (CPUE) data of the purse seine test fisheries in Area 12 and 20 ([Chapter B4](#)), historical annual test fishery catchability estimates ([Chapter B15](#)) and genetic stock identification estimates ([Chapter B7](#)). In-season run size and timing estimates are obtained through the application of a Bayesian time-density model ([Chapter B15](#)) fit to CPUE data for Fraser River pink salmon from marine purse seine test fisheries. Because pink salmon catchability estimates used in combination with CPUE data cannot be updated in-season, pink salmon run size estimates derived from the traditional time-density model are often highly uncertain. A variety of alternative assessment approaches are therefore considered in-season when estimating pink salmon run size ([Chapter B16](#)). The accuracy of these assessments still relies on underlying assumptions of marine timing and test fishery catchability. While not intending to replace the traditional time-density model, consistency in run size estimates across different methods increases confidence in the results.

In-season fisheries opportunities are determined by the availability of international total allowable catch (TAC, [Chapter B17](#)). This is calculated as the Fraser River pink salmon abundance available after the spawning escapement target (SET) and the expected catch in panel authorized test fisheries are deducted. If there are pink salmon available for harvest, the United States share will not exceed 25.7 percent of the TAC. The remaining pink salmon TAC is assigned to Canada.

A1. Run size, timing and diversion rate forecast

M.R. Forrest

Summary

Fisheries and Oceans Canada (DFO) provides run size, timing and diversion rate forecasts to the Pacific Salmon Commission (PSC) as part of their obligations under the Pacific Salmon Treaty (Chapter 4, Paragraph 4, PST 2023). The forecasted return, timing and diversion rate of Fraser River pink salmon (*Oncorhynchus gorbuscha*) are key inputs into pre-season planning for fisheries. Prior to the start of the season, the run size forecast is used directly in calculations of management objectives (e.g. spawning escapement targets, total allowable catch, [Chapter A2](#)) and in simulations of alternative fishing scenarios ([Chapter A3](#)). Along with the run size forecast, the timing and diversion rate forecast also play an important role in the early in-season management of Fraser River pink salmon. They are used prior to the availability of updated estimates based on in-season information and are utilized throughout the fishing season as informative prior probability distributions for stock assessment models ([Chapter B15](#)).

Run size is forecasted using fry abundance estimated at Mission during the downstream migration in combination with sea surface salinity data. The forecasts for run timing and diversion rate rely on historic timing and diversion rate estimates, in combination with a variety of environmental covariates. Selection of the models used to produce the pink salmon forecasts is based on retrospective evaluations of the performance of the multiple models and subsequent ranking of the models based on various performance and selection criteria.

Introduction

Fisheries and Oceans Canada (DFO) provides run size, timing and diversion rate forecasts prior to the fishing season to the Pacific Salmon Commission (PSC) as part of their obligations under the Pacific Salmon Treaty (Chapter 4, PST 2023). Although there is genetic variability among the pink salmon stocks within the Fraser River, they are all considered part of the same conservation unit and managed as one management unit (DFO 1998). In addition, Fraser River pink salmon have a strong bi-annual pattern with significant returns of adult pink salmon only occurring in odd years. The Fraser River pink salmon return forecast, timing and diversion rate are therefore generated for only one management unit and only during odd years. The forecast of run-size, timing and diversion rate for Fraser River pink salmon play an important role in the pre-season planning and in-season assessments of stock size. Run size forecasts for Fraser River pink salmon are a key input into DFO's Integrated Fisheries Management Plan, or IFMP (DFO 2023). Key management objectives such as spawning escapement targets (SET) and total allowable catch (TAC) are directly influenced by the size of the pink salmon return ([Chapter A2](#)). In addition, the PSC utilizes the run size forecast, timing and diversion rate to evaluate the sensitivity of fishing plans and the probability of achieving management objectives across a range of run size scenarios using a fisheries simulation model ([Chapter A3](#)). Prior to the availability of in-season data which are used to refine estimates of run size, timing and diversion rate, early management decisions rely on the results of the pre-season simulations to evaluate catch proposals made by each country. Finally, while the Fraser River Panel typically adopts updated run sizes based on in-season assessments, the forecasts and the mean

and standard deviation (SD) of the probability distributions provided by DFO pre-season continue to be used as priors in Bayesian run size assessments ([Chapter B15](#)).

Data

Methods used to estimate pink salmon recruitment have varied across the years. From 1957 to 1991, escapement was estimated through stream-specific spawner estimates. Between 1993 and 2001, a system-wide mark-recapture program was used to estimate escapement and from 2003 to 2007, estimates were based on marine test fishery data. Since 2009, escapement estimates have been based on hydroacoustic passage estimates at Mission. Due to the variety in methods, the accuracy and precision of the recruitment estimates vary substantially and impact interannual comparisons.

The Fraser River pink salmon run size forecast relies on fry abundance data as a predictor variable due to the changing methods to estimate recruitment and the resulting uncertainty. When pink fry emerge from the gravel in early spring following the years the eggs were deposited, they migrate immediately to the Fraser estuary into the Strait of Georgia. The peak downstream migration occurs between mid-April and early May. DFO annually collects Fraser River pink salmon fry data at Mission (Grant et al. 2014). In addition to the fry data, the pink forecast also relies on sea surface salinity data collected during the summer of the outmigration year. Sea surface salinity data are averaged across two light house locations (Amphitrite Point and Race Rocks) and across July to September or July to August. Freshwater and ocean survival conditions during pink salmon migration are also discussed and evaluated to provide a qualitative estimate of expected returns to the Fraser River (DFO 2021).

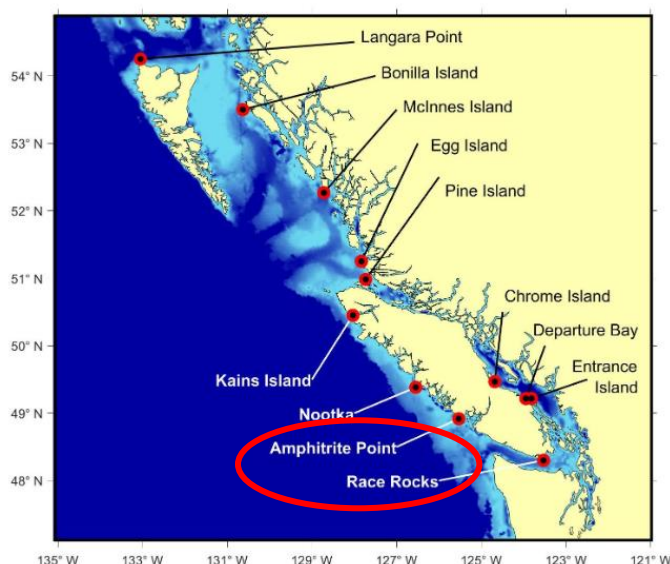


Figure 1. Map of BC Lighthouses (<https://www.dfo-mpo.gc.ca/science/data-donnees/lightstations-phares/index-eng.html>). Sea surface salinity data are collected at Race Rocks and Amphitrite Point lighthouse stations (circled in red).

For Fraser River pink salmon marine timing and diversion forecasts, models rely on historic timing and diversion rate estimates. The annual estimate of marine migration timing for Fraser pink salmon is derived from post-season daily marine reconstructed abundances estimates ([Chapter B14](#)) based on CPUE data from marine test fisheries and catchability estimates. The marine timing is defined as the date when the cumulative marine abundance of Fraser pink salmon exceeds 50% of the total run size. Annual post-season estimates of northern diversion rate of Fraser pink salmon are estimated by dividing

the total abundance migrating through the northern (Johnstone Strait) approach by the sum of Mission passage plus seaward catch (Hague 2022). Timing and diversion rate forecasts for pink salmon also rely on environmental covariates that include sea surface temperature and current velocity vectors across four different polygons in the Pacific Ocean from January to June (Figure 2).

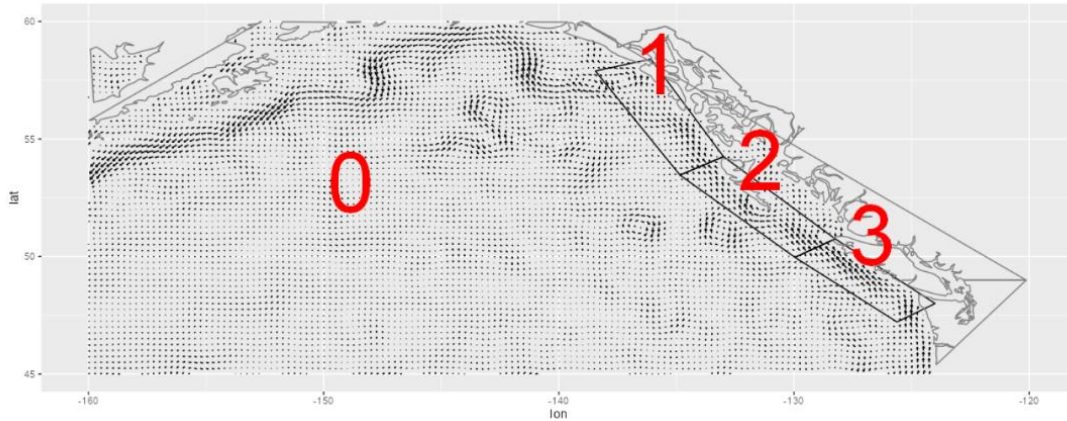


Figure 2. Map of the Pacific Ocean depicting the polygons where environmental covariates are collected to fit timing and diversion rate forecast models.

Method

There are generally three Bayesian models used for the Fraser River pink salmon run size forecast and they all depend on juvenile fry abundance. The non-biological model is the mean recruits-per-juvenile (MRJ) model and assumes no underlying biological mechanism. It calculates return forecasts based on historical estimates of survival and the juvenile fry abundance estimate of the brood year (DFO 2012). The two biological models are Power models fit to juvenile data, and either incorporate sea surface salinity data as covariate or not. During exceptional years, when no juvenile fry data are available (e.g. in 2021 due to the COVID-19 pandemic restricting data collection in 2020), both non-biological models as well as Ricker and Power models using environmental covariates similar to the suite of covariates considered for Fraser sockeye stocks (Michielsens and Martens 2022) were evaluated (DFO 2021).

The selection of the model used to forecast run size is based on retrospective analyses of the performance of the different models. The subsequent model ranking relies on five performance measures to determine their ability to provide precise and unbiased predictions: mean raw error, absolute mean raw error, absolute mean error, mean square error, root mean squared error. The results of the top ranked models are presented to a group of technical experts, who will review the model results as well as the model selection criteria (Hawkshaw et al. 2020). Expert judgement is used to ensure the productivity implied by the selected forecast model does not greatly exceed recently observed productivity. The model to generate the forecast is selected by consensus by the group of technical experts (DFO 2021).

For the Fraser River pink salmon timing and diversion rate forecasts, two types of models are used: naïve models that rely on historical timing and diversion rate estimates and models that include environmental covariates at different levels of resolution (DFO 2021). The latter are only used in June (or July when providing an updated forecast) as environmental data collected closer to the season have a better ability to predict timing and diversion, while the former are used in April. The model-based forecasts of timing and diversion rate are generated by model averaging across the top 10 models, ranked through cross validation over 5 generations (DFO 2021).

Results

Uncertainty in the forecast results is expressed in terms of a probability distribution which is described in the forecast document in terms of the following percentiles: 10%, 25%, 50%, 75%, and 90% (Table 1, Dionne and Liu 2024). The median forecast (50th percentile, or p50) represents an equal chance (i.e., a one in two chance) that the return will fall above or below the forecast value (Grant et al. 2010, DFO 2018). In comparison, there is a one in four chance that the actual number of returning pink salmon will fall at or below the forecast associated with the 25th percentile (p25 probability level). Unlike previous forecast methodology (Grant et al. 2010), the current p50 forecast no longer assumes long term average productivity will be maintained. Instead, the productivity implied by the p50 forecast should be similar to the recently observed productivity while the p25 and p75 forecasts imply productivity below and above average recent productivity, respectively.

In 2023, the Fraser pink salmon run size was forecasted using the mean recruits-per-juvenile (MRJ) model (Table 1, Dionne and Liu 2024). The top-ranked model based on retrospective analyses was the Power model that incorporates sea surface salinity data and the second-ranked model was the Power model without covariates. The forecasts generated by these models were considered to be optimistic considering recent returns and productivity observations in addition to the flooding in the Lower Fraser Valley in November 2021. The median or p50 forecast for 2023 was 6,135,000 pink salmon (Dionne and Liu 2024). At the 10% (p10) probability level, there was a one in ten chance that the actual return would fall at or below 3,247,000 fish, while at the 90% (p90) probability level, there was a one in ten chance the actual return would be above 11,591,000 fish.

Table 1. Fraser River pink salmon run size forecast results in 2023 based on the Mean Recruits per Juvenile model (MRJ), expressed in terms of a probability distribution (Dionne and Liu 2024).

	Forecast model	Probability that returns will be at/or below specified run size				
		10%	25%	50%	75%	90%
Pink salmon	MRJ	3,247,000	4,389,000	6,135,000	8,575,000	11,591,000

For the timing and diversion rate forecast in 2023, all top ranked models incorporated environmental variables. The timing forecast for the 2023 Fraser pink salmon marine timing was August 25. The forecast was generated using a model averaging method based on the top 10 models (Table 2), which were ranked through cross-validation across five generations (Gao and Dionne 2023). The range in the median timing forecast among the top 10 ranked models is from August 23 to August 27. The forecast models are described in terms of where and when the environmental data was collected that they rely on to produce the forecast. For covariates, the description will also include details of the data used such as sea surface temperature [sst], eastward current velocity [u] and northward current velocity [v]. The top model indicates that the sea surface temperature in May in polygon 0 and current velocity vectors in February in polygon 1 most strongly influence the timing forecast for Fraser River pink salmon (Table 2).

The 2023 Fraser pink salmon diversion rate forecast was 62%. This forecast was also generated using a model averaging approach based on the top 10 ranked models (Table 3), which were ranked through cross-validation across five generations (Gao and Dionne 2023). The median diversion rate forecast ranges from 23 to 80% among the top 10 ranked models. The top model suggests that sea surface temperature in polygon 1 in June and current velocity vectors in polygon 3 in May are the most important predictors of the diversion rate of Fraser River pink salmon (Table 3).

Table 2. Top 10 ranked 2023 Fraser pink salmon marine timing forecast models. (sst=sea surface temperature, u=eastward current velocity, v=northward current velocity, Goa and Dionne 2023)

Rank	Median	Lower 95% PI	Upper 95% PI	Data Type	Polygon	Month
1	21-Aug	12-Aug	31-Aug	sst, u, v	0,1,1	5,2,2
2	24-Aug	14-Aug	03-Sep	sst, u, v	1,2,2	2,3,3
3	27-Aug	18-Aug	06-Sep	sst, u, v	1,1,1	7,4,4
4	21-Aug	11-Aug	01-Sep	sst, u, v	0,2,2	2,3,3
5	20-Aug	13-Aug	27-Aug	sst, u, v	1,2,2	7,7,7
6	22-Aug	12-Aug	02-Sep	sst, u, v	2,3,3	7,2,2
7	24-Aug	14-Aug	03-Sep	sst, u, v	1,2,2	3,3,3
8	23-Aug	14-Aug	02-Sep	sst, u, v	0,2,2	6,3,3
9	24-Aug	15-Aug	02-Sep	sst, u, v	1,1,1	7,3,3
10	24-Aug	14-Aug	03-Sep	sst, u, v	2,2,2	4,3,3

Table 3. Top 10 ranked 2023 Fraser pink salmon northern diversion rate forecast models. (sst=sea surface temperature, u=eastward current velocity vector, v=northward current velocity vector, Gao and Dionne 2023)

Rank	Median	Lower 95% PI	Upper 95% PI	Data Type	Polygon	Month
1	0.74	0.14	1.06	sst, u, v	1,3,3	6,5,5
2	0.80	0.46	1.13	sst, u, v	3,3,3	7,5,5
3	0.59	0.23	0.96	sst, u, v	0,3,3	4,5,5
4	0.48	0.19	0.78	sst, u, v	3,2,2	7,2,2
5	0.23	-0.15	0.61	sst, u, v	1,2,2	4,5,5
6	0.70	0.37	1.03	sst, u, v	2,3,3	6,5,5
7	0.62	0.25	1.00	sst, u, v	0,3,3	4,5,5
8	0.60	0.16	1.03	sst, u, v	0,3,3	1,5,5
9	0.80	0.39	1.20	sst, u, v	3,3,3	7,5,5
10	0.62	0.19	1.05	sst, u, v	2,3,3	1,5,5

Planned Changes and Potential Areas for Improvement

Short-term fluctuations and long-term shifts in environmental conditions can lead to non-stationarity in stock recruitment parameters (DFO 2021). Being able to relate changes in marine survival to environmental indices would improve forecasts. With increasing uncertainty in freshwater and ocean environments there should be a renewed focus on the collection of freshwater limnological data and improved recruitment data.

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A2. Spawning escapement plan and incidental harvest restrictions

M.R. Forrest

Summary

Fisheries and Oceans Canada (DFO) provides pre-season escapement plans to the Pacific Salmon Commission (PSC) as part of their obligations under the Pacific Salmon Treaty (Chapter 4, Paragraph 4, PST 2023). Currently the spawning escapement plan for Fraser River pink salmon is developed through the implementation of Harvest Control Rules (HCRs) described in the Fraser Pink Salmon Decision Guidelines (IFMP 2023). Unlike the HCR for Fraser River sockeye salmon, it accounts for fishing mortality but not for natural mortality due to adverse environmental conditions or en route mortality. The resulting spawning escapement target (SET) is based on an allowable exploitation rate (ER), which changes depending on the size of the Fraser pink return. The available TAC is calculated as the pink salmon abundance available after the spawning escapement target and the expected catch in Panel-authorized test fisheries are deducted from the run size. Based on the current Treaty (PST 2023), the U.S. portion of the available pink salmon TAC should be constrained to 25.7 percent.

Conservation concerns for Fraser River sockeye salmon in recent years have increased the focus on non-retention of sockeye in pink-directed fisheries, ensuring incidental sockeye harvest rates are 'small but acceptable' and the reporting of fishing induced mortality (FIM) of sockeye salmon. FIMs relate to sockeye being incidentally killed by the fishing gear but not counted as catch because they are not retained. While sockeye FIMs are not counted against the Total Allowable Catch (TAC), they are incorporated into estimates of total sockeye exploitation rate, and therefore may restrict fisheries targeting pink salmon, despite available pink salmon TAC.

Introduction

As part of Fisheries and Oceans Canada (DFO) obligations under the Pacific Salmon Treaty (Chapter 4, PST 2023), Fraser River pink salmon escapement targets are provided to the Pacific Salmon Commission (PSC) prior to the fishing season. These spawning escapement targets are defined through Harvest Control Rules (HCRs) described in the Fraser Pink Salmon Decision Guidelines (IFMP 2023). These guidelines consider both the run size and the corresponding allowable exploitation rate, upon which estimates of available pink salmon Total Allowable Catch (TAC) are based. In addition to the spawning escapement plan and the Fraser Pink Salmon Decision Guidelines, pink directed fisheries may also be affected by the incidental harvest of one or more overlapping sockeye management groups with little or no TAC. In this case, ensuring the incidental harvest of sockeye in pink directed fisheries is 'small but acceptable' forms an important additional consideration during pre-season planning of Fraser River pink salmon fisheries.

Data

The Fraser pink salmon escapement plan as outlined in the Fraser River pink salmon Decision Guidelines is based on expected and observed run size. A Fraser River pink salmon run size forecast is provided by DFO (Dionne and Liu 2024) prior to the start of the season and is described in [Chapter A1](#).

Harvest Control Rule

The current harvest control rule (HCR) for Fraser River pink salmon was first implemented in 1987. It defines the allowable exploitation rate, and the associated escapement target depending on the run size (Figure 1). Overall, three different management zones are defined: 1) for a run size below 7.059 million pink salmon, the maximum allowable exploitation rate increases from 0% when there are no pink salmon to 15% when the run size is 7.059 million, 2) if the run size is between 7.059 and 20 million, there is a fixed escapement goal of 6 million pinks with the remainder of the run available for harvest, and 3) for run sizes exceeding 20 million, the maximum exploitation rate is 70% and the spawning escapement target is 30% of the total run. Unlike the HCR for Fraser River sockeye salmon, the pink salmon HCR does not take into account adverse environmental conditions and pink directed fisheries are always allowed regardless of the run size. The rationale for the current HCR set out in the Fraser Pink Salmon Decision Guidelines has not been properly documented but seems to be based on an egg deposition target of 5 billion eggs to generate the desired production and associated adult escapement target (handwritten International Pacific Salmon Fisheries Commission memo, 1983). Ricker's (1989) maximum removal reference rate (U_{MSY}) estimate of 70% for Fraser River pink salmon supports the current HCR.

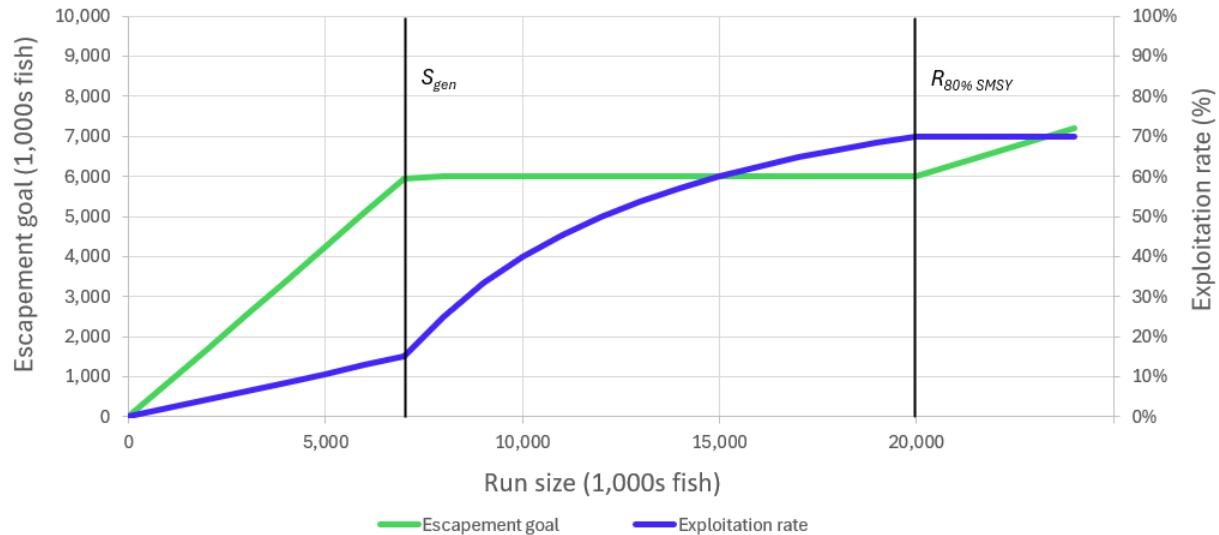


Figure 1. Illustration of the harvest control rules for Fraser River pink salmon in terms of the Spawning Escapement Target (SET) and exploitation rate (ER) depending on run size. The vertical lines denote S_{gen} , the spawning abundance that allows for stock rebuilding to S_{MSY} in one generation in the absence of fishing and the Upper Fishery Reference Point ($R_{80\% SMSY}$), which is the run size above which the exploitation remains fixed.

With the increasing potential for climate change impacts, increased inter- and intraspecific competition in the ocean and shifting demographics, there has been a need to update the understanding of Fraser pink salmon stock dynamics and status. Glaser et al. (2025) re-examined the population dynamics and

the sustainability of the current HCR and demonstrated that the existing HCR yields better outcomes compared to alternative options in terms of maintaining Fraser pink stocks at or above the level necessary to promote the sustainability of the stock taking into account the biology of the fish and the environmental conditions affecting the stock. They determined that the current HCR for Fraser pink salmon presents a very low probability (<5%) of the stock falling below the Limit Reference Point (S_{gen}) which denote the spawning abundance that allows for stock rebuilding to S_{MSY} in one generation in the absence of fishing (Holt 2009). Furthermore, there is a relatively high probability (87.5%) of spawner abundance being above the Upper Stock Reference Point (80% S_{MSY}) over the next 10 years. An additional robustness test, reducing the productivity by 10%, increased the probability of falling below the Limit Reference Point (S_{gen}) over the next 10 years from <5% to 9%. Glaser et al. (2025) also evaluated an alternative HCR which more strictly adheres to DFO's Precautionary Approach Framework. However, while this alternative showed similar biological performance, it resulted in poorer fisheries performance.

Table 1 illustrates the application of the HCR and Fraser Pink Salmon Decision Guidelines based on the 2023 pre-season run size forecast. If the forecast is lower than 7.059 million, the HCR translates the allowable exploitation rate into available harvest and the remainder forms the Spawning Escapement Target (SET). If the run size is greater than 7.059 million, the available harvest are the pink salmon in excess of the SET of 6 million. The available TAC for international sharing is based on the available harvest minus the deduction for test fishing catch. The Treaty states that the U.S. share of the annual Fraser River pink salmon Total Allowable Catch (TAC) will not exceed 25.7 percent of the pink salmon TAC (PST 2023). The remainder of available catch is deemed Canada's share.

Table 1. Spawning escapement plan for Fraser River pink salmon in 2023, provided to the Panel by Fisheries and Oceans Canada based on the 2023 run size forecast and Fraser Pink Salmon Decision Guidelines (IFMP, 2023).

	2023 Pre-season Forecast Return				
	p10	p25	p50	p75	p90
Run size forecast	3,247,000	4,389,000	6,135,000	8,575,000	11,591,000
Spawning escapement target	3,023,000	3,980,000	5,335,000	6,000,000	6,000,000
Allowable exploitation rate (ER)	7%	9%	13%	30%	48%
Available Harvest (TF, US, CDN)	224,000	409,000	800,000	2,575,000	5,591,000

Incidental harvest restrictions on comigrating sockeye

The application of the harvest control rule and resulting estimates of Total Allowable Catch (TAC) is not the only management consideration stipulated within the Pacific Salmon Treaty when considering fisheries targeting Fraser River pink salmon. Since 2014, Annex IV, Chapter 4, paragraph 3g of the Treaty (PST 2014) notes that the Panel needs to take into consideration the overlap in sockeye and pink salmon migration, and the available sockeye TAC when planning pink directed fisheries. More specifically the Treaty stipulates that, to the extent practical, pink directed fisheries should minimize the impact on overlapping sockeye management groups with little or no TAC (PST 2023). In addition, the Treaty indicates that overlapping pink and sockeye migration may result in a 'small but acceptable' (SBA) rate of incidental harvest on one or more sockeye management groups that have little or no TAC.

Implementation of this paragraph in the Treaty results in consideration of sockeye retention/non-retention in pink directed fisheries. In addition, the release of sockeye salmon from the catch, has required both countries to report fishing induced mortality (FIM) associated with sockeye releases. As annual sockeye returns have declined, fishing induced mortalities have become increasingly important.

There have been disagreements between Canada and the U.S. about the interpretation of paragraph 3g, most notably in 2023 (PSC 2024). Both countries however agree that the definition of ‘small but acceptable’ is context specific. Preseason it is therefore important that both countries identify the various contextual situations that may occur in-season and include them among the alternative scenarios during pre-season fisheries planning modelling ([Chapter A3](#)).

Planned Changes and Potential Areas for Improvement

Fraser pink salmon are currently assumed to represent a single Conservation Unit (CU) and are therefore managed as one management unit. However, emerging evidence of genetic and life history differences between pink salmon that spawn above and below Hells Gate suggests a need for a review of the population structure of Fraser River pink salmon (Glaser et al. 2025). Should a new understanding of stock-structure and/ or -dynamics become available, a reassessment of the current HCR should be triggered to ensure the development of a precautionary and risk adverse HCR and Fraser pink salmon escapement plan.

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A3. Fisheries planning model

E. Taylor

Summary

The Fraser River Technical Committee collaborates with PSC staff to develop preseason fishing plans for Fraser River sockeye and pink salmon that balance conservation with fishing objectives while meeting international and domestic allocation requirements. This is done using a fisheries simulation model, referred to as the PSC Planning Model. While the sockeye related model components have been discussed in detail in Michielsens and Martens (2022), this report focusses on the pink salmon components. Fraser River pink salmon run size, timing, spread, and diversion rate forecasts are used as inputs into the model. The movement of pink salmon is modeled similarly to sockeye salmon in marine areas, but pinks are not modelled in the Strait of Georgia and the Fraser River, given the substantial uncertainty and variability in their migration behaviour in these areas. The model includes harvest control rules that define the Spawning Escapement Targets (SET) and the Total Allowable Catch (TAC) for the U.S. and Canada at various run size abundances. Harvest rates are in general the same as those for sockeye salmon, though some fishery or gear specific adjustments are made based on knowledge of how those fisheries operate when targeting or encountering pinks compared to sockeye. For some marine fisheries, the model incorporates inputs such as fishing effort and timing of pink salmon fisheries to predict catches, while for other fixed-input fisheries, catches are predetermined by the Technical Committee Chairs. In addition to assessing the sensitivity of fisheries plans on the achievements of management targets for Fraser River pink salmon under different biological scenarios, the Planning model also evaluates the impact of these plans on sockeye salmon, either through catches or fishing induced mortality (FIM), following the release of sockeye caught.

Introduction

Preseason, the Fraser River Technical Committee works with PSC Staff to develop a fishing plan for Fraser River sockeye and pink salmon for each country. The goal of these plans is to optimize trade-offs between conservation and fishing objectives by developing fishing scenarios that meet Spawning Escapement Targets and come as close as possible to meeting the international TAC allocations as well as domestic allocation requirements. Another goal is to create a provisional fisheries schedule that meets Panel objectives (PST 2023, Chapter 4, paragraph 10) under key pre-season assumptions of run size, timing, spread and diversion rate, and to explore the impact of different biological assumptions on the achievement of these objectives. This is done through the use of the PSC Planning model (Michielsens and Martens 2022). This chapter will focus on the pink salmon related model assumptions, the biological, management and fisheries inputs, and the main model results.

Model Assumptions

The PSC Planning Model simulates the daily migration of all Fraser River pink salmon as one single group. The movement of pink salmon through fishing areas relies on assumptions associated with forward run reconstructions as outlined in detail in [Chapter B14](#). The modelling of the movement of pink

salmon follows the same processes as for sockeye salmon, except for the following. First, pink salmon migration in marine area is modelled to occur slower than for sockeye and at the same speed as the slower sockeye stock groups, i.e. Harrison and the Late run groups. Second, due to the high variability and uncertain upstream migration behavior, pink salmon are only modelled through the marine approach areas. Pink salmon migrating through Johnstone Strait cease their modelled migration in Pacific Fisheries Management Area (PFMA) 17, whereas pink salmon migrating through Juan de Fuca Strait cease their modelled migration in Puget Sound Salmon Management and Catch Reporting Area 7A. As a result, pink salmon directed fisheries in the Strait of Georgia or within the Fraser River cannot be modelled through a harvest rate. Instead, pink salmon catches in these areas are predetermined inputs.

Model inputs

A. BIOLOGICAL INPUTS

A description of the key pink salmon biological inputs in the PSC Planning Model is presented in Table 1. Pre-season estimates of run size, timing, spread and diversion through Johnstone Strait are used to parameterize normal distributions of daily abundance of pink salmon entering Johnstone Strait and Juan de Fuca Strait. Fisheries and Oceans Canada (DFO) provides pre-season forecasts of Fraser pink salmon run size based on fry abundance in combination with sea surface salinity data (Grant et al. 2014, [Chapter A1](#)). The uncertainty around the run size forecast is expressed in terms of a probability distribution. As stated in the Treaty (PST 2023), the median forecast (p50) is used as the default input for the base case planning scenario, but the Panel may also choose to adopt a more precautionary or optimistic forecast until the in-season run size estimates are available. A key sensitivity analysis during pre-season fisheries planning is to vary the assumed run size from the default median (p50) estimate to either a lower or higher run size, e.g., the p25 forecast, assuming there is a 25% chance that returns will be at/or below the specified run size, and the p75 forecast. Preseason run size forecasts are typically available in February.

Table 1. A description of the key biological inputs in the PSC Planning Model, including the data source on which estimates are based and the organization responsible for providing forecasts.

Input	Description	Data source	Responsibility
Run Size	Pre-season run size forecast	Stock-recruit time-series	DFO
Timing	Index of migration timing, i.e. date when 50% of the run will have migrated through marine areas	Historical estimates	PSC, DFO
Spread	Number of days required for 95% of the run to migrate through an area	Historical estimates	PSC
Diversion Rate	The proportion of the run expected to migrate through Johnstone Strait	Historical estimates	PSC, DFO

Preseason forecast of timing, spread and diversion are based on historical estimates. The preseason forecasts for run timing and diversion rate generated by DFO rely on historic timing and diversion rate estimates, in combination with environmental covariates such as sea surface temperature and current velocity ([Chapter A1](#), Gao and Dionne 2023). For Fraser pink salmon, the best performing forecast models, when evaluated retrospectively, rely on environmental data collected in June or July, making these forecasts unavailable in April and June for input in the Planning Model. Instead, the model relies

on medians of historical data. Typically, a recent-year median is used as the input for the model, given recent shifts in timing and diversion rate. Unlike the biological inputs for sockeye salmon, biological model inputs for pink salmon are only updated once a year, during the model seeding process in April.

B. MANAGEMENT INPUTS

The harvest control rules that define the Spawning Escapement Targets (SET) for Fraser River pink salmon ([Chapter A2](#), DFO 2023) are provided by Canada, pursuant to guidance in the Pacific Salmon Treaty (PST 2023). In addition, PSC staff provide test fishing deduction estimates, i.e., the number of Fraser River pink salmon expected to be retained in Panel-approved test fisheries, including both non-discretionary catch as well as discretionary retention (pay fish) to offset program costs, if applicable (Michielsens and Martens 2022). The pink salmon TAC is calculated by removing the spawning escapement target (SET) and the Panel approved test fishing catch from the run size ([Chapter B17](#)).

The Treaty (PST 2023) assigns 25.7% of the International TAC for pink salmon to the United States with the remaining balance assigned to Canada. In addition, each country allocates their respective share to various allocation groups following pre-season consultations and co-manager meetings. These percentages are then used as objectives to help guide the fishing plans in the PSC Planning Model. Canada assigns allocations to different commercial fishing sectors: Area B seine, Area D gill net, Area E gill net, Area H troll, and Area G troll. Allocation targets are also specified for marine, Lower Fraser River, and interior First Nations fisheries as well as marine and in-river recreational fisheries. In the US, allocation percentages divide the U.S. share of the TAC between Treaty Tribe and All Citizen fisheries.

C. FISHERIES INPUTS

Pink directed derby-style fisheries can be modelled dynamically with inputs such as effort, fishing days, and fishing hours and include: U.S. fisheries in Areas 4B, 5, and 6C and Areas 6, 7, and 7A, Canadian Area D commercial gillnet fisheries, and Canadian FSC fisheries in Areas 12, 13, and 20. Pink directed ITQ fisheries can be modelled dynamically with inputs such as effort, quota targets, fishing days, and fishing hours. These fisheries include: Canadian Area B and H commercial fisheries in Areas 12 and 13. Many pink directed fisheries are entered into the model as fixed catch inputs and are not modelled. Catches associated with fisheries in the Strait of Georgia and the Fraser River are all entered as fixed inputs as the pink salmon migration and associated delay in these areas is not modelled. These fixed inputs are provided by the Technical Committee Chairs. Fixed input fisheries include: marine and in-river recreational fisheries, in-river FSC and Economic Opportunity fisheries, and Area B and H commercial fisheries in Area 29.

Harvest Rates

Harvest rates for pink directed fisheries in the Planning Model are by default the same as for sockeye directed fisheries. However, in some cases pink salmon specific modifications are made to the form of the harvest rate or by applying a pink salmon scalar to adjust the sockeye harvest rate to a rate more applicable to pink salmon. Gillnet fisheries, including the U.S. Areas 4B, 5, and 6C fishery and the Canadian Area D commercial fishery, have a 1% harvest rate scalar applied given their inefficiency to catch pink salmon. Canadian troll fisheries and Canadian marine FSC fisheries in Area 12, 13, and 20 have pink salmon specific harvest rates applied, however these are not implemented if the fishery is a quota fishery. Pink directed fisheries also allow for the retention of sockeye or incur sockeye release mortalities which are discussed in more detail in [Chapter B17](#).

Results

The PSC Planning Model summarises the model result in a series of tables collating fishery-specific and management related statistics (Tables 2 and 3). The Technical Committee chairs use these outputs to refine preseason fishing plans and to communicate results of final model runs to the Fraser River Panel. At the end of the June meeting, a Panel-approved base case model scenario is adopted which can be referenced in-season to help guide decision making for early fisheries, in particular prior to the peak of the run when in-season run size assessments may not yet be available. The alternative model runs allow Panel and Technical Committee members to evaluate the sensitivity of the base case scenario to different biological inputs. Model results are communicated at various levels of resolution so that fishing plans can be evaluated in terms of meeting international as well as domestic objectives. In addition, model results may be used during the domestic consultation process to help communicate anticipated fishery plans.

Table 2. PSC Planning Model TAC summary from 2021 based on the 90th percentile of the pre-season sockeye run size forecast, and the median run size forecast for pink salmon.

p90 Sockeye & p50 Pink Salmon										
TAC SUMMARY										
	p90	p90	p90	p90					p50	
	EARLY STUART	EARLY SUMMER	SUMMER	LATES	TOTAL SOCKEYE				PINKS	
TAC MODEL OUTPUTS										
ALLOWABLE EXPLOITATION RATE	10.0%	28.5%	45.5%	10.0%					6.4%	
TOTAL EXPLOITATION RATE (INCL TF & FIM)	3.3%	22.1%	31.9%	15.0%					6.8%	
OVER/UNDER (INCL TF & FIM)	6.7%	6.4%	13.6%	-5.0%					-0.4%	
TAC FOR INTERNATIONAL SHARING (EXCL AFE)	0	57,500	1,670,100	0	1,727,600				188,500	
TOTAL CATCH (EXCL TF & FIM INCL AFE)	1,300	79,100	1,409,400	80,900	1,570,700				204,300	
TOTAL MODELLED CATCH	1,400	78,300	1,399,800	79,600	1,559,100				103,400	
TOTAL FIXED CATCH INPUTS	0	800	9,600	1,200	11,600				101,300	
OVER/UNDER (EXCL TF & FIM)	-1,300	-21,600	260,700	-80,900	156,900				-15,800	
U.S. SHARE OF TAC (INCL PAYBACK)	0	9,500	275,200	0	284,700				48,400	
U.S. CATCH (EXCL FIM)	0	12,300	245,700	23,000	281,000				47,600	
U.S. FIM	0	0	1,000	400	1,400					
OVER/UNDER (INCL FIM)	0	-2,800	28,500	-23,400	2,300				800	
% OVER/UNDER (INCL FIM)	0.0%	-29.5%	10.4%	0.0%	0.8%				1.7%	
BALANCE TO CANADA (INCL AFE)	0	92,700	1,750,200	0	1,842,900				140,100	
CANADIAN CATCH (EXCL FIM)	1,300	66,800	1,163,700	57,900	1,289,700				157,100	
CANADIAN FIM	0	0	0	2,300	2,300					
OVER/UNDER (INCL FIM)	-1,300	25,900	586,500	-60,200	550,900				-17,000	
% OVER/UNDER (INCL FIM)	0.0%	27.9%	33.5%	0.0%	29.9%				-12.1%	
ESCAPEMENT	27,100	208,500	2,846,200	250,300	3,332,100				2,804,300	
OVER/UNDER	-19,900	20,800	595,200	-49,700	546,400				-12,700	
TAC MODEL INPUTS										
TOTAL RUN	47,000	375,300	4,502,000	572,000	5,496,300				3,009,000	
TOTAL DEDUCTIONS	80,300	317,800	2,831,900	592,500	3,822,500				2,820,500	
ESCAPEMENT TARGET	47,000	187,700	2,251,000	300,000	2,785,700				2,817,000	
AFE	0	44,700	355,300	0	400,000				NA	
pDBe	-0.41	-0.3	-0.08	-0.49					NA	
MANAGEMENT ADJUSTMENT	32,400	80,700	202,600	288,000	603,700				NA	
TEST FISH	900	4,700	23,000	4,500	33,100				3,500	
TAC FOR INTERNATIONAL SHARING	0	57,500	1,670,100	0	1,727,600				188,500	
ALLOWABLE EXPLOITATION RATE	10.0%	28.5%	45.5%	10.0%					NA	
U.S. SHARE OF TAC (INCL PAYBACK)	0	9,500	275,200	0	284,700				48,400	
BALANCE TO CANADA (INCL AFE)	0	92,700	1,750,200	0	1,842,900				140,100	
MARINE FSC	0	12,500	254,300	0	266,800				39,000	
IN-RIVER FSC	0	89,800	694,200	0	784,000				101,300	
MARINE REC	0	800	9,600	1,200	11,600				0	
IN-RIVER REC	0	1,600	19,100	2,400	23,100				0	
COMMERCIAL	0	0	773,000	0	773,000				0	

Table 3. Example of the pink salmon catch summary table from 2021 pre-season planning, corresponding to the TAC table in Table 2.

Pinks					
		TARGET CATCH	TOTAL CATCH	TARGET %	MODELLED %
U.S.		48,400	47,600		
	TREATY TRIBE	24,200	23,700	50.0%	49.8%
	ALL CITIZEN	24,200	23,900	50.0%	50.2%
CANADA		140,100	157,100		
COMMERCIAL		0	20,500		
	AREA B	0	18,400	82.5%	89.8%
	AREA D	0	100	4.0%	0.5%
	AREA E	0	0	3.0%	0.0%
	AREA G	0	0	0.5%	0.0%
	AREA H	0	2,000	10.0%	9.8%
	In-River EO BS	0	0		
RECREATIONAL		0	0		
	IN-RIVER	0	0		
	MARINE	0	0		
FIRST NATIONS		140,300	136,700		
	MARINE	39,000	35,400	27.8%	25.9%
	IN-RIVER	101,300	101,300	72.2%	74.1%
TEST FISHING		3,500	400		

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A4. Test fishing and hydroacoustics schedule

T. Sutherland

Summary

The Pacific Salmon Commission (PSC) operates two main field programs to aid in the assessment of Fraser River sockeye and pink salmon abundances: the test fishing program ([Chapter B1](#)) and the hydroacoustics program ([Chapter B8](#)). The proposed annual schedule for the various test fisheries is developed using a template that incorporates the historical timing of the different management groups. The actual in-season start and end dates for the test fisheries are subject to change, depending on pre-season and in-season management considerations and at the discretion of the Fraser River Panel (FRP). The start date of the PSC hydroacoustics program is determined by the historical timing of the Early Stuart management group. The program ends when sockeye and pink salmon migration past the site have terminated. Unlike the test fishing program, the schedule for the hydroacoustics program is determined and approved by PSC staff. Similarly, the Qualark hydroacoustics program located upriver from the Mission site is operated and scheduled by Fisheries and Oceans Canada (DFO).

Introduction

Under the Pacific Salmon Treaty (PST 2023, Chapter 4), PSC staff are responsible for providing recommendations for in-season estimates of run size for Fraser River sockeye and pink salmon. To fulfill this responsibility, the PSC operates two field programs to gather the necessary data and information: the test fishing program, and the Mission hydroacoustics program. Each year, PSC staff develop a pre-season test fishing and hydroacoustic schedule based on the expected timing and abundance of the returning sockeye and pink salmon, following pre-designed scheduling templates. Further adjustments may be made to the schedule depending on year-specific conditions or guidance from the FRP.

Methods

Improvements to developing the pre-season test fishing schedule occurred in 2018, following the review and workshop of Fraser River test fisheries (Nelitz et al. 2018). The workshop report recommended creating a formal test fishing scheduling template that could be followed each year. This was achieved by analyzing the historical timing of the four sockeye management groups as well as pink salmon from 1986 to 2018, summarizing the historical migration timing for each group, and determining a framework for proposing start and end dates for the test fisheries that would be consistent by cycle line. The schedule derived from the template is used as the base case scenario, and modifications may be proposed depending on year-specific considerations as directed by the FRP.

Different cycle lines have different timing characteristics as well as different stock and species compositions. The three resulting scheduling scenarios are: a) High sockeye abundance, no pinks (2022 cycle line), b) moderate sockeye abundance plus pinks (2021 and 2023 cycle line), and c) low sockeye abundance, no pinks (2020 cycle line). The schedule templates based on these 3 scenarios are discussed in further detail in the sections below.

Test fishing schedules proposed in February or April based on these templates may be modified in June based on the timing forecast for Early Stuart and Chilko provided by DFO ([Chapter A1](#)). Only when the forecast in June indicates the timing is 4 or more days earlier than previously assumed would the schedule be moved forward 3 days (Figure 1). Adjustments to delay the opening of marine gillnets are usually not considered given the uncertainty in the forecast. In-season data collected from the marine and in-river gillnets allow for the in-season adjustment of the start timing of the purse seine test fishery. In July, if the timing of earlier components of the run assessed by the in-river and marine gillnets appears to be 4 or more days later than the June forecast, the opening of the marine purse seine test fishery could be delayed by 3 days. Further pre-season and in-season modifications of the schedule, such as decisions about test fishery end dates, will depend on the potential return abundance, conservation concerns and fisheries management considerations.

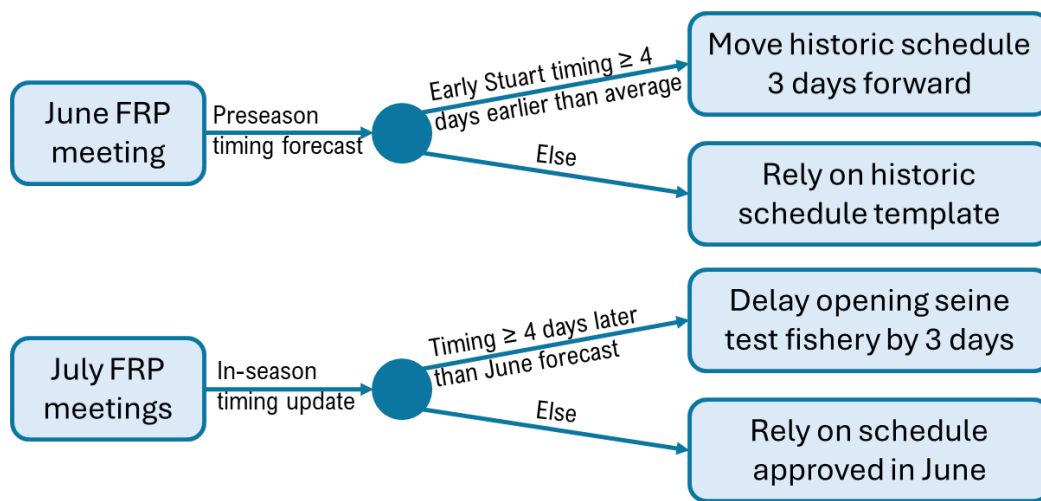


Figure 1. Decision rules associated with adjustments to the test fishing schedule based on pre-season and in-season timing estimates.

MARINE TEST FISHERIES

The core marine test fishing program consists of the marine gillnet and purse seine test fisheries in Areas 12 and 20. These test fisheries are scheduled on all cycle lines, regardless of sockeye and pink salmon abundance (Nelitz et al. 2018, Table 2). Historically, the marine gillnet test fisheries aim to assess Early Stuart and Early Summer run sockeye abundance while the marine purse seine test fisheries are used to assess Summer and Late run sockeye and pink salmon abundance. Marine gillnet test fisheries can be used to assist in the assessment of the Summer run but do not produce abundance estimates that are as precise as those produced by the purse seine test fishery. Gillnet test fishery data are not reliable for the assessment of Late run and pink salmon. On low abundance sockeye years, marine gillnets may be excluded from the core test fishing program depending on the in-season assessment needs and conservation concerns for Early Stuart and Early Summer run stocks, e.g. 2024 (PSC 2025).

Table 1. Overview of the marine test fisheries considered under different abundance levels and species composition scenarios (x = included, (x) = depends).

Marine test fisheries	High sockeye abundance, non pink year	Moderate sockeye abundance, pink year	Low sockeye abundance, non pink year
Area 12, 20 gillnets	x	x	(x)
Overlap with purse seines	x	(x)	
Area 12, 20 purse seines	x	x	x
Area 13	(x)		
Gulf Troll	x		
Area 5 gillnet	x	(x)	
Reefnet	x	x	(x)

In general, the proposed start dates for each marine test fishery are designed to ensure that a specified proportion of the earliest management group that it is intended to assess is not missed prior to test fishery start-up. These dates are determined by considering the historical marine timing dates for each management group ([Chapter A1](#)). Additionally, these fisheries need to generate at least 6 days worth of paired data with the Mission hydroacoustics program to provide reliable in-season estimates of the expansion line (inverse catchability, see [Chapter B14](#)). As these fisheries vary spatially with respect to their distance from Mission, additional days are added or subtracted from the Area 20 timing date to account for differential fish travel time to the Mission hydroacoustic site.

The start and end dates of the Area 12 and 20 test fisheries in the test fishing schedule template are derived to offer optimal coverage of the run to inform in-season management decisions associated with marine fisheries targeting Fraser sockeye and pink salmon. In this case, optimal means having at least 6 days of matching test fishing and Mission hydroacoustic data before the peak migration timing, resulting in the availability of an in-season expansion line which can greatly improve the accuracy and precision of the daily abundance estimates. The end dates for the Areas 12 and 20 marine gillnets are selected to either provide adequate coverage of the Early Summer run migration or to provide a sufficient overlap with the purse seine test fisheries for in-season assessment and management needs (Figure 2).

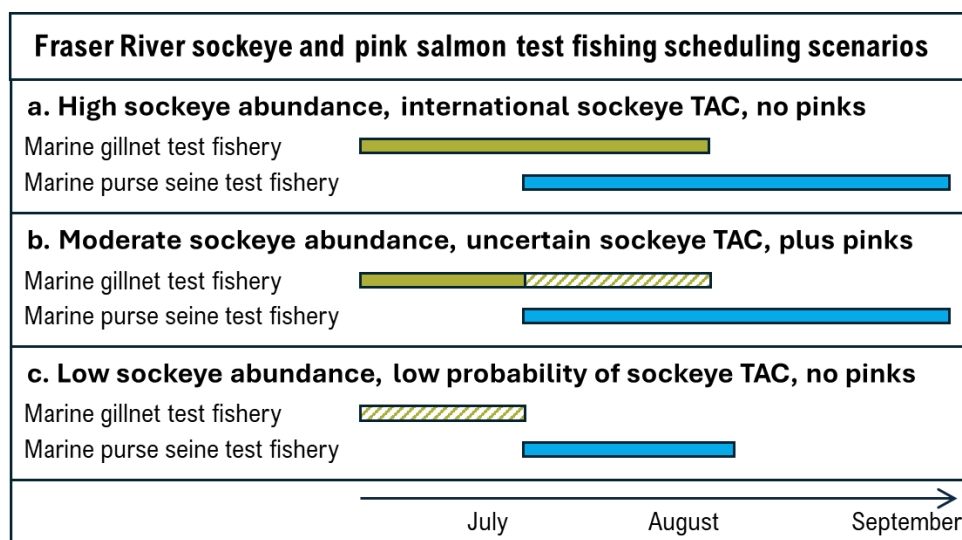


Figure 2. Overview of the different marine test fishing schedules depending on sockeye and pinks salmon abundance and the potential for international sockeye TAC. A twelve day overlap between gillnet and purse seine test fisheries ensures the availability of an in-season catchability estimates at the time the gillnet test fishery is terminated. Shaded test fishing periods may be removed depending on sockeye abundance forecast and the probability of international TAC e.g. 2024 management season.

On high abundance years, at least 12 days of overlap are desired between gillnets and purse seine test fishery data. This ensures that the less precise purse seine test fishery abundance estimates using the historical expansion line is to a certain extent compensated for by the increased abundance precision provided by operating the gillnet and purse seine test fisheries simultaneously. During high abundance sockeye years, the marine gillnet test fishery may operate longer than this, if it is expected that the benefits to in-season assessment (e.g. additional stock identification samples, operational redundancy, and independent/alternative abundance estimates) outweigh the costs (i.e. financial expenses and fish mortality). On years when there is a high probability that return abundances will be too low to generate harvestable surplus or international total allowable catch (TAC), there may be no overlap of the gillnet and purse seine test fishery in the scheduling template and the first 12 days of purse seine derived abundance will be based on the historic expansion line.

The end dates for the Area 12 and 20 purse seines are based on the historical migration timing of sockeye and pink salmon through marine areas. On years with Fraser pink returns (odd years), or when Late run abundance is high enough to generate harvestable surplus, the marine purse seines continue into September to provide near full coverage of Late run sockeye or pink salmon. Because these groups exhibit delay behaviour, the marine purse seines are the primary source of in-season assessment information available in a timely manner for the prosecution of marine fisheries. On even years, the Area 20 purse seine in Juan de Fuca Strait may be scheduled to end earlier than the Area 12 purse seine in Johnstone Strait as the diversion rate is generally high at the end of the season. On years without pink salmon, and a small forecasted return of Late run sockeye, the marine purses seines may be scheduled to provide coverage of the marine migration of the Summer run with an end date in early August. If no marine fisheries are planned, the Late run can be assessed once these salmon pass the Mission hydroacoustic site. Figure 3 illustrates the marine test fishing scheduling differences across different cycle-line years for 2020 to 2023.

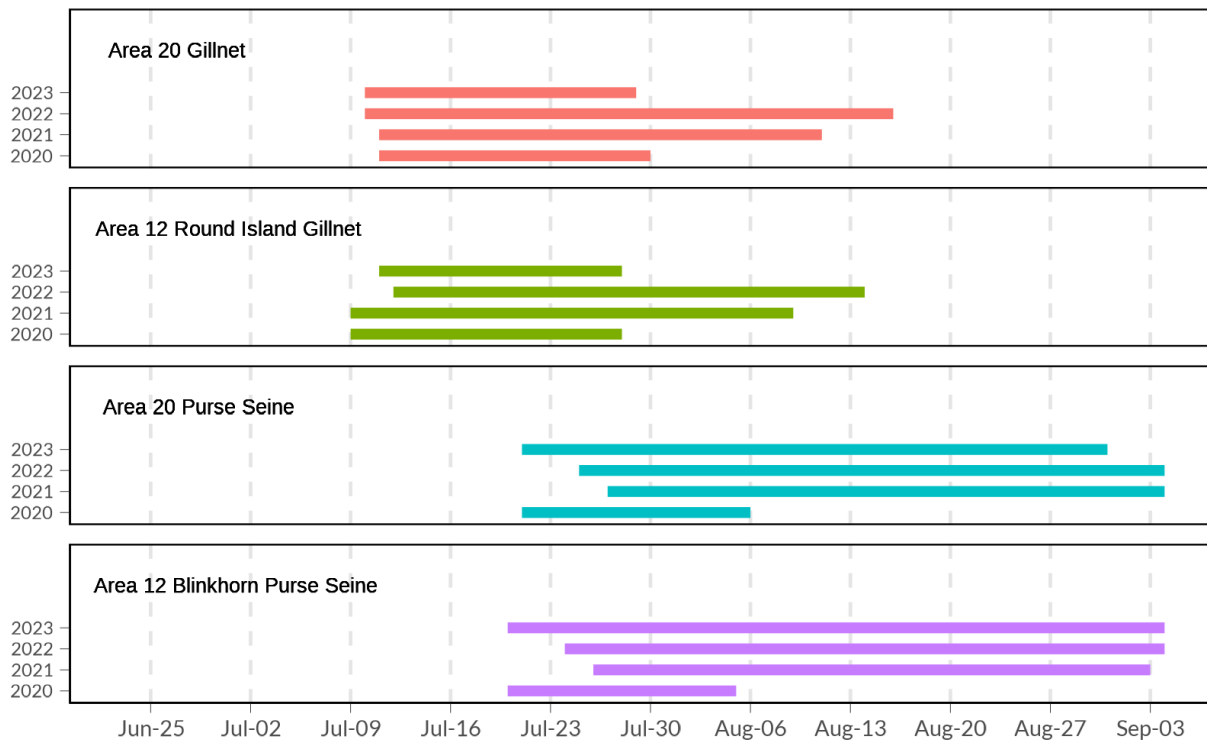


Figure 3. Comparison of different marine test fishing schedules across cycle years.

The Area 13 purse seine test fishery has been consistently used to confirm abundances in Johnstone Strait on high abundance years, but analyses have indicated that for most years there is limited difference in run size assessments when including the Area 13 versus relying on Area 12/20 data only, and the limited differences can signify both decreased as well as increased error in the run size (Nelitz et al. 2018). In some years, including the Area 13 can provide a stronger early signal that abundances are lower than anticipated. This test fishery is therefore usually only scheduled on high sockeye abundance years during periods when run size estimates are still uncertain, but high-impact fisheries may be scheduled to be executed.

The Area 29 Gulf Troll test fishery is not used directly to estimate abundances of daily migration blocks, but rather to provide snapshot estimates of the abundance of sockeye delaying their upstream migration in the Strait of Georgia. This fishery is used to assess delaying Late run stocks on the Shuswap dominant years (2022 cycle) by sampling 6 quadrants over 3 consecutive days in both August and September. The Gulf Troll test fishery generally operates for 4-weeks but may be extended in-season at the discretion of the FRP. The start date for the troll test fishery is based on the Late run peak in Area 20 and incorporating a 4-day travel time to Area 29. This test fishery is not effective on moderate or low abundance years. Potentially, Gulf Troll test fishing data could be used to assess pink salmon but since starting pink salmon enumeration at Mission, the Gulf Troll test fishery has only been run to a limited extent in two previous pink years (2009 and 2011). Substantially more data would need to be collected to evaluate if this could be a reliable test fishery for pink salmon assessments.

The Area 5 marine gillnet and the Area 7 reefnet test fisheries are uniquely scheduled to precede commercial or Treaty Tribal openings for Fraser River sockeye or pink salmon. Typically, 10 days are approved each year for each of the Area 5 and Area 7 test fisheries, with the exact dates being assigned

in-season at the direction of the FRP. The Area 5 gillnet has historically preceded U.S. commercial fisheries in U.S. Areas 4B, 5, and 6C during the last week of July. When sockeye abundance estimates are moderate, it will depend on US fishing opportunities whether the Area 4B, 5 and 6C is needed. Following the Summary of a Review of Fraser River Test Fisheries (Nelitz 2018) this test fishery has only operated on the dominant Late Shuswap cycle line. The Area 7 reefnet test fishery is typically deployed as needed for 3-days preceding a U.S. commercial fishery in U.S. Areas 6, 7 and 7A.

IN RIVER TEST FISHERIES

The Whonnock and Qualark test fisheries are used to assess the species composition for the hydroacoustic sites at Mission and Qualark, respectively ([Chapter B13](#)). The Whonnock test fishery's catch per unit effort is also used for all passage calculations prior to, and after the operation of the Mission hydroacoustics program and to estimate sockeye abundances when pink salmon dominate abundances in the river. The Whonnock test fishery is the first to begin operations in the season and its start date is based on historical Early Stuart reconstructed daily abundance estimates above 100 fish. The start date for the Qualark test fishery is July 2 annually, one day later than the scheduled start of the Qualark hydroacoustics program, except it may be delayed on low abundance years (e.g., 2024) when there are conservation concerns (e.g., Early Stuart, Bowron). It is operated and scheduled by Fisheries and Oceans Canada (DFO).

The below bridge test fishery, historically the Cottonwood test fishery, is primarily used for stock identification purposes to have an early indication of the stock composition of sockeye moving into the river. The start date for Cottonwood is based on the historical 50% migration date for Early Stuart. Since 2024, the Cottonwood test fishery has been replaced by the Brownsville Bar test fishery following a Southern Endowment Fund project investigating the appropriateness of this alternative fishing location that generates larger sample sizes than Cottonwood (Sutherland et al. 2023). See [Chapter B3](#) for more information.

The in-river test fisheries are scheduled to operate until the daily reconstructed abundances are estimated to be below 100 fish. In practice, the Whonnock test fishery continues operating until there are 3 consecutive days with a catch of 0 sockeye, whereas the Cottonwood/Brownsville Bar test fishery will typically end earlier as its usefulness in assessing stock identification decreases late in the season when the majority of the fish are Late-run sockeye or pink salmon, or when samples are low. The Qualark test fishery operates until the end of the Qualark hydroacoustics program. Figure 4 illustrates the start and end dates for different cycle-lines between 2020 – 2023 for the in-river test fisheries.

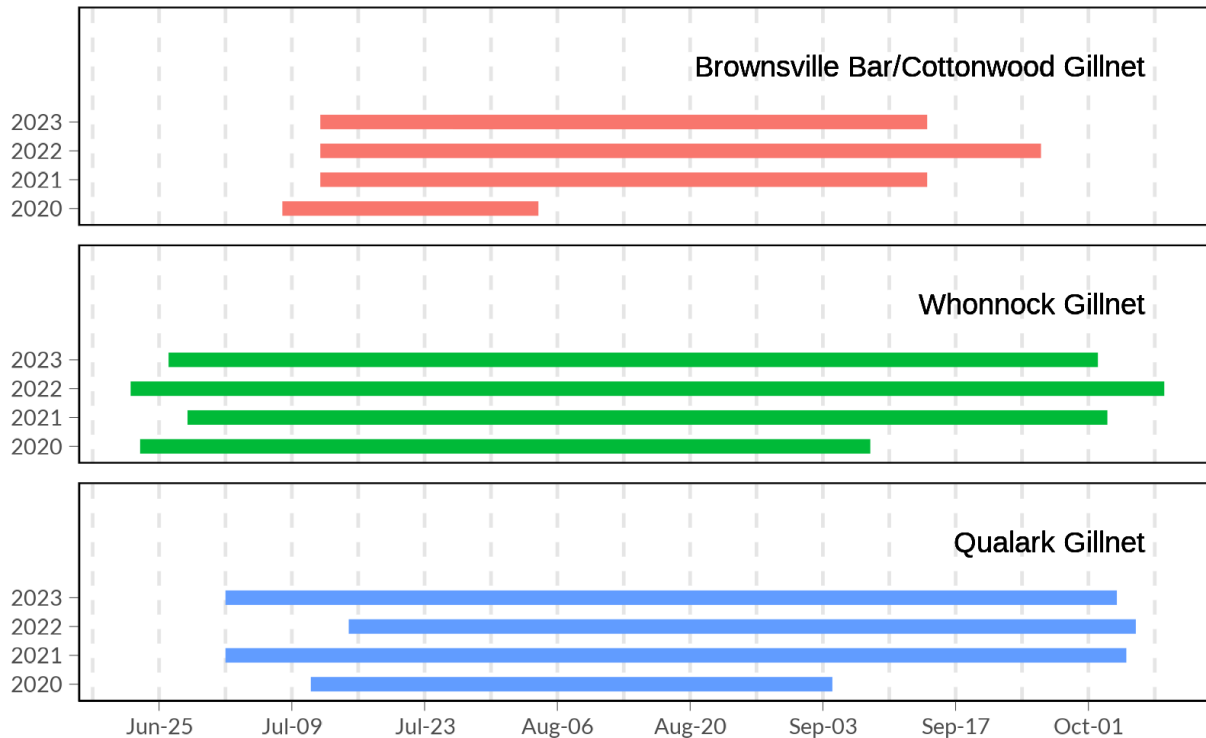


Figure 4. Comparison of the start and end dates for the in-river test fisheries between 2020 and 2023. These years cover the transition period from the Cottonwood test fishery to the current Brownsville Bar test fishery which are represented jointly in this figure.

HYDROACOUSTICS

In addition to the test fishing program, the PSC operates a hydroacoustics program at a site near Mission, B.C. ([Chapter B8](#)). Unlike the test fishing program, the Mission hydroacoustics schedule is developed and determined by PSC Staff. The schedule for the Mission program is dependent on the cycle-line and timing of the sockeye and pink migration. The start date for the Mission program is based on the ability to capture the peak of the Early Stuart run. This date is determined by the marine timing date of the Early Stuart group and assuming a 6-day travel time to the Mission site. On higher discharge years, the program may modify operations to the system on the left bank and on the transecting vessel only. At normal, or low discharge years, the programs may begin operations at full capacity. The end date for the Mission hydroacoustics program is determined in-season by its usefulness in capturing the tail of the pink run or the final upstream migration of delaying sockeye. The Mission program may operate until the first week of September or extend until the first week of October, depending on the cycle-line. On Late Shuswap-dominant sockeye years, pink salmon dominant years, or years with a significant amount of delaying sockeye stocks, the season extends into October. For more details on the hydroacoustics operations and data collection, see [Chapters B8-B12](#).

The goal of the Qualark hydroacoustics program is to provide additional insight on fish passage during in-season assessments (Conrad et al. 2019). It is scheduled to begin operations on July 1 annually and is operated by DFO. The in-season start date of the hydroacoustic program may be delayed due to high discharge. The end date for this program is based on the Mission hydroacoustics program end date and typically ends 2 – 3 days later. Figure 5 illustrates the start and end dates for both the Mission and the Qualark hydroacoustics programs between 2020 – 2023.

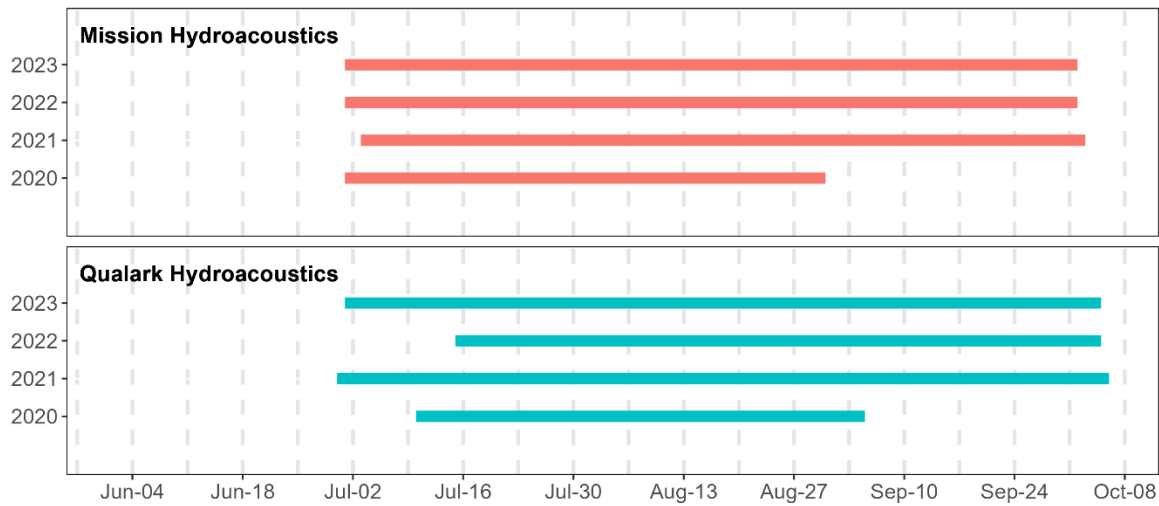


Figure 5. Comparison of start and end dates for the Mission and Qualark hydroacoustics programs between 2020 to 2023.

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B1. PSC test fisheries

E. Taylor

The Pacific Salmon Commission funds and operates test fisheries to inform bilateral decisions of the Fraser River Panel through the collection of data on Fraser River sockeye and pink salmon in southern British Columbia and northern Washington State. These test fisheries provide information on abundance, timing, and diversion rates as well as species and stock composition information for use in stock assessments to inform fisheries management. PSC Secretariat involvement in these test fisheries ranges from financial assistance to complete responsibility for day-to-day operations. This report outlines the purpose of Panel approved PSC test fisheries, administrative responsibilities, as well as funding of the test fishing program.

Introduction

The Pacific Salmon Commission (PSC), and its predecessor the International Pacific Salmon Fisheries Commission, have operated test fisheries to obtain data required to inform bilateral decisions of the Fraser River Panel since the 1960s. These test fisheries are authorised under the Pacific Salmon Treaty to assess Fraser River sockeye and pink salmon and occur in three key geographic areas (Figure 1): the northern and southern marine approaches to the Fraser River (Johnstone Strait, and the Strait of Juan de Fuca, respectively) and the lower Fraser River.



Figure 1. Map of PSC test fisheries, consisting of marine test fisheries in Johnstone Strait (Area 12 Round Island gillnet test fishery, Area 12 Blinkhorn and Area 13 purse seine test fisheries) and Juan de Fuca Strait (Area 20 gillnet and purse seine test fisheries, Area 5 gillnet test fishery and Area 7 reef net test fishery), in the Strait of Georgia (Gulf troll test fishery) and in-river gillnet test fisheries at Brownsville Bar, Whonnock and Qualark. The map also indicates the location of the Mission hydroacoustic site.

Test fishing is the deployment of fishing efforts to gather information about fish either moving through or residing in a particular area. This is done by deployment of consistent fishing effort in a particular area so that quantitative catch and biological data can be used for fisheries stock assessments ([Chapters B5 and B6](#)). Test fisheries are sometimes equipped with specialized fishing gear in order to target or avoid certain species or stocks. Additionally, test fisheries have observers aboard the vessels to monitor effort and catch ([Chapter B4](#)) as well as collect biological data and samples ([Chapter B5](#)) for use in stock assessment. Gear types used by the PSC test fisheries include purse seines, gill nets (both single and variable mesh), troll/hook and line, and reef nets.

Purpose of PSC test fisheries

The specific purpose of each PSC test fishery varies, but collectively their data are used in conjunction with information from the in-river hydro-acoustics program to provide in-season estimates of run size, timing and diversion of Fraser River sockeye and pink salmon management units. Table 1 provides an overview of the different PSC Panel approved test fisheries.

Table 1. Overview of PSC test fisheries, currently approved by the Fraser River Panel, in terms of the area of operation, administrative responsibility, period of operation, gear used, species and management group assessed, monitoring purpose, data use and derived abundance estimates.

	Current Panel approved PSC test fisheries										
	Area 20 Gillnet	Area 20 Purse seine	Area 12 Gillnet Round Island	Area 12 Purse seine Blinkhorn	Area 13 Purse seine	Area 29 Browsville Bar Gillnet	Area 29 Whinnock Gillnet	Area 29 Gulf Troll	Area 5 Gillnet	Area 7 Reefnet Observation	Qualark Gillnet
Region											
Fraser River & Georgia Strait	X	X				X	X	X			X
Juan de Fuca Strait & US Waters			X	X	X				X	X	
Johnstone Strait											
Panel Area											
Panel Area Waters	X	X				X	X	X	X	X	
Non-Panel Area Waters			X	X	X						X
Period of operation											
1960s	X	X					X				
1970s	X	X					X				
1980s	X	X	X	X			X	X			
1990s	X	X	X	X	X		X	X		X	
2000s	X	X	X	X	X		X	X	X	X	X
2010s	X	X	X	X	X		X	X	X	X	X
2020s	X	X	X	X	X	X	X	X	X	X	X
Gear											
Gillnet	X		X			X	X		X		X
Purse Seine		X		X	X						
Troll								X			
Reefnet										X	
Management group											
Early Stuart	X		X			X	X		X		X
Early Summer	X		X			X	X		X	X	X*
Summer	X	X	X	X	X	X	X		X	X	X*
Late run	X	X		X	X	X	X	X		X	X*
Pink		X		X	X		X			X	*
Monitoring purpose											
Core in-season assessment	X	X	X	X	X	X	X	X		X	X
Qualitative	X	X	X	X	X	X	X	X	X	X	X
Quantitative	X	X	X	X	X	X	X	X		X	X
Research						X					X
Data uses											
Timing	X	X	X	X	X		X	X	X	X	
Abundance	X	X	X	X	X		X	X	X	X	
Stock ID	X	X	X	X	X	X	X	X	X	X	X
Diversification	X	X	X	X	X						
Specie composition							X				X
Harvest rate					X						
Late-run management		X		X	X		X	X			
Pink management		X		X	X		X				
Project Mission escapement	X	X	X	X	X	X	X	X			
Project abundance entering US	X	X							X	X	
International allocation	X	X	X	X	X	X	X		X	X	
Verification					X	X					X
Estimate abundances in											
Marine areas	X	X	X	X	X						
Commercial catches	X	X	X	X	X				X	X	
US Waters	X	X	X	X	X				X	X	
Strait of Georgia		X	X	X	X	X	X	X			
Fraser River at Mission	X	X	X	X	X	X	X				

*Qualark test fishery only provides information for stocks that migrate past Qualark

The raw data provided by the test fisheries are catch by stock and species (based on sampling), effort, and other biological information such as age, sex, and weight ([Chapter B6](#)). Collectively across the test fishery program, these data are used as inputs to the PSC models to assess abundance ([Chapter B14](#)), timing, diversion rate, stock ([Chapters B7](#)) and species composition ([Chapter B13](#)), vulnerability (which stocks are susceptible to capture by particular gear in particular areas) and catchability (the proportion of the available abundance captured per unit of effort) ([Chapters B14](#)). In addition to providing inputs into the PSC's in-season modeling process, the data from various test fisheries are sometimes used to project the magnitude of catches in potential fisheries. Individual test fisheries can also provide relevant information on local abundances for certain users. Finally, many of the test fisheries also catch non-target stocks and other salmon species, which provides an incidental source of information on those stocks and species.

During 2016 and 2017, two workshops were commissioned to compile available information on historic and existing test fisheries, to gather input from a variety of experts in both Canada and the United States, as well as to undertake technical analyses. The results of these workshops and resulting technical review was published in a technical report and provides further details regarding the purpose of the various test fisheries (Nelitz et al. 2018).

Administration

Panel approved test fisheries are operated in-season to provide information to the Panel in support of Fraser River sockeye and pink salmon management. All Panel approved test fisheries are overseen by PSC Secretariat staff and the Panel. They are funded and approved through the Panel process and any decisions that 1) influence the financial state of the PSC test fishing program, 2) affect mortality of Fraser River sockeye and pink salmon, or 3) affect the Panels ability to manage Fraser River sockeye and pink salmon are made by the Panel with advice from PSC staff. In general, day-to-day operations are the responsibilities of PSC staff, DFO staff, and First Nations administrators and major decisions and overall direction are the responsibility of the Panel.

Test fisheries fall under two categories depending on whether they occur within Panel Area waters (Figure 2). Test fisheries occurring in Areas 12 and 13 as well as upstream of the Mission Bridge take place in Non-Panel Area waters, are operated by Fisheries and Oceans Canada (DFO), and tend to involve administrative assistance from First Nations whose traditional territory the test fisheries are operated within. The test fisheries within Johnstone Strait are administered by the Namgis A-Tlegay Fisheries Partnership. The Qualark Gillnet test fishery, located in the Fraser Canyon near Yale, is operated by DFO with support from Yale First Nation. DFO is responsible for selecting test fishing contractors and fish buyers. The remaining test fisheries occur within Panel Area waters and are operated by PSC Secretariat staff. Selection of test fishers and buyers, as well as financial accounting for these test fisheries are all performed by PSC Secretariat staff.



Figure 2. *Hierarchy table of Panel approved PSC test fisheries depending on location.*

Funding

The funding of test fisheries has changed substantially over the years. In 2006, a decision from the Federal Court of Canada determined that it was illegal for the federal government to set aside a portion of a public resource, i.e. fish, to finance research activities (Larocque v. Canada 2006). Prior to the Larocque decision, test fishers could be paid based on a portion of the value of the test fishing catch and fish could be retained above and beyond the amount needed to pay for the test fishing program. Between 2006 and 2012, the Canadian federal government's ability to retain fish to finance research activities was in flux. These years, referred to as "The Larocque Years", were characterized by changes to fisher payments and policies regarding the retention of fish. Fishers were required to be paid a fixed daily rate, and only fish required for samples and those unavoidably killed during test fishing activities could be sold. Currently, fishers are still paid a fixed rate but additional fish retention to fund test fishing activities is possible under the Test Fishing Policy (PSC 2021a).

While the test fishing program is generally funded through the sale of fish, recently the sale of fish from the test fisheries is insufficient to cover the costs of the test fishing program in most years. In this case, Canada and the U.S. are responsible for funding the remainder of the test fishing costs and do so through the use of the Test Fishing Revolving Fund (TFRF). The PSC maintains the TFRF to stabilize the financial status of the PSC test fishing program. Contributions to the revolving fund are either made directly by the Parties, or from surpluses from the sale of fish caught and retained in the test fisheries. Withdrawals from the revolving fund occur in years where test fishing operational costs exceed incomes generated from the sale of fish. The Test Fishing Policy and Financial Regulation was developed by the Parties in 2021 to outline the criteria required for the discretionary retention of fish as well as to define the regulations determining how deficits and surpluses would be shared by the Parties (PSC 2021b).

Planned changes and potential areas of improvement

Many of the planned changes and potential areas of improvement are outlined in the Summary of a Review of Fraser River Test Fisheries (Nelitz et al. 2018). In addition, there are ongoing modifications to the test fishing program to reduce costs and increase the information gained per dollar spent.

References

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PSC 2021a. Pacific Salmon Commission Test Fishing Policy. Feb. 10, 2021. 3p.

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B2. Marine Test Fisheries

J. Maguire

Summary

Fraser River Panel-approved marine test fisheries operate along the southern and northern marine approach routes around Vancouver Island to the mouth of the Fraser River. These test fisheries provide information on marine abundances, timing, and diversion of Fraser River sockeye and pink salmon ([Chapter B14](#)) and collect biological samples for demographic analysis and stock identification ([Chapter B7](#)) to inform fisheries management decisions. Four gear types are used for marine test fisheries: gillnets, purse seines, reef nets, and troll/hook-and-line. This report summarises the purpose, timing, and operations of each marine test fishery for the assessment of Fraser River sockeye and pink salmon. It also summarises the numerous analyses evaluating the impact of different test fishing factors on the precision of resulting abundance estimates. A more general overview of PSC test fisheries including a location map can be found in [Chapter B1](#) while further details regarding the operational periods of each fishery is described in [Chapter A4](#). Catch and CPUE data from the various marine test fisheries can be found in the [Fraser Panel Data Application](#) (2024).

Introduction

As per the Pacific Salmon Treaty (PST 2023), the Fraser River Panel is responsible for conducting test fisheries to monitor Fraser River sockeye and pink salmon. Marine test fisheries are used to estimate abundances, timing, and diversion of Fraser River sockeye and pink salmon through Johnstone Strait and Juan de Fuca Strait in Canadian and U.S. waters and to collect biological samples for demographic analyses and stock identification. The marine gillnets and purse seine test fisheries in Area 12 and 20 form the core of the in-season assessment program, assessing the abundance of non-delaying stocks on average 6 days prior to their migration past the Mission hydroacoustics site. For Harrison sockeye, delaying Late-run sockeye and pink salmon, the marine test fisheries are the only source of assessment information timely enough for in-season marine fisheries management decisions. Other marine test fisheries enhance the available information (e.g. the Area 13 purse seine test fishery) or are used to support U.S. fisheries planning (e.g. the Area 5 gillnet and the Area 7 reefnet test fisheries). Assessments of Fraser River pink salmon relies primarily on marine purse seine test fisheries as gillnets are inefficient at catching pinks and operate too early in the season to support assessments. This report will detail the purpose that each Panel-approved marine test fishery serves in the assessment and management of Fraser River sockeye and pink salmon, as well as their timing, operations and limitations. Additionally, this report also summarises the research evaluating the different test fishing factors impacting the precision of resulting abundance estimates.

Marine Gillnet Test Fisheries

The marine gillnet test fisheries in Area 20 and Area 12 are used to assess the abundance, timing, and diversion of Early Summer and Summer-run sockeye through Juan de Fuca and Johnstone Strait, respectively. Operated annually, the marine gillnets begin in the second week of July and conclude between late-July and mid-August depending on assessment and management needs ([Chapter A4](#)). A matching set of Area 20 and 12 CPUE data are needed in-season to produce daily estimates of

abundance for migration graphs and for the predictions of abundance en route to Mission. While particularly effective for the assessment of Early Summer run sockeye, the effectiveness of these test fisheries decreases as salmon catchability decreases as the season progresses. As a result, these test fisheries are not considered suitable for the assessment of Late run-sockeye and pink salmon.

While the marine gill net test fisheries are not used for pink salmon assessments, they do provide valuable information for sockeye assessments. A summary of the three gill nets including their start year, gear fished as well as the benefits for sockeye assessment are outlined below.

AREA 20 SAN JUAN GILLNET

The Area 20 San Juan Gillnet test fishery has been in operation annually since 1962, north of the international boundary in Juan de Fuca Strait. The gillnet fished is 300 fathoms long and 90 meshes deep, with a 5.125" multistrand mesh. In 2023, this test fishery started transitioning to an Alaska Twist net which is a 5" mesh size. The multistrand net will eventually be phased out. Fishing occurs between San Juan Point and Sombrio Point at depths between 40 and 140 fathoms, between the hours of 8 p.m. and 6 a.m. Each night, two vessels complete two 3-hour sets each. Using two vessels instead of one allows for greater coverage of the salmon migration and reduces the chance of missing data. Operating two vessels also benefits safety but doubles the cost. Non-target stocks and species of note encountered by the Area 20 gillnet are Lake Washington sockeye, Puget Sound pinks, Fraser River coho and Chinook as well as other Canadian and U.S. salmon stocks (Nelitz et al. 2018).

AREA 12 ROUND ISLAND GILLNET

The Area 12 Round Island gillnet test fishery has operated annually since 1986, 1 to 1.5 nautical miles east of Round Island in Queen Charlotte Strait. A 200 fathom, 60-mesh deep Alaska Twist gillnet with a 5" mesh size is used. Starting in 2019, the Round Island Gillnet started a multi-year transition from the use of the older style 5.125" multistrand nets to 5" Alaska Twist nets (Labelle and Van Will 2022). The full transition occurred in 2023. One vessel is used each night, completing three sets taking approximately 2 to 3 hours each. Non-target stocks and species of note encountered by the Area 12 gillnet include Sakinaw and Nimpkish sockeye, Canadian South Coast and Puget Sound pink salmon, Fraser coho and Chinook and other Canadian and U.S. salmon stocks (Nelitz et al. 2018).

AREA 5 JUAN DE FUCA GILLNET

The Area 5 Juan de Fuca gillnet test fishery began operating in 2005 on the U.S. side of Juan de Fuca Strait between Kydaka Point and Pillar Point. At the discretion of the Panel, it operates in years with planned U.S. Area 4B/5/6C commercial fisheries. This test fishery targets Early Summer and Summer-run sockeye and lands all catch, including non-target species. It begins operating 7 to 10 days prior to the scheduled start date of the commercial fisheries and operates for 7 to 14 days. Although net configuration has varied across vessels, a 440 fathom, 200-mesh deep Alaska Twist gillnet with a 5.125" mesh size is most commonly used to complete two overnight sets each day. During pink salmon years, this test fishery can also be used to assess the proportion of pink salmon versus sockeye salmon in the catch. Due to the early timing of this test fishery, non-Fraser pinks may dominate the pink salmon catch.

Marine Purse Seine Test Fisheries

The marine purse seine test fisheries are used to assess the abundance, timing, and diversion rate of Summer and Late-run sockeye, and on odd years, pink salmon. Like the gillnet test fisheries, a matching set of Area 20 and 12 CPUE data are needed to produce total daily estimates of abundance and for the predictions of abundances en route to Mission. Purse seines are generally not used to assess Early

Summer-run given their larger daily operating costs versus using gillnets in marine areas. Compared to gillnets, purse seine nets are much deeper which results in less of a reduction in catchability when salmon migrate deeper in the water column. This is often believed to be the case for Late-run sockeye salmon and pink salmon. For Summer-run stocks, purse seine data allows for the assessment of abundances 6 days prior to their migration past Mission, but for stocks that delay their migration prior to migrating into the Fraser River (i.e. Harrison sockeye, certain Late-run stocks, and pink salmon), it provides in-season run size assessments up to 3 weeks prior to their migration past Mission. Purse seine catches are also used to predict sockeye encounter rates and fishing induced mortality in pink-directed fisheries. With the exception of those salmon collected for sampling and stock identification purposes, and in rare cases, retained at the discretion of the Fraser River Panel to be sold to cover program costs, purse seine test fishing catch is released, resulting in limited impacts on target and non-target species. The resulting mortality following release from the purse seine test fisheries is expected to be negligible. The impact of purse seine test fishing can be further reduced by releasing fish following live sampling, which has proven to be feasible but requires additional funding as well as the necessary technical support (PSC 2025). When retaining discretionary catch for sale (pay fish), injuries and mortality of non-target species is increased. The marine purse seine operation starts annually between mid-July and early August and conclude between late August and early September, depending on assessment and management considerations ([Chapter A4](#)).

AREA 20 SAN JUAN PURSE SEINE

The San Juan Purse Seine has been in operation continuously since 1962. This test fishery uses an 875-mesh deep net with a length of 300 fathoms (549 metres), colloquially known as a “westcoast” net. Six sets per day are completed between Bonilla Point and Owen Point on the west coast of Vancouver Island in Juan de Fuca Strait at depths between 40 and 180 fathoms. Sets are attempted to be made perpendicular to shore along the “Blue Line”, i.e. the western border of the statistical Area 20, however tides, weather, and sockeye abundance may influence set locations. Non-target stocks and species of note encountered by the Area 20 purse seine are Lake Washington sockeye, Puget Sound pinks, Fraser River coho and Chinook as well as other Canadian and U.S. salmon stocks (Nelitz et al. 2018).

AREA 12 BLINKHORN PURSE SEINE

The Blinkhorn Purse Seine has operated annually since 1986. This test fishery uses a 575-mesh deep net with a length of 217 fathoms (397 metres), colloquially known as an “inside” net. Six sets are completed at shore tie-off points between Blinkhorn Peninsula and Fine Beach on the east coast of Vancouver Island in Johnstone Strait. The location of each set is determined by tides, weather, salmon abundances, and distributions. Overall, there is a high variability in catch between sets within a day. Of the different environmental conditions, cloud cover and wind speed have the biggest impact on test fishing CPUE estimates in Area 12 (Siegle and Ma 2020). The first set of the day is executed at the most eastward test fishing locations, often Robson Bight or Fine Beach, and the next 5 sets follow in a westward direction (Figure 1). Commercial or FSC fishing, when scheduled, are expected to occur eastward of the test fishery to limit their impact on in-season assessments. When the entire set is retained in the Area 12 test fishery, the overall mortality of non-target species is less than in the Area 20 seine test fishery given their lower relative abundance. Non-target stocks and species of note encountered by the Area 12 purse seine include Sakinaw and Nimpkish sockeye, Canadian South Coast and Puget Sound pink salmon, Fraser coho and Chinook and other Canadian and U.S. salmon stocks (Nelitz et al. 2018).

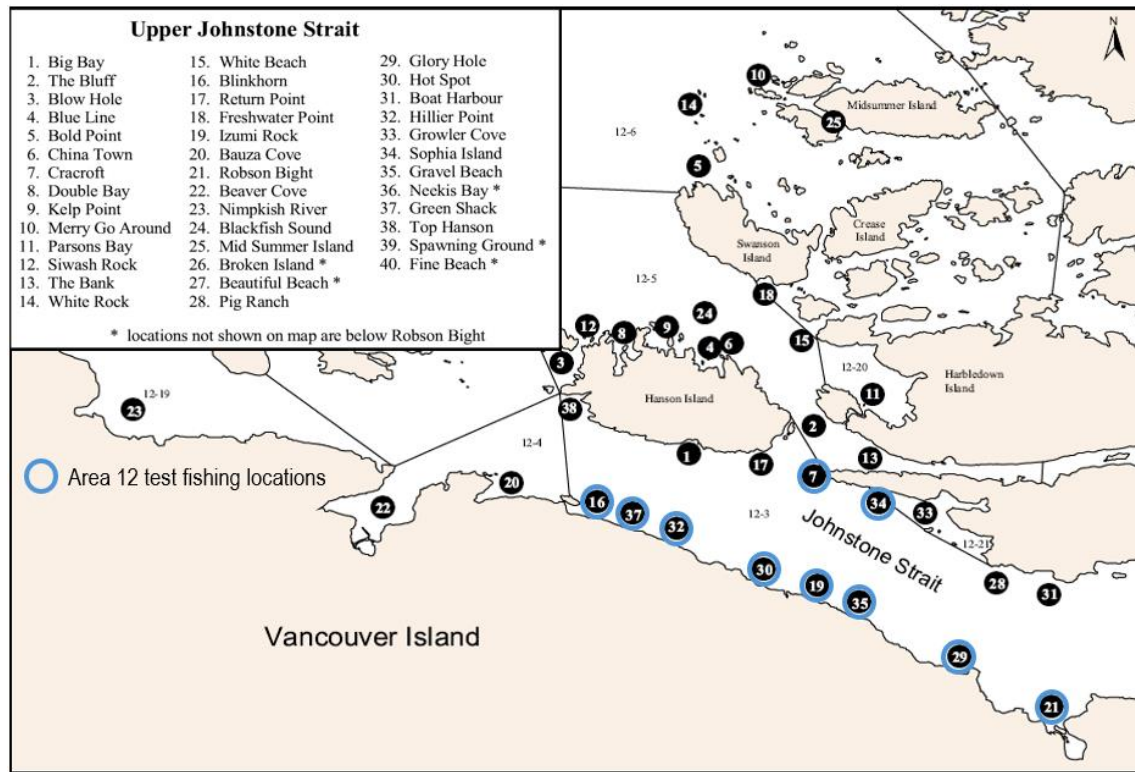


Figure 1. Location of Area 12 test fishery set locations in Johnstone Strait used for the assessment of Fraser River sockeye and pink salmon (blue circles). Map courtesy of DFO.

AREA 13 PURSE SEINE

The Area 13 Purse has operated since 1995, usually in higher abundance sockeye years and pink years. It is designed to assess abundance of Summer and Late-run sockeye and is not as effective for assessing Early Summer-run sockeye. Similar to the Area 12 purse seine test fishery, this test fishery uses a 575-mesh deep net with a length of 217 fathoms (397 metres), colloquially known as an “inside” net. Operations typically start between the third week of July and first week of August and continue until the beginning of September. The test fishing vessel aims to complete 6 sets per day at shore tie-off points on Sonora, Quadra, and Vancouver Island (Figure 2). The location of each set is determined by tides, weather, and salmon abundances and distribution. Of the different environmental conditions, current speed and tidal cycle phase have the biggest impact on test fishing CPUE estimates in Area 13. Catches in Area 13 in general tend to be higher than in Area 12 due to the narrower width of the Strait in Area 13, and due to a higher propensity for salmon to aggregate in set locations influenced by strong tides and currents.

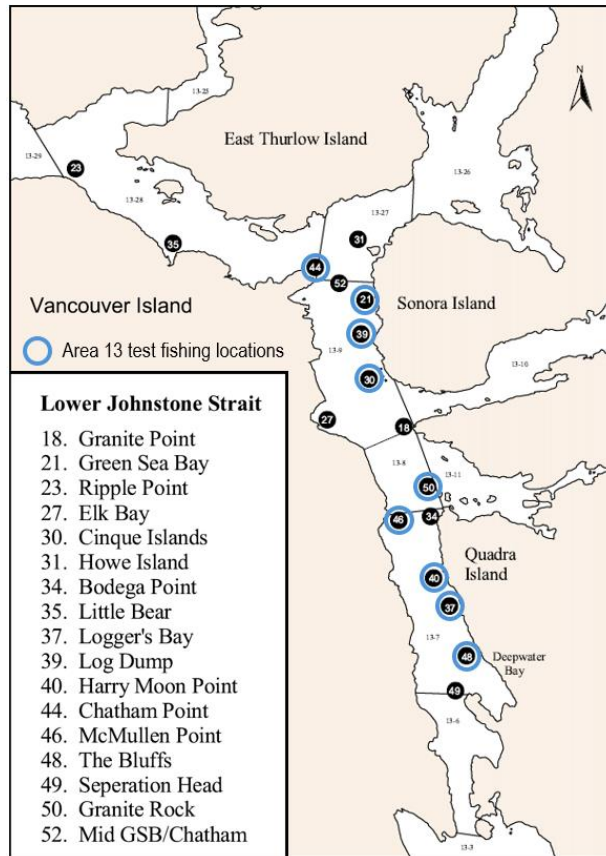


Figure 2. Location of Area 13 test fishery set locations used for the assessment of Fraser River sockeye and pink salmon (blue circles). Map courtesy of DFO.

Area 29 Gulf Troll

The Area 29 Gulf Troll test fishery is used to assess the abundance of Late-run Fraser River sockeye in the Strait of Georgia. The fishery was first operated in 1987 and is operated in years where there are high abundances of delaying Late run sockeye in the Gulf, prior to their migration up the Fraser River. While Gulf Troll data were regularly used in the 80s and 90s to verify the extent pink salmon were delaying, the limited amount of Gulf Troll data that can be linked to daily reconstructed Fraser River pink salmon abundance estimates (2009 and 2011 only) prevents estimates to be used in quantitative assessments. For Late run assessments, this test fishery provides several sequential estimates of abundance over the season as well as a perspective on the timing of the upstream migration. It is generally assumed that catchability declines in September as fish stop feeding and are less attracted to gear. In addition, catch rates also drop when sockeye move onto the 'flats' of the Fraser River delta where they are inaccessible to the fishing gear and/or when they migrate upstream. Gulf Troll test fishing operations begin between late August and early September, depending on Late-run timing. Operations conclude approximately 10 to 30 days following the start of the fishery, depending on management requirements. Two vessels operate independently, each fishing within one of 6 pre-defined quadrants in the Strait of Georgia between Bowen Island and Georgina Point Lighthouse on Mayne Island (Michielsens and Martens 2022). Fishing occurs for approximately 8 hours per day, 3 days per week, with both vessels fishing the same days to ensure each quadrant is assessed. Each vessel is equipped with 6 mechanical reels and lines, or gurdies, and 10 to 20 artificial lures per gurdy. Encounter

rates of non-target species are generally low and their mortality can be negligible with careful handling of the gear.

U.S. Area 7 Reef Net

The U.S. Area 7 Reef Net test fishery is used to determine the presence of Early Summer, Summer, and Late-run sockeye, as well as Fraser River pink salmon in U.S. Panel waters. In addition, the reef nets provide information on the sockeye to pink salmon ratio, and, particular in years with sockeye conservation concerns, can be helpful in planning pink salmon directed fisheries. This test fishery has been operated since 1997 in years where there are scheduled U.S. commercial fisheries in Panel waters. The test fishery begins prior to these scheduled fisheries in early July. This fishery is observational, and no fish are retained unless directed to by the Fraser River Panel. Observations occur for approximately 8 hours per day at 2 sites near San Juan Island and Lummi Island to cover the primary migration routes through U.S. Panel waters. Observations are conducted from a platform above the reef net gear and hourly counts are reported. The hours of observation shift daily to align with the appropriate tide needed for observation. This test fishery is highly susceptible to environmental conditions as overcast skies, rain, winds, tides and water clarity affect the consistency of the observation (Nelitz et al. 2018). The fixed gear positions do not allow movement to better sites as fish distribution changes. Of the reef net locations, Lummi Island CPUE data provides the best indicator of daily abundance, but across years, the CPUE data from reef net test fisheries is a poor predictor of daily abundance (Nelitz et al. 2018).

Test fishing related research

Marine test fisheries are a core part of the in-season assessment program for Fraser River sockeye and pink salmon. As such a considerable amount of research has been undertaken to ensure the PSC test fisheries provide the best possible CPUE data to estimate marine abundance. This has resulted in numerous analyses of the impact of different test fishing factors on the precision of resulting abundance estimates, e.g. the type of test fisheries (gillnet versus purse seine), the number of vessels and number of sets, and the test fishing or set location. The following section provides a brief overview of some of the research results. Further details on the individual analyses can be found in the referenced reports.

In general, the precision of abundance estimates based on purse seine data is greater than based on marine gillnet data, especially later in the season when salmon catchability in marine gillnet test fisheries decrease ([Chapter B4](#), Michielsens and Martens 2022). Using a second boat to calculate the marine gillnet CPUE has a limited impact on the resulting precision in abundance as the inter- and intra-annual variability in catchability has a much bigger impact (Nelitz et al. 2018). In the Area 20 gillnet test fishery, having a second test fishing boat results in a more precise estimates of CPUE, but leads to only a modest increase in run size precision (4%, Nelitz et al. 2018). In Area 12, there is little evidence that an alternative gillnet test fishing location at Naka Creek, operated for 10-12 days per year from 2009 to 2015, would produce more precise estimates of salmon abundance than the current test fishery at Round Island (Nelitz et al. 2018).

Test fishery results are more robust when averaging estimates across statistical fishing areas or across days (Nelitz et al. 2018). Averaging the daily abundance estimates derived from Area 13 and Area 12 test fishery data improves the daily estimates by removing some of the daily variability but has a lower impact on abundance over 6-day periods (Nelitz et al. 2018). Increasing the purse seine test fishing effort in the same statistical area from 1 to 4 vessels reduces the variation in the CPUE but this would result in only a modest gain in certainty of in-season run size estimates (Gazey 2001). Environmental factors like tide, current, cloud cover and wind speed have also been explored to improve abundance

estimates based on test fishing CPUE data. The adjusted R^2 between Area 12 and Area 13 purse seine CPUE estimates and abundance only increase by 2.4% and 2% respectively when including environmental covariates, regardless of whether fine-scale data or publicly available area-wide environmental data are used (Siegle and Ma 2020).

Substantial research has been conducted to evaluate and/or improve the test fishing or set locations. Sheringham Point, 50 km south-east of the “Blue Line”, has been explored as an alternative/additional test fishing location for the Area 20 purse seine test fishery but overall CPUE estimates were lower, potentially due to a shift in the migration to the United States side of Juan de Fuca Strait between the “Blue Line” and Sheringham Point (Cave 2003). In Area 12, two sites (Cracroft Point and Sophia/Splash Island) tend to catch fewer fish and are more variable than other sites (Nelitz et al. 2018). These locations are unique among the commonly used locations because they are on the opposite sides of the Strait and are open water sets in contrast to the other locations that are beach sets (Figure 1). While these locations tend to catch fewer fish, they help inform the amount of sockeye migration through the north side of the Strait. Excluding these two infrequently sampled sites from daily CPUE estimates does not result in an improved relationship between daily CPUE and abundance (Nelitz et al. 2018). In Area 13, one site, McMullen Point, is an open water set at the west side of the strait and tends to catch fewer fish than the other beach sites (Figure 2). Another site, Chatham Point, tends to catch more fish than other sites. Exclusion of these two sites to calculate the CPUE does not result in an improved relationship between daily CPUE and abundance (Nelitz et al. 2018).

In 2014, it was evaluated if the morning purse seine sets at Fine beach or Neekis Bay in the Area 12 purse seine test fishery could be eliminated and replaced with unlimited Area B ITQ fishing at either location, given that the precision of the ITQ catch-per-set information is more strongly related with daily abundance estimates compared to test fishery data (Ma et al. 2019). This experiment was not successful as only a limited subset of Area B data reached PSC staff in-season and with at least a 4-day time lag (PSC 2015). A subsequent feasibility study in 2018 indicated that the data challenges could be overcome by adopting eLog software and supporting technology but the usefulness for in-season assessments was restricted by not having similar data available in Juan de Fuca Strait (Ma et al. 2019). Similar to using ITQ data to supplement test fishery data, it was evaluated if marine FSC data, as well as CPUE data from participating First Nation harvesters, could provide reliable estimates of daily abundance. Results indicated that these data, in the form in which they were received for this study, were not a consistent and reliable source to supplement the PSC test fishery program and could not be used to generate unbiased estimates of daily abundance (Alameddine et al. 2023).

Constraints and potential areas of improvement

Marine mammal presence has increased in test fishing areas in recent years. Avoiding encounters and interactions with marine mammals can cause delays to test fishing operations and sometimes prohibit them all together. Acoustic deterrents are being explored as a potential option to avoid interactions. Incidental by-catch of non-target salmonids can also be unavoidable. During years of low abundance of Fraser River sockeye salmon, live sampling has been explored onboard purse seine test fisheries as an option to avoid mortality for sampling purposes (PSC 2025).

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B3. In-River Test Fisheries

J. Maguire

Summary

In-river test fisheries operate throughout the reaches of the lower Fraser River to inform fisheries management decisions for Fraser River sockeye and pink salmon. These test fisheries provide stock and species composition estimates that are used to generate stock-specific daily abundance estimates when combined with the total salmon estimates generated by the in-river hydroacoustics programs ([Chapter B8](#)). The Whonnock test fishery can also be used to generate sockeye abundance estimates based on CPUE data and is primarily used once pink salmon dominate abundances at Mission (Michielsens and Martens 2022). The primary in-river test fisheries operated in support of the Fraser River Panel use gillnets, however, mesh sizes and net structure vary depending on each fishery's purpose. This report summarises the purpose, timing, operations, and constraints of these in-river test fisheries. This report also provides similar summaries for two additional test fishing operations: the Albion Chinook and chum salmon test fishery as well as the lower Fraser River fish wheel. Neither are core test fisheries for the assessment of Fraser River sockeye and pink salmon, but they do provide data used to estimate species composition ([Chapter B13](#)).

Introduction

Under the Pacific Salmon Treaty (PST 2023), the Fraser River Panel is responsible for conducting test fisheries to aid in the in-season management of Fraser River sockeye and pink salmon. The in-river test fisheries deployed annually are used to estimate stock composition and abundance of sockeye and pink salmon entering the Fraser River. Additionally, they collect information on the species composition of all salmonids and the data are used to produce species specific hydroacoustic abundance estimates at Mission and Qualark ([Chapter B8](#)). The core test fisheries all use gillnet gear, with the structure of the net varying between fisheries depending on their assessment use. This report details the timing, operations, purpose and constraints of each in-river test fishery used in the Fraser River Panel management process.

Area 29 Whonnock Gillnet

The Whonnock Gillnet test fishery has operated yearly since 1958. This test fishery serves three purposes: 1) to collect species composition information to generate daily sockeye abundance estimates when used in combination with the total salmon estimates generated by the Mission hydroacoustics site, 2) to estimate sockeye abundances when pink salmon dominate migration passage (Michielsens and Martens 2022) as well as before and after the Mission hydroacoustics site is operational, and 3) to obtain sockeye stock identification data based on DNA samples collected. The latter has become more important in recent low abundance years when sample size requirements were not being met in the Cottonwood test fishery prior to relocating this test fishery to Brownsville Bar. One major downside of using Whonnock for stock identification purposes however, is the lack of Pitt and Widgeon in the catch samples.

This test fishery typically begins during the last week of June and operates daily until late September or early October depending on Late run sockeye timing ([Chapter A4](#)). Sets are conducted at two locations depending on water heights. During periods of high water levels, typically during freshet, sets are conducted at Glen Valley Bar at the southern tip of Crescent Island in order to improve catchability. When water levels decrease, sets are conducted further downstream, closer to the middle of the river channel at the Whonnock Channel site (Figure 1). Two 20-minute sets are conducted each day during the “slack water” conditions when the river current is counteracted by the flooding tide. Given the focus on species composition estimates, this test fishery uses a 7-panel, 175-fathom multistrand gillnet consisting of 7 different mesh sizes: 4”, 4.625”, 5.25”, 6”, 6.75”, 7.75”, and 8.75”. The gillnet is rotated between sets, so each end of the net is fished nearest to the shore each day. Catchability tends to decrease when transitioning from a late evening to an early morning drift and this discrepancy is more pronounced early in the season when catches are low. The CPUE calculations of this test fishery take into account the length of the net as well as the time the gillnet is in the water, i.e., the soak time. When more than 50 salmon are caught, a correction factor is applied that is meant to correct for gear saturation and the loss of fishing efficiency when the net is being picked ([Chapter B4](#)). Details on the Whonnock expansion line (inverse of the catchability) used in combination with the CPUE estimates to calculate the sockeye abundance migrating past the test fishing site can be found in Michielsens and Martens (2022).

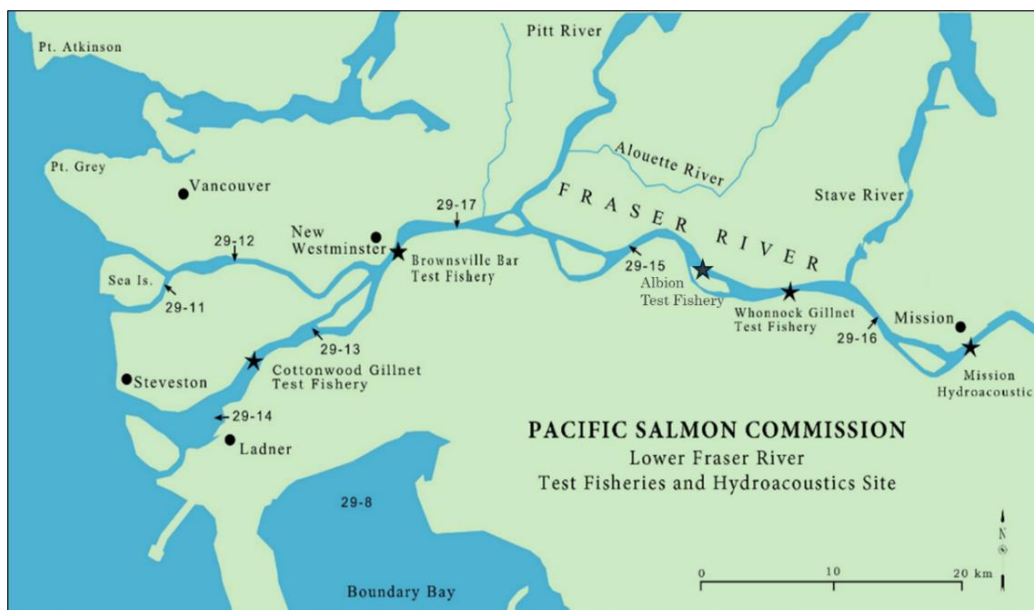


Figure 1. Map of the Lower Fraser River, indicating the location of PSC gillnet test fisheries at Cottonwood, Brownsville Bar and Whonnock as well as the Albion test fishery site. The Qualark test fishery is located upstream, near Yale.

Whonnock catches also include Chinook, coho, chum, and steelhead. Since 1998, PSC observers have sampled Chinook and coho catches and submitted samples and data to DFO. Non-lethal sampling of steelhead catches has also been conducted since 2019. Chinook, coho, and chum that are not required for sampling purposes and that would be expected to have a good chance of survival are released. All sturgeon and steelhead are released. Potential injury and mortality is however unavoidable.

There have been some concerns about biases in both species and stock composition estimates at Whonnock. Because the gillnet samples the offshore section of the river, catches may underrepresent species and stocks migrating closer to shore. More specifically, the Whonnock test fishery catch tends to

underestimate the proportion of pinks given that they migrate closer to shore and overestimate the proportion of Chinook that migrate further offshore than sockeye (van Dam-Bates et al. 2024).

Area 29 Brownsville Bar Gillnet

The Brownsville Bar Gillnet test fishery is used to gather information for stock identification of sockeye entering the Fraser River for all management groups ([Chapter B7](#)). Unlike the Whonnock test fishery, it intercepts all Fraser sockeye stocks, including Pitt and Widgeon and is therefore essential to generate total Fraser River sockeye run size estimates. Operated annually, this test fishery begins in mid-July and concludes in early September. A 120-fathom, 60-mesh multi-panel Alaska Twist gillnet is used with 4 different mesh sizes: 4.25", 4.75", 5.25", and 5.75", all aimed at catching sockeye salmon. As a result, this test fishery is not suitable to derive species composition estimates. All sets are conducted at an area colloquially known as Brownsville Bar located downstream of the Patullo Bridge. This area is a well-known and highly productive gillnet fishing location above the confluence of the north and south arms of the lower Fraser River. Two 20-minute sets are conducted during "slack water" conditions each day during the season. The gillnet is rotated between sets, so each end of the net is fished nearest to the shore each day.

The test fishery has operated annually since 2021 as part of a Southern Boundary Restoration and Enhancement Fund project to assess its suitability to replace the Cottonwood Gillnet test fishery in the lower Fraser River (Sutherland et al. 2023). The Fraser River Panel elected to officially replace the Cottonwood test fishery with the Brownsville Bar test fishery in 2024. Overall, the transition to the new location substantially increased sockeye sample sizes available for stock identification. In addition to low catches at Cottonwood, there had been concerns about stock identification bias, given that the Cottonwood test fishery did not intercept salmon migrating through the North Arm of the Fraser River. In addition, Cottonwood tended to overestimate Late run stocks as delaying sockeye tend to push in and out of the river before making their final migration upstream. Brownsville Bar is less impacted by this behaviour given its location further upstream (Sutherland et al. 2023). In addition to the low catches and biased stock identification, the Cottonwood test fishery had also suffered from substantial amounts of commercial vessel traffic, seal predation, a strong tidal influence and the build up of debris from high discharge events. From 2009 to 2016 an electric net had been used at Cottonwood to reduce seal predation (Forrest et al. 2009). In the past there has been variable success in using Cottonwood CPUE data to estimate sockeye and pink salmon abundances. To what extent the Brownsville Bar test fishery has improved the representativeness of the stock identification, and the accuracy of CPUE-derived sockeye and pink salmon abundance estimates is still under examination. Brownsville Bar catches also include pink salmon, Chinook, coho, and steelhead. DFO provides updated sampling and retention procedures to the PSC annually.

Area 29 Qualark Gillnet

The Qualark Gillnet test fishery first operated in 2000 and is located approximately 1 kilometer upstream of Emory Creek. Test fishing operations coincide with the Qualark hydroacoustics program, as the primary purpose of the test fishery is to derive stock composition and species composition assessments for the hydroacoustics program. Test fishing operations typically begin between late June and early July, and end between late September and early October.

The nets used at Qualark are 16 fathoms of a single mesh size. Six different mesh sizes are used: 4", 4.75", 5.25", 5.75", 6.75", and 8". The test fishing vessel conducts 3 sets each morning and evening, all nearshore of the right bank. The meshes are organized into two groups: one group includes 4", 5.25",

and 6.75", while the other includes 4.75", 5.75", and 8". Each group is fished in sequence, starting with the smallest mesh size and progressing to the largest. One group is fished in the morning, and the other in the evening. Which group is fished first alternates daily. This ensures that each set uses only one mesh size, and all six mesh sizes are fished once per day. A 7th set is conducted 1-2 times per week in the offshore portion of the river using the 5.25" mesh size to assess offshore species composition. Most, if not all the migration occurs in close proximity to the right and left bank. One major downside of the Qualark test fishery, in particular for the assessment of Fraser River sockeye salmon, is that several stocks including Chilliwack, Pitt, Harrison, Widgeon, Birkenhead, Big Silver, Weaver and Cultus do not migrate past Qualark. As a result, Qualark test fishery data in combination with Qualark hydroacoustic estimates can only be used to assess between 30 to 80% of the total Fraser sockeye run depending on the year (Conrad et al. 2019).

Area 29 Albion Gillnet

The Albion Gillnet test fishery, which is operated by Fisheries & Oceans Canada, provides information for the assessment of Fraser River Chinook and chum salmon and is located at Albion, near Fort Langley near the old Albion ferry crossing. This test fishery is not within the scope of the Fraser River Panel. Test fishing operations begin in April and end at the end of November.

The Chinook test fishery is used to collect CPUE and stock composition information during the Chinook migration to inform Canadian domestic fisheries management decisions related to the Chinook chapter of the Pacific Salmon Treaty (PST 2023, Nelitz et al. 2018). This test fishery runs every day until the end of August and every other day through October 20. The Chinook test fishery uses two different gillnets, both 200 fathoms long: a standard Chinook net with an 8" mesh, and a multi-panel net with 4 different mesh sizes: 6", 7", 8" and 9". The multi-panel net aims to obtain a representative Chinook sample, taking into account the wide range of Chinook sizes. The chum test fishery collects CPUE and stock composition information during the chum migration period used to inform decisions related to the chum chapter of the PST (PST 2023, Nelitz et al. 2018). It runs on alternating days starting in September and uses a gillnet that is 150 fathoms long with a 6.75" mesh. From October 21 onwards, the chum test fishery operates daily. While this test fishery catches sockeye and pink salmon, overall catches of these species are lower compared to the sockeye and pink salmon directed test fisheries, and the resulting species and stock estimates are assumed to be biased (Nelitz et al. 2018).

Lower Fraser River Fish Wheel

Fish wheels have been used in the Fraser River to catch, sample and tag salmon since 2009 with the aim to assess en route losses in addition to providing species and stock composition information and information on fish health (Robichaud et al. 2010). Over the years, two different fishwheels have been operated approximately 9 km downstream of the Mission hydroacoustics site. The small fish wheel has three baskets (3.4 m long × 3.0 m wide × 2.1 m deep) that are framed with aluminum tubing (3.8 cm square) and lined with white, knotless, nylon mesh (6.4 cm stretch, English et al. 2018). The baskets are designed to fish up to 3 m below the water surface. The large fish wheel has larger baskets (6.1 m long × 4.3 m wide × 3 m deep) are designed to fish 5.8 m below the water surface (English et al. 2018). The lower Fraser River Fish Wheels have been operational on odd years since 2009 and on a couple of even years due to tagging and brood stock collection for Big Bar research purposes within the Lower Fraser River (2020 and 2022). Prior to 2023, the fish wheels were independently operated by Matsqui First Nations in collaboration with LGL Limited and the Lower Fraser Fisheries Alliance. Although this program was not part of the Fraser River Panel test fisheries, the fish length data collected has been used in mixture models to derive species composition estimates (Grant et al. 2014; [Chapter B13](#)). In 2023, the

Fraser River Panel agreed to pay for the operation of the fish wheel for a short period during early August in order to supplement the species composition information available to PSC staff. In addition, in odd years, daily estimates of sockeye and pink salmon abundances can be derived by combining Mission hydroacoustic counts with species composition estimates from the Matsqui fishwheels for the nearshore area (e.g., first 50 m) and Whonnock test fisheries for the offshore area (Robichaud et al. 2010; English et al. 2016; 2018). Fish wheels may however overestimate pink proportions in nearshore areas (English et al. 2018) due to the fact that fish wheels do not cover the entire nearshore area and that pink salmon migrate closer to shore than other salmon species (Van Dam-Bates et al. 2024).

Potential consolidation of in-river test fisheries

Nelitz et al. (2018) reviewed and evaluated potential refinements to and consolidations of the current suite of in-river test fisheries. The analysis recognised opportunities but did not provide a definitive basis for deciding upon the optimal configuration of in-river test fisheries. One of the benefits of consolidating different in-river test fisheries are savings in terms of program cost and fishing mortality. However, in all cases when reducing or combining in-river test fisheries, potential mitigative measures would have to be taken and the associated costs would offset potential savings. In addition, additional calibration studies would need to be conducted prior to substituting test fisheries and these would require sufficient years of data during which both the old and new test fishing configurations are run. The feasibility of reconfiguring test fisheries or operational periods would also include logistical considerations, e.g. mesh sizes, program location and duration, and discussion of potential mitigation measures that would span multiple Chapters of the PST (PST 2023, Nelitz et al. 2018). Other groups beyond the Fraser Panel would need to be engaged, in particular when considering changes to the Albion test fishery.

Constraints and Potential Areas of Improvement

Because of their location in the lower Fraser River, operations at Brownsville Bar and Whonnock can be delayed due to marine traffic, preventing sets from being made on the optimal high slack tide. Additionally, marine mammal predation can affect CPUE estimates, especially during periods of low abundance. Acoustic marine mammal deterrents are currently being explored as an option to improve data quality in these test fisheries.

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B4. Catch-per-unit-effort (CPUE) calculations

T. Sutherland

Catch-per-unit-effort (CPUE) is arguably the most important test fishing data to estimate abundances. The Pacific Salmon Commission (PSC) relies on two different test fishing gear types to assess the abundance of Fraser River pink salmon: seine nets and gill nets. Seine nets are the primary gear used to assess pink salmon in marine test fisheries while gill nets are used for in-river assessments. In most cases the calculation of CPUE is based on catch and fishing effort, whereby the effort will be gear dependent. But in some cases, the CPUE may be corrected to account for gear saturation or other factors that may bias the relationship between abundance and CPUE. The following report provides an overview of the calculation of CPUE for the different PSC test fisheries.

Introduction

As part of the Pacific Salmon Treaty agreements (PST 2023, Chapter 4), the Fraser River Panel is responsible for conducting test fisheries on Fraser River pink salmon. Test fishery data include catch-per-unit-effort (CPUE) data that, when multiplied by an expansion line (inverse catchability, [Chapter B14](#)), provides an estimate of daily abundance. CPUE data are calculated differently depending on the type of gear and the associated measure of fishing effort. The two gear types employed by PSC test fisheries to assess Fraser River pink salmon are purse seines and gill nets. Additionally, the in-river gill nets differ slightly from their marine counterparts and require the use of a catchability correction factor when catches are above a certain level. The following report will describe the calculation of CPUE for each of the two gear types.

Data

Before discussing CPUE calculations, it is important to define what catch and fishing effort data will be used in the calculation of CPUE. During test fishing operations, the quality of catch data is often negatively impacted by weather, equipment failure, and/or tides and currents. Under these circumstances, the test fishing skipper and observer are asked to assign a quality score of 2, 1, or 0 to the collected data. A score of 2 signifies that the data is of good quality and there were no issues to note. A quality score of 1 signifies that there were one or more issues with the collected data, but that the skipper and observer agreed that the issues did not result in the catch being unrepresentative of what would have been caught had there been no issues. Finally, a quality score of 0 signifies that the skipper and observer deem the catch being unrepresentative of what would have been caught had no issues occurred. All catch data with a set quality score of 0 are excluded from calculations of CPUE.

Methods

PURSE SEINE TEST FISHERIES

The pink salmon CPUE in the purse seine test fisheries is calculated as the total pink purse seine catch on a given day (C) divided by the number of assessment sets performed, i.e. the fishing effort (E):

$$(1) \quad CPUE = \frac{C}{E}.$$

Under normal circumstances, the purse seine test fisheries perform six sets per day. In case of mechanical failure or in case the quality of a set is deemed compromised, the number of sets and the catch are adjusted accordingly.

GILL NET TEST FISHERIES

Gill net test fishery CPUE calculations are a bit more complicated as gill net fishing effort (E) calculations consider the length of the net as well as the length of time the fishing net is in use, i.e., the soak time:

$$(2) \quad E = \frac{\text{Net Length (fathom)} \times \text{Soak Time (min)}}{1000}.$$

The soak time is calculated as the time the net is entirely in the water, plus half of the time that it takes to set the net and to retrieve it:

$$(3) \quad \text{Soak Time} = \text{Start In Time} - \text{Full Out Time} \\ + \frac{\text{Full In Time} - \text{Start In Time}}{2} + \frac{\text{Full Out Time} - \text{Start Out Time}}{2}.$$

The CPUE is then calculated by the total number of pink salmon caught, divided by fishing effort (equation 1).

The efficiency of salmon gill nets is affected by several technical and biological factors. One such technical factor, gear saturation, occurs when the gill net loses its efficiency as a greater number of target individuals are present in the net. In the lower Fraser River gill net test fisheries, this saturation results in a reduced catch rate or catchability through either space limitation, or gear avoidance. Catchability correction factors are used to adjust the catch rate when the total number of salmon caught in the gill net is so large that it restricts the catch rate of additional salmon. Historically, a catch of 50 total salmon in a single set is thought to be the point where the relationship between total salmon CPUE and total salmon catch begins to become non-linear, to the extent that a catchability correction factor should be applied.

When the total salmon catch is larger than 50, the pink salmon CPUE is calculated as:

$$(4) \quad CPUE_{pink} = C_{pink} \times \text{correction factor}.$$

The methodology used to calculate a correction factor is the slope of the regression line fitted through catch and CPUE data of sets with less than 50 salmon caught. Under these conditions, it is believed that gear saturation is minimal. The total salmon catch is the independent variable and the uncorrected total salmon CPUE is the dependant variable. When this linear regression is performed, the intercept is forced to zero. Figure 1 illustrates the derivation of the correction factor for the Whonnock gill net test fishery.

This regression is re-run each year separately for the Whonnock and Brownsville Bar gill net test fisheries. The analysis is performed on a subset of historical data, based on the fisher, the net used, and recency. Updates to the gill net correction factor are only made when it deviates substantially from other years. Quantitative analyses have not been performed to determine the catch level where the relationship becomes non-linear.

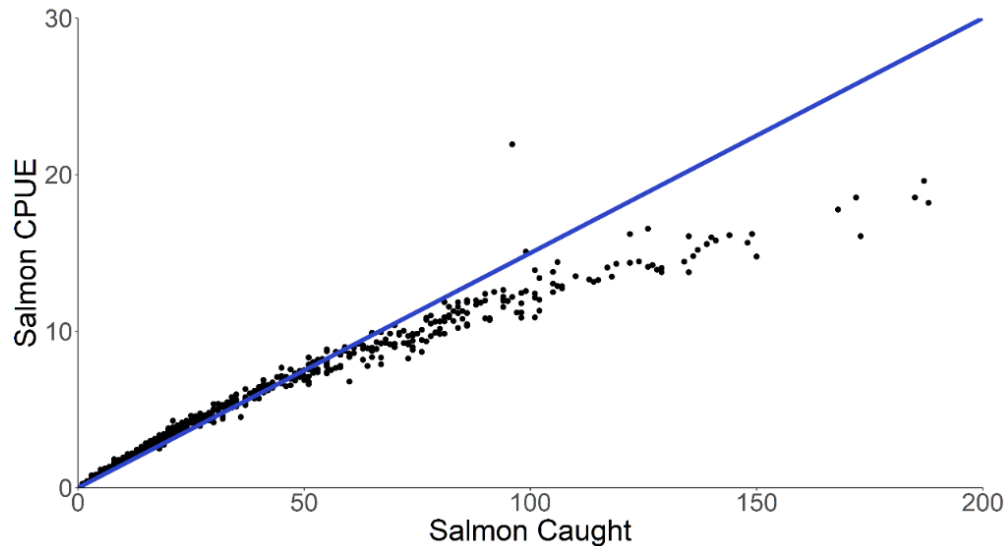


Figure 1. *Salmon catch totals and catch-per-unit-effort (CPUE) in Whonnock gill net test fishery sets in the years 2010, 2014, and 2018. The blue line represents a slope of 0.15 and was generated by running a linear regression on sets where less than 50 salmon were caught. As total salmon catch increases past 50, the salmon CPUE does not continue to increase linearly. This effect is believed to be due to gear saturation of the gill net.*

Missing test fishing sets and data imputation

Matching sets of Area 20 and Area 12 CPUE data are needed in-season to produce daily estimates of abundance for migration graphs, for predictions on route to Mission, or when calculating multi-day average for diversion rates and expansion lines. Missing daily CPUE may occur in season due to adverse weather, mechanical failure, fishing gear repairs, or refueling. When daily CPUE data are unavailable or determined to be unrepresentative, imputation of missing daily CPUE is recommended. Imputation of single days of missing CPUE data is done by averaging the CPUE of the days before and after. Imputation of one day of missing CPUE data versus assuming the data are not available has limited impact on run size estimates derived by the time-density model ([Chapter B15](#)).

Most test fisheries rely on more than one fishing set to generate daily CPUE estimates. This reduces the probability of missing daily estimates but may still result in less than the optimal sets being available. Some causes of non-attempts of fishing sets are controllable, e.g. mechanical or fishing gear repairs, refueling, time cutoffs for sample and fish delivery schedules, while most are not, e.g. weather and tidal conditions, marine mammal presence, extremely large catches including catches of non-salmonid species that are more challenging to remove from the net. In addition, fishing sets are only included in assessments of abundance if they are determined to be good, i.e. representative of underlying abundances. In most cases this will mean fewer sets will be available to derived daily CPUE estimates. Marine purse seine test fisheries normally require 6 sets per day and the impact of a reduced number of sets has been evaluated. Overall, missing sets have a bigger impact in Area 12 than in Area 20, as catchability tends to be more variable across set locations, particularly on low abundance days (Table 1). As more sets are completed, the resulting CPUE becomes more predictive of the final CPUE based on six sets.

Table 1. Adjusted R^2 values when using CPUE based on 1 to 5 sets to predict final CPUE across a full six sets assessments. The analyses for days with less than 120 pinks caught represent low abundance days.

Set	<i>All Days</i>		<i>Days with less than 120 pink salmon caught</i>	
	Area 12	Area 20	Area 12	Area 20
1	0.44	0.85	0.19	0.68
2	0.71	0.90	0.27	0.77
3	0.90	0.93	0.51	0.83
4	0.94	0.97	0.62	0.95
5	0.97	0.99	0.84	0.98
6	1.00	1.00	1.00	1.00

Planned changes and potential areas of improvement

Under the current workflow, gill net correction factors are calculated pre-season based on historic data and this correction factor is applied to in-season catches. In the future, it may be beneficial to calculate season specific correction factors and make in-season adjustments to the daily CPUEs.

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B5. Sampling protocol

D. Brkic and A.M. Phung and S. Latham

The sampling design relevant to in-season assessments of pink salmon is reviewed here. DNA and scale samples are collected regularly from test fisheries and opportunistically from commercial fisheries. This sampling design is intended to provide up-to-date stock composition data for in-season Fraser River Panel (FRP) meetings which occur twice per week. Three to five days typically pass between the sampling of a pink salmon in a fishery and the integration and reporting of stock composition data at FRP meetings. The delay is influenced by the geographic location of the fishery, availability of shipping services, and prioritization relative to other sockeye and pink salmon samples. This latter factor can vary depending on changing management needs. When sampling, one scale sample and one DNA sample are collected per fish and stored in a scale book and on a sheet of Whatman filter paper, respectively. Scale samples are shipped to the Pacific Salmon Commission (PSC) Secretariat office and metadata is stored in a database. DNA samples are shipped to DFO's Pacific Biological Station for analysis. Once the DNA has been analyzed, the resulting data are further processed by biologists at the PSC Secretariat office.

Introduction

During the in-season period, the Pacific Salmon Commission (PSC) operates a suite of test fisheries along the northern (Johnstone Strait) and southern (Juan de Fuca Strait) approaches and in the lower Fraser River ([Chapter B1](#)). These fisheries are required to produce estimates of abundance of pink salmon returning to the Fraser River, prior to their enumeration at the Mission hydroacoustics site ([Chapter B8](#)). The proportion of pink salmon that are of Fraser River origin is estimated using DNA ([Chapter B7](#)) collected from catches in marine test fisheries, and this proportion can be applied to overall abundance to estimate the number of pink salmon returning to the Fraser River. Scale samples provide information on growth rate. Lengths and weights of fish are also often recorded during the sampling of test and commercial fisheries ([Chapter B6](#)).

In addition to sampling test fishing catches, commercial catches are also sampled in-season. These samples are collected at fish processing facilities. The main objective of the commercial catch sampling program is to gather DNA information from marine catch samples in order to estimate the proportion of Fraser River pink salmon in the total commercial catch. Whereas test fisheries collect information on pink salmon migration (including pink salmon that are not caught) in a stratified random design, commercial fisheries are sampled with a focus on estimating the catch of Fraser and other stocks, and therefore commercial sampling prioritizes large catches. Nevertheless, when large numbers of samples are obtained from commercial fishery openings, these can contribute valuably to evaluation of the migration and run size assessments.

The number and magnitude of commercial fishery openings vary from year to year depending on the Fraser pink salmon run size, market conditions, and constraints imposed by other comigrating salmon species, particularly sockeye. During Canadian commercial fisheries openings, processing plants in the vicinity of Vancouver are targeted for sampling landings. For commercial openings in northwest Washington State, processing plants in Bellingham are primarily targeted to sample landed catches.

Sampling design

TEST FISHERIES

The goal of sampling test fishery catches is to provide reliable, up-to-date stock composition information for in-season FRP meetings. The geographic location of test fisheries coupled with limitations in air carrier services can lead to delays in data flow in-season. Delays in stock composition estimates are mitigated by modeling stock composition patterns using intra-annual trends to supplement recent GSI results ([Chapter B7](#)). Catches are targeted regularly for sampling throughout the Fraser pink salmon migration to provide comprehensive estimates of the trend in stock composition. The sampling schedule for collecting biological information varies depending on the test fishery. Table 1 shows a hypothetical sampling schedule assuming all test fisheries are running and lists the daily sample size targets for each test fishery. A sample consists of one DNA tissue “punch” (obtained using a one-hole punch on the adipose fin), one scale, and biological data including length, weight, and sex ([Chapter B6](#)). The schedule and sample sizes may vary among years depending on shipping logistics and size of the catch ([Chapter A4](#)). Note that pink salmon samples are generally not collected at marine gillnet test fisheries due to the relatively late return and low catchability of Fraser pink salmon in these fisheries.

Table 1. Pink Salmon DNA and scale samples collected per day for each PSC test fishery.

PSC test fishery	Number of boats	Schedule	Samples per day
Brownsville Bar	1	Mon-Fri	20 (100/week)
Whonnock	1	Mon-Fri	20 (100/week)
Area 20 Purse Seine	1	Mon, Thurs	100
Blinkhorn Area 12 Purse Seine	1	Mon, Fri	100
Area 13 Purse Seine	1	Mon, Fri	100
Qualark GN	1	Daily	15 (100/week)
U.S. Area 7 Reefnet	3	Twice a week	100

The sample sizes shown in Table 1 are the maximum sample sizes under ideal conditions. The sampling schedule is modified at the start and end of the pink salmon run when abundance is low. For all test fisheries, if the DNA sample size target cannot be met, the difference is compensated for on the following day. For example, if the Area 20 purse seine test fishery caught only 40 pink salmon on a scheduled sampling day, additional pink salmon would be sampled on subsequent non-scheduled sampling days until 60 more individuals were sampled.

COMMERCIAL FISHERIES

Commercial fishery samples are collected opportunistically as fisheries occur. Generally, the target for a sampling trip is to collect 100-200 samples from each commercial fishery opening by gear type and key statistical area. This usually results in about 200-300 samples per sampling trip. Some commercial fisheries are sampled more intensively than others depending on catch numbers, logistics, and utility of the collected information for FRP deliberations. When sampling purse seine commercial fishery catches, ideally more than 100 samples would be collected per area as catches tend to be higher than for other gear types. Unlike test fisheries which follow a strict sample collection schedule outlined pre-season, samples for commercial fisheries are more challenging to schedule due to uncertainty around where and when catches are going to be landed. Table 2 provides a summary of guidelines for sampling frequency during a year with ample available TAC. Canadian commercial catches from Areas B, D, E and H are sampled at fish processing plants in Vancouver. Catches from Areas B, D, G and H have been sampled at

fish plants in Nanaimo, although this has rarely occurred in recent years. U.S. commercial catches (All Citizen (US-AC) and Treaty Tribes (US-TRB)) in Areas 7 and 7A are sampled at fish plants in Bellingham. In-season communication with fish plant representatives is crucial to planning sampling trips that maximize the amount of information that can be obtained.

Table 2. *Sampling frequency guidelines for commercial fisheries by key statistical area in a high TAC year. Sampling frequency describes the number of sampling trips, not the total number of samples collected. Multiple statistical areas are often sampled in a single sampling trip.*

Fishery User	Gear Type	Key statistical areas	Sampling frequency
Area B	PS	Area 12, 13, 29	3 times per week
Area D	GN	Area 12, 13	2 times per week
Area E	GN	Area 29	After every opening
Area H	TR	Area 12, 13 and 29	Infrequent
Area G	TR	Area 125, 126, 127	Infrequent
US-AC	PS, GN, RN	Area 7, 7A	2 times per week
US-TRB	PS, GN, RN	Area 7, 7Aa	2 times per week

Method

The protocol for collecting DNA and scale samples and biological information is similar for test fisheries and commercial fisheries. Samplers distinguish pink salmon from other salmon species by following guidelines outlined in the sampling manuals for test fishing observers and port samplers. Scale samples, DNA samples, and/or biological data, such as fish length, weight, and sex are collected on the boat, after landing, or at a processing plant. DNA, scales, and biological data are primarily collected as “matched samples,” meaning each piece of information can be traced back to the same fish. This permits comparisons of size, sex, and growth among stocks. Scale samples for pink salmon are analyzed post-season, but they are easy to collect and have been used for management in the past. For commercial sampling, time can be a limiting factor and sampling information is triaged. DNA has the highest priority, followed by scales, lengths, sexes, and finally weights. If sampling is constrained due to scheduled fish plant operations, samplers may opt to exclude lower-priority information from the collection.

Sample collection aims to be representative with respect to the population of inference. In marine purse seine test fisheries, efforts are made to sample from each test set. A subset of the catch of each set is put aside for sampling. Additional individuals must be put aside in early sets to mitigate against poor catches in sets conducted later in the day. In marine commercial landings, multiple vessels are targeted, and care is taken to sample early, middle, and late offloads. For fisheries that use variable mesh gillnets such as the Whonnock and Brownsville Bar test fisheries, pink salmon are sampled from each mesh proportional to the total catch as distributed among those meshes.

For each fish, a scale sample is placed in a scale book alongside the matching biological data for each individual salmon, including the DNA sample number. The “preferred scale” is selected from each salmon unless it is missing or damaged and is located on the left side of the salmon, on the second scale row above the lateral line in a diagonal line from the posterior of the dorsal fin to the anterior of the anal fin (Figure 2). If the preferred scale is missing, the next closest scale is taken as long as it is at least two scale rows above the lateral line and posterior to the front of the dorsal fin. Scales higher than four scale rows above the lateral line may be sampled in rare cases if all scales near the preferred scale location are missing. This is because the characteristics of the scales vary dorso-ventrally. In such a case, the sampler notes that a non-preferred scale was used. If there are no usable scales on the left side of

the fish, a right-side scale may be used, but the sampler must take note of this because it can affect how the scale is read. If neither side of the fish has appropriate scales to sample, the sampler should pick another fish if there is an adequate number of fish to sample.

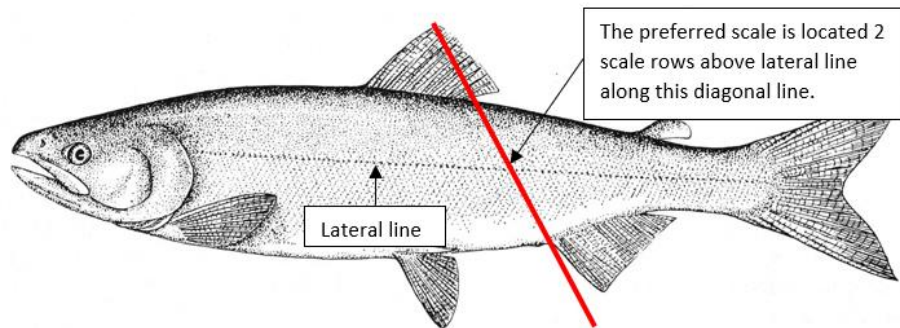


Figure 2. *The preferred location of the scale to sample. Scales higher than four scale rows above the lateral line are non-preferred.*

DNA samples are collected by using a one-hole punch and punching one small, thin disk from the margin of the adipose fin of the salmon. If the adipose fin is missing, a caudal fin clip is taken instead. While the tissue sample is still wet, it is placed on a Whatman sheet. The alternative storage of DNA in ethanol vials is less desirable but is used in cases where Whatman paper is not available or if heavy wind and/or rain make using Whatman sheets difficult. To prevent contamination, sampling equipment is ideally rinsed after each fish is sampled.

DNA samples are analyzed by the Molecular Genetics Laboratory at the Pacific Biological Station (PBS) in Nanaimo. For Johnstone Strait test fisheries, test fishing observers drop off biological samples at an air carrier service to be shipped as soon as possible to Vancouver. In-river DNA samples from Brownsville Bar and Whonnock are generally delivered to the PSC office by staff. The same is true for test fishing and commercial samples collected in Bellingham and for commercial samples collected in Vancouver. Qualark samples are delivered to the PSC office by Canada Post. DNA samples from each of these fisheries are flown to Nanaimo using an air carrier service. For Area 20 test fisheries, the test-fishing observer delivers biological samples to a contractor in Port Renfrew who drives samples to AC Taxi in Nanaimo in the evening. In the morning, AC Taxi delivers the DNA samples to PBS and the scale samples to an air carrier service (scales are picked up from the air carrier service in Vancouver by PSC staff).

Potential Areas for Improvement

Investigations are needed to determine possible deficiencies in the representativeness of samples. Pink salmon can vary greatly in morphology depending upon sex and reproductive maturity. Sexual dimorphism, including the large hump and teeth that males display as secondary sex characteristics, may influence the relative likelihood of catch and sampling. Gillnet fisheries (such as those operating in the lower Fraser River) may be biased toward catching larger males. As noted, test fisheries in the lower Fraser River use variable mesh gillnets. It will be important to examine how various mesh sizes in this gear interact with fish of different sizes and other morphological characteristics, as this could affect estimates of length that are used as model priors for estimating species composition by hydroacoustic length estimates ([Chapter B12](#)).

B6. Length, Weight, and Sex

D. Brkic and A.M. Phung

Biological information of salmon collected by the Pacific Salmon Commission (PSC) includes length, weight, and sex information. Length measurements are used as inputs into models that differentiate fish species based on hydroacoustic lengths, i.e., length-based mixture models ([Chapter B12](#)). Weights in combination with lengths are important for understanding fish condition but also provide the fishing industry with information on the potential value of expected catches. Sex information is equally important as analyses of lengths and weights often requires separation of the sexes. Lengths are measured and recorded in terms of fork length, postorbital fork length (POF), and postorbital hypural length (POH). Length measurements are taken using a “POF stick” while weights are measured using industrial scales. Sex is determined by making an incision in the abdomen and inspecting the gonads by touch.

Introduction

The Pacific Salmon Commission (PSC) collects and stores biological information – including length, weight, and sex – from salmon sampled from commercial and test fishery catches. Fish lengths help distinguish different species within a mixture of different length estimates obtained from hydroacoustic data ([Chapter B12](#)). Multi-year records of length and weight may reveal deviations from average, which could be important in fisheries planning as larger fish are more valuable in terms of catch. Determining the sex of sampled fish is important as morphological differences between the sexes may lead to differential catchability in fishing gears as well as varying offload weights when fish are sold. Analyses done on length and weight data also generally require separation of the sexes.

Length definitions

The Pacific Salmon Commission collects three different types of length measurements: fork length, postorbital fork length (POF), and postorbital hypural length (POH). Figure 1 shows the difference between fork length, POF, and POH.

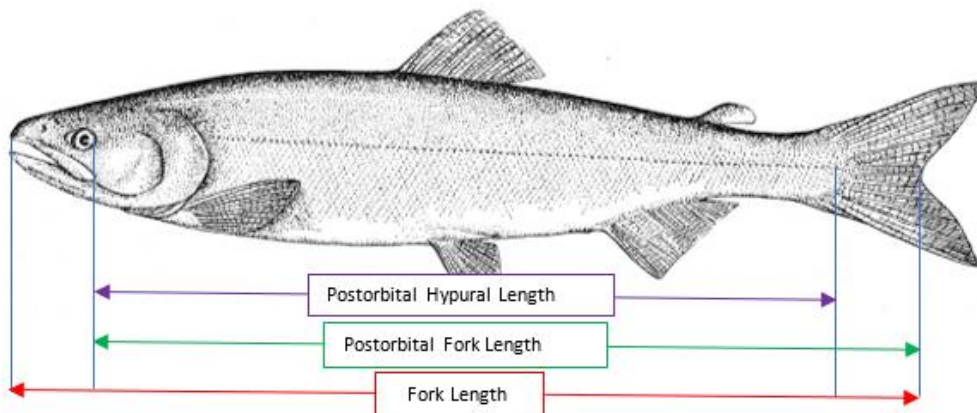


Figure 1. Illustration of the different salmon length measures recorded by the PSC.

Fork length is the length from the anterior-most part of the fish to the posterior end of the middle caudal rays. Fork length is best used to determine the overall size of a fish when it has deeply forked tails and difficult-to-distinguish hypural plates as is the case for salmon. The PSC uses fork lengths in the hydroacoustic length-based mixture models.

The postorbital fork (POF) length measures the length from the posterior of the orbit (the back of the eye) to the posterior end of the middle caudal rays. Excluding the snout of the fish in the measurement helps circumvent the impact of highly variable snout lengths, as male salmon tend to develop distinct hooked snouts during maturation. POF is used to track changes in length across return years.

The postorbital hypural (POH) length is the length from the posterior of the orbit to the hypural notch. This length measure is especially used during sampling on the spawning ground when the caudal fins tend to degrade, especially among females, causing the POF to become highly variable. Both the orbit and hypural notch, used to determine the POH, can be identified on even highly degraded carcasses.

Other types of fish lengths include mid-eye fork length (MEF) and standard length. These lengths are generally not taken by the PSC but are entered into the PSC's scale database when samples are received from other organizations. MEF is the length from the middle of the orbit to the fork in the tail. MEF length is generally taken in fishery samples by the Alaska Department of Fish and Game. Standard length is the length from the tip of the snout to the hypural notch and is generally taken for spawning ground samples by Fisheries and Oceans Canada.

Sampling design

There are five main types of biological data collected in the field by the PSC: fork length, POF, POH, weight, and sex. Table 1 shows which lengths are taken at each fishery, whether weights are taken, and the sample sizes for lengths and weights.

Fork lengths are generally only measured at the Whonnock gillnet test fishery and the Brownsville Bar gillnet test fishery. Forks lengths from Whonnock and Brownsville Bar are typically used within hydroacoustic length-based mixture models ([Chapter B12](#)). If there are insufficient fork length samples available from Whonnock and Brownsville Bar, additional fork lengths data may be required from other test fisheries or commercial fisheries.

Postorbital fork (POF) lengths are measured at all PSC test fisheries and when commercial fisheries are sampled. For commercial fisheries and reef net test fisheries, sample sizes for length are determined by catch sizes and DNA sample requirements. Every fish sampled for DNA has an associated POF measurement unless the samplers are facing extreme time limitations at fish plants.

Postorbital hypural (POH) lengths are the primary length measurements for spawning grounds samples, which are opportunistically sampled in recent years given that spawning ground surveys of Fraser River pink salmon were terminated in 1991 (Grant et al. 2014).

Weights of individual fish are measured only at the gill net fisheries at Brownsville Bar, Whonnock, Qualark, and the reef net fishery in Area 7. Individual weights are also measured for commercial fishery samples. Weights are not measured for individuals that are incomplete such as fish that are damaged by seals or dressed. For commercial samples, individual weights may not be measured if time is a limiting factor. Bulk weights, which is the net weight of a tote, may also be recorded and are used to calculate the average weight.

Sexes are recorded for all pink salmon whenever possible. For commercial samples, sexes may not be determined if time is limiting.

Table 1. Pink sampling summary by fishery on odd years only. On even years, the Area 12 PS test fishery sometimes samples up to 100 pinks per week.

Fishery	Length type	Weight	Sample Size (up to)
Brownsville Bar GN	FL/POF	Yes	100/week
Whonnock GN	FL/POF	Yes	100/week
Area 20 PS	POF	No	100/week
Area 12 PS	POF	No	100/week
Area 13 PS	POF	No	100/week
Qualark GN	POF	Yes	100/week
Gulf Troll	POF	No	100/week
Area 7 RN	POF	Yes	Variable
Commercial	POF	Yes	Variable
Spawning Grounds	POH	No	Variable

Method

All lengths are measured using a “POF Stick”: a custom-made 1-meter aluminum ruler with one fixed post at the zero marker and one sliding post. The posts are 6-7 cm long and generally have a fine-pointed tip. The accuracy of POF sticks is tested by setting the POF stick measurement to 50 cm, then measuring from the inner edge of the fixed post to the point of the sliding post using measuring tape or another ruler (Figure 2). Lengths are recorded in centimeters or millimeters and are rounded to the nearest millimeter.

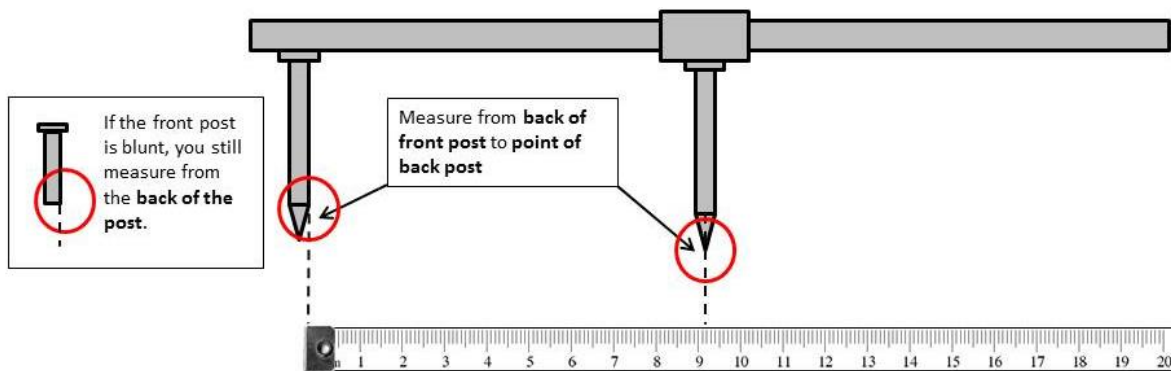


Figure 2. A POF stick and how it can be used to measure lengths. Lengths are measured from the back of the front fixed post to the point of the sliding post

Fork lengths are measured by placing the inner end of the fixed post of the POF stick in front of the fish snout and moving the point of the sliding post to the fork in the tail. Fork length is not measured if damage to the snout or tail prevents an accurate reading.

Postorbital fork (POF) lengths are measured by placing the fixed post of the POF stick into one of the eye sockets of the fish. The point of the sliding post is then moved to the fork in the tail. POF lengths are not taken if damage to the eye sockets or tail prevents an accurate reading.

Postorbital hypural (POH) lengths can be measured in three different ways. For the first method, the flesh covering the hypural plate is cut away with a knife to reveal the hypural notch. The fixed post of the POF stick is then inserted into the eye socket and the sliding post is pointed at the hypural notch. This is the preferred method for spawning grounds sampling as it is the most accurate. For the second method, the sampler feels the tail of the fish to estimate the location of the hypural notch. The hypural

plate is distinctly elevated at the base of the caudal fin rays. The measurement is taken from the eye socket to the estimated position of the hypural notch. This method is preferred for test fishery sampling as it is the most time-efficient and does not damage the fish and reduce retail value. The third method involves folding over the rays of the caudal fin until it can no longer be bent. The measurement can then be taken from the eye socket to the position of the final bend. This method is another time-efficient alternative to the first method but is less accurate.

Weights are measured using a Kilotech industrial dial scale or an AND SK-WP digital scale. Scales are calibrated using two known weights: 1.000 kg and 3.915 kg. Weights are recorded either in pounds or kilograms and are always rounded to one decimal place. Average weight is calculated by dividing the total weight of fish in a sample by the sample size. If bulk weight was recorded, the average is calculated by dividing the net weight of a tote by the number of fish in it.

To determine the sex of a fish, a cut is made in the belly approximately two inches long from between where the pectoral fins originate and along the midline of the stomach. The sampler inserts their finger into the cut until the spine is reached, feeling along the outside of the internal organs. If the fish is female, the lumpy texture of the egg-filled ovaries can be felt. If the fish is male, the smooth testes can be felt. If the sampler is inexperienced or if the sex is indistinguishable by feel, the cut in the belly can be extended further to the posterior and the body cavity opened for a visual examination. For spawning grounds samples, the sex can be determined by visual examination of exterior morphology, but the body cavities of females are still examined to evaluate egg deposition or success of spawn.

Planned Changes and Potential Areas for Improvement

Erroneous or anomalous length and weight measurements can enter the database unnoticed despite some existing preventative measures. An error-checking tool is under development to detect outliers in length-weight data so errors can be caught and rectified earlier. If the source of an error cannot be identified or if it can't be fixed, anomalous data can be flagged and subsequently excluded from analysis if desired. Obvious errors can be removed, such as when fork lengths are shorter than POF lengths. The tool can also track data accuracy by fishery, allowing fishery-specific sources of errors to be addressed.

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B7. DNA-based stock ID and stock ID projections

A.M. Phung and S. Latham

Summary

In-season management of Fraser River pink salmon relies on genetic stock identification (GSI) to track their proportions in marine areas. Pink salmon within marine catch samples are classified to three regional stock groups for in-season management: Fraser, B.C. South Coast, and Washington. Since 2007, genetic analyses have been performed using microsatellites instead of allozymes. Fish are identified by comparing their DNA in mixed-stock fishery samples with known-origin genetic samples. These known-origin samples come from spawning grounds and constitute the “baseline” reference. Unlike Fraser sockeye, pink salmon in the Fraser watershed have low genetic differentiation compared to other Pacific salmon species. Fraser River pink salmon stocks are difficult to distinguish from one another (Araujo et al. 2014) and have been managed as a single management unit.

Pink salmon DNA samples are collected once or twice per week from test fisheries, resulting in a delay of typically three to five days before GSI results are available to managers ([Chapter B5](#)). Missing stock composition estimates are imputed between sampling dates and prior to the availability of new GSI results. A Bayesian model was developed that incorporates historical information while updating predictions with new GSI data. This model is used to predict stock proportions in marine areas, while all pink salmon that enter the Fraser River are assumed to have originated from Fraser stocks. The prediction model is updated with new GSI results as they are produced, and predictions are re-generated for the entire season with every update.

Introduction

In marine areas, Fraser River pink salmon co-migrate with B.C. South Coast and Washington pink salmon. Estimating the proportion of Fraser River pink salmon in marine catch samples is crucial to in-season assessments of pink run size and migration timing. Until 2007, stock identification of Fraser River pink salmon was based on analyses of allozymes which are proteins that indicate underlying genetic differences (Carvalho and Hauser 1994). Since 2007, Genetic Stock Identification (GSI) of Fraser pink salmon has been based on variation in microsatellites which are segments of DNA characterized by different lengths of short, tandem repeats (Beacham et al. 2012). Microsatellites have provided more accurate stock identification for pink salmon than allozymes (e.g., Olsen et al. 2000). Compared to sockeye, pink salmon demonstrate lower genetic differentiation across a given spatial geographic scale, so they are partitioned into only three regional stock reporting groups: B.C. South Coast, Washington and Fraser (Beacham et al. 2012). Further accurately partitioning into more granular stock groups is challenging (Araujo et al. 2014), possibly owing to a higher stray rate of pink salmon from their natal streams (Beacham et al. 2012). Even at this coarse, 3-reporting group resolution, identifications frequently demonstrate low confidence, with collections of pink salmon from lower Fraser River fisheries averaging only 90% Fraser origin with the current GSI method (unpublished PSC data).

In the Fraser River Panel’s typical in-season GSI sampling program, which operates in odd-numbered years, there is typically a delay of three to five days before DNA results are available to be used for assessment purposes ([Chapter B5](#)). A data imputation method is used to fill the data gaps between

sample collections. Using in-season GSI data in combination with historical trends in stock composition estimates across the season can be a powerful tool to improve predictions of in-season stock proportions (DeFilippo et al. 2020). Model predictions are generated for the entire season, including for days when GSI results are available. These predictions incorporate all available GSI samples and, for pink salmon, are considered more reliable than point estimates alone, which are subject to a high degree of inter-sample variability. Uncertainty in pink salmon GSI estimates is too great to discern nuanced differences from the model predictions. This report provides a summary of the pink salmon GSI program, and the modelling approach used to predict Fraser River pink salmon proportions in fishery management areas.

Data

Fraser River pink salmon DNA is collected from pink salmon caught in test fisheries and opportunistically from pink salmon caught in commercial fisheries ([Chapter B5](#)). DFO's Molecular Genetics Laboratory (MGL) in Nanaimo extracts DNA from the samples and analyzes the microsatellites from 16 genetic locations (i.e. loci) to determine stock-of-origin (Beacham et al. 2012). The pink salmon "baseline," containing genetic samples of known origin, relies on a reference DNA dataset comprising tissue samples collected from spawning grounds since 1987. This genetic baseline includes 19 rivers from the Fraser region, 19 rivers from B.C. South Coast, and 15 rivers from the Washington region (Table 1). Samples from mixed-stock fisheries in marine areas are assigned probabilities of belonging to one of these three regional stock groups based on how similar they are to known-origin baseline samples collected on spawning grounds (Table 2). This has been done using the program ONCOR via conditional maximum likelihood and bootstrapping 100 times to obtain a 95% confidence interval (Kalinowski et al. 2007). A typical collection in an analysis comprises around 85-95 pink salmon individuals.

Table 1. Pink salmon DNA baseline from B.C. South Coast, Fraser and Washington regional stock groups.

B.C. South Coast		Fraser		Washington	
East Coast Vancouver Island	Adam_R	Lower Fraser	Chilliwack	Hood Canal	Hood_Canal
	Big_Qualicum_R		Chehalis_R		Dosewallips_R
	Cluxewe_R		Harrison_R		Duckabush_R
	Keogh_R		Weaver_Cr		Hamma_Hamma_R
	Nanaimo_R		Coquihalla_R		Dungeness_R
	Oyster_R		Fraser_R		Elwha_R
	Puntledge_R	Upper Fraser	South_Thompson	North Puget	Nooksack_R
	Quatse_R		Little_R		Skagit_R
	Quinsam_R		Nicola_R		Snohomish_R
	Salmon_R		North_Thompson_R		Stillaguamish_R
Southern mainland	Kakweiken_R		Thompson_R		Nisqually_R
	Glendale_R		Louis_Cr		Green_R
	Lull_Cr		Upper_Fraser_Tribs		Puyallup_R
	Ahta_Cr		Bridge_R		Skokomish_R
	Phillips_Heydon		Cayoosh_Cr		Union_R
	Indian_R		Gates_Cr		
	Klinaklini_R		Nahatlatch_R		
	Squamish_R		Portage_Cr		
	Wakeman_R		Seton_Cr		

Table 2. Example ONCOR output of stock composition estimates for the three regional stock groups based on a sample of 100 fish caught in Area 12 purse seine test fishery on Aug 14, 2023.

Regional Stock Groups	Mean proportion	95% Confidence Interval
Washington	0.25	(0.13, 0.39)
Fraser	0.24	(0.11, 0.36)
B.C. South Coast	0.51	(0.37, 0.62)

To predict regional stock proportions, a given year's in-season DNA results (Table 2) are used in combination with historical pink stock proportion estimates. In general, proportions of Fraser pink salmon in marine areas increase throughout August (Figure 1). The temporal trend in these data is used to inform stock prediction models to predict Fraser pink salmon proportions. Only proportions based on microsatellite data from 2009 onwards are used to inform the predictive model (2007, a trial year, is excluded).

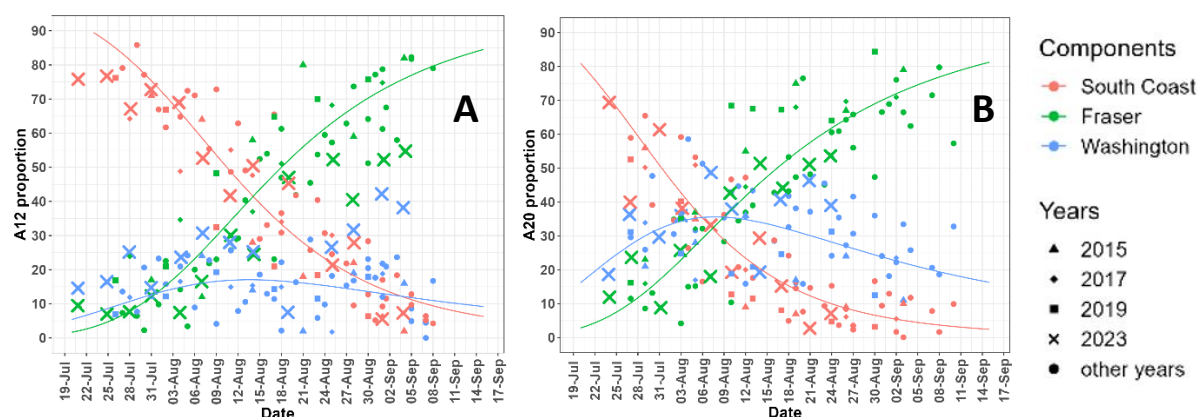


Figure 1. Genetic results for Area 12 (A) and Area 20 (B) across the summer for each odd year from 2009-2023. The date represents the day fish were caught. The points represent regional stock proportions from GSI while the lines in the plots represent trends in the data (i.e., a multinomial regression model fit).

Methods

To estimate Fraser pink salmon proportions in-season, both the in-season data and historical trends in stock proportion estimates are used. A Bayesian multinomial logistic regression model predicts the change in regional stock groups over time, which is assumed to be a linear function (at the logarithmic scale) of the observed stock composition (Albert and Chib 1993). The multinomial distribution is used to represent the proportions of the three regional stocks, while the Bayesian framework combines prior information and new observations to make future predictions for each day (within the year of interest). In the prediction model, the prior information comprises daily stock proportion estimates from previous years, while new in-season GSI samples are used to update the model. The model is fitted to the stock composition samples of each fisheries management area separately, i.e., Areas 12, 13, 20, 7, 7A. The model is run using WinBUGS software and is implemented through the statistical application R (Lunn et al. 2000).

While samples from Areas 12 and 20 are expected to comprise higher proportions of B.C. South Coast and Washington stocks, respectively, differences between proximal areas within the same migratory route are less clear, e.g., Area 7 and Area 7A. Thus, a retrospective analysis was conducted to examine the benefit of using samples from one area to predict proportions of a nearby area. This work concluded

that new Area 12 samples could be used to predict Area 13 stock proportions by linear regression, whereas Area 20 samples should not be used to predict stock proportions in Areas 7 and 7A (Latham 2023, unpublished). For Areas 7 and 7A, the Bayesian prior should be assumed until samples from these areas become available to update stock proportions in the model; new Area 7 and 7A samples may be used interchangeably for model predictions when samples are scarce (Latham 2023, unpublished).

Results

Stock proportion estimates for each regional group are generated by the prediction models for Areas 12, 13, 20, 7 and 7A. Model output of Fraser proportions in Areas 12 and 20 are shown in Figure 2, where the stock proportion predicted for each date is represented by a boxplot. Uncertainty in predictions, reflected in the interquartile range of each boxplot, becomes reduced when more genetic samples are acquired throughout the season. Daily predicted median estimates are used to apportion pink salmon catch and marine abundance estimates of pink salmon to reconstruct the Fraser pink salmon run (Chapter B14). All pink salmon within the Fraser River are assumed to originate from Fraser River spawning grounds when accounting for catch and escapement and conducting run reconstructions.

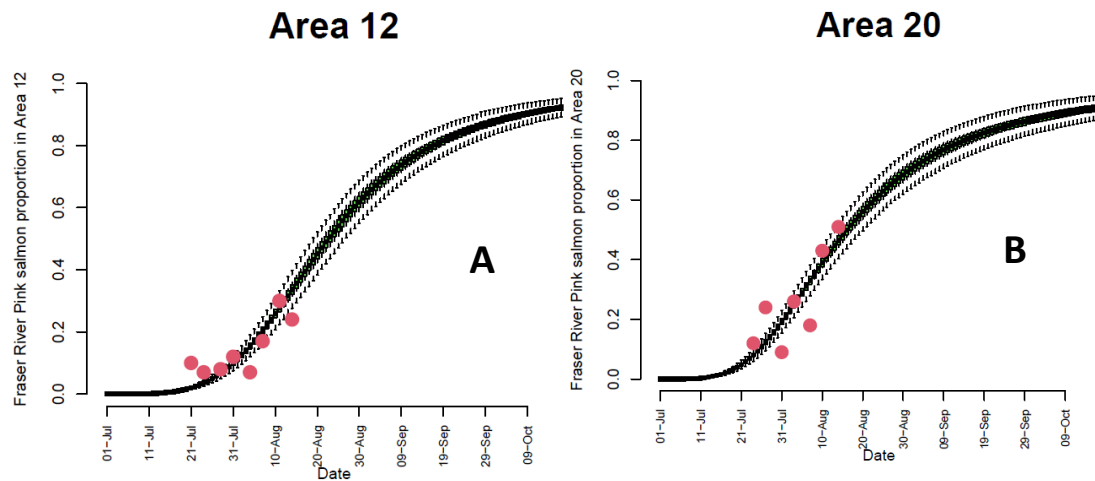


Figure 2. Sample estimates and predicted proportions of Fraser River pink salmon as of August 17, 2023, in Area 12 (A) and Area 20 (B). The red points are the observations used to update the model while the curve comprises boxplots of daily predictions (representing the posterior model output). Boxes show the interquartile range, and the whiskers show an additional 1.5x of the interquartile range.

Planned changes and potential areas for improvement

Additional spawning ground samples were recently collected to improve the pink salmon DNA baseline, but only small improvements in assignment accuracy were detected (Phung et al. 2022). Rondeau and Rycroft (2023) assessed the use of SNPs instead of microsatellites for pink salmon GSI and found that improved individual assignment accuracy was possible with a new baseline of 500 SNP loci. The SNP method employed by Rondeau and Rycroft (2023) would require more processing time at the MGL, but the impact of this on the Fraser Panel's in-season pink salmon assessments is minor. This is because fitted model predictions of pink salmon stock proportions are preferred to the results of highly variable direct samples, and because the fitted model reduces reliance on uncertain most-recent results during in-season fisheries management. Funding has been secured to compare SNP and microsatellite results for fishery samples, to evaluate a switch from ONCOR to rubias analytical software (to facilitate greater

standardization among genetics laboratories), and to examine how historical and future genetic results can be integrated into stock composition prediction models across different methods.

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B8. Estimation of daily salmon passage at Mission

J. Maguire, C.R. Lagasse and Y. Xie

Summary

The PSC operates a hydroacoustic site near Mission, BC, that provides daily estimates of salmon passage in the Fraser River throughout the summer. When used in combination with daily species composition estimates ([Chapter B13](#)), these estimates contribute to in-season assessments by providing daily sockeye and pink salmon abundance information for run reconstructions ([Chapter B14](#)) and predictions of Fraser sockeye and pink salmon escapement to the spawning grounds. To sample the entire width of the river, a configuration of multiple ARIS imaging sonar systems is operated at the site, including two shore-based sonars ([Chapter B9](#)) and a mobile, downward looking sonar ([Chapter B10](#)). The cross-river location of each sonar and its observed fish targets are determined based on GPS coordinates and then input into a flux estimation model to determine the total daily salmon passage.

Introduction

Accurate estimates of daily migration abundance are an integral component of in-season assessments of Fraser sockeye and pink salmon. Hydroacoustic monitoring provides a non-invasive, continuous means of monitoring fish migration that is widely used by fisheries agencies for assessing salmon populations. The PSC (and its predecessor the IPFSC) have operated a hydroacoustics monitoring facility on the lower Fraser River every summer since 1977 to assess upstream passage of sockeye and pink salmon starting in 2009. By providing accurate and timely estimates of passage, information from the PSC hydroacoustics site contributes to in-season run reconstructions ([Chapter B14](#)) of Fraser sockeye and pink salmon runs and predictions of Fraser sockeye and pink salmon escapement to the spawning grounds.

The PSC hydroacoustics site is located two kilometres upstream of the Mission Railway Bridge and approximately 80 kilometres from the mouth of the Fraser River (Figure 1). This location was originally selected because it is just above the commercial fishing boundary and almost all sockeye populations migrate past it on their upstream migration (with the exception of Pitt River and Widgeon sockeye). The river is approximately 400 metres wide at the site and influenced by tidal changes in water height.

Due to the large width of the river, a combination of three hydroacoustic systems are deployed to monitor the salmon migration at Mission (Figure): two ARIS imaging sonars to monitor the nearshore (40 metres) left and right bank and a mobile, downward looking ARIS imaging sonar to monitor the remaining offshore region. To produce a daily estimate of salmon passage, the data collected by each hydroacoustic system is processed, analyzed and inputted into a flux estimation model. This report describes the sonar sampling design based on a configuration of multiple sonars and the abundance estimation process at the Mission site.

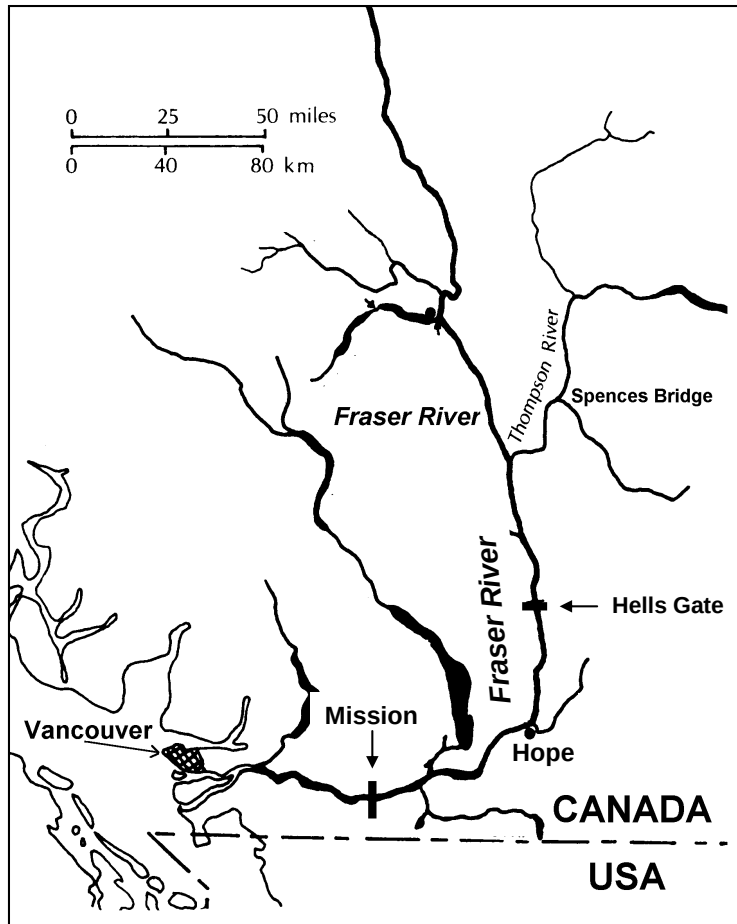


Figure 1. Map of the Lower Fraser River indicating the Mission hydroacoustics monitoring site.

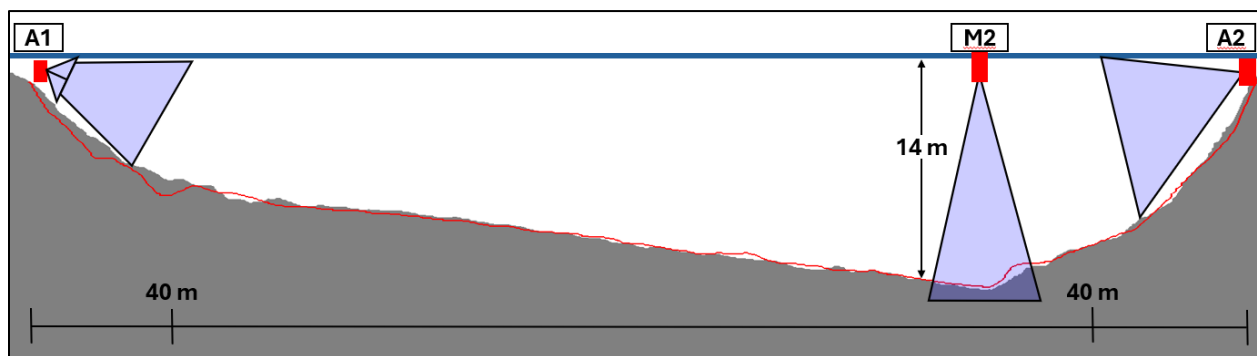


Figure 2. Cross-river view of the sampling geometry of the sonar systems operated at the Mission hydroacoustics site. The three systems shown are the left bank ARIS (A1, covering 0 to 40m), the mobile ARIS (M2, covering the offshore area), and the right bank ARIS (A2, covering final 40m). The offshore area is the total range between the 40-metre marks. The approximate beam geometries of the systems are represented by the shaded triangles. The gray filled area represents the river bottom. Note that the cross-river range scale on the x-axis is compressed relative to the vertical depth scale on the y-axis.

Data

Due to the large channel width at Mission, a combination of three hydroacoustic systems are deployed to adequately monitor the salmon migration (Figure 2). The nearshore areas (40 metres closest to shore) are monitored using ARIS 1800 imaging sonars ([Chapter B9](#)). The nearshore left bank area, where most of the upstream migration typically occurs, is the key focus of monitoring efforts at Mission, while the nearshore right bank area typically observes less than 20% of the daily upstream salmon migration. Both systems are mounted at the end of fish deflection weirs to prevent any salmon passage from occurring behind the system. Each hour, the right bank ARIS system systematically records fish passage for 15 minutes in each of the four 10-metre range bins. In the first left bank range bin from 0 to 10 metres, two ARIS aims are needed to sample the entire water column due to the shape of the nearshore river bottom on the left bank ([Chapter B9](#)). Accounting for the additional aim in the first 10 metres, the left bank ARIS system systematically records fish passage for 10 minutes each hour for each of the five stratified spaces. In addition to abundance information, the ARIS systems on both the left and right bank also provide estimates of salmon species composition based on acoustically observed fish lengths using a mixture model ([Chapter B12](#)). The remaining offshore region is monitored by a mobile, downward looking ARIS 3000 imaging sonar deployed from a sampling vessel that transects the river about 180 to 200 times per day ([Chapter B10](#)).

All the ARIS systems operated at the Mission hydroacoustics site sample throughout the day and night with the shore-based systems operating continuously for 24 hours a day. Assuming there are no gaps in data collection, each estimate of daily salmon passage is based on 24 hours of monitoring data. When unforeseen data gaps do occur, an imputation process is used to fill them ([Chapter B11](#)). To group each day and night period into the same assessment interval, the daily estimates do not coincide with calendar days but instead begin at 05:00 each day. For example, the estimate of daily salmon passage at Mission for July 4 would include data beginning at 05:00 on July 4 and continuing to 04:59 on July 5.

Methods

To determine salmon passage across the entire river channel at the Mission hydroacoustics site, the passage estimates from the three monitoring systems (left bank ARIS, A1; mobile ARIS, M2; and right bank ARIS, A2) must be combined. To accomplish this, the cross-river width is divided into 5-metre range bins, then for each range bin, the salmon passage from a single monitoring system is applied. The range bins sampled by each system are determined from their GPS location along with their sampling range and compass bearing. These sampling areas are updated throughout the field season as the river levels drop and the systems are moved further offshore. The analysis of the positioning, selection, and addition of sonar system configurations for the daily estimate are completed using the Flux Estimator software developed by the PSC (Lagasse 2019).

If a range bin is sampled by multiple systems, only the most accurate system is used for the salmon passage estimate, while other estimates are excluded to avoid double-counting. Estimates from shore-based systems are preferred over mobile estimates due to their higher sampling intensity and greater precision.

Data collected by each of the systems is reviewed and processed by 8:30 am every morning by PSC staff throughout the field season to generate the estimate of salmon passage for the previous day. Summary statistics are calculated for the daily estimate of salmon passage including the ratio of fish travelling downstream (A1/M2 Ratio downstream, Rd), the fish speed, the proportion of daily passage observed by each sonar system, the percentage of passage extrapolated in unsampled areas, the number of transects performed by the mobile sampling vessel and the number of daily targets observed by the

mobile vessel (Table 1). The summary statistics also include total salmon estimates based on alternative system configurations (e.g., M2 and A1+M2). Once the daily estimate of total salmon passage is published, the species composition of salmon ([Chapter B13](#)) is estimated to determine the daily passage of sockeye and pink salmon past Mission.

Results

The distribution of salmon passage across the river channel tends to change throughout a season depending on river flows, species composition, tidal fluxes, and other factors. River flows and turbidity are higher in July than August or September, and a greater proportion of the migration occurs in the offshore areas observed by the mobile system. As flows decrease, the tidal influence on water heights increases and fish passage becomes more concentrated along the shorelines (Table 1). During odd-numbered years when pink salmon return to the Fraser River, migration past the Mission hydroacoustics site is highly concentrated in near-shore areas, with less than 10% of daily passage observed in offshore regions.

Table 1. Summary statistics for the estimate of daily salmon passage using August 12, 2024 as an example. JD is the Julian calendar date.

Mission Date	JD	A1 Flux Proportion	Mobile Flux Proportion	A2 Flux Proportion	Total Salmon Official	Lower 95% CI	Upper 95% CI	Systems For Estimate																																								
Aug 12, 2024	225	41%	51%	8%	16,618	14,665	18,758	A1+M2+A2																																								
<table><tr><th colspan="4">Total Salmon Estimates by Sonar Configuration</th></tr><tr><th>A1+M2+A2</th><th>A1+M2</th><th>M2</th><th>Imputation</th></tr><tr><td>16,618</td><td>13,607</td><td>9,992</td><td>N/A</td></tr><tr><td colspan="4">Other statistics:</td></tr><tr><th colspan="3">Downstream Ratios</th><th>Expansion</th></tr><tr><th>A1</th><th>A2</th><th>M2</th><th>A1</th></tr><tr><td>6%</td><td>7%</td><td>6%</td><td>3%</td></tr><tr><th colspan="4">Data Collected</th></tr><tr><th>Hours A1</th><th>Hours A2</th><th>Transects M2</th><th>Targets M2</th></tr><tr><td>24</td><td>24</td><td>95</td><td>75</td></tr></table>									Total Salmon Estimates by Sonar Configuration				A1+M2+A2	A1+M2	M2	Imputation	16,618	13,607	9,992	N/A	Other statistics:				Downstream Ratios			Expansion	A1	A2	M2	A1	6%	7%	6%	3%	Data Collected				Hours A1	Hours A2	Transects M2	Targets M2	24	24	95	75
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Planned Changes and Potential Areas for Improvement

The PSC Flux Estimator program has been re-coded to the R coding language. It includes the same core calculations with updated features. Beginning in 2025, this new program will be run alongside the original Flux Estimator program to produce daily estimates.

PSC staff are investigating the use of multiple automation methods to facilitate automation of the daily estimate (e.g., Echoview, machine learning). In the future, portions of the estimate may be calculated from automated processes.

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B9. Shore-based imaging sonar systems

J.L. Nelitz and R.L. Hornsby

Summary

Imaging sonar technology, such as the ARIS system, provide visually intuitive data used by the PSC hydroacoustic program to estimate salmon abundance and species composition in the Fraser River. This technology has been utilized officially at the Mission hydroacoustics monitoring site since 2009. This document outlines the deployment, sampling design, and fish counting methods for the imaging data generated by the Sound Metrics ARIS 1800 system as it is currently used by the hydroacoustics program.

Introduction

The Pacific Salmon Commission (PSC) hydroacoustics program has been enumerating adult salmon passage through the lower Fraser River at Mission since 1977. Over the history of the site, various technologies have been tested and adopted to improve the accuracy of salmon passage estimates ([Chapter B8](#)). The ARIS imaging sonar systems deployed on both the right and left bank are the official shore-based systems in use and capture approximately 60-80% of the total daily salmon passage (Conrad et al. 2019). Past shore-based hydroacoustic configurations and set ups can be found in Michielsens and Martens (2022). A downward looking ARIS system on a vessel continuously transecting the river has been used to assess the fish passage in the mid-section of the river ([Chapter B10](#)). This mobile system was adopted as the official offshore abundance estimator during the 2023 season, following two years of testing (Xie et al. 2024). This document focuses on the side looking ARIS data collection and counting methodology used to produce nearshore abundance estimates.

Method

SYSTEM DEPLOYMENT AND DATA COLLECTION

The PSC Mission hydroacoustic site is located 80 km upstream from the mouth of the Fraser River where the maximum width of the river is approximately 400 m, and the maximum depth varies from 13 to 20 metres depending on discharge levels. The site is operational during the sockeye and pink salmon migration periods, generally from early July to September or October each year. The shore-based data collection occurs on the left bank field site, which houses the majority of the field site equipment, and the right bank field site, directly across the river from the left bank site.

Right bank

The right bank field site is an off-grid location, powered by a battery bank which is charged by solar and gas-generator power. The ARIS system is mounted with a pole-mount to an aluminum cross arm attached to the end of a telescopic fish weir (Enzenhofer and Cronkite 2005). Fully deployed, the fish weir extends 20 m from the riverbank. The river profile on the right bank has a gradual downward slope which is ensonified by an ARIS 1800 unit using one vertical aim, varying between -2° to -5° depending on water levels, to a maximum range of 40 m. The aim is split into four 10-meter range bins (Figure 1) and the ARIS system is programmed to monitor fish passage in each range bin for 15 minutes per hour, 24 hours per day. The resulting files are transferred wirelessly to the left bank trailer for on-site processing.

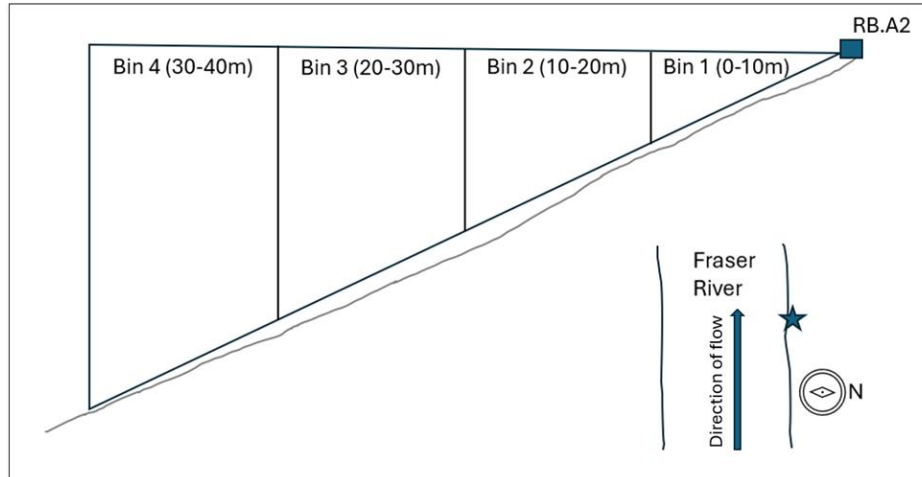


Figure 1. Side-view diagram of the right bank ARIS sampling scheme at Mission, BC. The right bank aim is split into four 10-meter range bins, which are each monitored for 15 minutes every hour.

Left bank

As much as 80% of the daily salmon passage is monitored on the left bank using an ARIS 1800 imaging sonar mounted to the end of a large fish weir. The ARIS system covers a total range of 40 m from the left bank. Due to the semi-convex shape of the nearshore river bottom on the left bank and the limited vertical beam-width of the imaging sonar, the ARIS system requires two vertical aims (approximately -15° , 0° depending on system deployment and water height) to sample the entire water column in the first range bin of 0-10 m (Figure 2). These two nearshore aims are configured to minimise “blind areas” near the river bottom and upper water column and allow to assess high salmon passage close to shore. The three farther range bins (10-40 m) are sampled using a single aim (approximately -4°) as the vertical beam width of the ARIS system can adequately cover the water column at those ranges. Each aim and range bin is sampled individually on a systematic hourly sampling schedule. Fish passage in each of the stratified spaces is monitored for 10 minutes every hour, 24 hours per day.

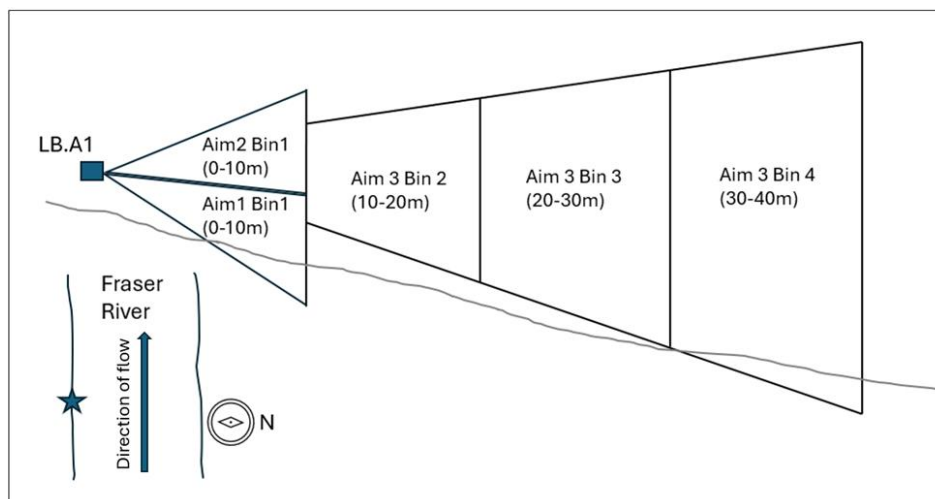


Figure 2. Side-view diagram of the left bank ARIS sampling scheme at Mission, BC. The left bank aim is split into five stratified aim/range bins, which are each monitored for 10 minutes every hour.

DATA PROCESSING

Counting Procedures

The ARIS data are collected hourly, and each aim/range bin is either sampled for 10 or 15 minutes per hour depending on location (Figure 1 and 2). The files are uploaded to the central processing computer where fish targets within the files are counted by hydroacoustics staff using the ARISFish software specifically designed by Sound Metrics for post-processing of ARIS data. The staff members count upstream and downstream fish targets $\geq 35\text{cm}$ with tally counters for the first 5 minutes of each file. The coefficient of variation (CV) associated with the resulting hourly fish count estimates is 6.5% (Xie and Martens, 2014). It is possible to count 10 minutes of each recording, but the gain in precision is minor (CV of 5.5%) and is not time efficient. During low abundance scenarios, the playback framerate of the sonar files can be increased to complete the counts faster. When passage rates increase, it becomes challenging to count the files in real time, so the framerate is decreased to ensure the counts are accurate.

To verify counts, a subset of files is chosen to be recounted. There are three approaches for choosing files to recount: 1) in season, a random number generator is used to select 3 hours per 8-hour time periods for each configuration (up to 9 files per configuration/day), 2) specific files from hours or days that seem misaligned with a secondary system covering the same area at Mission or misaligned with Qualark estimates, and 3) specific files covering the periods when abundances or environmental conditions change dramatically, i.e., at the start of peak pink migration or during large tidal swings. In season, the number of files recounted is subject to time availability. Post-season, additional files may be recounted to fill in gaps or to further explore misalignments (method 2). Typically, counts that deviate by less than 10% from the recounts are acceptable, except when abundances are extremely low, e.g., 1-2 fish in a file. If a recount differs by more than 10% from the original count, a third counter may be used to determine which count is correct. Counts and recounts are typically evaluated for outliers using 1:1 plots and evaluated across the season through basic frequentist statistical tests.

Length Measurement Procedures

PSC staff measure sonar lengths for the first 20 fish $\geq 35\text{cm}$ within each file during every 3rd hour (5 am, 8 am, 11 am, 2 pm, 5 pm, 8 pm, 11 pm, 2 am) in the stratified areas covering the 30m closest to shore. Due to beam spreading and intra-frame motion artifact at the far range, lengths from the 20 to 30m range are used to represent the 30 to 40m range. These lengths are used in a length-based mixture model ([Chapter B12](#)) as a method of species composition ([Chapter B13](#)).

Generating an Imaging Sonar Passage Estimate.

Once fish counts are completed for the 24-hour period, a total daily near-shore fish passage estimate for each bank is calculated using the following method:

$$(1) \quad N = \sum_{j=1}^C \frac{24 \times 60 \sum_{i=1}^{n_j} x_{ij} / t_{ij}}{h_j}$$

Where:

- x_{ij} is the count for the i -th period in configuration j , with 4 stratified areas on the right bank and 5 stratified areas on the left bank,
- t_{ij} is the number of minutes counted for the i -th period in configuration j , normally 5 minutes,
- n_j is the total number of available i period counts in a day for configuration j , normally 24 counts,

- h_j is the total number of hours recorded for configuration j , normally the number of hours is the same as the number of counts,
- C is the total number of stratified areas within a configuration, normally 5 on the right bank and 4 on the left bank,
- N is the total abundance for the given bank.

In general, this method converts the 5-minute counts per hour for the different aim/bin ranges to number of fish per day before summing the estimates for the different aim/bin ranges. If the abundance is not recorded for an individual aim/bin for an hour (e.g. during system malfunctions), an average hourly count can still be produced for that aim/bin range and combined with estimates for the other stratified areas. If entire hours are missing across the stratified areas, then a linear or non-linear hourly data imputation ([Chapter B11](#)) is used to fill in the data gap while accounting for heterogeneity in fish passage throughout the day. Once a nearshore abundance estimate is produced for each bank, it is combined with the offshore abundance estimate ([Chapter B10](#)) within the salmon density model to produce a total daily salmon passage estimate for the site ([Chapter B8](#)).

Planned changes and improvements

Multiple aims are used on the left-bank to cover the 0-10m region. However, depending on water heights, approximately 10% of the water column in the 0-20m range remains un-sampled by the ARIS. Currently, a geometric expansion is used to extrapolate counts from the sampled region out to the unsampled underwater region. Work is underway to more accurately extrapolate abundance to the unsampled areas.

As the Mission site is moving towards the automation of salmon counts, the different tools for hydroacoustic data processing are being tested, such as Echoview. This work is in the initial stages, but starting in 2025 this tool will be tested in-season to allow comparisons with manual counts.

Unlike counts, verification of lengths is not a well-defined process. While the length measurement methodology is detailed and repeatable, it is more difficult to conduct large scale repeat length measurements by different staff in-season. Developing a more efficient process for measuring lengths is a priority and automation through Echoview may be an alternative method for large scale verification.

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B10. Offshore salmon passage based on transecting mobile ARIS

J.L. Nelitz and R.L. Hornsby

Summary

At the Mission hydroacoustics site, salmon are known to utilize the full 400m width of the Fraser River for upstream migration. On average between 20 to 40% of the salmon migrate offshore. Offshore abundance may however increase substantially when fisheries take place at the Mission site ([Chapter B11](#)), as well as during periods of high discharge and when salmon tend to mill more, in particular later in the season. As of 2024, salmon migrating more than 40 meters offshore, beyond the range of shore-based sonars, are monitored by a downward looking mobile ARIS 3000 deployed from a transecting vessel. The transect sampling of the river by the mobile ARIS acquires information on fish density and swim direction. This information is combined with shore-based swim speed statistics through a salmon density model to produce daily estimates of offshore salmon passage.

Introduction

The Pacific Salmon Commission (PSC) hydroacoustics program has operated a mobile split-beam system to estimate total fish passage since 1977 (Michielsens and Martens 2022). Since 2004, the focus has been on the estimation of fish passage beyond the range of shore-based sonars ([Chapter B9](#)). Estimating offshore fish passage requires data on fish density, along with behavioural statistics such as fish swim direction and speed. Conrad et al. (2019) highlight several challenges with the mobile split-beam system that introduced biases in the offshore fish passage estimates. These challenges include 1) ambiguous targets and difficulty distinguishing migrating salmon from debris; 2) narrow sampling volume, which amplifies the effect of near-shore vessel avoidance (Xie et al. 2008); and 3) the reliance on fish direction and speed derived from the left-bank sonar, rather than directly observing these metrics in the offshore region. This lack of direct observations increases uncertainty regarding the effects of fishing events on fish behaviour, such as milling or offshore holding.

In recent years, the introduction of the ARIS 3000 (Adaptive Resolution Imaging Sonar) offered a solution to the long-standing challenges associated with the mobile split beam. The ARIS 3000 possesses a large sampling volume compared to the narrow sampling volume of the split-beam (30° vs. 6°). This increases coverage of the mid-river sampling area and may reduce the effect of nearshore vessel avoidance. The ARIS 3000 operates at high frequencies (1.8 or 3.0 MHz) characteristic of imaging sonars and offers the choice between 128 or 64 narrow vertical beams. The resulting high-resolution image allows to easily differentiate targets from debris, to determine fish swim direction and to a certain extent fish swim speed (Xie et al. 2024). In 2023, after two years of experimental data collection and analysis, the mobile ARIS 3000 was officially implemented as the offshore sonar to address the long-standing challenges of offshore estimation at the site.

Data

SYSTEM DEPLOYMENT

The mobile imaging sonar data are collected using a downward looking (-90°) ARIS 3000 housed in a specially designed tow-body mounted on the starboard side of a vessel (Figure 1). The sonar is towed by a vessel that transects the Fraser River every 5-minutes over a 24-hour period, at a speed of approximately 1.33m/s. On average, the vessel completes 180 to 200 transects per day, stopping every 3 hours for shift changes and/or data extraction.

The current tow body has a few limitations when collecting data. First, it cannot operate effectively when discharge levels within the Fraser River are high, as high flows disrupt the tow-body's flight and make it difficult to keep the sonar submerged. This happens at flows greater than 14,000 m³/s at Mission, which occur when discharge at Hells Gate exceeds 9,000 m³/s. These flows also exceed the theoretical threshold for sockeye passage, reducing the concern of missing salmon passage data when discharge levels are this high. Second, special care is required when changing direction at the end of each transect to avoid reducing the tow-body's -90° angle, thereby misplacing targets and exaggerate their depth, leading to calculation errors.

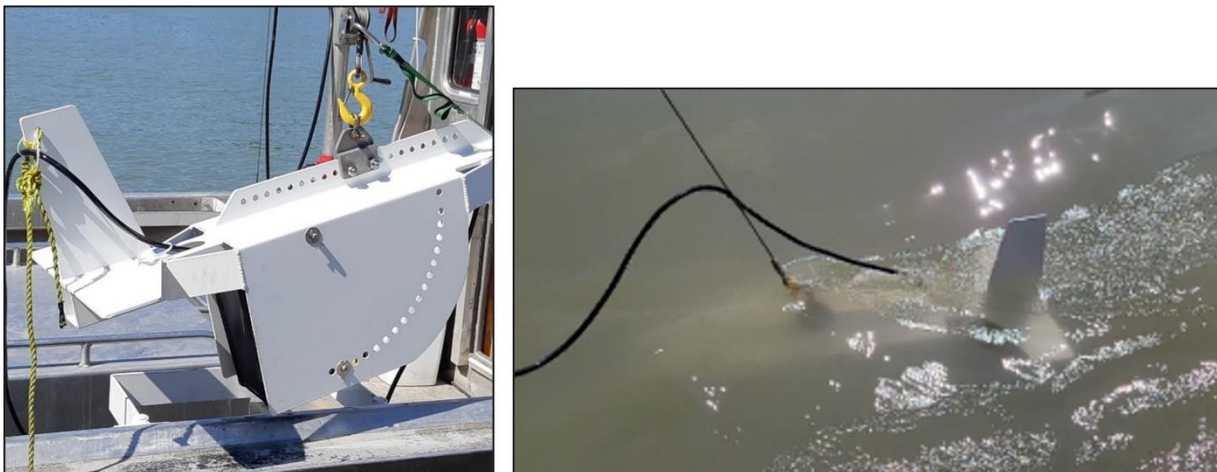


Figure 1. (Left) The tow-body housing the downward looking ARIS 3000 imaging sonar; (Right) the tow-body being towed by the vessel during data collection.

DATA COLLECTION

Obtaining a clear image with minimal intra-frame distortion using the mobile ARIS 3000 depends on two key settings: the number of samples and the frame rate. The frame rate is influenced by both the sampling range and the number of beams used. The ARIS 3000 is capable of utilizing 128 beams to a maximum depth of 20 m; however, achieving an optimal frame rate of 12 fps or higher requires reducing the number of beams to 64 and limiting the depth to a maximum of 15m. The optimal settings for generating a clear, continuous image of targets were determined through testing during the 2021 season and have been consistently applied since then (Table 1). The high number of samples ensures sufficient data for accurate length and speed measurements. Further details on data collection settings can be found in Xie et al. (2024).

Table 1. Optimal settings used when collecting data from the ARIS 3000 imaging sonar.

Depth	Number of beams	Number of samples	Frame rate (fps)
≤15m	64	1500	≥12.0

An external GPS receiver operates alongside the ARIS 3000 and is integrated into the ARIS software to assign GPS coordinates to the vessel transects (10 records per second). Each identified fish target is associated with a latitude and longitude, ensuring accurate placement within the salmon density model. Proper spatial placement of fish targets is essential for eliminating the risk of double counting in nearshore areas where coverage of shore-based and offshore systems overlaps.

DATA PROCESSING

ARIS 3000 data files are viewed using the ARISFish program developed by Sound Metrics. Upon opening the file in ARISFish, the field of view in the imaging sonar window is inverted. Since the mobile ARIS collects data from a down-looking perspective, the sonar footage in the file must be flipped to correct the orientation. Next, an echogram is generated to display the entire file with multiple transects. The echogram also allows for selecting fish targets and determining their direction of travel (Figure 2). Once fish targets are selected, related information, such as target depth, latitude, and longitude, and swim direction, is compiled into an output file.

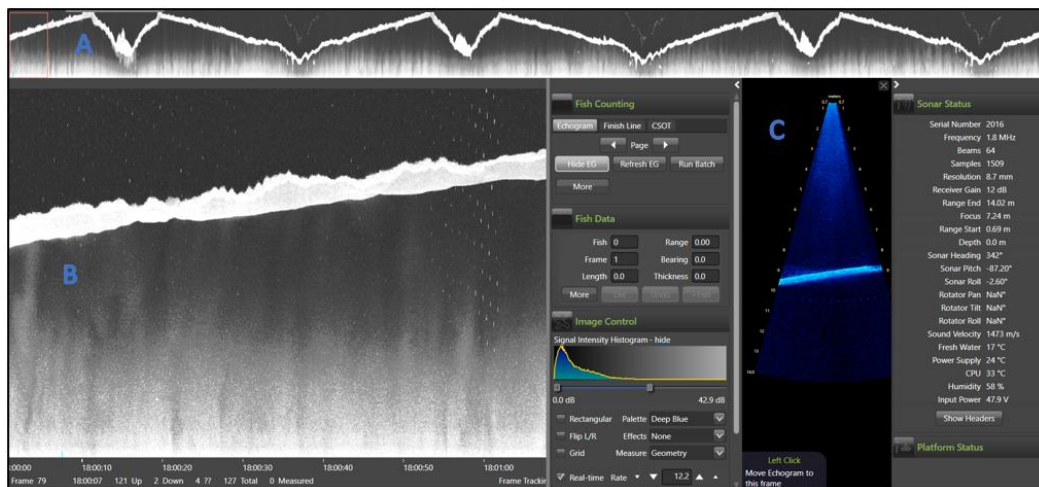


Figure 2. (A) Transect view of entire data file; (B) echogram view; (C) sonar view using ARISFish software.

Method

DETERMINING FISH TARGETS

When analyzing a mobile ARIS file, identifying potential targets involves using the sonar view, echogram view, and transect view of the file (Figure 2). Once an object is located in the echogram, the sonar view is used to confirm whether the object is a fish target, debris or bottom profile feature. If the object is identified to be a fish target, the approximate length is measured by marking the body from nose to tail using the sonar view. Only salmon-sized fish targets greater than 35 cm are counted. Decision metrics for determining whether to classify an object as a salmon target are outlined in Table 2.

Table 2. *Decision metrics for determining whether to classify an object as a salmon.*

Salmon identification metrics	
Necessary metric	- The object has a brighter echo intensity relative to surrounding backgrounds on the echogram view. - The object does not have a repeated presence across multiple transects.
Supportive metrics	- The object shows a 'V' shaped trace on the echogram view. - The side-view shape of the object looks like a fish on the image view, e.g., head, tail, fins can be identified. - The object flexes like a fish when moving.
Sufficient metric	The object's length is salmon-sized, i.e. larger than 35 cm.

DETERMINING FISH SWIM DIRECTION

Fish swim direction can be directly observed from the mobile ARIS and is categorized into one of three groups: upstream, downstream, or undefined. The "undefined" category is used when the direction can not be determined, i.e. when fish move parallel to the transect while milling or holding, or when the vessel is turning nearshore. Both the transect echogram view and sonar image view are necessary to determine swim direction, as the interpretation depends on whether the vessel is transecting from the left bank to the right bank or from right bank to left. If the vessel is travelling left to right bank, then upstream fish will travel right to left through the sonar image view (Figure 3A). While if the vessel is travelling right to left bank, then upstream fish will travel left to right through the sonar image view (Figure 3B). Once a fish target is identified using the salmon identification metrics (Table 2) and assigned a swim direction, it is selected (Figure 3C). The resulting data for all selected salmon include count and swim direction information. The summary of these data is exported into text files.

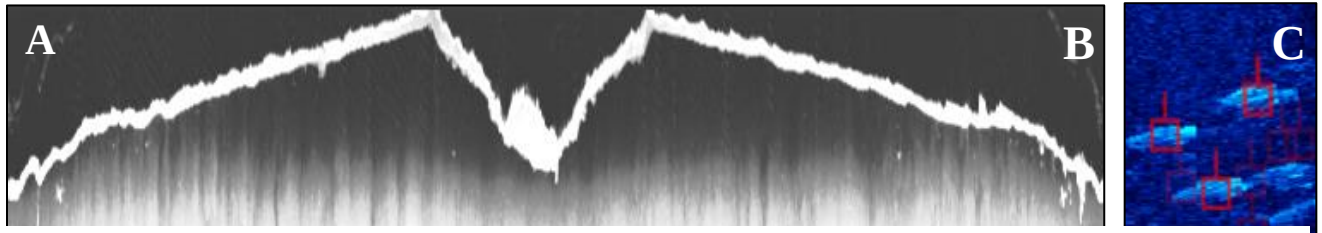


Figure 3. (A) Vessel travelling from left to right bank; (B) vessel travelling from right to left bank; (C) selecting fish and direction of travel (red-upstream; green-downstream; yellow-undefined).

DETERMINING OFFSHORE SALMON PASSAGE

A salmon density model is used to calculate daily offshore salmon passage. The model currently uses two main sources of information: the daily number of salmon migrating upstream as well as downstream in the offshore area, and both upstream and downstream swim speeds from the left-bank sonar. Mobile ARIS count data are imported into the PSC Flux Estimator program along with associated GPS information allowing the cross-river spatial distribution of the fish to be plotted (Figure 4). To derive the total daily abundance in the offshore area, the offshore salmon density data are summarized in individual 5 x 1m cells. Passage from individual cells is summed to create a net daily upstream passage for the offshore region. As shown in Xie et al. (2005), the daily salmon passage in each cell can be calculated by combining salmon count density data with behavioural statistics of swim direction and speed using the following formula:

$$p = \frac{m_T v_u}{L} \left[1 - \left(1 - \frac{v_d}{v_u} \right) \cdot \left[\frac{n_d}{n_d + n_u \cdot v_d/v_u} \right] \cdot \left[1 - 2 \frac{n_d}{n_d + n_u} \right] \right]$$

Where:

- L is the full-width of the sound-beam at mean depth of the cell,
- m_T is the mean number of salmon detected per transect at the cell over a 24-hr sampling period by the mobile ARIS system,
- v_d is the mean downstream speed of salmon detected by the left-bank sonar,
- v_u is the mean upstream speed of salmon detected by the left-bank sonar,
- n_d is the total number of downstream salmon detected by the mobile ARIS over the 24-hr sampling period,
- n_u is the total number of upstream salmon detected by the mobile ARIS over the 24-hr sampling period, and
- p is the salmon passage for the individual cell

This is the same formula applied previously for the mobile split-beam, with the improvement of obtaining the upstream and downstream swim directions directly from the offshore area through the mobile ARIS, rather than the left-bank sonar.

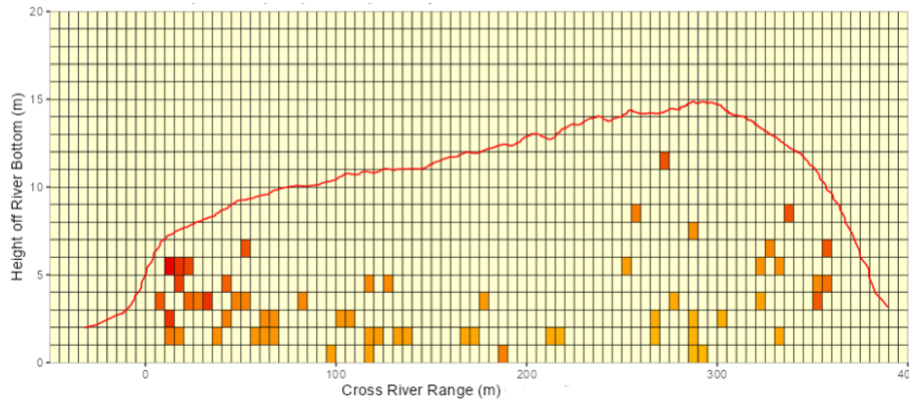


Figure 4. A plot of July 31, 2024 hourly cross-river salmon passage: number of fish migrating upstream through individual cells (5m horizontal by 1m vertical) per hour with darker coloured cells representing a higher number of fish migrating upstream. The total passage estimated by the mobile system for this day is 476 fish/hour. Note: the passage data is displayed in the plot using the river bottom as the vertical reference so that the flat surface waterline is transformed to a curvy line (the red line), which mirrors the river bottom.

Planned Changes and Improvements

There are two key changes planned for the offshore estimation related to model inputs:

- 1) **Source of speed data:** Currently, the left-bank sonar provides the mean upstream and downstream speeds used in the salmon density model. This approach assumes that swim speeds are statistically similar between the left-bank nearshore and the offshore region. Recent work by Xie et al. (2024) has demonstrated that swim speeds can be directly observed in the offshore by using the mobile ARIS, with adjustments made using the left-bank swim speed data

to account for vessel motion. Although in season time constraints have previously hindered the implementation of offshore mobile ARIS speeds, efforts have been made to integrate this process into the in-season workflow. We plan to test the use of offshore speeds during the 2025 season.

- 2) **Stratified offshore swim speed and swim direction:** Currently it is assumed that ratios of upstream to downstream salmon migration and upstream and downstream speeds are uniform across the entire offshore area. However, as demonstrated by Xie et al. (2007), fish behaviour can vary significantly across the river, from left-bank to right-bank. To address this, work is underway to modify the Flux Estimator program, enabling each 5 x 1m cell to have its own directly observed up/down swim speeds and up/down swim direction ratio.

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B11. Imputation of abundance during fishing periods

K.M. Hayward

Summary

The estimation of daily salmon abundance at the PSC Mission hydroacoustics site assumes that 24 hours of monitoring have occurred. However, any fishing activity within site boundaries results in temporary cessation of offshore data collection and could introduce biases in abundance estimation by impacting fish behaviour. As of 2022, the Mission Imputation Protocol has enabled the PSC to address data quality concerns by interpolating data that are impacted by fishing activity. Customized R scripts are used to produce the Mission Imputation Report, which documents options (linear or non-linear) for imputation of sonar-specific daily abundances, results of each potential method, and relevant information for decision-making. Using the report and applied knowledge, PSC biologists select an imputation approach for each sonar system. On average, percent error associated with imputed estimates of daily salmon abundance is less than half the error of simpler interpolations, such as use of daily averages or assuming the previous day's abundance. The resulting imputation method can also be applied to fill in missing data due to other causes, e.g., when systems are moved, during system malfunctions.

Introduction

The Mission hydroacoustics site uses three sonar systems to monitor salmon abundance: one ARIS for each nearshore area and one mobile, downward looking ARIS for the offshore region ([Chapter B8](#)). Estimates of daily abundance from each area assume that 24 hours of monitoring data are available. However, data gaps may occur due to technical issues (e.g. relocation of systems due to changing water heights, system malfunctions, vessel mechanical issues), or safety concerns (e.g. docking of the mobile transecting vessel due to weather). If less than 24 hours of data are available, an imputation of missing data is required.

In 2022, Semá:th First Nation, DFO, and the PSC signed a memorandum of understanding that exempts Semá:th Food, Social, and Ceremonial (FSC) driftnet fisheries from fishing boundary closures at the PSC Mission hydroacoustic site (Semá:th, DFO, and PSC 2022). This operational protocol stipulates that the PSC will cease mobile transecting during FSC fisheries, in order to respect Semá:th First Nation's inherent rights and allow fishing to occur safely. Cessation of transecting, however, creates data gaps that violate the assumption of 24-hour monitoring in the site's offshore region. In addition, fish behavioural responses (e.g., milling, holding, altered cross river distributions) during and directly after fisheries can introduce bias to both shore- and mobile-based estimates (Conrad et al. 2019).

The Mission Imputation Protocol aims to mitigate these concerns and improve quality of daily abundance estimates for days with FSC fishing at the Mission site. Development of the imputation involved a retrospective analysis, which compared daily salmon abundance estimates obtained by imputing artificial and historical fishing data gaps to corresponding, original daily estimates from both Qualark and Mission. As of 2022, the resulting imputation procedure has been implemented as needed during in-season monitoring. On days that FSC fisheries occur (or data gaps are otherwise produced),

the imputation is performed once system-specific data have been processed and the standard procedures for abundance estimation based on available data has already occurred ([Chapter B8](#)).

Methods

INTERPOLATIONS

The Mission imputation provides two options for interpolating data: one linear and one non-linear method. Both approaches use data from non-imputation hours (i.e. data from outside of the data gap for a given day) to “fill” in or impute salmon abundance during the data gap for a target day (Figure 1a). For both methods of interpolation, the abundance from non-imputation hours (n_t) and interpolated abundance from imputation hours (i_t) are recombined to provide a daily estimate of total salmon abundance (N_t) on the target day:

$$(1) \quad N_t = i_t + n_t.$$

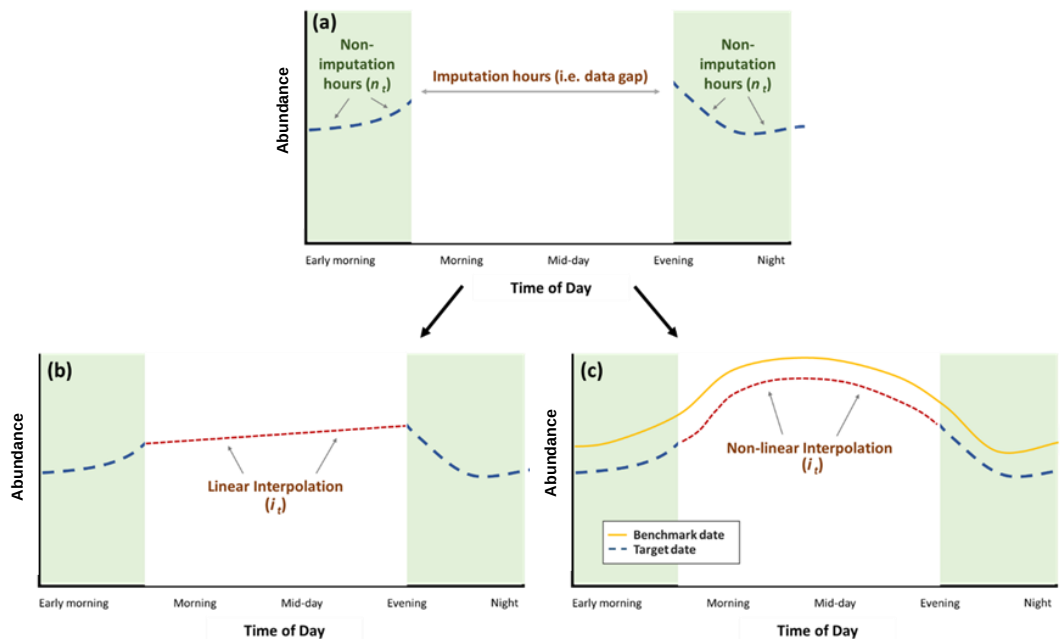


Figure 1. The Mission Imputation is required when a “target day” has a data gap i.e., consists of non-imputation and imputation-required hours (a). There are two methods to interpolate missing hourly abundance data: (b) a linear interpolation that linearly approximates between the hours directly before and after a data gap, and (c) a non-linear interpolation that applies the ratio between salmon abundance during non-imputation (n_t) and imputation (i_t) hours from a previous benchmark day to the target day.

How the abundance during the hours with missing data (i_t) is estimated differs between the two interpolation methods. The linear method performs a simple linear approximation to connect abundance immediately before and after a data gap (Figure 1b). In contrast, the non-linear approach requires data from a previous day (typically one directly preceding a target day) to be used as a ‘benchmark’ (Figure 1c), and assumes that hourly abundance patterns on benchmark and target days will be similar due to daily tidal patterns. A benchmark day is selected based on proximity to the target day and absence of data continuity or quality concerns (e.g., due to fishing, system moves). To perform

the non-linear interpolation, data from the benchmark day are designated into imputation (i_b) and non-imputation (n_b) hours to mirror the target day (Figure 2).

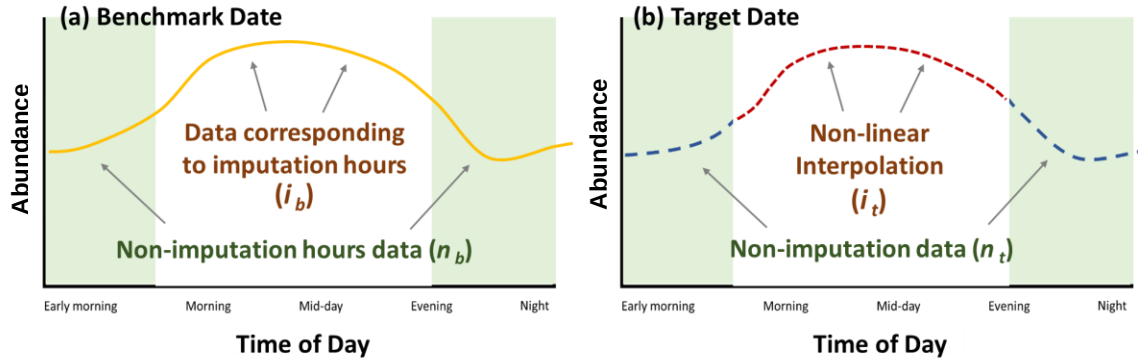


Figure 2. The non-linear imputation involves: (a) splitting benchmark day data into imputation (i_b) and non-imputation (n_b) hours, which are coincident with (b) a data gap (imputation hours, i_t) and available data (non-imputation hours, n_t) from the target day, respectively.

Based solely on benchmark day data, a ratio of salmon abundance during imputation (i_b) to non-imputation hours (n_b) is calculated. This ratio is then applied to non-imputation data (n_t) from the target day to interpolate abundance for the target day's imputation hours (i_t):

$$(2) \quad i_t = \left(\frac{i_b}{n_b} \right) n_t .$$

Combining Equations 1 and 2, the daily abundance for a target day using the non-linear imputation is:

$$(3) \quad N_t = \left(\frac{i_b}{n_b} \right) n_t + n_t .$$

RETROSPECTIVE PERFORMANCE

To test the performance of the interpolation methods prior to in-season implementation, a retrospective analysis using a four-year dataset (2018-2021) was conducted (Bzonek and Hornsby, 2022). Linear and non-linear methods were applied to: (1) artificially simulated fisheries, produced by removal of offshore data from non-fishing days, and (2) historical fishing days. Evaluations also explored impact of fishery length (simulated or historical) and consecutive fishing days on the performance of the imputation methods. Performance was assessed by comparing imputed daily abundance estimates to corresponding, non-imputed (original) estimates from both Mission and Qualark.

Applying the imputation to simulated and historical fisheries reduced daily estimates by 1.5% and 0.4% over full seasons, respectively. Overall, the imputation brought Mission- and Qualark-based abundance estimates 1% closer (Bzonek and Hornsby, 2022). Imputed Mission abundance estimates specifically had an unweighted average bias of -4%, with bias being slightly larger for linear (-5%) than non-linear interpolations (-3%) and the linear bias being more pronounced during high and very high abundance days. Relative to simpler interpolation methods such as using daily averages or assuming the previous day's abundance, imputed Mission estimates displayed half the percent error compared to the simpler methods.

Both linear and non-linear interpolation methods show relatively low bias when applied to short fisheries openings (<10 hours). However, the performance of the linear method is negatively impacted by long fisheries (10 hours+). Linear interpolations significantly underestimate abundance during long fisheries, which is likely due to smoothing over daily, tidal-related patterns of salmon migration. In contrast, performance of the non-linear method was affected by consecutive days of fishing. As the

relevance of the benchmark day to the target day decreases with more days in between, consecutive fishing days result in larger potential error. To reduce error, the PSC has recommended shortening fisheries openings, particularly on a third day of consecutive fishing, to enable use of the linear method. Overall, these findings have informed a default preference for the linear method during short and medium-length fisheries and the non-linear method during long fisheries and high abundances (with an exception in the case of consecutive fishing).

IN-SEASON APPLICATION

For days requiring imputation, a daily total salmon estimate is produced using available data and the standard abundance estimation protocols ([Chapter B8](#)). Once an estimate is created, customized R scripts can be used to produce the Mission Imputation Report. Within the scripts, users can specify which sonar systems require imputation, target and benchmark days, and hours requiring imputation. Imputation is performed for each sonar system individually and thus, users decide for each system: (1) whether to use non-imputed abundance or imputed abundance estimates and (2) which method to use if imputation is selected (non-linear, linear).

Selection of an interpolation approach is complicated by multiple factors that influence imputation performance. Decision-making is currently assisted by diagnostics provided in the Mission Imputation Report, visual inspection of system data, and assessment of contextual cues and expectations. The report suggests a “best” method for each system based on length of imputation period and three diagnostic flags (two linear, one non-linear). For imputations less than 10 hours, the report will typically advise the linear method. The non-linear method is favored for longer time periods, during high abundance (e.g. peak pink salmon), and when the linear method displays poor fit (two diagnostic flags) during shorter periods (Bzonek and Hornsby 2022). If diagnostics raise concerns for both methods, the report will default to the linear method.

Both the linear diagnostics attempt to identify extreme values that could have undue impact on / bias the linear estimate. The first linear diagnostic provides a flag when abundance values directly adjacent to an imputation period are extreme, i.e. within the most extreme 10% of hourly values. The second linear diagnostic provides a flag when the value directly following the imputation period differs drastically from the average of the next two hours. The non-linear diagnostic aims to assess the level of mismatch between the chosen target and benchmark days, providing a flag when the total difference between their scaled hourly values is flagged as high based on historical simulations (Bzonek and Hornsby, 2022). The level of mismatch in temporal patterns between the benchmark and target days should also be evaluated using the plots provided by the Mission Imputation Report.

The suggestions provided by the Mission Imputation Report are best used to inform and guide, rather than provide sole justification for decision-making. Users may or may not select the method proposed by the report, as it is still currently limited in its ability to assess all factors impacting imputation performance. Prior to generating the report, users should consider migration conditions and how fishing activity (e.g., effort) may impact fish behaviour. Of particular note are the characteristics of the fishery (location, effort), as well as changes in observed fish behaviour, e.g., milling/holding, shifts in cross-river distribution between target and benchmark days. Once the imputation is performed, users should assess whether the imputed values make sense in the observed context. Due to this inherently subjective nature of decision making, a decision tree was created to aid standardization (Figure 3).

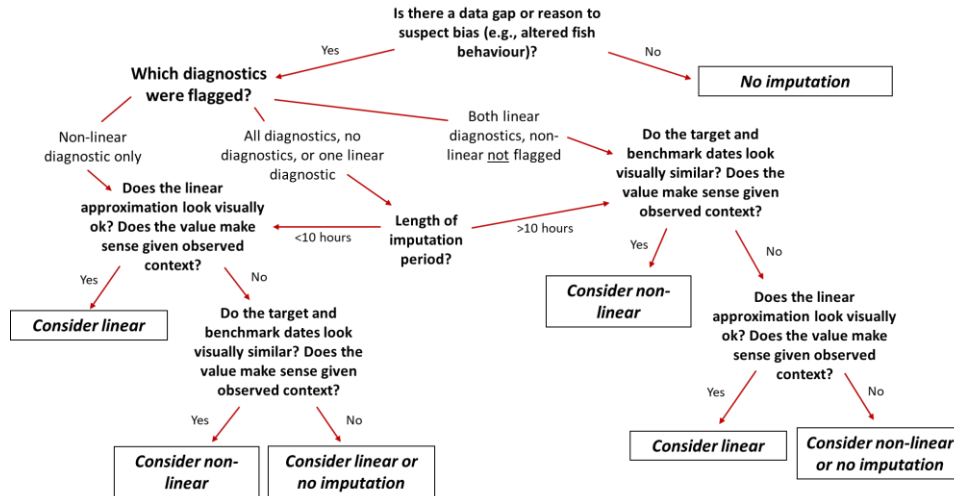


Figure 3. A decision-tree to facilitate the selection of imputed values for the different sonar systems based on the information provided in the Mission Imputation Report.

Planned Changes & Potential Areas for Improvement

Current planning includes exploration into improving the current diagnostics and development of new ones to aid decision-making and reduce subjectivity. Some prospective diagnostics include comparing shore-based:offshore abundance ratios between benchmark and target days, indicators of altered fish behaviour (e.g. based on downstream ratios), and environmental markers. Other interpolation methods may also be investigated, along with work on improving the current methods (e.g. added ability to impute across days).

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B12. Length-based mixture model for imaging sonars

K.M. Hayward, J.L. Nelitz, C. Lagasse, and Y. Xie

Summary

The PSC has multiple methods at its disposal to assess relative abundances of co-migrating salmon species ([Chapter B13](#)). Since 2011, information collected from imaging sonars on the left and right banks of the PSC hydroacoustic site at Mission, BC has been used for one such method of species composition evaluation. Current procedures involve staff measuring a subsample of fish lengths from 24 hours of ARIS data. As of 2024, only targets larger than 35cm in length (excluding sturgeon) are included. A mixture model with test fishing-derived priors for species-specific fish lengths is fitted to the distribution of unweighted daily length data through maximum likelihood estimation. The model ultimately generates nearshore proportion estimates of jack Chinook, adult Chinook, sockeye, and pink salmon, with the latter two used for in-season assessments of Fraser River sockeye and pink salmon.

Introduction

The PSC hydroacoustics program at Mission, BC uses Adaptive Resolution Imaging Sonars (ARIS) to enumerate salmon migrating along both banks of the Fraser River ([Chapter B9](#)). As the mandate of the Mission program specifically relates to sockeye and pink salmon, co-migrating species must be differentiated. At various times, sockeye and pink migration overlap with each other (mid-August to September), as well as adult/jack Chinook (June through October), chum (late September), and coho (late September) salmon. The PSC deploys multiple methods to evaluate species composition in these nearshore areas ([Chapter B13](#)), including a mixture model that relies on hydroacoustic-derived fork length measurements. In 2011, Mission began applying this model to officially estimate sockeye and pink-specific nearshore abundances. This document describes the key data and procedures for application of the length-based mixture model used to evaluate nearshore species composition at the PSC Hydroacoustics site in Mission, BC.

Data

The mixture model requires two data inputs to create length-based estimates for nearshore species composition: 1) fork length measurements from shore-based imaging sonars on the left and right bank, and 2) prior information on salmon fork lengths from current and historical test fishing data.

ACOUSTIC-DERIVED FORK LENGTHS

Daily, a total of 8 hours (per sonar configuration) of sonar imaging data are subsampled for fork length measurements ([Chapter B9](#)). The 8 hours are evenly distributed throughout the 24-hour period (5 am, 8 am, 11 am, 2 pm, 5 pm, 8 pm, 11 pm, 2 am). For both left and right bank ARIS, lengths are measured on all sonar configurations up to a range of 30 metres. Beyond 30 meters, image quality is unsuitable for length measurements. Hydroacoustic staff use Sound Metrics' ARISFish software to measure the first 20 targets identified as larger than 35cm, excluding sturgeon. Since 2024, only targets with fork lengths larger than 35cm are counted and measured. It is assumed all fish larger than 35cm are salmon, while smaller targets are assumed to be small resident fish (e.g., Peamouth Chub, Red-sided Shiners) or jack Chinook. Using the software, lengths are completed on selected targets by measuring from nose to tail

fork. Although measurements are subject to random error associated with image resolution (i.e., blurring of nose or tail fork), comparisons between biological and acoustic-derived measurements of sockeye show no directional bias (Xie et al. 2013). By sampling each sonar configuration up to 30 meters offshore, up to 640 salmon-sized targets are measured each day using left bank ARIS data, while up to 480 targets are measured daily using right bank ARIS data.

TEST FISHING-DERIVED PRIORS

Prior information on mean fork length and coefficient of variation (CV) are required as inputs for the mixture model. Typically, mean fork length is calculated based on the observed lengths of Whonnock test fishery catch during the previous 7 days. This is to ensure that priors reflect current in-season lengths of actively migrating stocks. If sample sizes from Whonnock are insufficient, such as early in season, either a longer period or historical prior may be used until sufficient data are obtained. During the migration of pink salmon, Whonnock has a known bias towards catching larger salmon. If the Matsqui fishwheel is operational, lengths from wheel-caught pink salmon will be included to help mitigate this bias.

Because acoustically derived fork length data are subject to random error due to factors such as target range and aspect angle, the model uses a sigma or CV that is larger than that of the true length distribution, i.e., 13% vs. 6% (Figure 1). A CV of 13% is assumed for both sockeye and Chinook length distributions. CV is assumed to remain constant throughout the season based on data collected during initial imaging sonar studies conducted at the Mission site (Xie et al. 2013).

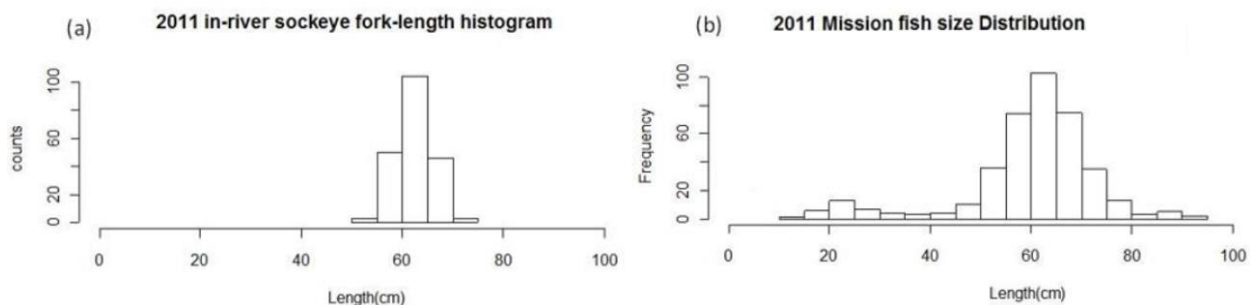


Figure 1. Fork Length data from Whonnock and Mission, Aug 17-20, 2011 (Xie et al 2013): (a) histogram of fork-length from 206 sockeye salmon caught at Whonnock, and (b) histogram of lateral length measurements of 394 Sonar fish images at Mission during the sockeye dominant migration period. The mean of the biological fork length is 62.4cm and the mean acoustically measured length is 62.3cm. The standard deviations of the 2 data sets are 3.6cm and 8cm, resulting in coefficients of variation of 6% and 13%, respectively.

Methods

To estimate the proportion of each salmon species based on salmon length measurements obtained from sonar imaging data, a mixture model is fitted to the distribution of hydroacoustic-derived fork length data. An unweighted, maximum likelihood estimation approach is used for each individual sonar configuration (range, aim configuration). The term unweighted refers to all length data collected throughout the day being assessed equally, rather than weighted by abundance for individual hours. In other words, for each sonar configuration, all length measurements are pooled for the day. On low abundance days when less than 20 salmon-sized targets can be identified and measured from the sonar imaging files, the approach automatically morphs into a weighted approach based on the number of available size measurements. For each individual configuration, daily fork length data are plotted as a

distribution and separate length-based mixture models are fit to each (Figure 2). Models are performed using customized R scripts (<https://rstudio.com/>). For each sonar configuration, the scripts require the following specifications:

- 1) the number of groups or species to be classified (3 or 4),
- 2) the mean fork length prior for each salmon group to be classified,
- 3) the modelling approach to be used: maximum likelihood estimation (MLE), discriminant function analysis (DFA), or a single-value-threshold (SVT) method. By default, the MLE (unweighted) model is used for species composition estimation. The other two models are for comparative purposes only.

The most common number of groups to fit to the data is 3: large resident fish/jack chinook, sockeye, and adult Chinook. Because lengths of Jack Chinook overlap significantly with lengths of large resident fish such as Northern Pike Minnow and Sucker fish, the model currently treats these as one group and is therefore unable to provide accurate estimates of Jack Chinook. On odd years, pink salmon may be added as a fourth group during their migration. Depending on the year and the difference in mean length between sockeye and pink salmon, the overlap in fork length distributions between pink and sockeye salmon may be substantially, thereby increasing the difficulty to obtain reliable model results.

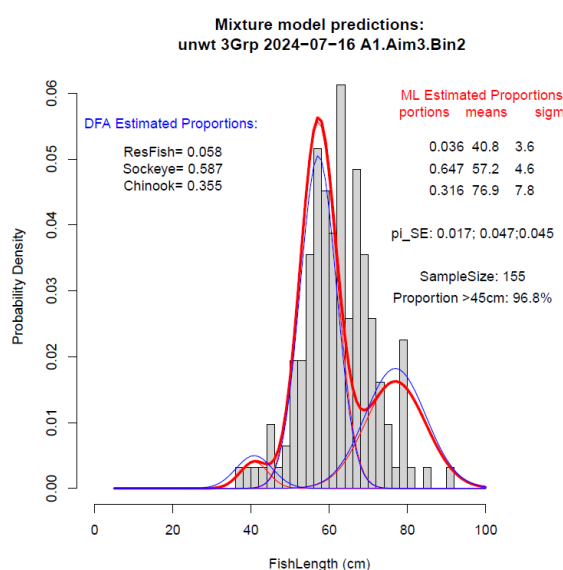


Figure 2. Fit of the length-based mixture model to fork length data from 155 targets (>35cm) imaged by the left bank ARIS in the 20-30 metre range on July 16, 2024. Using the length distribution and provided priors, the mixture model (unweighted, MLE option) estimates 3.6% large resident fish/jack Chinook, 64.7% sockeye, and 31.6% adult Chinook salmon. In this figure, the term “ResFish” refers to a mixture of large resident fish and jack Chinook.

Planned Changes & Potential Areas for Improvement

In 2024, significant changes were made to the total salmon estimation process by excluding targets smaller than 35cm, negating the need for a length-based model to differentiate small resident fish from salmon. This has resulted in the discontinued use of the previous mixture model methods outlined in Michielsens and Martens (2022).

However, species composition estimates continue to be subject to large uncertainties during periods of pink migration and/or relatively high Chinook jack abundance. This is due to large overlaps in average fish lengths among species, as well as biases in test fishing-derived priors, e.g., due to differing and changing relative catchability among species.

Due to limitations associated with the MLE model, a new species composition modelling approach is currently being developed (Davis et al. 2023). The project aims to estimate species composition proportions at both Mission and Qualark by applying a Bayesian integrated model. This model will integrate hydroacoustic-derived fork length measurements, species-specific test fishery counts, and relies on additional information like species-specific differences in the distance to shore and variation in species-specific catchability.

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B13. Species composition in pink salmon years

C.G.J. Michielsens

Summary

Species composition estimates are essential for translating daily fish passage estimates at the hydroacoustic site at Mission, BC, into daily sockeye and pink salmon abundance estimates. Traditionally, salmon species composition at Mission has been derived from catch data collected by the Whonnock test fishery ([Chapter B3](#)), but there have been some concerns about biases in the resulting estimates. Because the Whonnock test fishery samples the offshore section of the river, catches underrepresent species migrating closer to shore. More specifically, the Whonnock test fishery catch tends to underestimate the proportion of pinks given that they migrate closer to shore and overestimate the proportion of Chinook that migrate further offshore than sockeye (van Dam-Bates et al. 2024). Alternative methods to estimate species composition exist but all have shortcomings that may bias species composition estimates under certain conditions. In-season, all the different methods are tracked, and the resulting species composition estimates are compared. Concurrence between methods provide increased confidence while deviation from other estimates will decrease a method's credibility. Currently, a new integrated model is being explored to improve species composition estimates (van Dam-Bates et al. 2024).

Introduction

As part of the Treaty agreements (Diplomatic Note of August 13, 1985), the Fraser River Panel is responsible for the collection of hydroacoustic data at Mission, BC, and to enumerate salmon passage past the site, specifically sockeye and pink salmon. Within the Fraser River, salmon species however also include Chinook throughout the sockeye and pink salmon migration, and to a lesser extent chum and coho salmon in September. The presence of other species results in the need to estimate species proportions following salmon enumeration. There are a multitude of different methods that can be used to determine species composition, and the different methods will be described here.

Methods

During pink years, three different in-river species composition scenarios are identified: 1) in July, sockeye and Chinook salmon dominate and no pink salmon are present, 2) in late August, September, pink salmon dominate in-river salmon abundances and 3) in early to mid-August the species composition transitions from sockeye to pink salmon dominance. The most complex species composition scenario, with potentially the greatest impact on in-season fisheries management decisions, is the transition period as underestimating pink salmon, once they start migrating in the river, results in an overestimation of the sockeye salmon and the available sockeye TAC, and risks not reaching sockeye escapement targets.

While different methods exist to estimate species composition in each of these three scenarios, they all have some shortcomings that may substantially bias species composition estimates under certain conditions. In-season, the different methods are executed jointly, and the resulting sockeye, Chinook and pinks salmon abundances are compared. Concurrence in abundance estimates when relying on

multiple different methods will provide increased confidence in the use of species composition estimates derived from those methods while deviation from other estimates will decrease its credibility. The following sections describe the individual methods.

TEST FISHING BASED SPECIES COMPOSITION

Traditionally, salmon species composition at Mission has been derived from catch data collected by the Whonnock test fishery with the proportions based on gilled and girthed catch. In case of low daily salmon catch numbers (<15), catches also include tangled salmon. When catches are low, these estimates are however very uncertain and highly variable. In extremely low abundance years like 2019 (12 sockeye caught during the first 46 days of operation), there may not even be sufficient data to use this method. In addition to the sample size issue, this method has some known biases because not all species have the same catchability. Pink salmon, who migrate primarily near-shore, tend to be less vulnerable to the Whonnock test fishery, resulting in an underestimation of pink salmon abundance (van Dam-Bates et al. 2024). This means the proportion of sockeye may be overestimated during pink salmon comigration. Chinook salmon on the other hand migrate further offshore where the Whonnock test fishery operates and tend to have a higher catchability, resulting in an overestimation of Chinook abundance compared to sockeye.

The Lower Fraser River fish wheel test fishery, operated by various parties (Matsqui First Nations in collaboration with LGL Limited, the Lower Fraser Fisheries Alliance), is another test fishery that can be used to derive species composition estimates, but is not consistently funded and operated. This fish wheel also overestimates pink proportions because pink salmon migrate closer to shore than other salmon species (van Dam-Bates et al. 2024). Daily species composition estimates can be improved through a stratified method that combines the species composition estimates from the Lower Fraser fish wheel for the nearshore area with the offshore Whonnock test fishery estimates (Robichaud et al. 2010; English et al. 2016; 2018). However, this may not entirely correct the overestimation of pink salmon because the fish wheel only covers a small part of the nearshore area where pink salmon are more likely to migrate than other species (English et al. 2018).

At Qualark, test fishing catches are also used to derive species proportion estimates. Unlike Whonnock, the Qualark test fishery takes place close to shore where most of the salmon migration occurs. But similarly to the Whonnock test fishery, the method does not account for species-specific differences in catchabilities and sample sizes during low abundance may be insufficient to derive reliable estimates. It has been identified that Qualark test fishing proportions tend to underestimate sockeye compared to Chinook and overestimate sockeye compared to pink salmon (van Dam-Bates et al. 2024). While the Qualark estimates are not used for in-season assessment, daily comparisons of total sockeye at Mission and Qualark are reviewed twice a week. These comparisons can flag problems with the programs but due to species composition challenges, comparisons between the two sites can be difficult to interpret.

At Brownsville Bar, the test fishery is designed to assess sockeye salmon, and the test fishing catch is therefore not considered representative of the in-river species composition. At Albion, both a standard Chinook net and a multi-panel net are used on alternating days through to August 31. The multi-panel net, consisting of panels of 6, 7, 8 and 9 inch mesh, aims to representatively sample the wide range of Chinook sizes. The resulting catch should however not be considered representative for species composition. Further details about the different in-river test fisheries can be found in [Chapter B3](#).

TOTAL SALMON MINUS NON-DOMINANT SPECIES

When either sockeye or pink salmon dominate, the most robust strategy to derive the abundance of the dominant species is to estimate the abundance of the non-dominant species and subtract these

estimates from the total salmon abundance. In the sockeye dominant period, this means assessing Chinook abundance through a variety of different methods (Michielsens and Martens 2022) while during the pink dominant period, the sockeye abundance is almost exclusively estimated based on the sockeye CPUE data collected by the Whonnock test fishery, used in combination with a historical expansion line ($1/\text{catchability}$, see next section). The smaller the proportion of the non-dominant species, the smaller the impact of potential biases in species composition on the dominant species.

TEST FISHING CPUE X EXPANSION LINE

Daily abundance estimates of individual species can be obtained by multiplying the species-specific CPUE data with historical expansion line estimates ($1/\text{catchability}$). In the case of Whonnock CPUE data for sockeye, this method is regularly relied on: early in-season when no hydroacoustic data are yet available and in pink salmon years when daily salmon abundances are dominated by pink salmon. While the daily sockeye abundance estimates derived from CPUE data may differ substantially from the hydroacoustic based sockeye abundance estimates when available, averaged over three days, the CPUE based method produces similar abundance estimates unless catchability in a given year deviates substantially from average. When applied to pink salmon CPUE data, this method is not as informative as the average pink salmon expansion line and variability of the expansion lines between years are both substantially larger than for sockeye salmon. Theoretically, the test fishing CPUE data collected at Brownsville Bar could equally be used to derive sockeye abundance estimates but insufficient historical data are available to derive reliable expansion line estimates, given that this test fishery has only been in operation since 2021 for part of the season and full-time since 2024.

The Chinook CPUE data from the Albion test fishery can be similarly used in combination with a historical expansion line estimate to derive daily Chinook abundance estimates at Mission (Hawkshaw 2018). The Albion test fishery that runs every day through to August 31 is designed to target Chinook salmon, but there are similar concerns about the representativeness of the historical Chinook catchability estimate in the assessment year. For example, the Albion test fishery greatly underestimated the record adult Chinook returns in 2023. Because of the Chinook-specific net used in this test fishery, the data collected by this test fishery can not be used to assess other salmon species. From September 1 through October 20, the Chinook specific net in this test fishery alternates with a chum specific net every other day. During this period, the resulting chum CPUE estimates can be used in combination with an historical expansion line to derive daily chum estimates. While the Albion test fishery has not been designed for the assessment of coho salmon, the coho CPUE data collected in the chum test fishery has been used in combination with the historical coho catchability to estimate the daily abundance of coho salmon (PSC 2024).

CATCHABILITY CORRECTION METHOD

The catchability correction model aims to reduce potential biases when using test fishing catches to derive species proportion by considering differences in catchability between species. The method assumes CPUE relates to abundance through a function that is linear at low abundance but accounts for gear saturation at higher abundance (Xie et al. 2025). The catchability between fish species is assumed to differ due to difference in swim speed, body size and/or spatial distribution across the river at Mission. For Chinook salmon, very strong gear saturation effects resulted in a failure to detect a very large Chinook run in 2023 (Xie et al. 2025). In addition, the correction to sockeye abundances in recent years have been limited due to the low sockeye catches. As a result, the overestimation of Chinook abundance, while generally reduced when using the catchability correction method, has remained substantial in low abundance years with limited to no sockeye catch, e.g. 2019.

LENGTH-BASED MIXTURE MODEL

The majority of the species composition methods discussed thus far rely on in-river test fisheries whose catches decrease with decreasing abundances. In recent years, it has been especially challenging to obtain catch data early in the season when abundances are lowest or for catches to be sufficiently large to obtain desired sample sizes from which to derive species composition estimates. Hydroacoustic length information has not experienced similar sample size challenges. A length-based mixture model has been developed to derive species composition estimates from fork length measurements collected from left and right bank sonar images ([Chapter B12](#)). In addition to these data, the model also relies on prior information of salmon fork lengths from current and historical test fishing data. Because the image quality of the sonar systems is unsuitable for length measurements beyond 30 meters offshore, the results are combined with the Whonnock test fishing results in a stratified species composition method. The method is stratified as it relies on the length-based mixture model for the species composition along the left and right bank and the Whonnock test fishing catch data for the species composition in the midsection of the river. The mixture model performs best when the different species vary substantially in mean lengths which is the case when distinguishing sockeye from adult Chinook. Pink and sockeye salmon are however more similar in length and especially in years with larger pink salmon and smaller sockeye, the limited difference in average lengths may result in more uncertain species composition estimates.

DAILY ABUNDANCE FORECASTS

In the past, there has been clear evidence that differences in catchability among species can lead to overestimated Chinook abundance, whereby the sum of the daily reconstructed Chinook abundance greatly exceed the total post-season run size of Fraser River Chinook. To ensure daily estimates are in-line with realistic total run size estimates for Chinook salmon, the preseason Chinook run size forecasts of 6 different Chinook groups (Spring 1.2, Spring 1.3, Summer, 1.3, Summer 0.3, Chilliwack and Harrison) are used in combination with the timing and spread of each stock group to forecast daily Chinook abundances across the season and the associated uncertainty around those daily estimates i.e. the 95% probability interval. In case no alternative species composition data are available due to a lack of test fishing catches or if the resulting estimates are considered unreliable, the median forecast of the daily Chinook abundance can be used to derive daily sockeye abundance estimates. Alternatively, the upper 97.5% confidence limit can be used to cap the daily Chinook abundance estimates derived from test fishing catch data. While it is possible to exceed the upper confidence limit on a given day or several days, consistently exceeding this limit would require that Chinook returns exceed the 97.5th percentile of the forecast.

Daily abundance forecasts are an unreliable method for Fraser River pink salmon given the substantial uncertainty associated with the pink salmon forecast, both preseason as well as in-season. In addition, the substantial uncertainty and variability in the migration behaviour of pinks makes it impossible to reliably predict their daily abundance at Mission based on observations from past years.

Planned Changes and Potential Areas for Improvement

Improvement to the estimation of the species composition has been one of the recommendations identified during the Hydroacoustic Review (Conrad et al. 2019). Currently an integrated modelling approach is being developed that incorporates multiple sources of data and knowledge, including test fishing and the hydroacoustic length information, to derive species composition (van Dam-Bates et al. 2024). The developed approach is aimed to be flexible enough to accommodate not only the different

conditions at Mission and at Qualark, but also the substantial difference between years in terms of number of species, abundance, and migration conditions.

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B14. Pink salmon marine reconstructions

M.J. Hague and C.G.J. Michielsens

Summary

Run reconstructions are a key tool for fisheries stock assessment and allow biologists to generate daily abundances and annual run size estimates. The Pacific Salmon Commission (PSC) is responsible for developing and applying run reconstruction models for Fraser River pink salmon as well as disseminating and archiving the resulting estimates. Forward reconstructions are used to estimate escapement into downstream fisheries based on daily abundances derived from catch-per-unit-effort (CPUE) data in marine test fisheries combined with historical catchability estimates and assumptions regarding migration speed and delay behaviour. Pink salmon migration behaviour prohibits the use of backwards reconstructions derived from daily passage estimates enumerated at the PSC hydroacoustic facility in the lower Fraser River. However, under certain conditions, U.S. commercial fishery CPUE data can be used in backward reconstructions to help refine in-season daily marine abundance estimates. Daily marine abundance estimates are used to develop time series of marine timing, run duration (i.e. spread), and diversion rate. The following report describes the basic structure and underlying assumptions of the pink salmon reconstruction model, the limitations compared to similar models for sockeye salmon, and the time series it generates.

Introduction

Management of Fraser River pink salmon fundamentally depends on both (1) accurate estimates of run size to determine the total allowable catch (TAC) and on (2) understanding migration behavior to determine how to effectively access the TAC. As part of the Pacific Salmon Treaty (PST) agreements (PST 2023, Chapter 4, paragraph 13(a)), PSC Secretariat staff are responsible for providing in-season updates of Fraser River pink salmon run size and timing.

Historically, pink salmon run sizes were rarely, if ever, updated in-season (PSC 1999). However, as sockeye abundances declined and market value for pink salmon increased, there was greater bi-lateral interest in actively harvesting, and managing, the pink salmon return. In the mid-2000s, the Fraser River Panel started to evaluate the impact of pink directed fisheries on sockeye salmon more rigorously, and to improve tools for in-season assessment of pink salmon. Following the underestimation of the Fraser River pink salmon run size in 2019, the PSC invested significant resources to further improve in-season assessment tools, including a revamped pink salmon reconstruction model (Hague and Michielsens 2022).

Run reconstructions have been a key tool for salmon fisheries management for over 80 years; their application has been thoroughly described by Starr and Hilborn (1988). PSC Secretariat Staff are responsible for developing and applying run reconstruction models for Fraser River sockeye and pink salmon (Cave and Gazey 1994). In-season, daily reconstructed pink abundances are used to provide the best in-season estimate of run-size, timing, and diversion and to project abundances of salmon expected to be vulnerable to different fisheries. While abundance estimates at Mission provide an opportunity to update pink salmon run size and catchability estimates in the post-season, the slow migration speed and variable amounts of migration delay of this species prevent the alignment of daily marine catches with

daily Mission pink salmon estimates. Instead, similar to delaying Late-run sockeye stocks, in-season estimates of pink salmon run size and timing traditionally depend on fitting time density models to test fishery CPUE data (Michielsens and Cave 2019). However, the accuracy of these estimates is compromised by the low, and highly variable, catchability of pink salmon in marine test fisheries ([Chapter B15](#)).

This document describes the application of run reconstruction models for Fraser River pink salmon. It highlights the forward reconstructions used to estimate escapement in downstream fisheries based on daily marine abundance estimates derived from test fishery CPUE data. It also describes the backward reconstructions that allow, under certain conditions, the use of U.S. commercial fishery CPUE data to refine in-season daily marine abundance estimates. The various time series generated based on daily abundance estimates are also described.

Data

In-season reconstructed daily marine abundances estimates along the Johnstone Strait and Juan de Fuca routes are derived from: catch-per-unit-effort (CPUE) data of the purse seine test fisheries in Area 12 and 20 ([Chapter B4](#)), historical annual test fishery catchability estimates ([Chapter B15](#)), U.S. commercial purse seine CPUE data, landed catches, and genetic stock identification estimates ([Chapter B7](#)). Of the various test fisheries, historical purse seine expansion lines derived for Area 12 and 20 are generally most precise ([Chapter B15](#)). Due to the low pink salmon catchability in gill nets, CPUE data from this gear are typically not used to inform pink salmon reconstruction estimates. Similarly, Area 13 purse seine test fishery data are not used because catches tend to be smaller and more variable than catches in Area 12 ([Chapter B15](#)). In addition to marine test fishing data, commercial U.S. purse seine CPUE data from Areas 6-7 can also be used to estimate marine abundance. Abundance estimates derived from the U.S. fisheries may be more precise than test fishery estimates given the larger size and more efficient fishing behaviour of the commercial fleet (Hague and Michielsens 2022). Genetic data is then combined with test fishing and commercial CPUE and landed catches to produce estimates specific to Fraser River pink salmon ([Chapter B7](#)). Pink salmon populations are less genetically distinct than sockeye, due to a higher degree of straying and lower levels of spawning stream fidelity (Beacham et al. 2012; Grant et al. 2014). Current genetic baselines only differentiate pink catch between Fraser, B.C. South Coast and Puget Sound/Washington stock-groups.

In-season estimates of total abundance based on Mission abundance plus seaward catch are not used for in-season reconstructions because pink salmon, unlike sockeye salmon, have a slow migration speed and experience variable amounts of delay on route to the Mission hydroacoustic site. While daily estimates from the Mission hydroacoustic program are not used in the construction of in-season run size, annual totals of Mission abundance plus seaward catch are used post-season to update the timeseries of historical annual catchability and to rescale abundances derived from in-season catchability and CPUE data.

To populate the reconstruction model, information is also required regarding migration distances between fishery areas, as well as assumed migration rates (Hague and Michielsens 2022). Tagging studies in the 1950s (Vernon et al. 1964) indicate pink salmon swim more slowly than sockeye salmon. Comparisons of annual marine versus in-river timing confirm these findings but also indicate that migration speeds differ more substantially between years for pink salmon than for sockeye salmon (Hague and Michielsens 2022). In 2023, the PSC assumed a migration rate of 36 km/d in marine areas at the start of the season, resulting in a 12-day offset between the Area 20 purse seine test fishery and the Mission hydroacoustic facility, located 434 km away. However, in some years, the days difference

between peak Area 20 and Mission timing has been up to 23 days (19 km/d). Assumed migration rates and offsets may be adjusted after post-season re-evaluation of the data.

Methods

A box-car run reconstruction model assumes salmon move in groups, i.e., box-cars, from the marine areas to the Fraser River through a series of fisheries that impact the number of salmon in a group (Cave and Gazey 1996). For pink salmon, this assumption is expected to hold during the marine migration from seaward test fisheries at the entry of Juan de Fuca and Johnstone Straits until the Strait of Georgia “Gulf” (Canadian statistical fishing Area 29) but then breaks down before fish enter the river. As a result, it is not possible to use forward reconstructions based on daily marine pink salmon estimates to predict daily abundances at Mission, nor is it possible to produce daily marine abundance estimates using backward reconstructions derived from daily Mission passage plus seaward catches. Instead, forward reconstructions based on marine test fishery data from Area 12 and 20 are used to predict pink salmon abundances only in marine areas seaward of the Gulf. When available, U.S. commercial CPUE data can also be used to inform estimates of pink salmon migrating through Juan de Fuca Strait.

For simplicity, dates in the reconstructions are adjusted to align with a single geographical reference point, traditionally associated with the Area 20 test fishery location. The dates associated with the data from other areas are adjusted based on the amount of time (rounded to the day) it takes for pink salmon to migrate to these areas from the reference location or from the equivalent location in Johnstone Strait. To simplify the following equations, we assume all abundances and catches are specific to Fraser River pink salmon following the application of genetic stock identification ([Chapter B7](#)).

TEST FISHING BASED FORWARD RECONSTRUCTIONS

Initial marine abundances along each migratory route around Vancouver Island are estimated from the most seaward test fishing locations, located in Canadian statistical fishing Area 12 in Johnstone Strait and statistical fishing Area 20 in Juan de Fuca Strait. In-season, daily CPUE estimates (I_d) are divided by an annual median historical catchability estimate (q_a , [Chapter B15](#)) to estimate daily abundances (N_d):

$$(1) \quad N_{d,a} = \frac{I_{d,a}}{q_a}$$

where a is the most seaward test fishing location or area in the reconstruction along each migration route, i.e. Areas 12 and 20. Abundances in fishing areas upstream of Area 12 and 20 can be calculated by removing catches between the two locations. Assuming catch dates have been aligned to the date of the reference location, the resulting pink salmon abundance is given by:

$$(2) \quad N_{d,a+i} = N_{d,a} - \sum_a^{a+i-1} C_{d,a}$$

However, due to the relatively slow swim speeds of pinks, fisheries may impact multiple migration “blocks” of salmon in a single opening (Figure 1 in Chapter B18, Michielsens and Martens 2022). The number of migration ‘blocks’ (n) vulnerable to a fishery (f) on a given day (d) is calculated as the length of the statistical fishery area divided by the pink salmon migration rate, i.e., assuming equal distribution of the fleet throughout the area. The catch is spread across the n migration days and the statistical area so that the sum of the catch proportions (p_n) equals the total catch reported:

$$(3) \quad C_{d,f,a} = \sum_1^n p_n \cdot C_{d-n+1,f,a}.$$

To simplify the calculation of CPUE indices, catch and effort for index fisheries are not spread across migratory blocks, i.e., total catch and effort for a single fishing day are used to calculate a single day of fish abundance.

For purse seine test fisheries, catchability is assumed to depend on the width of the area sampled in relation to the size of the fishing net ([Chapter B15](#)). Because the relative width of the pink migration channel in Juan de Fuca is 3 times larger than the width in Johnstone Strait, it is assumed that the catchability of the purse seine test fishery in Area 12 (q_{A12}) is 3 times greater than the catchability in Area 20 (q_{A20}):

$$(4) \quad q_{A12} = 3 \cdot q_{A20}.$$

To combine CPUE estimates along both migration routes in order to estimate total marine abundance, the Area 12 CPUE data is therefore re-scaled by 1/3 to reflect the differences in catchability between the Area 12 and Area 20 test fisheries:

$$(5) \quad I_d = I_{d,A20} + \frac{1}{3} \cdot I_{d,A12}.$$

In-season catchability estimates are based on historical data, calculated by dividing the total test fishery CPUE (I) by the total abundance at Mission ($N_{Mission}$) plus seaward catch (C), i.e. the total run size:

$$(6) \quad q_{A12} = \frac{\sum_{d=1}^D I_d}{\sum_{d=1}^D N_{d,Mission} + \sum_{a=1}^A \sum_{d=1}^D C_{d,a}}.$$

One of the most significant challenges associated with in-season pink salmon reconstructions is the low, and highly variable (both inter- and intra-annually) test fishery catchability estimates. Without the ability to use daily Mission abundances to update the catchability in-season, the test fishery-based estimates are very uncertain (Hague and Michielsens 2022). To commence the 2023 season, a catchability estimate of 1/300 was assumed for the Area 12 purse seine test fishery, and a catchability of 1/900 was assumed for the Area 20 purse seine test fishery. These estimates were derived from the historical median annual catchability since 2011. This shorter timeseries corresponds to the period in which Fraser River pink salmon run size has been based on Mission escapement estimates ([Chapter B8](#)). In the post-season, the Area 20 annual catchability was found to be approximately four times higher (1/220) than the pre-season assumption, leading to a gross over-estimation of run size based on CPUE data.

U.S. COMMERCIAL CATCH BASED BACKWARD RECONSTRUCTIONS

Catchability in commercial U.S. purse seine operations in Areas 6, 7 and 7A is both higher, and less variable than in the test fisheries (Hague and Michielsens 2022). This may be due to the larger size and more efficient fishing behaviour of the commercial fleet when compared to the singular test fishery vessels which are required to fish in a consistent pattern. When there are U.S. fisheries openings in Areas 6, 7 (A6/7), daily abundances of pink salmon can be calculated using the resulting CPUE data in combination with the historical median of the catchability for the Treaty Tribal purse seine fishery ($q = \sim 1/49$):

$$(7) \quad N_{d,A6/7} = \frac{I_{d,A6/7}}{q_{A6/7}}.$$

A backwards reconstruction is used to align abundances estimated from the U.S. fishery data to equivalent days of migration estimated from the Area 20 purse seine test fishery. Once catches seaward of the commercial U.S. fishery have been spread out across migration days and indexed to the reference date, pink salmon abundance in Area 20 is calculated by adding these catches to the daily pink salmon abundance in the Area 6/7:

$$(8) \quad N_{d,A20} = N_{d,A6/7} + \sum_{a=A6/7-1}^{A20} C_{d,f,a}.$$

While abundances derived from the U.S. fisheries may be more accurate, correctly aligning the Area 20 test fishing-based and U.S. commercial fishery-based abundance estimates is prone to errors in assumptions regarding migration time between locations, particularly when fishery openings are short and infrequent. In-season, a set of detailed decision criteria (Hague and Michielsens 2022) are used to evaluate whether to rely on test fishery or U.S. fishery-based abundances for Juan de Fuca Strait, or an average of both. The decision criteria are then re-evaluated in the context of additional post-season information. Figure 1 (Hague and Michielsens 2022) illustrates examples of alignment between Area 20 and Area 6/7 based abundance estimates. CPUE data from area 7A is generally not included as it is unclear to what extent salmon caught in this area are actively migrating, versus salmon delaying their upstream migration.

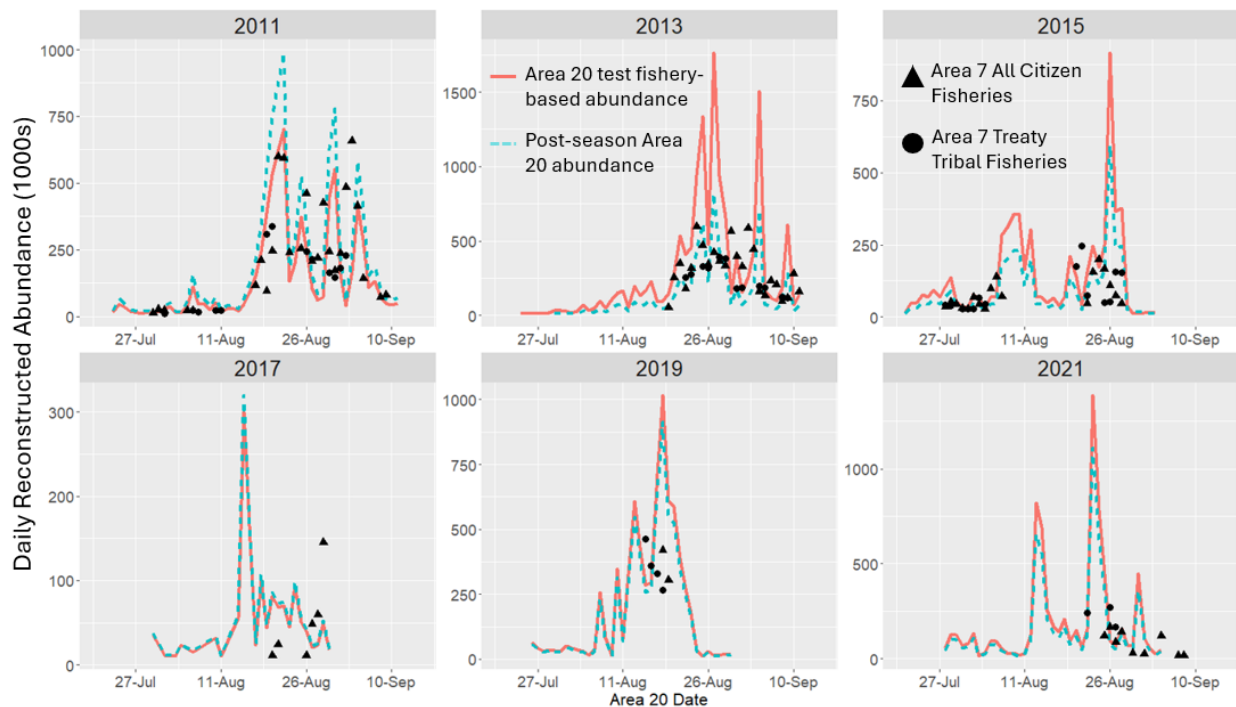


Figure 1. A comparison of Area 20 purse seine-based marine abundances (catchability: 1/1050) vs. Area 7-based abundances (catchability: 1/49) assuming a fixed historical catchability across all years. The solid line shows in-season abundance estimates assuming a historical catchability, while the dashed line rescales the test fishery-based abundance estimate based on the post-season Area 20 catchability (Hague and Michielsens 2022).

Derived time series

The daily marine reconstructed abundances are essential to derive time series of diversion rate through Johnstone Strait as well as the timing and the spread of the run. These historical time series are used in forecasting models ([Chapter A1](#)) that set pre-season expectations, allow for the prediction of fisheries impacts ([Chapter A3](#)) and serve as informative prior probability distribution inputs into the in-season stock assessment models ([Chapter B15](#)). The daily percentage of the run migrating through Johnstone Strait (i.e. northern diversion, Putman et al. 2014) is calculated using a 5-day moving average given the high variability in the CPUE-based abundances. Peak, or median, migration dates can be assessed separately for each migration route but can also be aligned to Area 20 to calculate an index of migration

timing for the aggregate run assuming all fish migrate through the south. Marine timing is quantified as the date when 50% of the abundance migrating through an area has passed a reference location. The spread, or duration of the run, is defined as the number of days of migration comprising 95% of the run. This is calculated by first determining the dates associated with the 2.5th and 97.5th percentile of the cumulative abundance and calculating the number of days difference.

Potential Areas for Improvement

The greatest sources of uncertainty in the pink salmon reconstruction model are (1) the daily catchability, particularly in the purse seine test fisheries, and (2) the assumed migration rates used to “move” fish forwards or backwards in space. The calculated difference between peak timing in marine approaches and peak timing observed at the Mission hydroacoustic facility can be used to calculate the number of migration days between areas, and to infer a constant speed. However, in recent years this difference has been highly variable (e.g. anywhere between 12 to 23 days) and it is unclear whether the fish move at a constant rate and/or delay in one or more locations along the migration route. Future research hopes to update information regarding Fraser River pink salmon migration behaviour using a combination of acoustic and radio tagging studies, in order to better inform reconstruction models and improve in-season estimates of run size, timing, and forecasts of catch in proposed fishery openings.

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B15. In-season time-density model

C.G.J. Michielsens

Summary

The in-season assessment of Fraser River pink salmon relies on the Bayesian implementation of a time-density model to estimate run size and associated run timing. This model is fit to available catch-per-unit-effort (CPUE) data collected in Areas 12 and 20 purse seine test fisheries ([Chapter B4](#)). The model relies on prior probability distributions of run size, timing, standard deviation (or spread), diversion rate, and test fishery catchability based on pre-season forecasts or historical observations ([Chapters A1](#)). The model produces updated posterior distributions for timing, abundance, diversion, and sometimes spread, but the catchability priors are not updated. Instead, the daily catchabilities are assumed to be fixed but uncertain inputs, based on historical estimates ([Chapter B14](#)). Early in-season, the model tends to underestimate the number of days for the salmon to pass through marine areas, and therefore the standard deviation of the migration (spread) is also considered a fixed but uncertain parameter. If necessary, this assumption can be relaxed after the peak of the run has been observed. This time-density model differs from the model used to assess sockeye salmon (Michielsens and Martens 2022) given the lack of timely reconstructed daily abundance estimates that match the pattern observed in the marine CPUE data.

Introduction

The Fraser River Panel is responsible for the in-season management of Fraser River pink salmon, as stipulated by the Pacific Salmon Treaty between Canada and the United States (PST 2023). Under the terms of the Treaty, Commission staff are responsible for providing the Panel and Technical Committee with in-season updates of run size. Historically, two different methods had been relied upon for the in-season assessment of salmon stocks: regression models relating indicators of abundance (or cumulative abundance) on a given date with total run-size estimates obtained post-season (Fried and Hilborn 1988, Ryall 1998) and time-density (or cumulative time-density) models that estimate the proportion of the migration on a given date (Walters and Buckingham 1975, PSC 1995, Springborn et al. 1998, Michielsens and Cave 2019). These time-density models rely on the date of peak abundance as well as the shape of the daily abundance profile over time. They can be fit to abundance indices such as catch-per-unit-effort (CPUE) data from commercial or test fisheries. Unlike time-density models for sockeye salmon, similar pink salmon models cannot be fitted to absolute estimates of reconstructed abundance given the much slower pink salmon migration and potential upstream migration delay. In addition, the daily reconstructed pink salmon abundance profile based on Mission hydroacoustic data may not replicate the daily abundance profile in marine areas, due to variability in the proportion of pinks delaying and the extent of the delay.

While time-density models have the advantage that the timing of the migration is an estimated model parameter compared to a fixed input as is the case for alternative in-season assessment models that rely on regression analyses using catch or CPUE (PSC 1995, Ryall 1998), the simultaneous estimation of timing and run size can also pose some challenges. The peak of the run can only be confirmed once more than 50% of the migration has been observed. Consequently, prior to the peak, runs that are small and early or late and large may be indistinguishable (Adkison and Cunningham 2015). The integration of

all available sources of data and information within the assessments is therefore important to ensure timely in-season management decisions. Bayesian methods offer an ideal platform for such analyses while also accounting for the uncertainty in the resulting estimates (Fried and Hilborn 1988, Hyun et al. 2005). This document describes a time-density model developed in a Bayesian framework for the in-season assessment of run size and timing for Fraser River pink salmon. This is a simplified version of the time-density model for sockeye salmon, given the exclusion of gillnet data as well as daily reconstructed abundance estimates (Michielsens and Martens 2022).

Data

The in-season assessment of Fraser River pink salmon relies on two types of data: test fishing catch-per-unit-effort data ([Chapter B4](#)), and stock identification data (Beacham et al. 2012, Araujo et al. 2014). The limited pink salmon catch in recent years has increased the reliance on test fishing CPUE information rather than commercial data as an index of abundance. The main marine test fisheries for in-season assessments are the purse seine test fisheries in DFO statistical Areas 12 (Johnstone Strait), and Area 20 (Juan de Fuca Strait). The CPUE data from these two Straits provide time series of relative daily abundance and are multiplied by Fraser pink proportion estimates ([Chapter B7](#)) to produce Fraser-specific CPUE timeseries for the Area 12 and 20. While theoretically, purse seine data from Area 13 can also be used within the time density model, these data have not been used given their higher variability compared to Area 12 CPUE data. In addition, unlike for sockeye salmon (Michielsens and Martens 2022), Area 13 pink salmon catches tend to be smaller in comparison to catches in Area 12, despite the narrower width of the Strait in Area 13.

Methods

The following model description assumes that all timeseries have been offset in order to align with a single geographical reference location associated with the Area 20 purse seine test fishing site ([Chapter B2](#)). Date indices corresponding to data from all other locations are adjusted accordingly based on pink salmon migration speeds.

IN-SEASON TIME-DENSITY MODEL

The in-season time-density model to assess the run size and timing of Fraser River pink salmon relies on a time-density function to represent the daily salmon migration past the marine test fishing locations (Mundy 1979, Cave and Gazey 1994, Springborn et al. 1998). The following paragraphs describes the model using purse seine CPUE data.

The daily abundance of salmon (N_d) passing the marine reference locations on a given day d can be represented as:

$$(1) \quad N_d = N \cdot f(d)$$

where $f(d)$ is the time-density function of migrating pink salmon, i.e., the daily proportion of the total run size and N is the total run size or the total recruitment of salmon, available to coastal fisheries. Given the quality of the purse seine data, it is possible to model the daily abundance estimates in Johnstone Strait separately from the daily abundance in Juan de Fuca Strait:

$$(2) \quad N_{d,A12} = N \cdot D \cdot f(d) \text{ and } N_{d,A20} = N \cdot (1 - D) \cdot f(d)$$

where $N_{d,a}$ is the daily abundance on a given day d in area a (A12 or A20), and D is the (northern) diversion rate, i.e. the proportion of the run migrating through Johnstone Strait (A12) ([Chapter A1](#)).

For Fraser pinks, we assume a normal distribution of migrating salmon over time (Gilhousen 1960, Cave and Gazey 1994):

$$(3) f(d|T, S) = \frac{1}{S\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{d-T}{S}\right)^2}$$

where T is the mean timing of the salmon migration and S is the standard deviation.

Based on the pink salmon abundance available on a given day in a given area ($N_{d,a}$), the associated CPUE by the purse seine test fishery on that day in the area ($I_{d,a}$) is given by:

$$(4) I_{d,a} = q_a \cdot N_{d,a}$$

where q represents the catchability coefficient, i.e., the proportion of the daily abundance taken as catch by one unit of effort.

For purse seine test fisheries, it is assumed that the catchability depends on the relative width of the area swept or sampled, i.e., the width of the migratory channel at the test fishing site in relation to the size of the fishing net. Because the relative width of the area swept in Juan de Fuca Strait is 3 times larger than in Johnstone Strait, it is assumed that the sockeye catchability of the purse seine test fishery in Area 12 is 3 times greater than in Area 20. Similarly, the catchability in Area 13 is assumed to be 4.5 times greater than in Area 20, but post-season analyses have indicated large annual variation in that ratio (1.3-9.6). The difference between the catchability in Johnstone Strait versus Juan de Fuca Strait is larger for pink salmon than for sockeye salmon, since it is assumed that pink salmon have a broader distribution across Juan de Fuca Strait. The purse seine CPUE on a given day in the Area 12 and 20 ($I_{d,a}$) is therefore respectively:

$$(5) I_{d,A20} = q_{A20} \cdot N_{d,A20}$$

$$(6) I_{d,A12} = 3 \cdot q_{A20} \cdot N_{d,A12}$$

While Area 13 CPUE data are traditionally not used given their higher variability, they could be included using the following equation:

$$(7) I_{d,A13} = 4.5 \cdot q_{d,A20} \cdot (N_{d,A12} - C_{d,A12})$$

where $C_{d,A12}$ is the total catch taken between Area 12 and 13 on a given day.

The observed CPUE data in the different marine test fishing area (a) differ from the model predictions assuming lognormal residual errors:

$$(8) I_{d,a}^{obs} = I_{d,a} \cdot \exp(v_{d,a})$$

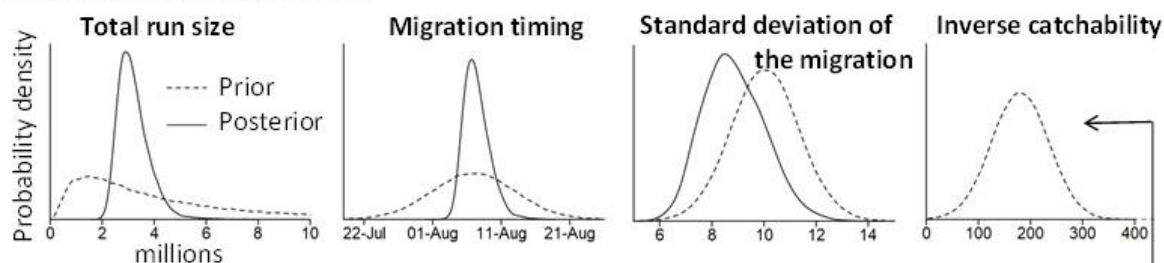
with $v_{d,a} \sim N(0, \sigma_{v,a}^2)$.

BAYESIAN IMPLEMENTATION INCORPORATING PRIOR KNOWLEDGE

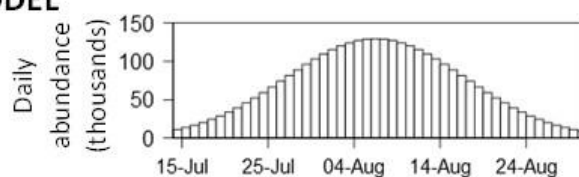
The time-density model described above requires the simultaneous estimation of total run size (N), timing of the migration (T), the diversion rate (D), and the variance of the residual error term (σ_v^2). For several of the model parameters, additional information is available to formulate informative prior probability distributions which can be incorporated using a Bayesian estimation approach (Gelman et al. 1995). The prior probability distributions for run size, timing and diversion rate are based on the pre-season forecasts ([Chapter A1](#)). The assumed distributions for run size, timing and diversion rates are respectively a lognormal, normal and beta distribution (Table 1). The normal prior probability distribution for the standard deviation of the migration (S) is based on historical data. Because early in-season, the model tends to underestimate the spread of the migration (i.e. the number of days it takes

for the 95% of the run to pass through the marine test fishing areas), this model parameter is considered fixed but uncertain by default. However, this model parameter can be estimated if in-season data clearly indicates a strong deviation from historical standard deviations. An uninformative gamma distribution is used as prior for the residual error term (σ_v^2).

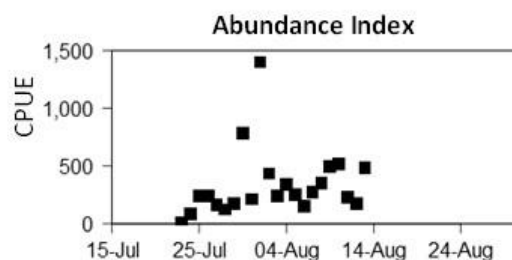
A. MODEL PARAMETERS



B. TIME-DENSITY MODEL



C. DATA



D. MODEL FIT

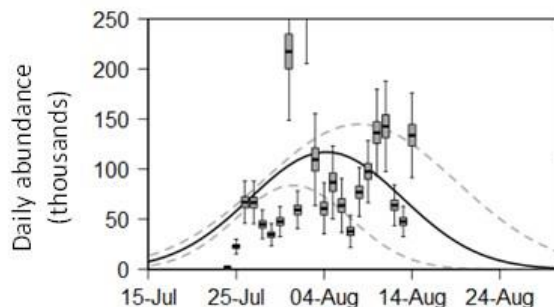


Figure 1. Graphical overview of the Bayesian time-density model when applied for the in-season assessment of Fraser River pink salmon. Prior probability distributions (A) based on preseason forecasts of run size, migration timing and standard deviation of the migration allow the prediction of the daily abundance of salmon assuming a normal distribution of migrating salmon over time (B). Marine test fishery CPUE data are collected continuously throughout the salmon migration (C) and the model predicted daily abundance estimates are fitted to these data (D). The uncertainty in daily abundance estimates derived from CPUE data and uncertain catchability estimates is represented using boxplots. Comparing the model predictions against the data allows the model to derive the posterior probability distributions of the model parameters (A). To simplify this figure, the probability distribution for the diversion rate and the variance parameters have been omitted.

Table 1. Probability density functions (pdfs) of the Bayesian time-density model and the parameter values of the prior pdfs used to assess Fraser River pink salmon.

Prior probability density function	Parameter values for Fraser River pink salmon
$R \sim \text{Lognormal}(\ln(m), 1 / \ln(1 + CV^2))$	Median and CV derived from the run size forecast
$T \sim \text{Normal}(\mu, 1 / (\mu * CV)^2)$	Mean and CV derived from the timing forecast
$S \sim \text{Normal}(\mu, 1 / (\mu * CV)^2)$	Mean and CV derived from historical data
$D \sim \text{Beta}(\mu * \eta, (1 - \mu) * \eta)$	Mean derived from the diversion rate forecast, $\eta = 20$
$q^{-1} \sim \text{Normal}(\mu, 1 / (\mu * CV)^2)$	Mean and CV based on historical data, later on in-season data
$1 / \sigma_v^2 = \tau_N \sim \text{Gamma}(0.001, 0.001)$	Mean = 1, variance = 1000
$1 / \sigma_w^2 = \tau_I \sim \text{Gamma}(0.001, 0.001)$	Mean = 1, variance = 1000

For the catchability coefficient (q), a normal prior probability distribution is assumed for the inverse of the catchability coefficient (q^{-1}), i.e., the expansion line. This prior probability distribution is based on historical data, and unlike other prior probability distributions is not updated by the model, given the lack of information in the data. In the past, this prior had been based on data going back to 1987, however, the quality of the annual estimates differed substantially based on the different methods to derive annual run size estimates ([Chapter A1](#)). Since 2011, pink salmon reconstructions have relied on Mission hydroacoustic estimates to estimate pink escapement into the Fraser River ([Chapter B8](#)) and this shorter time series has been used to derive the prior probability distribution for the catchability coefficient. Focusing on more recent years decreased the median Area 12 expansion line from 350 to 280, and the corresponding Area 20 expansion line from 1,050 to 840.

Figure 1 provides a graphical overview of the Bayesian time-density model as described above. This model was developed and is run in WinBUGS 1.4 (Spiegelhalter et al. 2003) and called from the statistical software package R (R Core Team 2013). All the model results undergo diagnostics to remove the impact of initial MCMC samples, to eliminate the negative impact of autocorrelation within the MCMC chains and to ensure convergence (Best et al. 1995). We assume the reported statistics of the posterior probability distributions represent the true underlying distributions.

PINK SALMON SPECIFIC ASSESSMENT CHALLENGES

While the time-density model has generally performed well for the assessment of sockeye salmon, including delaying Late run stocks (Michielsens and Martens 2022), its performance to assess the abundance of pink salmon has been less successful. This is in large part due to the lower precision in pink salmon CPUE data compared to sockeye, the larger variability in pink salmon catchability and the large variability in migration behaviour: migration speed and timing, the proportion and amount of the run that delays upstream migration into the Fraser River (Figure 2) and the diversion rate. The lower precision in pink salmon CPUE data has been especially a concern in recent years. In the past, entire purse seine sets would be landed, resulting in accurate catch estimates. Due to limited harvestable surplus of and conservation concerns for sockeye, the majority of the salmon caught in marine test fisheries nowadays are released with the exception of the salmon used for biological samples ([Chapter B6](#)). The precision of the pink salmon catch and CPUE estimates is much larger when spilling fish across the cork line or releasing all pinks caught compared to when landing most if not all the salmon catch.

Currently, the main in-season assessment tool for Fraser River pink salmon relies on test fishing CPUE data used in combination with historical catchability estimates. Unlike for sockeye salmon, the historical test fishing catchability for pink salmon cannot be updated based on in-season information due to the fact that pink salmon delay their upstream migration into the Fraser River. The larger variability among

catchability estimates for pink salmon compared to sockeye exacerbates the greater uncertainty associated with the in-season run-size estimates for Fraser River pink salmon.

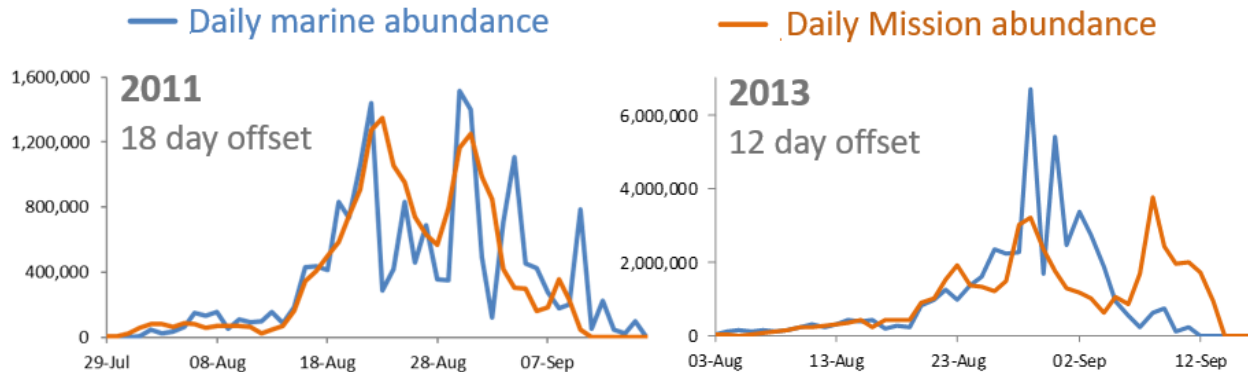


Figure 2. Illustration of the impact of the variability in the proportion of pink salmon delaying and the extent of the delay on the ability of test fishing-based CPUE abundance estimates to match reconstructed daily abundance estimates.

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B16. Alternative pink salmon run size estimation methods

S. Wong and M.J. Hague

Summary

The accuracy of in-season Fraser River pink salmon run size assessments is limited for a variety of reasons, including variable and unpredictable migration behaviour, slow migration speed, and low catchability of pink salmon. Unlike sockeye salmon, catchability estimates used in combination with catch-per-unit-effort (CPUE) data cannot be updated in-season using Mission hydroacoustic data. As a result, pink run size estimates from the traditional time-density models ([Chapter B15](#)) are often highly uncertain. A variety of alternative approaches are therefore considered when estimating in-season pink salmon run size. The accuracy of all these assessments still fundamentally relies on underlying assumptions of marine timing and test fishery catchability. While not intending to replace the traditional run size assessment model, consistency in run size estimates across different methods increases confidence in the results and may allow managers to update pre-season forecasts in a timelier manner.

Introduction

Under the terms of the Pacific Salmon Treaty (PST), Commission staff are responsible for providing the Fraser River Panel Technical Committee with in-season updates of Fraser River pink salmon run size (PST 2023). However, pink salmon behaviour limits the effectiveness of many of the preferred stock assessment tools used for in-season analysis of Fraser sockeye salmon. For example, pink salmon migrate more slowly through marine approach areas and redistribute prior to migrating upriver, making it impossible to reconstruct marine daily abundances based on hydroacoustic estimates and seaward catches ([Chapter B14](#), White 1998). As a result, it is challenging to update daily in-season catchability estimates for pink salmon. In addition, the historical catchability of Fraser pink salmon in marine test fisheries is both lower than sockeye salmon, and more variable, resulting in lower quality run size estimates for pink salmon compared to sockeye. The resulting bias can be substantial. For example, in 2013, an in-season run size estimate of 26 million pink salmon derived from test fishery CPUE and historical catchability estimates was revised post-season to 16 million—a bias of 78% (PSC 2019). Given these uncertainties, a suite of alternative methods of run size estimation are monitored in-season and used to provide evidence for or against various run sizes.

Alternative in-season pink salmon run size estimation methods include: (1) total run size based on cumulative marine abundance-to-date expanded by the historical percentage of seaward abundance, (2) doubling the cumulative abundance up to and including the forecasted marine timing date, (3) regression between run size and total CPUE over a specified date range, (4) regression between run size and cumulative CPUE-to-date and (5) regression between total escapement and cumulative escapement-to-date past Mission, plus seaward catch. Except for the approach using Mission escapement, the accuracy of these pink run size assessment models depends on both the quality of the CPUE data and meeting underlying assumptions of timing and catchability.

Data

The pink salmon stock assessment models described in this report rely on: historical pink salmon run size estimates based on total abundances at Mission plus seaward catch ([Chapter B14](#)), pink salmon daily and total escapement at Mission, Area 20 migration dates (i.e. the date 50% of the run would have passed through Area 20 assuming all pink salmon would migrate through Juan de Fuca Strait), daily CPUE from the Area 12 and 20 purse seine test fisheries ([Chapter B4](#)), and historical annual estimates of test fishing catchability.

Methods

1. ABUNDANCE-TO-DATE EXPANDED BY HISTORICAL PROPORTION SEAWARD

This method estimates run size based on the in-season estimate of the cumulative abundance (N) to-date and the predicted proportion (p) of the run left to come.

The in-season prediction of the daily abundance ($\hat{N}_d$) of pink salmon in marine areas is based on daily (d) CPUE (I) data from the Area 12 and 20 purse seine test fisheries, used in combination with an assumed annual catchability (q) estimate, where the Area 12 catchability is assumed to be three times higher than the catchability in Area 20 ([Chapter B14](#)):

$$(1) \quad \hat{N}_d = \frac{I_{d,A12}}{\hat{q}_{A12}} + \frac{I_{d,A20}}{\hat{q}_{A20}} = \frac{I_{d,A12}}{3 \cdot \hat{q}_{A20}} + \frac{I_{d,A20}}{\hat{q}_{A20}}.$$

The cumulative abundance-to-date sums the daily predicted abundances for all the past k estimates:

$$(2) \quad \hat{N}_{d_1 \rightarrow d_k} = \sum_{d=d_1}^{d_k} \hat{N}_d.$$

The predicted proportion of the run left to come is calculated as the median historical proportion-to-come, after Area 20 migration dates of those past years are aligned to the predicted Area 20 migration date for the current year. For each historical year, the predicted proportion of the run left to come is given by:

$$(3) \quad \hat{p}_{d_{k+1} \rightarrow d_n} = \sum \hat{N}_{d_{k+1} \rightarrow d_n} / \sum \hat{N}_{d_1 \rightarrow d_n}.$$

The total run size is then calculated by expanding the abundance-to-date by the historical proportion of the run still expected seaward of the test fisheries:

$$(4) \quad \hat{N}_{d_1 \rightarrow d_n} = \sum \hat{N}_{d_1 \rightarrow d_k} / (1 - \sum \hat{p}_{d_{k+1} \rightarrow d_n}).$$

The bias in the prediction is primarily affected by the assumed Area 20 migration date for the year of interest. The precision in the predicted run size is affected by the variability in the shape of the historical run distributions (deviation from normal, and standard deviation), and the shape of the current distribution (Figure 1). This method is often applied early in the season, when 50% of the run has not yet been observed and when there is insufficient data to fit a time density model ([Chapter B15](#), Michielsens and Cave 2019). Retrospective analyses indicate this model performs best when applied 5-days prior to the peak of the run. While the significant inter-annual variability in historical run size distributions contributes to uncertainty in this approach, it can still provide a useful early indication of run size.

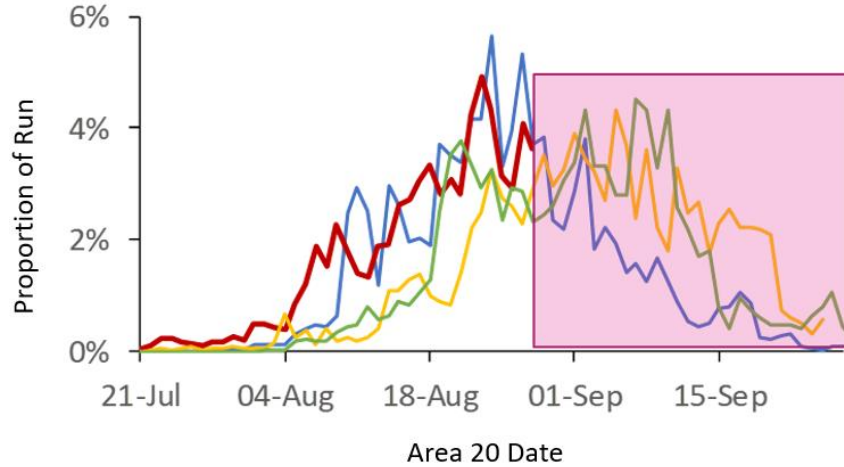


Figure 1. Illustrative example of the abundance-to-date pink salmon run size approach. The thick red line represents the hypothetical abundance observed to date, while the shaded error represents the uncertainty in the proportion of the run remaining seaward of test fisheries based on historical observations.

2. MARINE TIMING AND CUMULATIVE ABUNDANCE OF 50% OF THE RUN

Once biologists have confidence that 50% of the run has been observed in marine areas, the total run size can be estimated by doubling the cumulative abundance up to, and including, the 50% migration date. This is essentially a modification of the first method, but with a fixed assumption that 50% of the run is remaining seaward of the test fisheries. Prior to the expected 50% migration date, this approach can also be used to produce an early estimate of the *minimum* pink salmon run size, assuming the earliest observed Area 20 50% date in the historical record.

$$(5) \hat{N}_{d_1 \rightarrow d_n} = \sum \hat{N}_{d_1 \rightarrow d_k} / (1 - \sum \hat{p}_{d_{k+1} \rightarrow d_n})$$

where $\sum \hat{p}_{d_{k+1} \rightarrow d_n} = 0.5$.

3. REGRESSION BETWEEN TOTAL CPUE OVER A DATE RANGE AND RUN SIZE

Early updates to pink salmon run size can also be derived using a log-log regression between the total CPUE (I) over a specified date range and the total run size:

$$(6) \log_{10} N = \alpha + b \sum \log_{10} I_{d_k \rightarrow d_{k+l}}$$

A retrospective analysis identified the best performance when using a 3- to 7-day range of CPUE values, 5- to 10-days prior to the assumed Area 20 date. The $\log_{10}$ -transformation constrains values to be positive and is more biologically realistic. The linear regression model assumes equal catchability across years and knowledge of the Area 20 migration date to correctly select the best range of CPUE values. However, at high CPUEs, the relationship disintegrates, and the accuracy of run size estimates becomes poor. Regressions performed in 2017 indicated that when total CPUE from August 23-26 exceeded 10,000, the model could only indicate that the run was large and could not give precise predictions. Estimates may also be biased if marine timing deviates substantially from the historical average. However, in-season sensitivity analyses exploring multiple dates, date ranges and offsets can be used to further inform the confidence in the results (Figure 2).

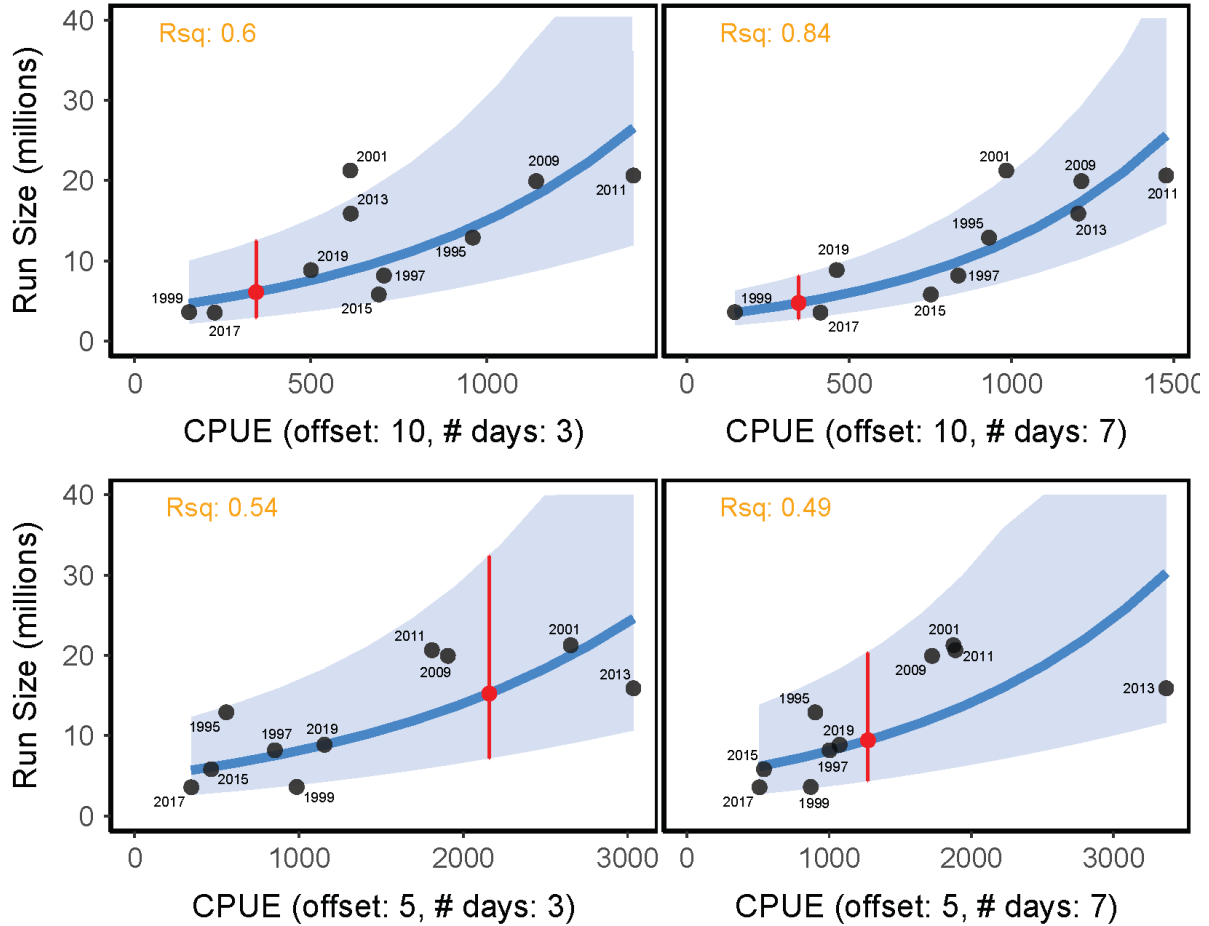


Figure 2. Outputs from the regression between marine CPUE averaged over 3 or 7 days and either 10 or 5 days prior to the expected Area 20 date and log₁₀-transformed pink salmon run size. The shaded blue region is the 80% prediction interval, and the red dot and line are the prediction and associated prediction interval for 2021 assuming an Area 20 timing of August 19. The end-of-season observed timing was August 20 and the abundance was 8.1 million.

4. REGRESSION BETWEEN CUMULATIVE CPUE-TO-DATE AND RUN SIZE

After 50% of the run is assumed to have passed through marine test fisheries, a regression between cumulative log-transformed CPUE-to-date (I) versus historical log-transformed run size (Figure 3) can also be used to predict the pink salmon run size:

$$(7) \log_{10} N = \alpha + b \sum \log_{10} I_{d_1 \rightarrow d_k}$$

Figure 4 shows the improvement in model fit as additional days of CPUE are added to the equation, demonstrating a rapid improvement in model fit after the peak of the run. While this approach does not require a direct estimate of in-season catchability, it does assume that test fishery catchability remains constant over time and results will be biased if the catchability deviates strongly from the historical average.

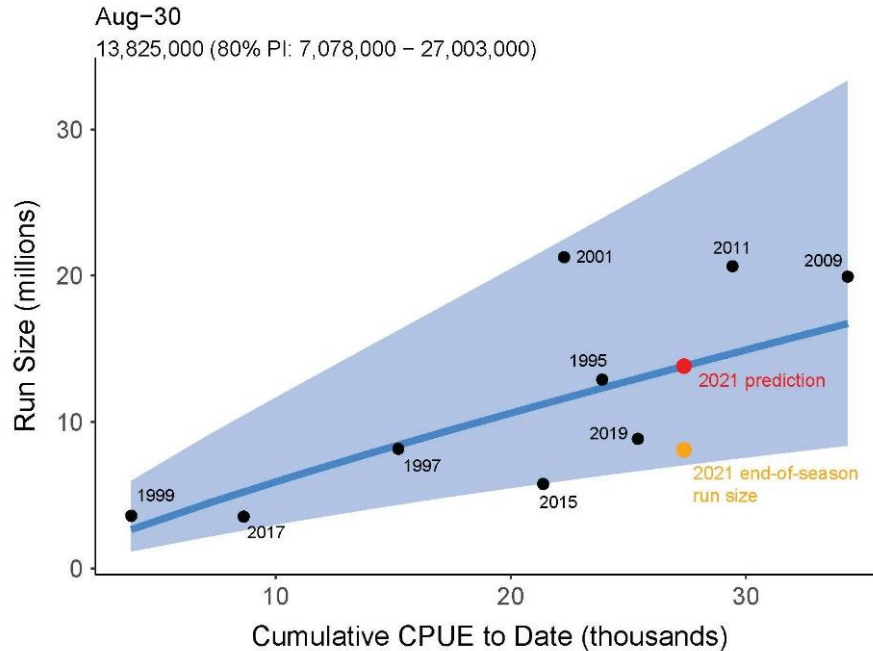


Figure 3. The relationship between run size and cumulative CPUE up to August 30. The shaded region is the 80% prediction interval, and the red point is the in-season prediction for 2021. The yellow point is the end-of-season 2021 run size of 8.1 million.

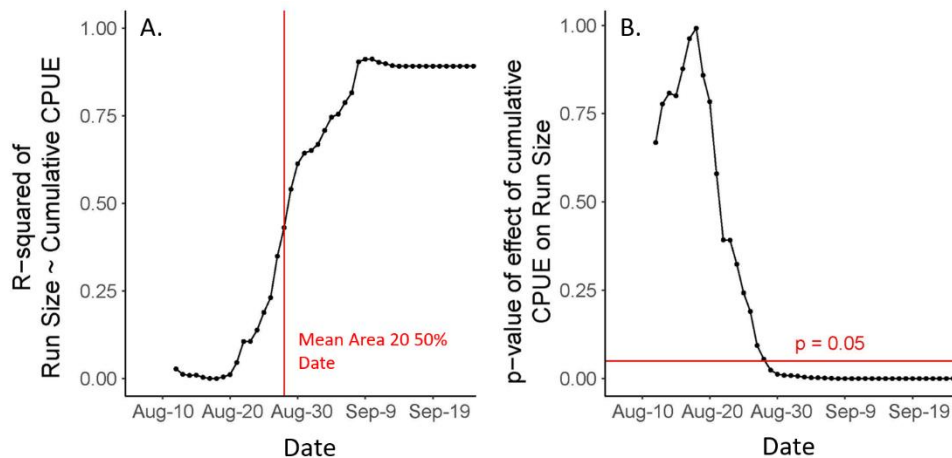


Figure 4. Impact of assessment date on the R-squared values (A) and p-values (B) of models that correlate cumulative CPUE-to-date with run size.

5. REGRESSION BETWEEN CUMULATIVE ESCAPEMENT PAST MISSION AND RUN SIZE

After the historical peak escapement date into the river, cumulative Mission escapement to date can be used to predict total Mission escapement (Figure 5) and seaward catch can be added onto the prediction to produce an estimate of run size. However, data are limited, as Mission-based estimates of pink salmon escapement are only available since 2009. While this approach does not provide information in time to make most fisheries management decisions, it can still provide updates that could impact regulations of upstream fisheries.

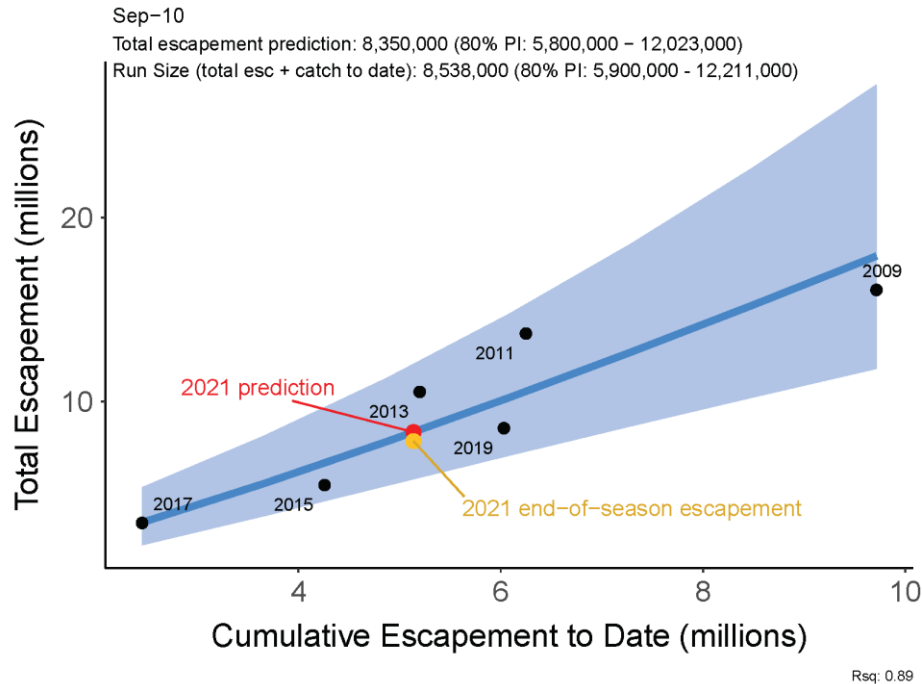


Figure 5. The relationship between total escapement and cumulative escapement past Mission up to September 30. The shaded region is the 80% prediction interval, and the red point is the in-season escapement prediction for 2021 of 8.35 million. The yellow point is the end-of-season 2021 total passage of 7.9 million. The 2021 end-of-season run size was 8.1 million.

Like the cumulative CPUE method, this method is only informative after the 50% migration date is observed at Mission (Figure 6). Given the limited historical time series and large prediction intervals associated with predictions made prior to mid-September, this method may be predominantly useful to give a qualitative sense of relative abundance compared to historical years rather than an exact number of salmon, at least until data from more years are available (Figure 7).

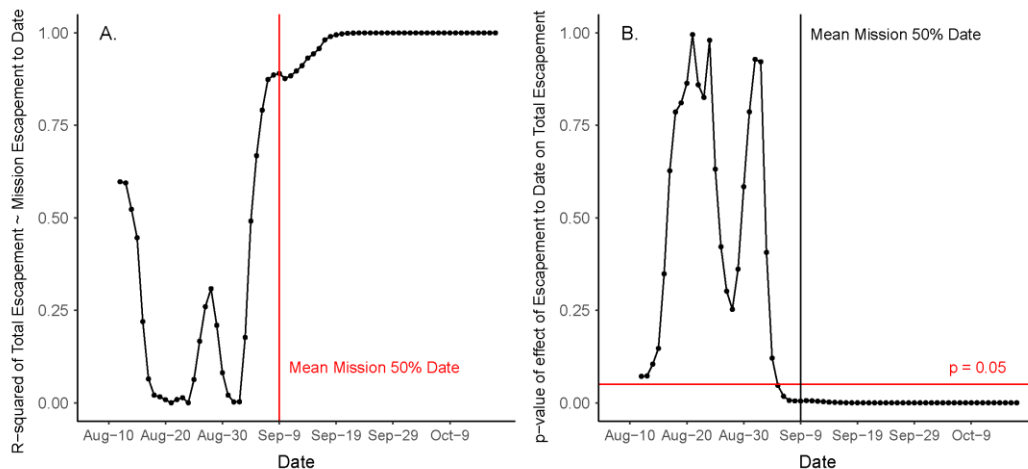


Figure 6. Impact of assessment date on the R -squared values (A) and p -values (B) of models that correlate cumulative escapement at Mission with total escapement.

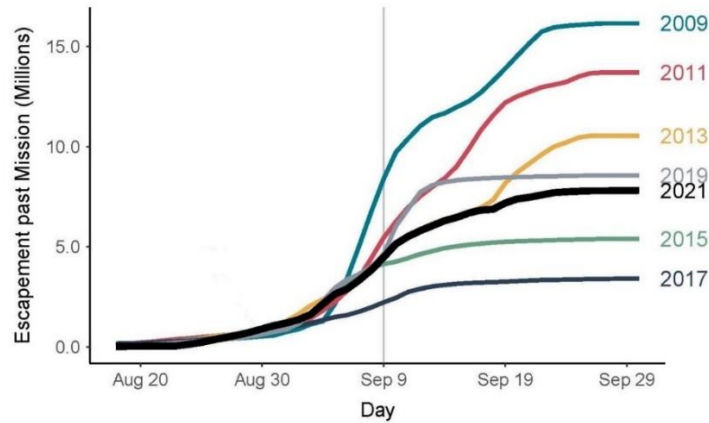


Figure 7. Cumulative escapement past Mission for various years. Lines start to differentiate around the mean Mission 50% date (September 9).

Next Steps

Due to the long and variable time it takes for pink salmon to migrate from the marine areas to Mission, pink salmon run size estimates are highly dependent on test fishery CPUE data and the assumed catchability. For example, the CPUE in 2023 was very high, resulting in a run size estimate exceeding 20 million (Figure 8). However, the post-season run size was only 10.2 million, indicating a higher catchability than had been observed historically. Thus, methods like the regression between cumulative CPUE and run size can provide misleading results when conditions vary from what has been observed historically. Ways to inform in-season catchability estimates independently of Mission data are essential for improving in-season pink salmon run size estimates. Some methods include revisiting the relationship between sockeye and pink salmon catchability or updating the catchability or expansion line using CPUE data from commercial fisheries.

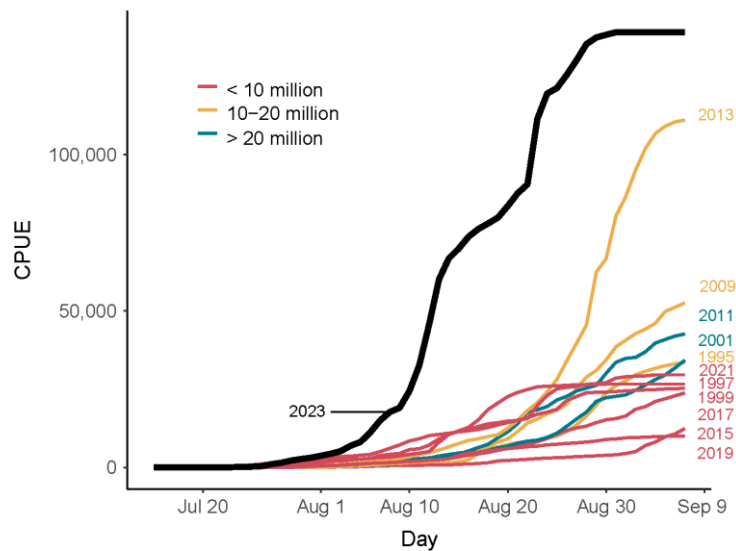


Figure 8. Cumulative catch-per-unit-effort (CPUE) for various years coloured by run size. Note that 2023 illustrates an exception where CPUE was high and suggested a large run size, but end-of-season run size was 10.2 million.

Most of the pink salmon run size assessment methods are sensitive to assumptions regarding the 50% migration date of the run. Therefore, tools focussed on improvements to pre-season and in-season timing forecasts ([Chapter A1](#)) could also lead to improved accuracy for in-season run size estimates. Currently, uncertainty associated with the additional assessment methods described in this report are communicated through sensitivity analyses and/or model prediction intervals. However, another potential improvement is to develop a Bayesian approach, which would allow a more direct quantification of the value of the historical priors combined with in-season observations.

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B17. Total Allowable Catch (TAC) and Fishing Induced Mortality (FIM)

M.R. Forrest

Summary

Available Total Allowable Catch (TAC) is an important pre-requisite for in-season fisheries. The Pacific Salmon Treaty (PST 2023, Chapter 4) describes the calculations for TAC for Fraser River sockeye and pink salmon. Fraser River pink salmon TAC is calculated as the remaining portion of the annual Fraser River pink salmon abundance available after the spawning escapement target and the expected catch in Panel-authorized test fisheries are deducted. If there is a remaining portion of pink salmon run size available for harvest in Fraser Panel Area waters, the United States (U.S.) share shall not exceed 25.7 percent of the TAC for pink salmon. This calculation is subject to adjustments for harvest overages or underages from previous years based on post-season catch estimates (Chapter 4, Paragraph 8a to 8d, PST 2023). The remaining TAC is assigned to Canada.

Harvest of Fraser pink salmon to achieve a party's TAC may be constrained by the management objectives for Fraser sockeye. Paragraph 3(g) of the PST (2023) notes that the Panel shall take into consideration the overlap in sockeye and pink salmon migration, and the available sockeye TAC when planning pink directed fisheries. In case there is no TAC for one or more of the overlapping sockeye management groups, pink directed fisheries may result in a 'small but acceptable' (SBA) rate of incidental harvest on one or more sockeye management groups that have little, or no TAC. To minimize sockeye mortality when there is no harvestable surplus, the Panel has moved towards non-retention of sockeye in pink directed fisheries in recent years. Due to the mortality associated with catch and release fishing practices, fishing-induced sockeye mortality (FIMs) are estimated in non-retention fisheries. FIMs are reported by the parties or calculated by the PSC. While FIMs impact the exploitation rate, they are not counted against the TAC.

Introduction

While the Fraser River Panel's primary objective, with regard to Fraser River pink salmon, is to reach Spawning Escapement Targets (SET) for the pink salmon management unit (MU), its second objective is to achieve international allocation of the Total Allowable Catch (TAC) (Chapter 4, PST 2023). The Treaty states that the U.S. share of the annual Fraser River pink salmon Total Allowable Catch (TAC) will not exceed 25.7 percent of the pink salmon TAC. The remaining available catch is deemed Canada's share.

Although Fraser River pink salmon TAC is managed separately from Fraser River sockeye salmon TAC, the Panel must take into consideration the impacts of pink salmon directed fisheries on overlapping sockeye management groups with little or no TAC (PST, Chapter 4). In recent years when the harvest of Fraser pink salmon has been constrained by the management objectives for Fraser River sockeye, pink salmon fisheries have required the non-retention or release of sockeye. However, capture and handling of the sockeye, prior to release, is associated with stress and injury. Fishing induced sockeye mortalities or release mortalities (FIMs) are therefore estimated in pink directed fisheries with non-retention of

sockeye. The FIM estimate conveys the impact of the fishing activity on sockeye that are released after catch. They are included in estimates of exploitation rate but are not counted against the sockeye TAC. TAC and FIMs are directly influenced by the size of the aggregate return (DFO 2023).

TAC Calculations

The two primary deductions used to calculate the Fraser River pink salmon TAC (Table 1) are the spawning escapement target (SET) and the Panel approved test fishing catch ([Chapter A2](#)). Each year, Fisheries and Oceans Canada (DFO) provides an escapement plan for the Fraser River pink salmon management unit (MU) as per Chapter 4, paragraph 3 of the PST. The spawning escapement plan is developed using the Pink Salmon Decision Guidelines (Table 2) that outlines the spawning escapement target and the allowable exploitation rate (ER) (DFO 2023). For pink salmon, Management Adjustments (MA) and Aboriginal Fishery Exemptions (AFE) are not accounted for in the TAC calculation.

Table 1. An example of the calculation of total allowable catch (TAC) and achievement of international catch shares for Fraser pink salmon in 2023.

		Fraser Pinks
RUN STATUS, ESCAPEMENT NEEDS & AVAILABLE SURPLUS		
In-season Abundance Estimate	10,300,000	
Spawning Escapement Target (SET)	6,000,000	
Test Fishing Catch (TF, post-seas. est.)	14,300	
Surplus above SET & TF	4,285,700	
DEDUCTIONS & TAC FOR INTERNATIONAL SHARING		
Total Deductions (SET + TF)	6,014,300	
Available TAC (Abundance - Deductions)	4,285,700	
UNITED STATES (Washington) TAC		
Propor. distrib. TAC - Payback	1,101,400	
Proportionally distributed TAC	1,101,400	25.7%
U.S. Payback	0	
Washington Catch	428,900	
Deviation from TAC - Payback	672,500	
CANADIAN TAC		
Propor. distrib. TAC + Payback + AFE	3,184,300	
Propor. distrib. TAC + U.S. Payback	3,184,300	74.3%
Canadian Catch excluding SSFSCatch	528,100	
Deviation from TAC + Payback	2,656,200	
TOTAL		
Available TAC + U.S. Payback	4,285,700	
Total Catch excluding SSFSCatch	957,000	
Deviation from TAC + U.S. Payback	3,328,700	

Table 2. *Fraser pink salmon Decision Guidelines (DFO 2023).*

Run Size	Escapement Plan and allowable Exploitation rate (ER)
Less than 7.059 million	The allowable ER increases linearly from zero percent at a run size of zero to 15% at a run size of 7.059 million (For run sizes less than 7.059 million, the allowable % ER is the run size expressed in million multiplied by 15%/7.059)
Between 7.059 and 20 million	The allowable ER increases from 15% to 70% The escapement goal is 6 million, the remainder is harvestable surplus.
Greater than 20 million	The allowable ER is 70% The escapement goal increases as the run size increases beyond 20 million

Preseason, the TAC is based on the preseason forecast as well as preseason expectations of in-season test fishing catches. Once the panel adopts an in-season Fraser pink salmon run size, the TAC table (Table 1) is updated to reflect the new run size and associated changes to the SET. These updates will determine if there is available TAC for pink salmon directed fisheries. After defining the TAC for international sharing, the PST indicates that the Panel shall develop and implement, to the extent practicable, a fishing plan that provides the U.S. fishery with the opportunity to harvest 25.7 percent of its share of the Fraser River pink salmon TAC. To accomplish this, the Panel must also take into consideration the availability of Fraser River sockeye salmon TAC.

As pink fisheries are executed, updated pink and sockeye catch numbers are provided by the countries to the PSC to evaluate the countries remaining Fraser River pink and sockeye TAC. In the case of non-retention of sockeye, countries report the associated Fishing Induced Mortalities. FIMs are not included in the TAC calculations but are part of the calculated exploitation rate.

In recent years, as sockeye catch and retention have become more restricted due to the lack of available harvest of sockeye salmon, unauthorised sockeye directed fisheries or unauthorized bycatch retention of sockeye in pink directed fisheries has increased. This catch is referred to as “other catch”. “Other catch” is considered part of a countries catch and is included in the TAC calculation. Terminal fisheries, named Single Stock Food Social and Ceremonial (SSFSC) fisheries are not included in the TAC calculation. Currently there are no SSFSC fisheries for pink salmon.

Adjustments to TAC Calculations

Adjustments are made to the U.S. share of the TAC in the case of previous-year(s) harvest overages (more fish caught than allocated share) or underages (less fish caught than allocated share from the previous year(s) (Chapter 4, Paragraphs 8a to b, PST 2023). Reasons for adjustments include the following: (1) management imprecision in U.S. fisheries (2) Canada impeding the U.S. from pursuing its in-season share. There are no adjustments for overages that are a result of TAC reductions after the scheduling of the last Panel approved U.S. fishery of the season, or underages resulting from an increase in the TAC at the end of the season (Chapter 4, Paragraphs 8c to d, PST 2023). Adjustments for underages are made if Canada directly impedes the US from obtaining its share of the TAC, but not because the U.S. failed to deploy sufficient effort, or fish were not accessible to U.S. fisheries due to

northern migration patterns or harvesting constraints. Adjustments, for previous year overages or underages, are limited so that the resulting TAC is not reduced by more than 5% or increased by more than 15% unless the Panel agrees otherwise. If there is an overage or underage from a previous season to be carried forward but no available TAC in the current year, the Panel may agree to carry the overage or underage forward to subsequent year(s). Any residual overage or underage on the last year of the negotiated Treaty will be carried forward to the next Treaty Period.

FIM Calculations

In planning and implementing Fraser pink fisheries, the Panel takes into consideration the availability of both the sockeye salmon TAC and pink salmon TAC, through the entire fishing season (Chapter 4, PST 2023). In recent years, when no sockeye TAC is available, pink salmon fisheries have been implemented with non-retention (release) of sockeye salmon caught in the fishery. Due to the stress of capture and handling, there is a mortality associated with the release of these sockeye. Fishing Induced Mortalities (FIMs) of sockeye that are released are therefore estimated in pink salmon fisheries.

FIM estimates are based on the proportion of sockeye within the catch and the release mortality associated with the gear. To limit FIMs, fisheries can be implemented when and where sockeye proportions are low and using gear that minimizes release mortality (Table 3). To achieve this, the PSC provides the Panel with predicted Fraser River sockeye mortality estimates by area, gear and date. This allows the Panel to make decisions regarding potential pink directed fisheries. FIM reporting has been inconsistent, with some fisheries reporting FIMs either in-season or post-season, while others rely on PSC staff to estimate FIMs based on catch reports. Although FIMs are not included in the TAC calculation it is included in the calculation of the exploitation rate, making it important to be properly accounted for.

Table 3. *Percent release mortality associated with different gear types.*

Gear Type	Release Mortality
Gillnets	60%
Purse seine nets	25%
Gulf troll	10%
Reef nets	0.5%

Small but acceptable incidental harvest

Both pink and sockeye TAC are important pre-requisites for in-season pink fisheries. Based on Annex IV, Chapter 4, paragraph 3g of the Pacific Salmon Treaty, the Panel needs to take into consideration the overlap in sockeye and pink salmon migration, and the available sockeye TAC when planning pink directed fisheries. More specifically the Treaty stipulates that, to the extent practical, pink directed fisheries should minimize the impact on overlapping sockeye management groups with little or no TAC (Chapter 4, PST 2023). If there is TAC available for both pink and sockeye management groups that are impacted by the proposed fishery, TAC is the main consideration. In case there is no TAC for one of the overlapping sockeye management groups, the Treaty indicates that overlapping pink and sockeye migration may result in a ‘small but acceptable’ (SBA) rate of incidental harvest on one or more sockeye management groups that have little or no TAC. For a U.S. fishery to be approved when there is no sockeye TAC, the resulting sockeye catches of the U.S fisheries proposal should be deemed small but acceptable by both parties. PSC Staff are involved in predicting the catch of proposed fisheries but are not involved in the evaluation of what should be considered ‘small but acceptable’.

There have been disagreements about the interpretation of paragraph 3g, most notably on August 18, 2023, when the U.S. proposed pink-directed Treaty Tribal Ceremonial and Subsistence (C&S) fisheries with retention of sockeye and on August 25, 2023, when the U.S. proposed pink-directed Treaty Tribal and All Citizen fisheries with non-retention of sockeye. On both occasions, the U.S. considered the incidental harvest rate of sockeye small but acceptable and in accordance with the Treaty, while Canada disagreed (PSC 2024).

Table 4 provides an overview of the run size, TAC, catch and exploitation rates for all years since paragraph 3g has been in effect. Of the five pink salmon years since 2014, four had no international sockeye TAC by the end of the season. For these past years without sockeye TAC but with pink-directed U.S. fisheries, Canada approved U.S. fishery proposals including the retention of sockeye in Treaty Tribal Ceremonial and Subsistence (C&S) fisheries, allowing for the non-commercial harvest of sockeye in Treaty Tribal fisheries for personal, ceremonial or community use (2017 and 2019). The retention of sockeye for commercial use, by U.S. Treaty Tribal and All Citizen fisheries, has not been allowed in any of the past years when there was no sockeye TAC. In 2015, U.S. sockeye catches were a result of available TAC at the time of the scheduling of the U.S. fisheries.

Table 4. Overview of run size, available international TAC, available harvest, Washington, Canadian and test fishing catch, exploitation rate (ER, landed catch/run size) and exploitation rate including Fishery-Induced Mortalities (FIMs) of sockeye in pink-directed fisheries. The run size, TAC and available harvest are the estimates adopted at the last in-season Panel meeting, in accordance with Annex IV, Chapter 4 of the Treaty (PST 2023). Note that, following common FRP practice, test fishing catch has been accounted for in the exploitation rate calculation.

	2015	2017	2019	2021	2023
Sockeye salmon					
Run size	2,120,100	1,487,000	500,000	2,553,000	1,667,000
Available TAC	0	0	0	175,600	0
Available harvest	68,100	0	0	575,600	0
Washington Catch	46,200	1,500	470	20	2,370
FIMs	530	0	72	1,429	872
Canadian Catch	187,900	71,900	9,860	80,230	15,040
FIMs	0	1,760	2,216	5,831	5,440
Test Fishing Catch	38,000	13,830	6,410	17,970	16,660
Exploitation rate	12.83%	5.86%	3.35%	3.85%	2.04%
ER incl. FIMs	12.86%	5.98%	3.82%	4.13%	2.42%
Pink salmon					
Run size	5,781,300	3,700,000	8,900,000	8,000,000	10,521,000
Available TAC	662,200	270,900	2,882,760	1,995,000	4,274,730
Washington Catch	330,900	102,200	233,290	195,970	436,480
Canadian Catch	116,500	37,200	300,260	79,780	493,460
Test Fishing Catch	48,900	17,700	17,240	4,320	14,270
Exploitation rate	8.58%	4.25%	6.19%	3.50%	8.97%

Potential Areas for Improvements

While FIMs are being reported more consistently by the two countries than in the past, the extent of reporting coverage across all fisheries intercepting Fraser sockeye remains unclear. Improving the documentation, as well as the reliability and accuracy associated with Fraser Sockeye FIMs was a part of the PSC staff recommendations following the 2023 Fraser Sockeye season (PSC 2024).

Although FIMs account for capture and release mortality, they do not include the additional mortality associated with encounters with fishing gear. A proper accounting of fishing-related incidental mortality (FRIM), that includes this additional mortality, is essential to account for the total mortality of Fraser sockeye as a result of pink directed fisheries (Patterson et al. 2017). The recommended methods to assess FRIMs, rather than just FIMs, is through a collection of fishery specific information, related to key factors, namely capture times, handling, injury, water temperature, and predation risk (Patterson et al. 2017). However, this information is not currently collected from fisheries that potentially intercept Fraser sockeye.

Small but acceptable incidental harvest has been a topic of debate since 2022 and has resulted in special reports following the 2022 and 2023 Fraser Panel management seasons (PSC 2024a, 2024b). Recently, Pacific Salmon Commission Tribal and First Nations Caucus Commissioners signed a Memorandum of Understanding (PSC 2025). This MOU has enabled members of the Fraser River Panel representing First Nations and Treaty Tribes to meet to devise a solution to address the definition and implementation of small but acceptable incidental harvest.

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Glossary of terms

Abundance: The number of fish or the size of a stock.

Acoustically measured fish length: Fork length measurements from the fish's nose to the fork of its tail using ARIS fish images.

Acoustic blind zone: Area from which the return echoes are excluded from the recording by an echo sounder system.

Acoustic ensonified zone: Areas from which the return echoes are recorded by an echo sounder system.

Acoustic ping: Transmission of a single or a group of acoustic pulse(s).

Adipose-clipped (ADC): A salmon that is missing an adipose fin without notable scarring. Hatcheries mark released smolts by removing their adipose fin.

Adipose-damaged (ADD): A salmon that is missing its adipose fin with notable scarring and may or may not be a hatchery clipped fish.

Adipose fin: A small fleshy fin without rays found on the back behind the dorsal fin of some teleost fishes such as salmon.

All Citizen fishery: Refers to a type of fishery in the U.S., as opposed to U.S. Tribal fisheries.

Allele: Alternative forms of a gene inherited from each parent.

Anal fin: The median, unpaired, ventrally located fin that lies behind the anus.

Area 20 date: An index of marine migration timing, assuming the entire run migrated through Canadian fishery management Area 20 in Juan de Fuca Strait.

ARIS: Adaptive Resolution Imaging Sonar hydroacoustic equipment used to count passing fish.

Bayesian: Statistical method based on Bayes' theorem which specifies how prior probability distributions and data interact in the generation of estimates.

Brood year (BY): The year in which an individual fish was spawned.

C&S: Ceremonial and Subsistence. This is a type of fishing conducted by Tribes in the U.S.

Catch per unit of effort (CPUE): A relative measure of the abundance of the target species.

Caudal fin: Often called the tail fin. It provides the main power for forward movement of the fish.

Coefficient of variation (CV): Statistical measure of the dispersion of data points around the mean.

Delay: Number of days pink salmon will delay in the Strait of Georgia during their migration to the Fraser River.

Density dependence: Stock-recruit dynamics whereby a large number of spawners are thought to have a negative effect on productivity such that subsequent recruit numbers are reduced.

Diversion rate (Northern diversion rate): Proportion of the salmon run that migrates through Johnstone Strait (northern approach) as opposed to Juan de Fuca Strait (southern approach).

Dorsal Fin: A median fin along the back of the fish which is supported by rays.

Dorsal hump: Distinct hump often developed by male salmon prior to spawning.

Echosounder: The topside, land-based component of the hydroacoustics system that provides power, data transfer, and signal processing to the submerged transducer.

Economic Opportunity (EO) fishery: Commercial Fraser River First Nations fishery in the Lower Fraser River.

El Niño Southern Oscillation: Inter-annual climate variability event in the Pacific Ocean that occurs every two to seven years and persists for less than 2 years, characterized by coupled variations in sea surface temperature and sea level pressure.

Escapement (SE): Spawning escapement of adult male and female spawners and jack spawners (precocious age 3 males) as estimated through assessment programs conducted on the spawning grounds or projected from other data when such programs are not conducted.

Expansion line (EL): Inverse of the catchability coefficient, which indicates the extent to which a stock is susceptible to fishing.

Exploitation rate (ER): The proportion of a fish stock or population removed by fishing.

Fish density: Number of fish per unit volume (fish m⁻³).

Fishery-induced Mortality (FIM): Mortality associated with the release of caught fish due to stress of capture or handling. Fishery-induced mortality is also referred to as release mortality.

Fishery Planning Model: A pre-season simulation model that allows the Fraser River Panel to evaluate the impacts of various fishery options on the achievement of management objectives, given pre-season expectations such as abundance, stock composition, migration timing, diversion rate, spawning escapement targets, management adjustments and catch objectives.

Fraser River Panel (FRP): Responsible for the in-season regulation of fisheries in Southern BC and Northern Puget Sound targeting Fraser River sockeye and pink salmon.

Fraser River Technical Committee (FRTC): Technical Committee that supports the work of the PSC Fraser River Panel.

Freshwater zone: The area on the salmon scale that represents the time the fish spent in freshwater.

Fry: Juvenile freshwater life history stage when salmon have emerged from the gravel, completed yolk absorption, and are less than a few months old.

Fork length: Length from the fish's nose to the fork of its tail.

Food, Social and Ceremonial (FSC) fishery: Non-commercial First Nations fishery.

Gear: Equipment used to fish.

Genetic differentiation: A measure of how different two populations are genetically based on what alleles they share.

Genetic profile (or multilocus genotype): A composite of genotypes from different locations of the genome.

Genotype: Genetic make-up at a particular location of the genome that is composed of alleles inherited from the two parents.

Gilled: A fish captured in a net by their gills, causing them to become entangled and unable to escape.

Gillnet (GN): A fishing net which is hung vertically such that fish attempting to swim through the net are entangle by their gills.

Harvest Control Rule (HCR): Operational component of a harvest strategy that conveys the pre-agreed rules that determine how much fishing can take place.

Hydroacoustics: Technology involving sonars to detect fish in the water.

Hypural plate: A wide, fan-like plate onto which the caudal fin rays are attached.

In-season assessments: Assessments to inform fisheries management in real time throughout the fishing season.

Integrated Fisheries Management Plan (IFMP): DFO document to communicate on the planning of fisheries and their management to DFO staff, co-management boards and other stakeholders.

International Pacific Salmon Fisheries Commission (IPSFC): International Commission formed in 1937 between governments of Canada and the United States for the protection, preservation and extension of the sockeye and pink salmon fishery of the Fraser River. The IPSFC was dissolved in 1985 following the signing of the Pacific Salmon Treaty.

Jack: A male salmon that spawns after spending a year or two less in the sea than most individuals of its species.

La Niña: Inter-annual climate variability event characterized by anomalous cool sea surface temperature and low sea level pressure.

Lateral Line: A sensory organ of fishes which consists of a canal running along the side of the body and allows perception of low frequency vibrations and pressure differences.

Local adaptation: A population that has evolved characteristics to survive and reproduce in specific local environmental conditions.

Locus (plural Loci): A location in the genome.

Low Abundance Exploitation Rate (LAER): The purpose of managing a sockeye management group in a LAER situation is to permit by-catch of that stock group in fisheries directed at other management groups or species with available surpluses, e.g. Fraser River pink salmon. The application of a LAER for a management group has the effect of limiting the exploitation rate (ER) of that group to a small amount, e.g., 10% or 20%.

Management Strategy Evaluation (MSE): A simulation model to test different potential harvest control rules to achieve the management objectives.

Marine growth: Growth of the fish during their time in saltwater.

Markov chain Monte Carlo (MCMC): Algorithm used in Bayesian analyses to approximate the posterior probability distribution by random sampling.

Maximum likelihood estimation (MLE): Statistical method to estimate model parameters, given the observed data.

Maximum sustainable yield (MSY): The largest average catch that can be removed from a stock over an indefinite period under existing environmental conditions.

Median: 50th percentile of the distribution

Microsatellite: A genetic marker characterized by repeating sequences of DNA where number of repeats are used to characterize alleles.

Migration date or 50% date: Dates when half (50%) of the total run would have passed a location.

Miscellaneous stock: A stock forecasted by DFO without a spawner-recruit relationship, given a lack of recruit data of sufficient length.

Multivariate method: A statistical method that uses more than one independent variable in the analysis.

Natal fidelity: Tendency of organisms to return to their birthplace to reproduce.

Nearest-neighbor method: A spatial statistical approach to predict missing values based on observations in neighboring areas.

Non-directed/targeted: Fish caught incidentally by fisheries targeting other species.

Non-retention: In fisheries where one species is targeted but by-catch of a second species is expected, regulations may specify that the fish of the second species be released, not retained. Non-target species that are released are assigned gear-specific fishing induced mortality rates (see FIMs), that are accounted for along with landed catches in estimates of total exploitation rates.

Northern Diversion rate: Proportion of the salmon run that migrates through Johnstone Strait (northern approach) as opposed to Juan de Fuca Strait (southern approach).

Pacific Decadal Oscillation (PDO): Atmospheric and oceanic index used to describe the inter-decadal variability in the climate of the North Pacific Ocean.

Pacific Salmon Commission: Regional Fisheries Management Organization (RFMO) overseeing the Pacific Salmon Treaty (PST) between Canada and the United States.

Pacific Salmon Treaty: Bilateral agreement between Canada and the United States addressing the conservation and allocation of Pacific salmon.

Panel Area Waters: Geographical area defined under the Pacific Salmon Treaty in which Fraser River sockeye and pink salmon management is subject to provisions of the Treaty.

Polymerase chain reaction (PCR): a molecular biology method to create many copies of targeted parts of the genome to allow further genetic analyses

Principal component analysis: A statistical method to summarize a set of variables that are correlated (e.g., scale data) by creating synthetic variables called principal components that are linear combinations of the original variables. Principal components are not correlated with each other and satisfy the independence assumption in many statistical methods.

Principal component scores: Transformed variable values after principal component analysis.

Prior (prior probability distribution): A probability distribution that express the information about a parameter before any observed data. Priors may be based on historical observations, theoretical expectations, etc.

Productivity: The ability of a salmon population to sustain itself, often defined as the number of adult fish produced per spawner.

Purse Seine (PS): A net that can be drawn into the shape of a bag using the line along the bottom of the net like the drawstring of a purse.

Reconstruction: Forward reconstructions predict daily escapement into the river based on marine daily abundance estimates while backward reconstructions add marine and lower river daily catches to daily escapement estimates to reconstruct daily abundances in marine areas.

Recreational fishing (sport fishing): Non-commercial fishing as a leisure activity or to provide food for personal consumption.

Recruit: A salmon that survives to maturity is considered a “recruit” from its parent generation, or brood year.

Recruits per spawner (R/S, RS): A measure of productivity of a population or stock. The number of salmon surviving to maturity per each adult salmon that successfully spawned in the freshwater spawning grounds.

Reef net (RN): A net suspended between two boats. The net is anchored for stability.

Resorption: The physical wearing down of the scales from the environmental stress of moving from marine waters to freshwater waters. It makes the scale difficult to age as the perimeter of the scale is worn away.

Return year: The year in which an individual salmon returns to freshwater with intent to spawn.

Ricker model: Model describing the density-dependent population dynamics between the number of spawners and recruits.

Run size: The total number of returning adult salmon prior to being impacted by fisheries en-route to the spawning grounds.

Scale: Thin plate of keratinized protein that grows continuously on the skin of a fish.

Set net: Gillnet anchored in position rather than drifted.

Single nuclear polymorphism (SNP): a genetic marker with alleles that differ at a single nucleotide base.

Single Stock FSC (SSFSC): FSC fisheries for individual Fraser sockeye spawning populations that may be considered if the projected number of spawners is expected to exceed the freshwater productive capacity of the system.

Spawner: Adult salmon that successfully migrate from marine environments to freshwater spawning grounds and have the opportunity to reproduce, after avoiding natural mortality and harvest.

Spawning Escapement (SE): Spawning escapement of adult male and female spawners as estimated through assessment programs conducted on the spawning grounds or projected from other data when such programs are not conducted.

Spawning Escapement Plan: The pink salmon escapement plan specifies escapement requirements that vary with run size and includes an abundance below which there are limited directed harvests allowed.

Spawning escapement target (SET): Target for total adult spawning escapement for each spawning population as defined each year by Canada’s Spawning Escapement Plan.

Spread: Number of days encompassing 95% of a stock’s migration.

Stock: A genetically distinct population of salmon, spawning at similar times and location.

Stock assessment: Use of statistical and mathematical calculations to estimate fish abundance as well as the impact of fisheries management decisions on fish abundance.

Tangled: A fish caught in a net by becoming entangled, without being gilled.

Time-density model: In-season run size assessment model that estimates allows to estimate run size and migration timing based on the proportion of the migration on a given date.

Transect sampling: Sampling from a mobile platform along pre-set routes.

Transducer: A piezoelectric device usually built from certain types of ceramics that transforms electrical energy to mechanical energy and vice versa. In other words, an acoustic transducer converts electric signal into an acoustic signal via vibrations of a ceramic element, and then receives the incoming sound wave and converts it back into an electric signal.

Total Allowable Catch (TAC): The abundance of pink salmon available to be caught after spawning and the expected catch in Panel-authorized test fisheries have been subtracted from the run size.

Whatman Sheet: Filter paper used from drying and preserving DNA samples.

Acronyms and abbreviations

AC	All Citizens
ADFG	Alaska Department of Fish and Game
AFE	Aboriginal Fishery Exemption
ARIS	Adaptive Resolution Imaging Sonar
BEST	Bivariate ENSO Timeseries
BY	Brood year
CI	Confidence Interval
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
CPUE	Catch per unit effort
CU	Conservation Unit
CV	Coefficient of variation
cyc	Cycle line
DBE	Difference between estimates
DFA	Discriminant Function Analysis
DFO	Fisheries and Oceans Canada
DIDSON	Dual-frequency Identification SONar
EFS	Effective Female Spawners
Ei	Entrance Island
EL	Expansion Line
EO	Economic Opportunity
ER	Exploitation rate
ESSR	Excess salmon to spawning requirements
EWatch	DFO Environmental Watch
F	Fishing mortality
FIM	Fishing-induced mortality
FN	First Nations
FPM	Fishery Planning Model
FRP	Fraser River Panel
FRTC	Fraser River Technical Committee
FSC	Food, Social and Ceremonial
GAM	General Additive Model

GAMM	Generalized Additive Mixed-effects Model
GLM	Generalised linear model
GN	Gill net
GSI	Genetic Stock Identification
GUI	Graphic user interface
HCR	Harvest control rule
HR	Harvest rate
HSM	Hope Statistical Model
IFMP	Integrated Fisheries Management Plan
IPSFC	International Pacific Salmon Fisheries Commission
ITQ	Individual transferable quota
JD	Julian date
JS	Johnstone Strait
LAER	Low abundance exploitation rate
LDA	Linear discriminant analysis
LRP	Limit Reference Point
M	Natural mortality
MA	Management Adjustment
MAE	Mean Absolute Error
MCMC	Markov chain Monte Carlo
MEF	Mid-eye fork length
MRE	Mean Raw Error
MSE	Management Strategy Evaluation
MSY	Maximum Sustainable Yield
MU	Management Unit
NEPSTAR	North East Pacific Salmon Tracking and Research
ONI	Oceanic Niño Index
OSCAR	Ocean Surface Current Analysis Real-time
p50	50 th percentile (similar for p10, p25, p75, p90)
PBS	Pacific Biological Station
PCA	Principal components analysis
PCR	Polymerase chain reaction
pDBE	Proportional Difference between estimates

PDO	Pacific Decadal Oscillation
PED	Passage estimate difference
PI	Probability Interval
Pi	Pine Island
pMA	Proportional Management Adjustment
POF	Postorbital fork length
POH	Postorbital hypural length
POM	Princeton Ocean Model
PS	Purse seine
PSC	Pacific Salmon Commission.
PSE	Potential Spawning Escapement
PST	Pacific Salmon Treaty
R	Recruits
REF	Retrospective Evaluation Framework
RMSE	Root mean square error
RN	Reef net
RS	Recruits per spawner
RSA	Run size adjustment
SARA	Species at Risk Act
SCAM	Shape constrained additive models
SE	Spawning escapement
SET	Spawning escapement target
SID	Stock Identification
SNP	Single nucleotide polymorphism
SOG	Strait of Georgia
SOI	Southern Oscillation Index
SSS	Sea surface salinity
SST	Sea surface temperature
TAC	Total Allowable Catch
TAM	Total Allowable Mortality
TF	Test Fishery
Tr	Tribal
TR	Troll fishing

TS	Target Strength
WDFW	Washington Department of Fish and Wildlife