Fisheries and Oceans Canada / Pêches et Océans Canada
Ecosystems and Oceans Science / Sciences des écosystèmes et des océans

MIGRATION SPEED, RUN TIMING AND MIGRATION ROUTE FOR INTERIOR FRASER STEELHEAD TROUT (*ONCORHYNCHUS MYKISS*)

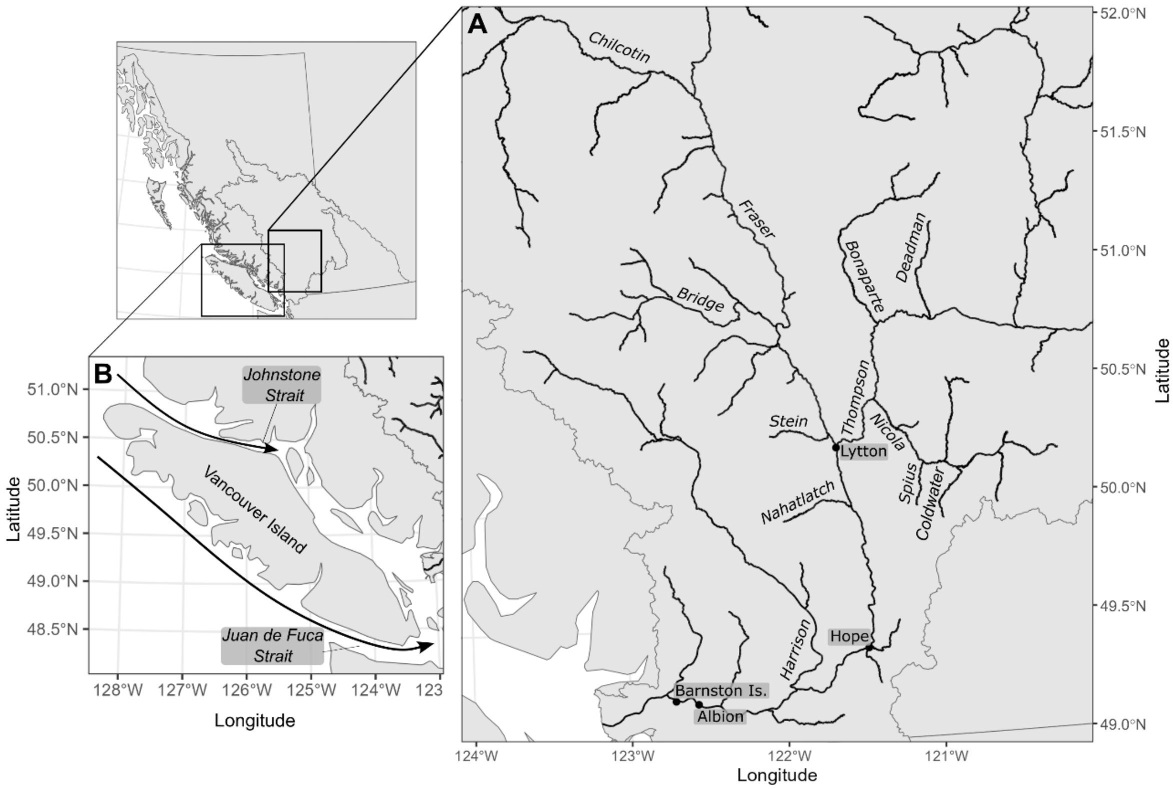

Figure 1. Map of freshwater and early/late marine migratory areas for Interior Fraser Steelhead Trout. Panel A depicts a subset of the Fraser River watershed with place names and rivers used in migration speed studies and test fishery data collection. Panel B depicts Vancouver Island with two possible marine migration routes used by Steelhead Trout from southern British Columbia.

Context:

Interior Fraser River Steelhead Trout (Thompson River and Chilcotin River Designatable Units) have recently been assessed as Endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2020) and abundance of this aggregate is at historic low levels. Fisheries and Oceans Canada (DFO) Fisheries Management has requested assessment and validation of information available to inform key input parameters required for the development of fishery planning models, including migration speed, run timing, and migration route, in a transparent way. The assessment and advice arising from this process will be used to develop fisheries management plans for Interior Fraser River Steelhead Trout, including the development of an exposure-based fishery planning tool that will be reviewed in a subsequent process. A key part of this work is the development and evaluation of potential models to estimate run timing of adult Interior Fraser River Steelhead Trout in the lower Fraser River, based on test fishery data.

This Science Advisory Report is from the January 31 to February 1, 2024, regional peer review on Migration Speed, Run Timing, and Diversion Rate for Interior Fraser River Steelhead. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

SUMMARY

- The purpose of this process was to compile information and estimate key parameters (run timing, migration speed and route) required for the development of a fishery planning tool to assess the risk to returning adult Interior Fraser River Steelhead Trout from marine and freshwater fisheries in Southern British Columbia.
- Existing information on the migration speed of returning adult Steelhead Trout, including but not limited to Interior Fraser River Steelhead Trout, in marine and freshwater habitats is sparse and variable, but could be used to parameterize the fishery planning tool.
- Adult Steelhead Trout appear to use migration routes on both sides of Vancouver Island, but available information is insufficient to estimate the proportion of Interior Fraser River Steelhead Trout that use each route.
- The timing of upstream migration of Interior Fraser River Steelhead Trout was estimated using data from the Albion test fishery in the lower Fraser River. A model with a hierarchical structure and asymmetric run timing predicts that 95% of Interior Fraser River Steelhead Trout pass the test fishing location between September 8 and November 23, with 50% passing by October 10.
- Sensitivity analyses indicated run-timing estimates were robust to data uncertainties and were not substantively affected by sparse Steelhead Trout catch data in recent years.

INTRODUCTION

The Thompson River and Chilcotin River Designatable Units (DUs) of Steelhead Trout (*Oncorhynchus mykiss*) have been assessed as Endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2020). These DUs are important parts of the Interior Fraser River Steelhead Trout aggregate, which is at historic low levels of abundance (Bison 2022). In order to minimize risks to Interior Fraser Steelhead Trout from incidental exposure to fisheries targeting other species, information about their spatio-temporal distribution is required. However, data on fisheries-dependent mortality patterns are scarce because monitoring programs for fisheries are incomplete and tend to focus on estimating target species catch, rather than bycatch. Consequently, complete estimates of catch of Interior Fraser River Steelhead Trout for use in conventional stock assessment procedures are not available for most Canadian salmon fisheries.

As a first step in developing a planning tool for estimating Steelhead exposure to fisheries, this process gathered available information to inform key input parameters. These parameters include freshwater and marine migration speeds, migration route around Vancouver Island (Figure 1, Panel B), and run timing for returning adult Interior Fraser River Steelhead Trout. Run timing was assessed by fitting statistical models to catch data from the Albion test fishery, in the lower Fraser River (Figure 1, Panel A). Estimates of run timing are for the Interior Fraser River Steelhead Trout aggregate as a whole because the historical time series of catch data used here (Albion test fishery data 1983–2022) does not differentiate the Thompson and Chilcotin populations from other Fraser River Steelhead Trout. Other Interior Fraser River populations, specifically those from the West Fraser (Bridge, Seton, Stein, Nahatlatch), tend to co-migrate with the Thompson and Chilcotin populations. Other Steelhead Trout populations present in the Fraser River, such as Coastal Summer and Coastal Winter populations, have different migration timing than Interior Fraser River Steelhead Trout and therefore would be unlikely to be encountered during this period.

Specifically, the objectives of this process were to:

1. Compile information on migration speed, migration route, and run timing of migrating Interior Fraser River Steelhead Trout and provide insights on information gaps.
2. Estimate historical run-timing parameters for Interior Fraser River Steelhead Trout based on the best available data.
3. Evaluate the models developed for (2) by examining and identifying uncertainties in the data and modelling approach. This will include using simulation analyses to provide insight into the reliability of the model given data quality.
4. Identify research needs to address data gaps and/or potential concerns.

ANALYSIS

Literature Review

Published estimates of upstream Steelhead Trout migration speed suggest that migration speed is highly variable and affected by various factors such as the river system, freshwater or marine environment, population, and water temperature. Median and mean estimates range from 6.2 kilometers per day (km/d) to 36.6 km/d overall. Limited data available on Steelhead Trout migrating in the Fraser River suggest adult Steelhead Trout migrate on average between 4.3 km/d and 24.7 km/d (Renn et al. 2001), likely dependent on river discharge and temperature. This high variability is expected based on Steelhead Trout biology, as Steelhead Trout that enter freshwater several months prior to spawning (often referred to as “premature migration”) leave the ocean with larger fat stores compared to salmonids that migrate just prior to spawning, and hold in various locations along their migration route, depending on environmental conditions.

Migration speeds in marine environments appear to be faster than in rivers, ranging from an average of 17.2 km/d to 33 km/d (Ruggerone et al. 2006; Burgner et al. 1992; Walker et al. 2000). Studies on the Skeena River and Columbia River identified different migration speeds than those in and nearer to the Fraser River, suggesting the importance of understanding how local factors affect specific populations.

Adult Steelhead Trout appear to use migration routes on both sides of Vancouver Island, but available information is insufficient to estimate the proportion of Interior Fraser River Steelhead Trout that use each route (also known as the “diversion rate”). There is a need to better understand the migratory route around Vancouver Island taken by Steelhead Trout to improve planning tools for marine fisheries that could impact Steelhead Trout. There are no detailed studies of Steelhead Trout migration routes currently available, but the potential to make limited inferences based on interception data in commercial and test fisheries was identified.

Run-Timing Analysis

To estimate adult Interior Fraser River Steelhead Trout migration timing, data from the Albion test fishery, located 60.4 km upstream from the mouth of the Fraser River (Figure 1, Panel B) were used. The test fishery operates a Chum-directed gillnet (6.75” mesh) and a Chinook-directed gillnet (8” mesh) on alternating days and intercepts Fraser River Steelhead Trout as bycatch. Daily catch data from 1983–2022, from August 1 to December 1 of each year, were used to ensure catches were most likely to be returning adults, as opposed to outmigrating kelts. An index of annual total return abundance to the Albion test fishery was compiled to scale the magnitude of the overall run-timing curve and estimate catchabilities for each gillnet configuration. These data include spawning escapement estimates, kept catch and release mortality estimates from recreational and Indigenous fisheries upstream of the Albion test fishery, and kept catch and release mortality estimates from the Albion test fishery.

A common approach to estimating run timing is to fit a normal curve to the underlying run timing, which is observed as abundance or catch. Within this framework, three run-timing models were compared:

1. Independent Normal: The first model estimates each year’s run timing as independent normal curves with Poisson observation error, as was assumed with previous analyses.
2. Hierarchical Normal: The second model includes a hierarchical structure for the estimation of each year’s run-timing parameters and negative binomial observation error to better account for variability in observed catch.
3. Hierarchical Asymmetric Normal: The third model expands on the second by allowing for an asymmetric run-timing curve.

Expected run timing was summarized by reporting medians, or 50% dates (date 50% of the run was estimated to have passed the test fishery site) and by computing migration windows that would encompass the passage of 95%, 90%, and 80% of the run past the Albion test fishery site (Table 1 and Figure 2C). All three models had similar median dates, giving estimates of October 10 or 11. The independent normal model yielded the widest 95% window (September 1–November 20); the 95% window estimated by the hierarchical normal model was slightly narrower (September 3–November 18). The hierarchical asymmetric normal model estimated a similar 50% date to the other two models, but the window was later, with September 8 and November 23 defining the 95% window.

The suitability of each model was assessed by simulating a new distribution of predicted values from model parameters, and comparing true observations to the distribution of simulated values. Diagnostics revealed poor model suitability for the independent normal model, while the other two models did not violate any model assumptions. Model suitability was also assessed by calculating the percentage of catch observations that fall within the 95% window predicted by each model. All three models performed well, with 96–97% of observed Steelhead Trout catches at the Albion test fishery falling within the 95% windows, over all years. The hierarchical asymmetric normal and independent normal models performed slightly better (capturing 97% of Steelhead Trout catch in the 95% windows) than the hierarchical normal (96%). Finally, the deviance information criterion (DIC), which balances model fit with model complexity (the number of parameters) were computed. The hierarchical asymmetric normal model had the lowest DIC values, indicating the best fit, followed by the hierarchical normal and independent normal models.

Based on model suitability, performance in capturing the timing of observed catches, and having the lowest DIC, the hierarchical asymmetric normal model was recommended as the best characterization of adult run-timing at the test fishery location observed from 1983 to 2022.

Sensitivity Analysis

For sensitivity analysis, three potential sources of uncertainty were confronted to understand their impacts on run-timing parameter estimates: the effects of over- and under-estimating the annual index of total return, the effects of years when there are few observations of Steelhead Trout in the test fishery, and the effects of modifying the seasonal period of test fishery data used.

Under-reporting of catches in fisheries upstream of the Albion test fishery and variability in release mortality from gillnets depending on fishing and handling techniques contribute to uncertainty in estimates of the index of total annual return abundance to the Albion test fishery. There was little effect on the run-timing windows when the hierarchical asymmetric normal model was re-run with the index of return increased or decreased by 50%. Increasing the return index by 50% did not change the windows and decreasing them by 50% narrowed the 95% window by one day at either end. In the second suite of analyses, adjustments were made to years when there may have been a bias in the estimates of Indigenous catch. With these adjustments it was found that the median date shifted earlier by one day, but that the 95% migration window was unchanged.

Both the index of total annual return abundance and the number of non-zero observations in the test fishery data have declined over time (Figure 2). To evaluate whether our migration windows were biased by potential low detection in low abundance years, the model was rerun excluding years where catches were low (< 15 days of fishing when there was one or more Steelhead Trout captured). There was no discernable difference in run timing, presumably because the hierarchical structure of our recommended model shares information across years and reduces sensitivity to years of sparse data.

Finally, the hierarchical asymmetric normal model was run with the test fishing data trimmed to a shorter period (August 20 to November 20) to increase the likelihood that the sampled Steelhead Trout were from Interior Fraser River populations. The results indicated that the 5^{th} percentile of the run-timing window (start of the 90% window) was shifted earlier by one day but no other quantiles were affected.

These results support the view that the recommended model is robust to the most significant uncertainties identified in the data.

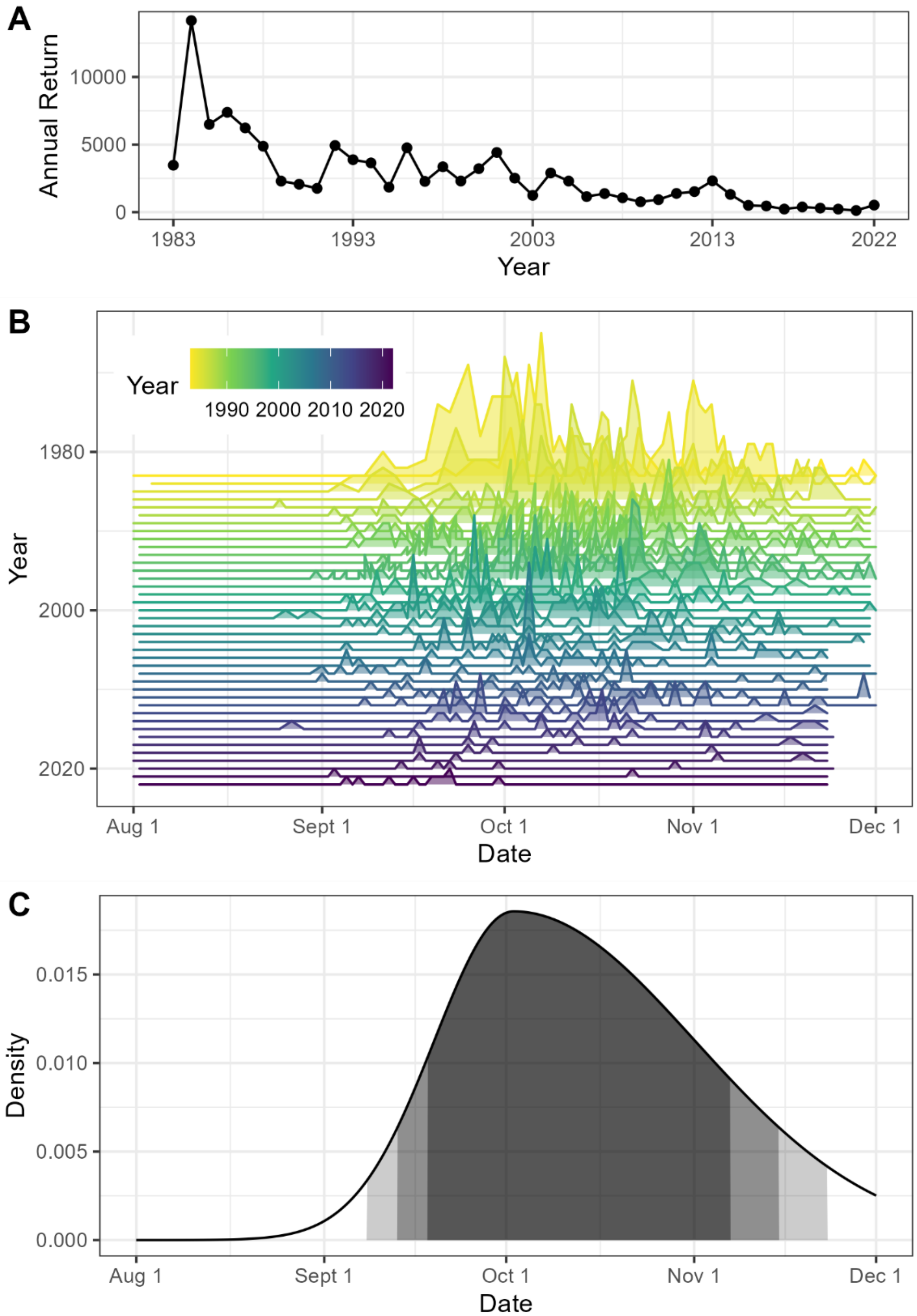

Figure 2. Data used for model fits and resulting run-timing curve. Panel A shows estimated index of total annual return for Interior Fraser Steelhead Trout. Panel B shows a ridgeline plot of daily catch data for each year, with each line coloured by year. Ridgelines are drawn on a vertical scale of five fish per grid box. Panel C shows the estimated run-timing distribution for the recommended model (hierarchical asymmetric normal) with shading for the 80% (dark grey), 90% (medium grey) and 95% (light grey) windows.

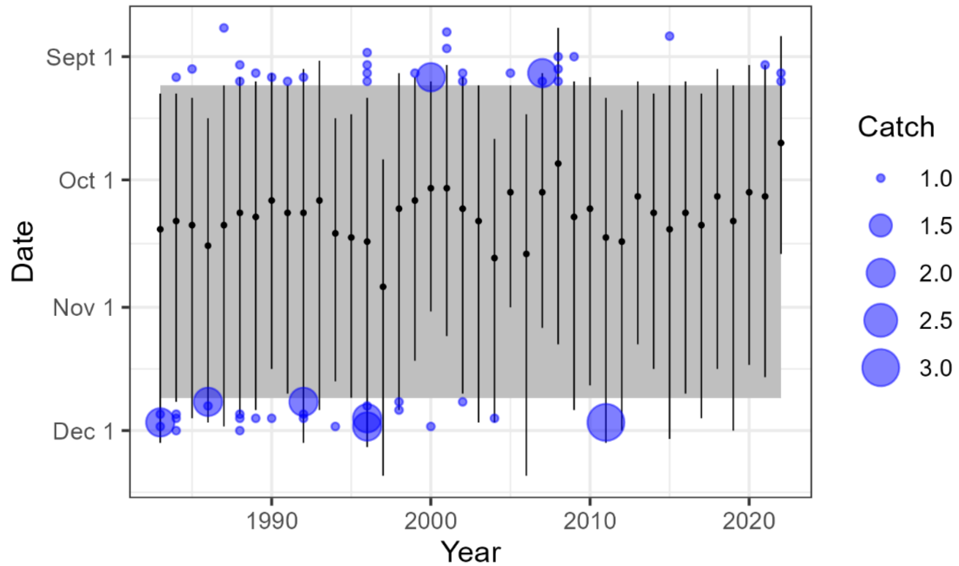

Figure 3. Annual run-timing estimated by the recommended hierarchical asymmetric normal, with 50% date (black point) and 95% window (black bar). Grey box indicates the average 95% window across all years. Blue circles indicate catches that occurred outside of this average window.

Table 1. Quantiles of average run-timing distributions past the Albion test fishing location (and associated 95% CIs to the right of each), across the three models presented.

Model	Run-timing Distribution Quantiles													
	2.5%		5%		10%		50%		90%		95%		97.5%	
Hierarchical Asymmetric Normal	8-Sep	5-Sep	13-Sep	9-Sep	18-Sep	15-Sep	10-Oct	6-Oct	7-Nov	2-Nov	15-Nov	10-Nov	23-Nov	17-Nov
		11-Sep		16-Sep		21-Sep		13-Oct		12-Nov		22-Nov		30-Nov
Hierarchical Normal	3-Sep	29-Aug	9-Sep	5-Sep	16-Sep	12-Sep	11-Oct	8-Oct	4-Nov	1-Nov	11-Nov	8-Nov	18-Nov	14-Nov
		7-Sep		12-Sep		19-Sep		13-Oct		8-Nov		15-Nov		22-Nov
Independent Normal	1-Sep	28-Aug	8-Sep	4-Sep	15-Sep	11-Sep	10-Oct	7-Oct	6-Nov	3-Nov	13-Nov	11-Nov	20-Nov	17-Nov
		5-Sep		11-Sep		17-Sep		12-Oct		8-Nov		16-Nov		23-Nov

Sources of Uncertainty

Despite having a relatively useful data set to inform run timing compared to migration speed and route, there are still several sources of uncertainty to be aware of. First, the Albion test fishery data is only a snapshot of adult Interior Fraser River Steelhead Trout migration timing, so it may not be representative of run timing in areas further upstream or in marine waters. Knowing that migration speeds are highly variable across space and time means that any inferences made about run timing at other locations, based on timing at the Albion test fishery, will be quite uncertain. Other data that could be used to validate estimates of run timing for other locations include spawning ground arrival timing, Steelhead Trout interceptions in marine test fisheries, and fish wheel tagging projects upstream of the Albion test fishery. Additionally, while the goal of this analysis is to infer the run timing of Thompson River and Chilcotin River Steelhead Trout, other Interior Fraser River Steelhead Trout populations are also likely observed in this data set. This means that the run-timing curve is likely to consist of several overlapping run-timing curves for component populations. As a result, variation in the relative proportions of these populations will impact the shape of this run-timing curve. Due to a lack of resolution in our data among component populations, it is currently not possible to characterize the underlying run-timing processes driving the shape of this curve, only the resulting phenomenon.

The run-timing curve characterized by these data may not reflect future potential run timing for several reasons. Steelhead Trout observed at the Albion test fishery would have had to pass through several marine and freshwater fisheries prior to being observed there. This means that observed catches are influenced by trends in fishing pressure (effort and timing) which, in turn, may impact (and potentially bias) our model estimates. If fishing pressure was consistently higher during the tail ends of Interior Fraser Steelhead migration, and specifically in data-rich years, which are more influential to overall model fit, this could have reduced detections early and late in the season, causing the model to estimate a narrower window. Similarly, if fishing pressure was historically higher early in the season, this could be contributing to the right-skew in our catch data and asymmetric normal model fits. Reductions in fishing pressure seen in recent years may help to uncover “true” underlying run-timing, but the simultaneous paucity of data in recent years makes parsing out these complex dynamics difficult.

Additionally, in the models, the catchability parameter is assumed to be constant within year. However, it is likely that catchability of Steelhead Trout varies within a given year, affected by environmental conditions and the abundance of co-migrating stocks. For example, during periods when flow is high, fish may migrate along the edges of the river and may be less likely to be caught in the test fishery. It is also possible that when co-migrating stocks are in very high abundance, the net could become saturated and Steelhead Trout could be less likely to be caught. Although residual analyses did not indicate the need for additional parameters to capture effects of other factors on catch, such as environmental covariates or downstream catch, these effects could be explored in future work.

Changes in abundance, climate, and/or environmental conditions could be causing run timing to change over time, and in recent years there may be a slight trend towards earlier timing. However, changes in relative abundance in component populations over time could affect aggregate-level run-timing estimates. Additionally, the number of adult Steelhead Trout observed at the Albion test fishery has decreased to very low levels in recent years (Figure 2, Panel B), making changes in run timing hard to detect and differentiate from spurious patterns caused by low detection. As the purpose of this project was to characterize average historical run timing, this was not pursued. Assessing these changes in a rigorous way would likely require a dedicated research program with additional data collection.

CONCLUSIONS AND ADVICE

Based on literature review, little is known about the tendency and variability of the coastal marine migration route chosen by Interior Fraser River Steelhead Trout. However, there is evidence that Interior Fraser Steelhead Trout migrate along either side of Vancouver Island during their return migration. Steelhead appear to migrate faster in marine waters than in rivers and in-river migration speed appears to be highly variable both within and among populations.

While the standard practice in estimating run timing of salmonids has been to use a normal distribution, here evidence is presented that an alternative run-timing form (the asymmetric hierarchical normal distribution) also captures the observed patterns in catch. Additionally, this model performs as well as, or better than, modelling approaches using the normal curve, in terms of the number of catch observations captured within the 95% timing window. Based on the asymmetric normal model and the available test fishing data to date, the majority (95%) of Interior Fraser Steelhead Trout have migrated past the test fishing site in the lower Fraser River between September 8 and November 23, with a median date of October 10.

The information presented in this paper is intended to support future work on a fisheries planning model that would estimate exposure of adult Interior Fraser River Steelhead Trout to fisheries throughout southern British Columbia. Given the uncertainty in the proportion of Steelhead Trout migrating around either side of Vancouver Island, migration speeds throughout the migration corridor, and modelled estimates of run-timing parameters, it is strongly recommended that the future exposure model not use one value for each of these parameters. Rather, a better understanding of the risk of fishery plans to Interior Fraser River Steelhead Trout would be obtained by drawing input parameters from a distribution and/or ensuring a sensitivity analysis is completed to understand how variation in these biological parameters may affect exposure estimates and subsequent management decisions. It is also recommended the assessment of risk of future fishery plans includes examination of the potential for outside factors (such as fishing pressure, abundance of co-migrating stocks or species, environmental conditions) to influence run timing.

Future research on Interior Fraser River Steelhead Trout will be complicated by the low abundance of these populations and the need to minimize any potential harm in support of conservation efforts. When feasible, key areas for future research may include:

- Non-lethal genetic sampling of Steelhead Trout intercepted in fisheries, which could be facilitated through collaborations with Indigenous groups, recreational and commercial fishers;
- Genetic analysis of historical Steelhead Trout samples from various fisheries and projects that may still reside in archives; and
- As tagging technology advances and becomes safer for fish, there may be an opportunity to develop a tagging program to answer questions about migration speed and route. This research is not recommended until Interior Fraser River Steelhead Trout populations recover to a level where they are less at risk.

In the meantime, future analyses will use assumptions of migration route and speed, and attempts will be made to validate these assumptions using data from fisheries in other areas and from the spawning grounds.

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SOURCES OF INFORMATION

This Science Advisory Report is from the January 31–February 1, 2024 regional peer review on Migration Speed, Run Timing, and Diversion Rate for Interior Fraser River Steelhead. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

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