Site C Clean Energy Project

Synthesis Review of the Fisheries and Aquatic Habitat Monitoring and Follow-Up Program (FAHMFP)

Construction Years 1 to 5 (2015 to 2019)

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June 2020

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Prepared for:

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EXECUTIVE SUMMARY

The Synthesis Review evaluates fish and aquatic habitat monitoring data, research, analysis, and associated retrospective analyses conducted as part of the Fisheries and Aquatic Habitat Monitoring and Follow-Up Program (FAHMFP)[1] during the five-year (2015-2019) period leading up to the review. The Synthesis Review also takes into account information on fish and aquatic habitat collected outside of the FAHMFP and prior to 2015. One outcome of the Synthesis Review is to describe whether the understanding of fish and aquatic habitat has been refined or, potentially changed, since the Site C Environmental Impact Statement (EIS)[2]. This evaluation is intended to help understand whether the FAHMFP is on-track to fulfill its objectives to (1) monitor fish and aquatic habitat during the construction and operation of the Site C Clean Energy Project (the Project); (2) understand the effects of the Project and the effectiveness of mitigation measures; and (3) evaluate and implement future mitigation and compensation options. The intended audience of the Synthesis Review is the Site C Fisheries and Aquatic Habitat Mitigation and Monitoring Technical Committee (the Committee), but the review also serves as a primer for others who are new to the FAHMFP.

The FAHMFP has 18 distinct monitoring programs and one follow-up program that will monitor the Site C Local Assessment Area (LAA) for 39 years (until 2053) (Appendix A). The Project is currently in the construction phase with river diversion planned for September 2020. For the purposes of the Synthesis Review, the changes to fish and aquatic habitat associated with Project construction up to 2019 are not of a spatial scale or intensity that would affect the population-level measures addressed in this Synthesis Review. Local changes to fish and aquatic habitat associated with construction and habitat enhancements to date are reviewed elsewhere (e.g., Golder 2020). River diversion is expected to be the first major change to the Peace River from construction of the Project, and therefore, the data collected over the last five years (and time preceding that) are considered baseline.

For 2019, the Synthesis Review largely focuses on the expected ability of the FAHMFP to diagnose causal mechanisms, the completeness and quality of the baseline data collected prior to river diversion, and any changes in the understanding of fish and aquatic habitat since the Site C EIS. Subsequent versions of the Synthesis Review (2024 onward) will begin to evaluate changes to fish and aquatic habitat associated with the Project.

The Synthesis Review is designed to have four different entry points to assessing the FAHMFP, as follows:

1. The simplest entry point is the report cards for each indicator species, which are found in the Executive Summary.
2. The body of the Synthesis Review provides a greater depth of information that highlights the monitoring tasks, important observations and adjustments, and a general status update for each indicator species.

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[1] Available at: https://www.sitecproject.com/sites/default/files/Fisheries-and-Aquatic-Habitat-Monitoring-and-Follow-up-Program.pdf

[2] Available at: https://iaac-aeic.gc.ca/050/evaluations/document/85328?culture=en-CA; Volume 2, Section 12.

3. The Diagnostic Tool Synthesis links observations to indicator species and monitoring plan tasks. It also highlights the importance, status, and adjustments to sampling protocols for each observation.
4. Finally, reports from BC Hydro and their consultants represent the most in-depth entry point to the FAHMFP; these reports are referenced throughout the review and finalized versions are readily accessible online[3].

The indicator species used as performance indicators for the FAHMFP are based on provincial guidance (MOE 2009, 2011), and include Bull Trout, Rainbow Trout, Arctic Grayling, Goldeye, Walleye, and Mountain Whitefish. Another category, the Fish Community and the associated indicators, aims to measure the effects of the Project on aquatic ecosystem values that are not captured by metrics for single indicator species. For each indicator species, the Synthesis Review presents the indicators used to assess abundance, age and size distribution, species distribution, population structure, and the findings to date for each performance measure. Kokanee will be monitored following creation of the Site C Reservoir, and as a result, are not included in the Synthesis Review. Mon-1a, Mon-1b, and Mon-2 of the FAHMFP are the primary programs for monitoring indicator species, while other programs provide information that support these plans and help to diagnose causes of observed changes.

The information collected by the FAHMFP is consistent with the current understanding of the indicator species as documented in the Site C EIS. The overall capability of the FAHMFP to meet the objectives was assessed by the development of Diagnostic Tools[4]. Overall, the data collected to date are complete and of high quality. The completeness of data is evaluated by comparing the tasks completed against the tasks planned in the FAHMFP. The quality of the data was assessed by whether the level of accuracy met or exceeded expectations. Where necessary from 2015 to 2019, adjustments to monitoring were made in consultation with the Committee. The adjustments were made to existing monitoring tasks rather than the introduction of new monitoring tasks. Generally, the monitoring tasks have not deviated far from what was planned when the FAHMFP was first developed (BC Hydro 2015).

The status updates for the indicator species are included as report cards in the Executive Summary. In the 2019 Synthesis Review, the status update intends to document the status of sampling and whether the findings differ from the information documented in the Site C EIS. In future Synthesis Reviews (2024 onward), the report cards will also document changes observed in the indicator species.

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[3] Available at: https://www.sitecproject.com/document-library/fisheries-and-aquatic-reports
[4] Available at: https://www.sitecproject.com/sites/default/files/site-c-diagnostic-tool-summary-report.pdf

BULL TROUT

Salvelinus confluentus

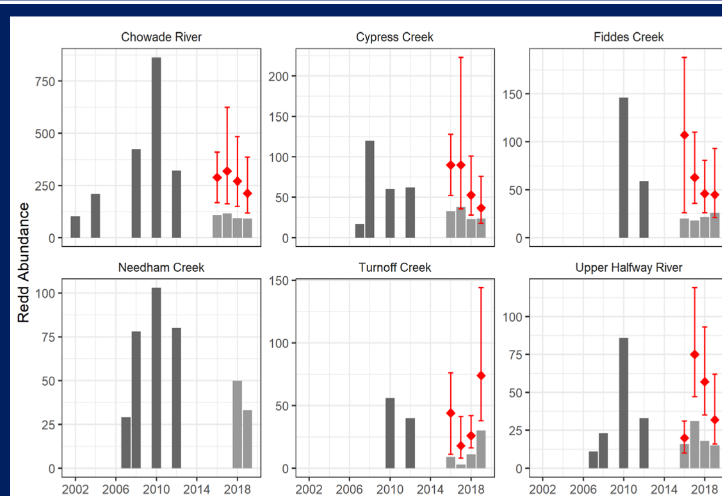
Description

Bull Trout are an indicator species that are representative of cold water fauna, highly migratory and top predators. Monitoring for Bull Trout is based on performance measures related to abundance, size structure, age structure, distribution, and population structure that are designed to meet management objectives at the species level.

Important Observations

Bull Trout are sampled in the Peace River through annual repetitive boat electroshocking surveys from Peace Canyon Dam to Many Islands, Alberta, and tributaries of the Halfway River through redd surveys, resistivity counters, passive integrated transponder (PIT) arrays, and backpack electrofishing.

The key indicator of the Bull Trout population is spawner abundance in the Halfway Watershed. The Peace River Bull Trout Spawning Assessment estimates spawner abundance through redd counts. Resistivity counters and PIT arrays provide independent estimates of spawner abundance and fish movements, respectively. The Peace River Large Fish Indexing Survey occurs when Bull Trout are spawning in the Halfway River, and thus this survey monitors sub-adults and non-spawning adults. Juvenile Bull Trout are sampled in tributaries of the Halfway River in July and August through backpack electrofishing.



Peak and AUC count estimates of Bull Trout redd abundance from 2002 to 2019 in tributaries of the Halfway River. The red points are the AUC estimates with 95% confidence intervals, dark grey bars are historic peak counts, and the light grey bars are recent peak counts conducted as part of the FAHMFP.

Based on peak redd counts (in the index collected prior to 2015), there may have been an increase in Bull Trout spawner abundance from 2002 to 2010, and a decline following 2010. There is no similar trend apparent with the catch rate of Bull Trout in the Peace River.

Consistent with previous work, Bull Trout captured in the Peace River and analyzed for genetics originated predominantly from the Halfway River (92%), with the remainder originating from the Pine River (5%) or of unknown origin (3%).

Bull Trout movement patterns are monitored from the redetection of PIT tagged fish in the Peace River and its tributaries, radio telemetry, and otolith and fin ray microchemistry. The understanding from these observations adds to and is consistent with the understanding of Bull Trout movements described in the Site C EIS.

Data Completeness and Quality

Data collected to monitor Bull Trout is considered complete and of high quality. Twenty-two of the 22 observations (100%) for Bull Trout were collected as planned, which include two high importance observations, 10 medium importance observations and 10 low importance observations.

The sampling design for juveniles in tributaries of the Halfway River involved tradeoffs between the objectives to increase the number of juvenile Bull Trout PIT tagged (to ultimately estimate juvenile-to-adult survival) and estimate juvenile density in all habitats. Since 2017, sampling focused on high quality habitat and achieved the tagging objective. As a result, juvenile density estimates will be based on high quality habitat.

Timelines and Adjustments

2016-2019 - Juvenile Bull Trout Monitoring in the upper Halfway River, Cypress Creek and Chowade River as part of Site C Reservoir Tributaries Fish Population Indexing Survey; Added Area Under the Curve (AUC) methods for estimating redd abundance alongside peak counts.

2017-2019 - Juvenile Bull Trout monitoring expanded to include Fiddes Creek; Shifted surveys to target ideal habitat areas in upper reaches of tributaries to Halfway River.

Status Update

Monitoring to date is for baseline data, which continues to be collected. Based on sampling from 2015 to 2019, our understanding of the Bull Trout population has improved since the Site C EIS because of an increased level of monitoring of Halfway River Bull Trout. Although peak redd counts from 2016 to 2019 are lower than those observed during some prior years, Bull Trout subadult and non-spawning adult population estimates in the Peace River do not suggest any directional changes in abundance. Natural variation in population abundance and observation error emphasize the need for integrating multiple data sources into a single assessment of trends in adult abundance.

RAINBOW TROUT

Oncorhynchus mykiss

Description

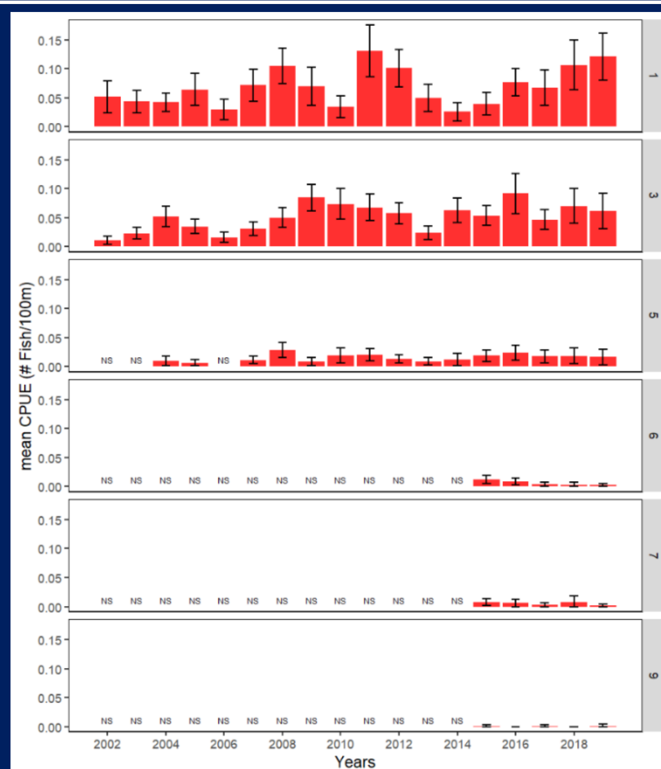
Rainbow Trout are an indicator species that are representative of cool/coldwater fauna, not tolerant of turbidity, and present in the Peace River and many of its tributaries in the LAA. Monitoring for Rainbow Trout is based on performance measures related to abundance, size structure, age structure, distribution, and population structure that are designed to meet management objectives at the species level.

Important Observations

Rainbow Trout are sampled in the Peace River through annual repetitive boat electroshocking surveys from Peace Canyon Dam to Many Islands, Alberta, and tributaries of the Peace River through backpack electrofishing.

The key indicators of the Rainbow Trout population are population abundance, age structure, and spatial distribution. The understanding of the spawning and rearing locations for fish that recruit to the Peace River has been refined through several information sources: redetection of PIT tagged fish, radio telemetry, and otolith and fin ray microchemistry. Genetic samples have also been collected and processed, and analyses are ongoing.

Data from boat electroshocking confirm that Rainbow Trout are more abundant in upstream sections, that measures of abundance vary from year-to-year, and that there appear to be no long-term trends in abundance. Future trends in abundance can be inferred from a combination of adult catch rates in the Peace River Large Fish Indexing Survey and juvenile catch rates from the Site C Reservoir Tributaries Fish Population Indexing Survey.



CPUE of Rainbow Trout captured by boat electroshocking in Sections 1, 3, 5, 6, 7 and 9 of the Peace River from 2002 to 2019. Error bars represent 1.96xSE. Analysis included captured fish only and all size cohorts Data Source: Peace River Large Fish Indexing Survey Database.

Data Completeness and Quality

Data collected to monitor Rainbow Trout is considered complete and of high quality. Nineteen of the 19 observations (100%) for Rainbow Trout were collected as planned, which include two high importance observations, 13 medium importance observations and four low importance observations.

Timelines and Adjustments

2016 - Juvenile Rainbow Trout monitoring in upper Halfway River, Cypress Creek and Chowade River as part of Site C Reservoir Tributaries Fish Population Indexing Survey.

2017-2019 - Juvenile Rainbow Trout monitoring in Kobes, Colt, and Farrell creeks - 2016 locations no longer sampled in the lower sections of these Halfway tributaries where juvenile Rainbow Trout were more abundant and Bull Trout were less abundant.

Status Update

Monitoring to date is for baseline data, which continues to be collected. Baseline data collection will be sufficient to monitor changes in the Rainbow Trout population, and the findings from the monitoring data from the FAHMFP are consistent with the findings documented in the Site C EIS. Data from the Peace River Large Fish Indexing Survey confirm natural variation in abundance from year-to-year.

ARCTIC GRAYLING

Thymallus arcticus

Description

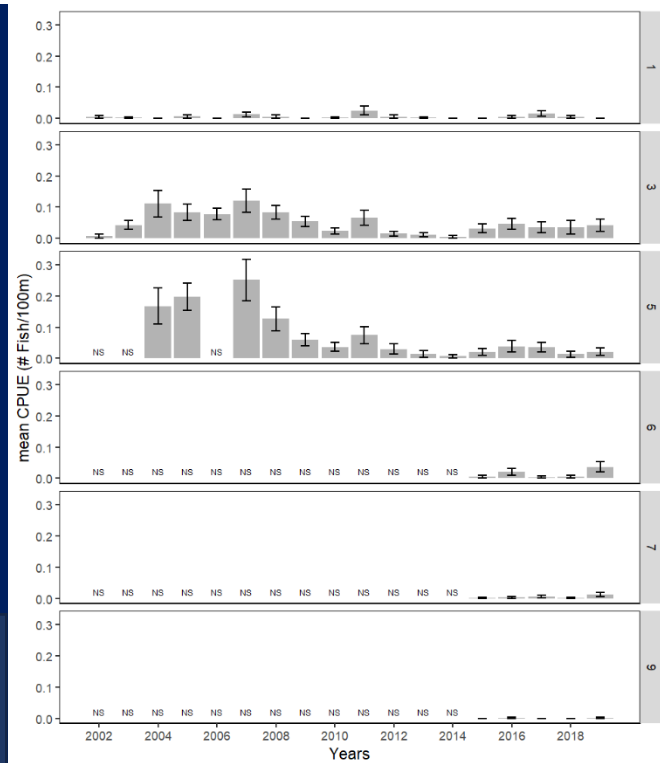
Arctic Grayling are an indicator species that are representative of cool/coldwater fauna and very sensitive to habitat change. Monitoring for Arctic Grayling is based on performance measures related to abundance, size structure, age structure, distribution, and population structure that are designed to meet management objectives at the species level.

Important Observations

Arctic Grayling are sampled in the Peace River through annual repetitive boat electroshocking surveys from Peace Canyon Dam to Many Islands, Alberta, and in the Moberly and Beatton rivers through backpack electrofishing.

The key indicator of the Arctic Grayling population is adult abundance in the Peace River. Measures of abundance are also obtained in several tributaries.

Population structure was assessed using genetic analyses, otolith and fin ray microchemistry, and movement data from PIT and radio telemetry. Together, these data suggest that most Arctic Grayling captured in Peace River spawn in the Moberly River, and that Arctic Grayling captured in the Halfway, Moberly, Pine and Beatton rivers each have a level of genetic differentiation.



CPUE of Arctic Grayling captured by boat electroshocking in Sections 1, 3, 5, 6, 7 and 9 of the Peace River from 2002 to 2019. Error bars represent 1.96xSE. Analysis included captured fish only and all size cohorts. Data Source: Peace River Large Fish Indexing Survey Database.

Data Completeness and Quality

Data collected to monitor Arctic Grayling is considered complete and of high quality. Twenty-five of the 25 observations (100%) for Arctic Grayling were collected as planned, which include one high importance observation, 14 medium importance observations and 10 low importance observations.

Data quality was as expected for monitoring abundance in the Peace River and refining the understanding of the population structure in tributaries. The quality of the data was lower than expected for measures of abundance in tributaries (14 of 25 observations) because of low catch rates during most study years. The assessment of trends in abundance is more complex when catch rates are low. Increased sampling effort and changes in the timing of sampling have resulted in increased encounter and tagging rates of Arctic Grayling in tributaries in recent years.

Timelines and Adjustments

2017 - Increased effort for Site C Reservoir Tributaries Fish Population Indexing Survey.

2018 - Earlier sampling for Site C Reservoir Tributaries Fish Population Indexing Survey.

2019 - Earlier sampling for Site C Reservoir Tributaries Fish Population Indexing Survey; Included angling for adult Arctic Grayling as part of the Beatton River Arctic Grayling Status Assessment.

Status Update

Monitoring to date is for baseline data, which continues to be collected. Baseline data collection will be sufficient to monitor changes in the Arctic Grayling population, and the findings from the monitoring data from the FAHMFP are consistent with the findings documented in the Site C EIS. The abundance estimates suggest that Arctic Grayling abundance may be declining in the Peace Region. If there are regional trends, it will more difficult to isolate the effects of the Project on this species. In addition to a vulnerability to overharvest, Arctic Grayling are sensitive to a wide variety of environmental impacts, including hydroelectric development, which in combination have led to widespread declines across their range (Northcote 1995).

GOLDEYE

Hiodon alosoides

Description

Goldeye are an indicator species that are representative of coolwater fauna, tolerant of turbidity, and highly migratory. Monitoring for Goldeye is based on performance measures related to abundance, size structure, age structure, distribution, and population structure that are designed to meet management objectives at the species level.

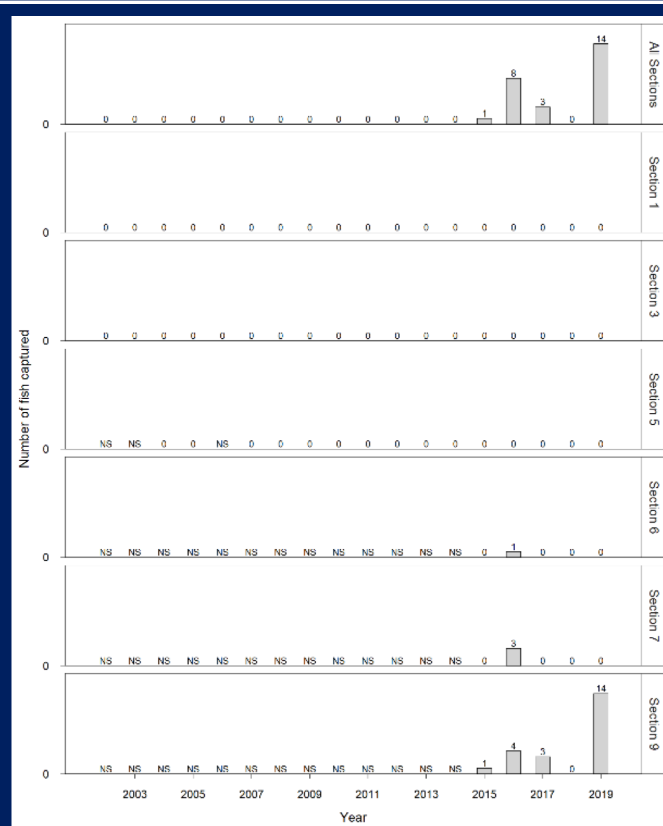
Important Observations

Goldeye are sampled in the Peace River through annual repetitive boat electroshocking surveys from Peace Canyon Dam to Many Islands, Alberta.

The key indicators for the Goldeye population are adult abundance and distribution. Goldeye were only encountered downstream of the Pine River in Sections 6, 7, and 9, which were not sampled consistently prior to 2015. Catch rates have been low.

Population structure was assessed using fin ray microchemistry data from 2016 to 2018. These data suggest that Goldeye captured by boat electroshocking in the Peace River originated from and spent their first summer in the Smoky River in Alberta, providing evidence that Goldeye that are captured by boat electroshocking in the BC portion of the Peace River likely spawned and reared in Alberta outside of the LAA. The information from fin ray microchemistry is consistent with the previous understanding from other data sources.

One key uncertainty is related to how the changes in conditions in the LAA will affect Goldeye adult abundance and distribution. With low catch rates, it will be difficult for the FAHMFP to detect changes in adult abundance statistically. BC Hydro may only be able to evaluate whether Goldeye distributions in the LAA are being maintained or the distribution is changing through monitoring the occurrence of Goldeye in boat electroshocking catches.



Number of Goldeye captured by boat electroshocking in Sections 1, 3, 5, 6, 7 and 9 of the Peace River from 2002 to 2019. Sample sizes are listed above each bar. NS denotes years in which no surveys occurred.

Data Completeness and Quality

Data collected to monitor Goldeye is considered complete and of high quality. Seven of the 7 observations (100%) for Goldeye were collected as planned, which include one high importance observation, five medium importance observations and one low importance observation.

Low catch rates, as anticipated, triggered a requirement for additional spring surveys, which were implemented in 2018 and 2019. Catch rates continue to be low, which suggests that the LAA remains on the periphery of the species distribution. For future analyses, presence/absence may be a better metric than abundance or catch-per-unit-effort to track over the long term.

Timelines and Adjustments

2018-2019 - Additional boat electroshocking surveys for Goldeye downstream of the Project in the spring, with the aim of increasing catch rates.

Status Update

Monitoring to date is for baseline data, which continues to be collected. Baseline data collection will be sufficient to monitor changes in the Goldeye population, and the findings from the monitoring data from the FAHMFP are consistent with the findings documented in the Site C EIS. Goldeye are more abundant in the downstream sections of the LAA, though the number captured continues to be low. The LAA represents the western edge of the Goldeye range.

WALLEYE

Sander vitreus

Description

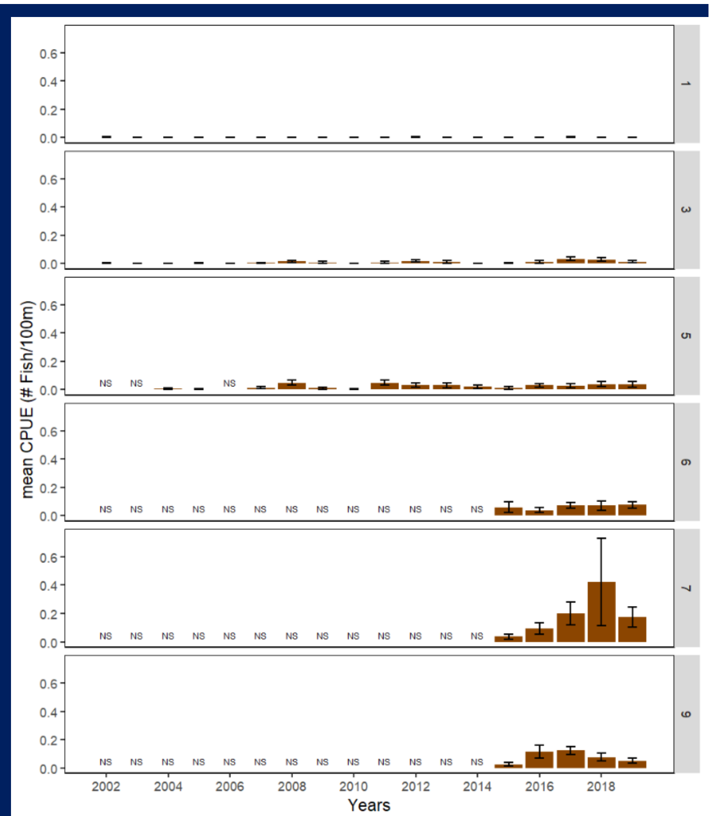
Walleye are an indicator species that are representative of warm/coolwater fauna, tolerant of turbidity, and highly migratory. Monitoring for Walleye is based on performance measures related to abundance, size structure, age structure, distribution, and population structure that are designed to meet management objectives at the species level.

Important Observations

Walleye are sampled in the Peace River through annual repetitive boat electroshocking surveys from Peace Canyon Dam to Many Islands, Alberta.

The key indicators for the Walleye population are catch rate and life history. Walleye were captured predominantly downstream of the Pine River in Sections 6, 7, and 9 of the Peace River, which were not sampled consistently prior to 2015. Data collected to date demonstrate that Walleye are found in higher numbers in the downstream sections of the LAA, but that they can be found upstream (as far as Section 1) during what is understood to be 'summer' feeding migrations.

One key uncertainty is related to how changes in physical conditions in the Peace River downstream of the Project will affect Walleye abundance and distribution. For example, whether the upstream feeding migration will change in response to changes in water temperature or turbidity.



CPUE of Walleye captured by boat electroshocking in Sections 1, 3, 5, 6, 7 and 9 of the Peace River from 2002 to 2019. Error bars represent 1.96xSE. Analysis included captured fish only and all size cohorts. Data Source: Peace River Large Fish Indexing Survey Database.

Data Completeness and Quality

Data collected to monitor Walleye is considered complete and of high quality. Nine of the 9 observations (100%) for Walleye were collected as planned, which include two high importance observations, six medium importance observations and one low importance observation.

Timelines and Adjustments

2018 - Boat electroshocking surveys for Walleye downstream of the Project in the spring, with the aim of increasing catch rates.

Status Update

Monitoring to date is for baseline data, which continues to be collected. Baseline data collection will be sufficient to monitor changes in the Walleye population, and the findings from the monitoring data from the FAHMFP are consistent with the findings documented in the Site C EIS. The increased sampling in Sections 6, 7, and 9 of the Peace River confirm the previous finding that Walleye are more abundant in the downstream reaches of the LAA.

MOUNTAIN WHITEFISH

Prosopium williamsoni

Description

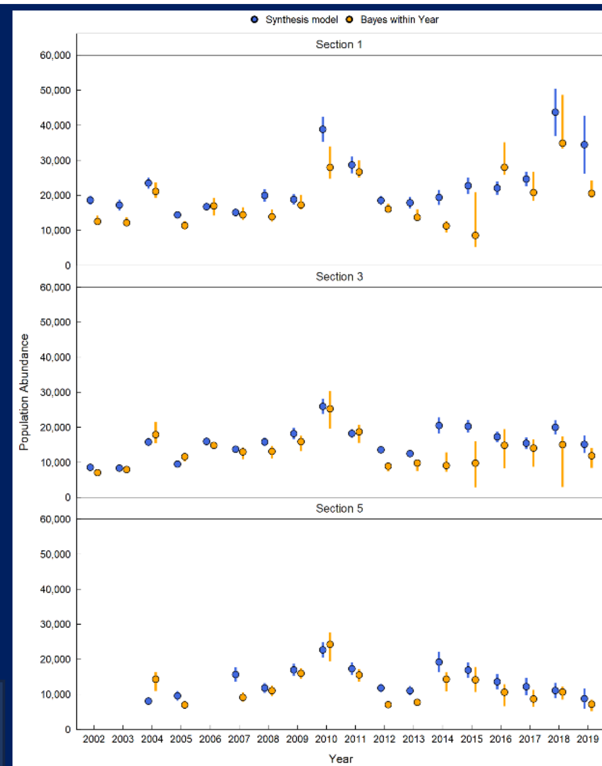
Mountain Whitefish are an indicator species that are representative of coldwater fauna, not tolerant of turbidity, and an important prey species for piscivorous fish. Monitoring for Mountain Whitefish is based on performance measures related to abundance, size structure, age structure, distribution, and population structure that are designed to meet management objectives at the species level.

Important Observations

Mountain Whitefish are sampled in the Peace River through annual repetitive boat electroshocking surveys from Peace Canyon Dam to Many Islands, Alberta.

The key indicators for the Mountain Whitefish population are population abundance, biomass, distribution, growth and age structure. Mountain Whitefish represent the most abundant large fish species sampled in the Peace River and therefore help generate the most reliable estimates of abundance and age-structure. This is valuable for examining interactions between fish capture and environmental covariates. These data are collected under the Peace River Large Fish Indexing Survey.

The high quality of Mountain Whitefish data plays a key role in evaluating catchability and recruitment processes associated with large fish species. Analysis of interactions between fish capture and environmental covariates has been used to identify factors that may generate significant variation in catchability at the daily to annual time scales. In the long term, associations between Mountain Whitefish year class strength and environmental variation will help identify environmental conditions that negatively affect recruitment at the annual and decadal time scales.



Estimated Mountain Whitefish abundance in the Peace River Sections 1, 3, and 5 based on the Synthesis Model and Bayes within year estimation methods. Section 5 was not sampled in 2002, 2003 and 2006.

Data Completeness and Quality

Data collected to monitor Mountain Whitefish is considered complete and of high quality.

Timelines and Adjustments

No adjustments have been made to date.

Status Update

Monitoring to date is for baseline data, which continues to be collected. Baseline data collection will be sufficient to monitor changes in the Mountain Whitefish population, and the findings from the monitoring data from the FAHMFP are consistent with the findings documented in the Site C EIS. Mountain Whitefish continue to be the most abundant large fish sampled in the Peace River upstream of the Pine River. Natural variation in population abundance continues to be higher than expected but this challenge is balanced by the long, relatively precise, time series of population estimates.

FISH COMMUNITY

Description	Monitoring the Fish Community and the associated indicators aims to measure the effects of the Project on aquatic ecosystem values that are not captured by metrics for single indicator species. Key uncertainties include the changes to fish species abundance (or biomass) and composition (or diversity).
Important Observations	Several monitoring tasks are grouped to represent the Fish Community. The key indicators of the Fish Community are fish biomass and diversity, which are estimated from the abundance and distribution of individual species. No obvious shifts in species-specific abundance or distribution were noted from 2015 to 2019, and the findings are consistent with the results documented in the Site C EIS. Coolwater indicator species (Walleye, Goldeye) still occur mainly in areas downstream of the Project. Coldwater species (Bull Trout, Arctic Grayling, Rainbow Trout, Mountain Whitefish) are common in the Peace River and its tributaries upstream of the Project. There were no changes in the understanding of the distribution of other species.
Data Completeness and Quality	Data collected to monitor fish community is considered complete and of high quality. Forty of the 42 observations (95%) for fish community were collected as planned, which include six medium importance observations and 36 low importance observations. Stomach content samples of Bull Trout (two medium importance observations) to examine food volume and species composition (diet) were not completed because of concerns from the Committee of causing undue harm during gastric lavage. Stable isotope analysis has been undertaken to understand the diet of Bull Trout in the LAA.
Timelines and Adjustments	2017-2019 - Annual Index Fish Stranding & Expanded Fish Stranding Assessments now include target and random sampling of both high and low risk sites.
Status Update	Monitoring to date is for baseline data, which continues to be collected. Baseline data collection will be sufficient to monitor changes in the Fish Community, and the findings from the monitoring data from the FAHMFP are consistent with the findings documented in the Site C EIS. Increased boat electroshocking in Sections 6, 7 and 9 since 2015 and in future years will increase the understanding of potential changes downstream of the Project. The Fish Community captures a range of information on changes in the fish community that may not be captured in the indicator species write-ups, such as species abundance and composition.

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ACRONYMS

AUC	Area Under the Curve
BC	British Columbia
BTIPM	Bull Trout Integrated Population Model
CPUE	Catch per unit effort
EAC	Environmental Assessment Certificate
EIS	Environmental Impact Statement
FAHMFP	Fisheries and Aquatic Habitat Monitoring and Follow-up Program
GBD	Gas Bubble Disease
LAA	Site C Local Assessment Area
MFLNRO	BC Ministry of Forests, Lands and Natural Resource Operations & Rural Development
MOE	BC Ministry of Environment and Climate Change Strategy
PIT	Passive Integrated Transponder
TDG	Total Dissolved Gas

INTRODUCTION

What is the FAHMFP?

BC Hydro developed the Fisheries and Aquatic Habitat Monitoring and Follow-Up Program (FAHMFP)[5] to (1) monitor fish and aquatic habitat during the construction and operation of the Site C Clean Energy Project (the Project); (2) understand the effects of the Project and the effectiveness of mitigation measures; and (3) evaluate and implement future mitigation and compensation options. Monitoring programs are scheduled to span the construction phase (2015 to 2024) and the first 30 years of operation (2024 to 2053) of the Project. Each program's monitoring plan includes a series of fisheries management questions and hypotheses that reflect uncertainties in predictions of the potential changes associated with the Project, as described in the Project's Environmental Impact Statement (EIS)[6].

The FAHMFP consists of a coordinated set of 18 spatially and logistically distinct monitoring programs and one follow-up program (Appendix A). Fish monitoring (i.e., abundance, age distribution, spatial distribution) is mainly conducted in Mon-1a, Mon-1b, and Mon-2, while the other monitoring programs are designed to assist in diagnosing causal mechanisms for changes in the fish community.

Ultimately, information collected from the FAHMFP will help describe changes to fish and aquatic habitat and provides a monitoring structure to understand the effectiveness of actions implemented to mitigate these changes.

What is the Synthesis Review?

The Synthesis Review aims to assess whether the understanding of fish and aquatic habitat has changed during the five-year period leading up to this review. For the 2019 report, this period encompasses the first five years of implementing the FAHMFP (2015 to 2019). The understanding of fish and aquatic habitat generated from these five years of data is compared to the understanding prior to 2015 and the baseline conditions presented in the Site C EIS (2013). As a result, the understanding of fish and aquatic habitat takes into account all available information on fish and aquatic habitat in the Site C Local Assessment Area (LAA). The Synthesis Review demonstrates the extent of monitoring and analysis, highlighting important information, and identifying key scientific and technical uncertainties associated with fish and aquatic habitat monitoring data. The intended audience of the report is the Site C Fisheries and Aquatic Habitat Mitigation and Monitoring Technical Committee (the Committee), but the review also serves as a primer for others that are new to the FAHMFP.

The Synthesis Review serves two important purposes:

1. **Looking Back** – to document the progress made in understanding fish and aquatic habitat as part of the FAHMFP during the five years leading up to the review; and
2. **Looking Forward** – to guide recommendations on how the FAHMFP should move forward for the next five years of implementation.

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[5] Available at: https://www.sitecproject.com/sites/default/files/Fisheries-and-Aquatic-Habitat-Monitoring-and-Follow-up-Program.pdf
[6] Available at: https://www.ceaa-acee.gc.ca/050/evaluations/document/85328

Looking Back – This Synthesis Review covers the first five years (2015 to 2019) of implementing the FAHMFP. The FAHMFP intends to monitor the LAA for 39 years (2015 to 2053). BC Hydro recognizes that this time frame inevitably means that staff will turnover, and new participants will require periodic summaries of past progress. The Synthesis Review will allow staff to understand the scope of the FAHMFP, document adjustments to the monitoring plan, and understand the thinking behind the decisions made by BC Hydro and the Committee in 2019.

Looking Forward – The Synthesis Review will help guide recommendations on how the FAHMFP should move forward for the next five years of implementation, through synthesizing and evaluating fish and aquatic habitat monitoring data, research, analysis, and associated retrospective analyses conducted during the five-year period leading up to the review. This second role is less prevalent in the 2019 Synthesis Review because data collection is still considered baseline. The Project is currently in the construction phase with river diversion planned for September 2020.

The Synthesis Review presents information for each indicator species, highlighting the rationale for monitoring, important observations, adjustments to monitoring, and provides a general update on the status of each indicator species. These status updates largely focus on evaluating whether the understanding of the baseline conditions for each species has changed since the Site C EIS, the completeness and quality of data, and noting any quantitative or qualitative trends.

Diagnostic Tools were developed to evaluate the ability of the FAHMFP to diagnose causal mechanisms for potential changes in fish and aquatic habitat metrics (Beaudrie et al. 2017). The Diagnostic Tools served as a foundational element for the evaluation of the Synthesis Review, and they are summarized in the Diagnostic Tool Synthesis. The Diagnostic Tool Synthesis is a useful resource for further information on monitoring tasks for each indicator species.

The Synthesis Review intends to provide four entry-points to the evaluation of the FAHMFP (Figure 1), as follows:

1. The report cards, located in the Executive Summary, provide a quick summary of the state of indicator species as monitored by the FAHMFP.
2. The body text of the Synthesis Review aims to expand on the information provided in the report cards, highlighting key monitoring observations, an overview of the completeness and quality of the data, and noting any adjustments that were made to the monitoring.
3. The Diagnostic Tool Synthesis links observations to indicator species and monitoring tasks and highlights the importance, status and adjustments to sampling protocols for each observation.
4. Finally, reports from BC Hydro and its contractors implementing each component of the FAHMFP provide the most detail about progress on the FAHMFP. These reports are referenced throughout the body of the Synthesis Review, and can be found at https://www.sitecproject.com/document-library/fisheries-and-aquatic-reports.

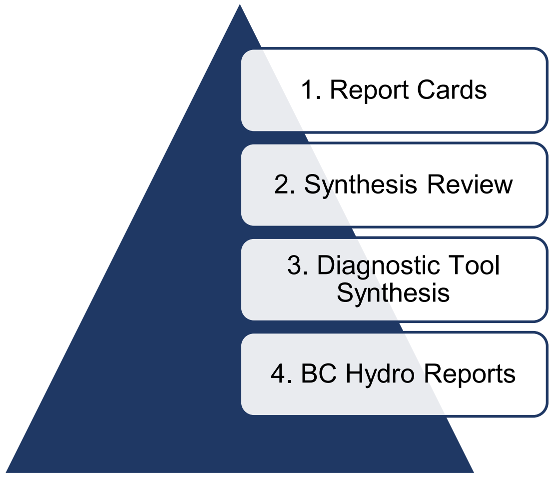

Figure 1: The four entry-points to evaluating the FAHMFP through the Synthesis Review.

The Synthesis Review is distinct from the "Fisheries and Aquatic Habitat Monitoring and Follow-up Program Annual Report[7]" (Annual Report). The Annual Report is meant to ensure the FAHMFP meets the annual monitoring requirements that are requirements of Condition 7 of the EAC, Schedule B. In contrast, the Synthesis Review aims to review the success of the FAHMFP in monitoring both the effects of the Project and the effectiveness of mitigation measures.

Geographic Setting

The spatial scope of the FAHMFP includes the Peace River from Peace Canyon Dam to Many Islands, Alberta, and major tributaries of the Peace River upstream of the Project. The spatial scope of the FAHMFP extends to include some data collected from upstream areas (Williston Reservoir, Dinosaur Reservoir) to take into account physical inputs to the Site C Reservoir, and some downstream tributaries of the Peace River to accommodate ecological linkages associated with fish movement in and out of the LAA (Figure 2). Figure 3 shows the sections used in the Peace River Fish Community Monitoring Program, which serves as the principal monitoring program for the Peace River during the construction phase of the Project.

[7] Available at: https://www.sitecproject.com/sites/default/files/Fisheries-and-Aquatic-Habitat-Monitoring-and-Follow-Up-Program-2018-Annual-Report.pdf

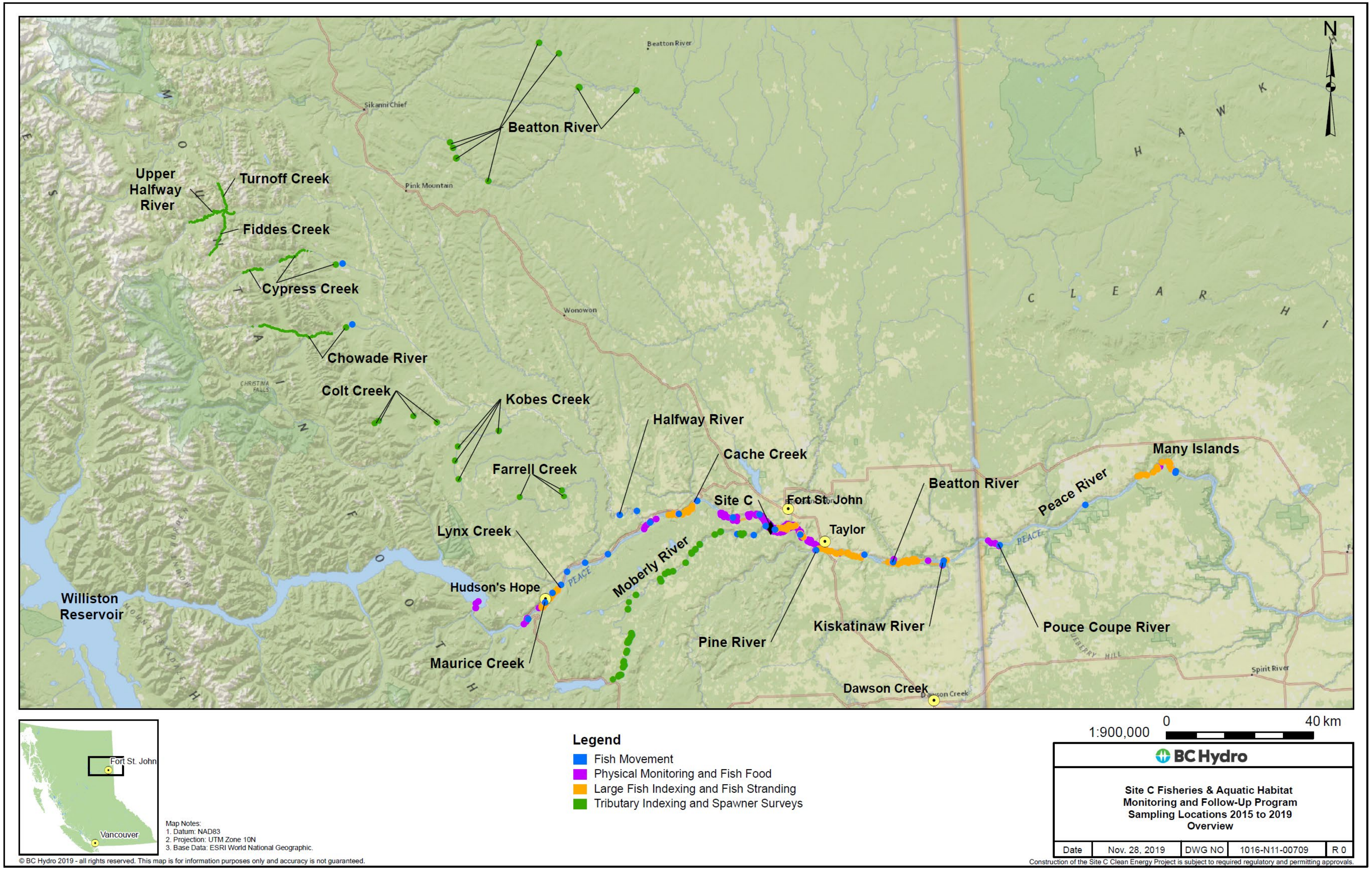

Figure 2: Major features of the Project and the Site C Local Assessment Area (LAA) including the upper (Peace Canyon Dam) and lower boundaries (Many Islands, Alberta). Locations of monitoring under the FAHMFP in the Peace River and its tributaries are shown as coloured points and lines.

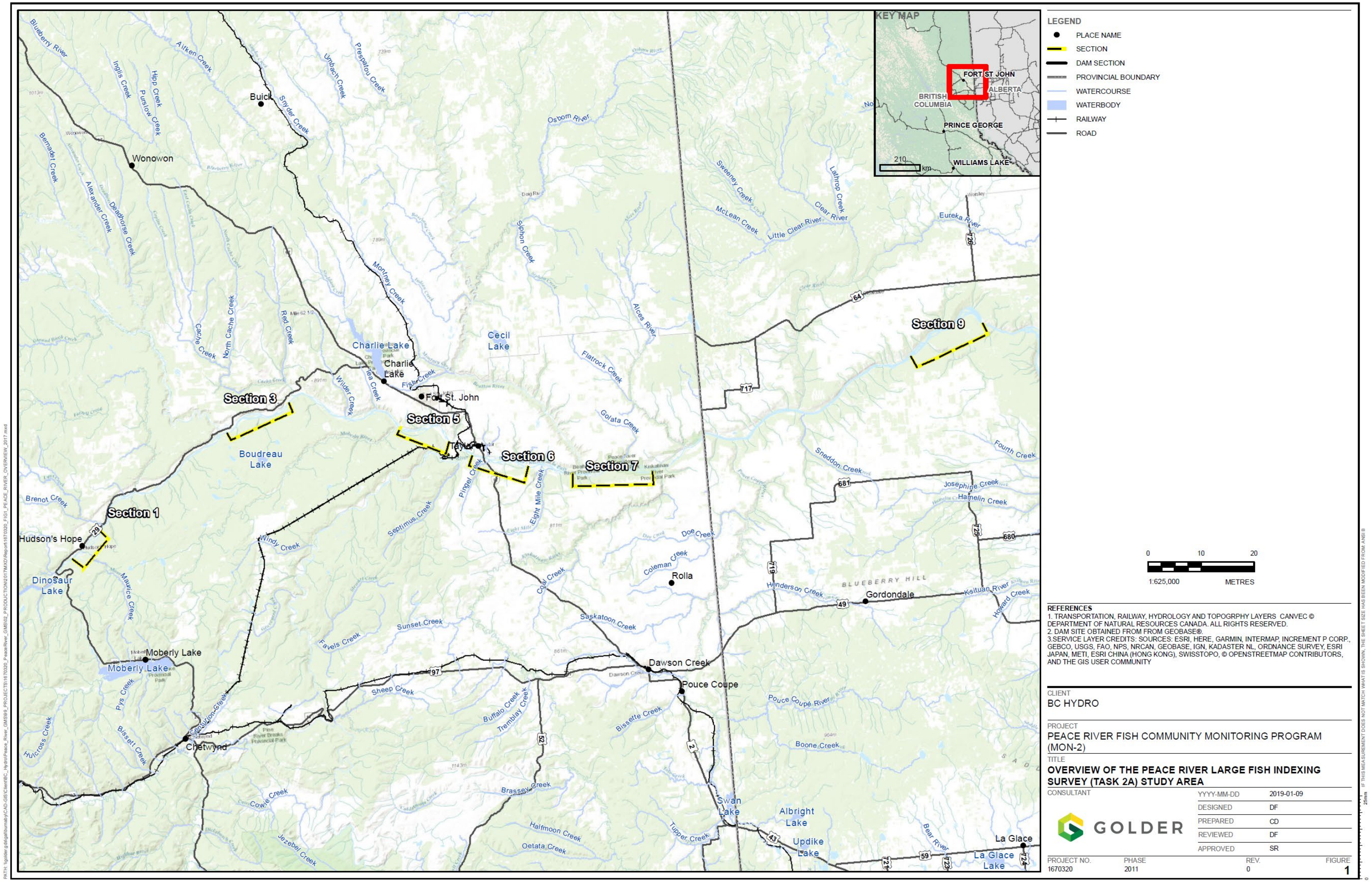

Figure 3: Sections of the Peace River sampled by the Peace River Large Fish Indexing Survey.

Schedule

Data collected during the first six years (2015 to 2020) of the FAHMFP is considered baseline data collection, contributing to the understanding of the baseline conditions of fish and aquatic habitat prior to 2015, which is summarized in the Site C EIS. The main change to fish habitat associated with the construction of the Project up to 2019 is construction of cofferdams on the left and right banks of the dam site to restrict the flow of the river to its main channel. For the purposes of the Synthesis Review, the changes to fish and aquatic habitat associated with construction up to 2019 are not of a spatial scale or intensity that would affect the population-level measures addressed in this Synthesis Review. Local changes to fish and aquatic habitat associated with construction and habitat enhancements to date are reviewed elsewhere (e.g., Golder 2020). River diversion is expected to be the first major change to the Peace River and aquatic ecosystem from construction of the Project, and therefore, the data collected over the last five years (and time preceding that) are considered baseline. This Synthesis Review intends to demonstrate that key baseline data have been collected prior to river diversion.

River diversion will represent the first major change to the aquatic ecosystem during the construction phase of the Project. In September 2020[8], the Peace River is scheduled to be diverted through two, 11-meter wide tunnels on the left bank to allow for construction of the earthfill dam in the center portion of the channel[9]. River diversion will create a headpond upstream (maximum length of 18 river km) that will fluctuate based on flows in the Peace River. River diversion is the first phase of construction expected to affect fish passage (BC Hydro 2020), and therefore most data collected after September 2020 will not be considered part of the baseline dataset.

What are the Indicator Species?

BC Ministry of Environment and Climate Change Strategy (MOE) identified several valued environmental components[10] for fish and aquatic habitat (MOE 2009, 2011). The FAHMFP focuses on the MOE objective of ‘ecosystem integrity and productivity’ and the sub-objectives and indicator species that support it (Figure 4). Beyond the indicator species identified by the MOE, Kokanee were also included because the Project is predicted to affect their abundance. Burbot were excluded from the list of indicator species explicitly considered[11] in the FAHMFP; they are expected to increase in abundance when the reservoir is created, and their distribution is not expected to change (MOE 2009). The sub-objectives reflect conservation and use goals as articulated in the Freshwater Fisheries Program Plan (Prov BC 2007), with “Species of Concern” and “Species, sub-Species Interface Zone” representing the conservation aspect of the plan and “Productive and Diverse Ecosystem” representing the use aspect. Bull Trout and Goldeye are the only species of concern that are affected by the Project (Figure 2).

[8] Available at: https://www.sitecproject.com/sites/default/files/site-c-construction-schedule-20190503.pdf
[9] Available at: https://www.sitecproject.com/sites/default/files/River-Diversion-Infosheet.pdf
[10] For reference, the Site C EIS included the Valued Component ‘Fish and Fish Habitat’.
[11] Information on Burbot continue to be collected, though they are not reported at an indicator species level.

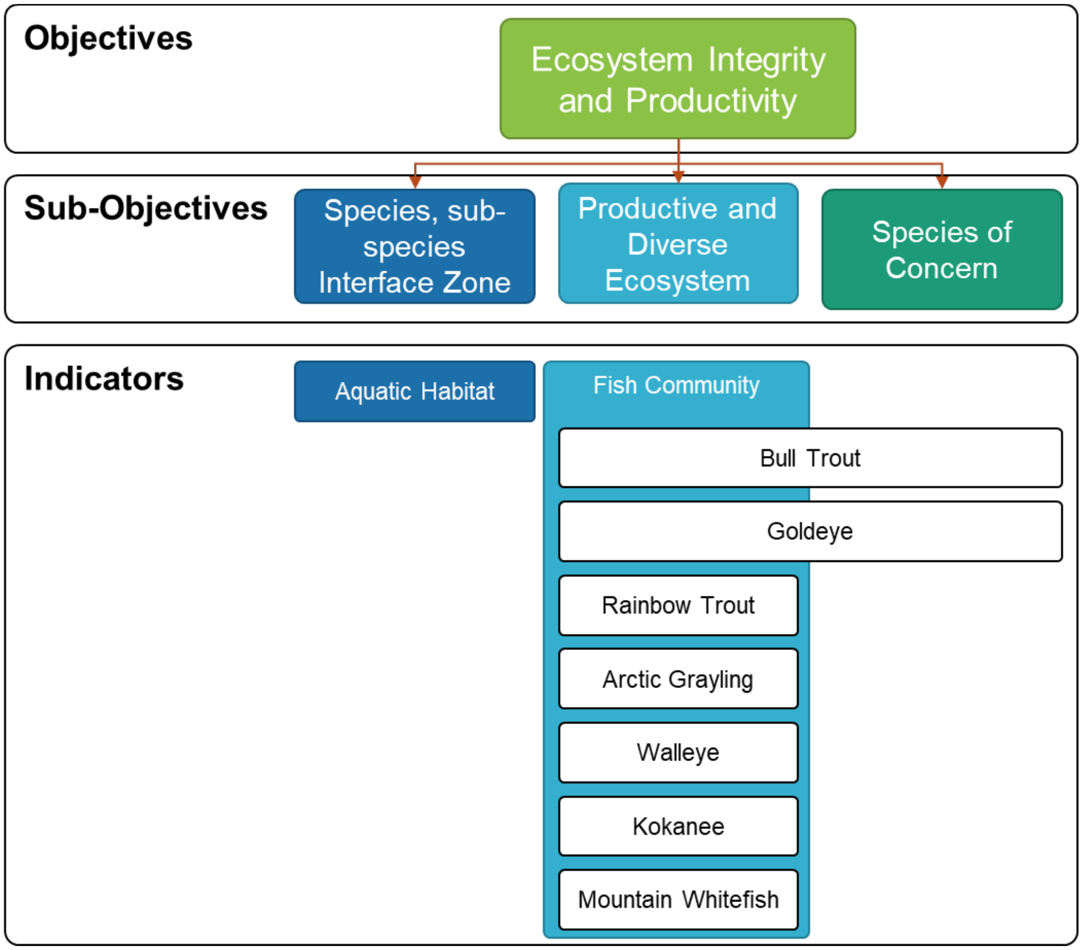

Figure 4: Indicator species identified by the MOE and BC Hydro.

The indicator species have the following measures (from MOE 2009, 2011):

> "*The suite of indicator species is intended to capture potential effects across a wide range of conditions and faunas in the LPRW [Lower Peace River Watershed]. For aquatic indicator species, the species-specific measures span a range of scales:*
>
> - ***Species distribution** represents the broadest scale and indicates the need to maintain a sufficiently large distribution to ensure healthy and viable populations that are resilient to natural perturbations. This includes maintaining or enhancing specific fisheries at traditional locations.*
> - ***Population structure** refers to the meta-population structure of a species within the [Lower Peace River Watershed] and is intended to measure the structure and function of interactions among sub-populations. The measure is aimed at assessing population structure at the sub-population level, including dispersal and exchange among sub-populations, and to examine possible project-related changes.*
> - *The **abundance/biomass** measure assesses the status of populations relative to conservation and use targets for a species' abundance in the [Lower Peace River Watershed].*

- *The **size and age distribution** measure assesses a populations' status relative to specific targets for size and age. Information collected for the indicator species may also be used to assess other subobjectives."*

Data for these measures are mainly collected in Mon-1a, Mon-1b, and Mon-2, and supplemented by the other monitoring programs (Appendix A).

Aquatic habitat and fish food are not indicator species, however the data and information from monitoring aquatic habitat and fish food are used to interpret the status and trends of indicator species in the LAA. Aquatic habitat and fish food observations do not measure indicator species status directly, but evidence from lower trophic levels and the environment can contribute to the weight-of-evidence evaluation of indicator species performance. Physical and chemical habitat data will be used to monitor changes in habitat suitability for all indicator species. Algal, benthic invertebrate and zooplankton biomass and production data will be used to assess the importance of bottom-up effects as mechanisms to explain changes in fish growth, survival, abundance and biomass (Schleppe et al. 2019). In some cases, taxonomy at the primary and secondary trophic levels will provide useful insight into energy flow to specialist consumers and energy sinks.

Periphyton and benthos are expected to respond to a variety of factors that are dependent (e.g. depth, velocity, exposure to air) and independent (e.g. turbidity, temperature, nutrients) of flow fluctuations. The Peace River Water Level Fluctuation Monitoring Program explores how lower trophic levels may change with changes in flow during operation of the Project (ESSA and Golder 2019).

The information collected for aquatic habitat and fish food under the FAHMFP is described in annual monitoring reports and is not explicitly summarized in the Synthesis Review. The key monitoring programs and reports are: Peace River and Site C Reservoir Water and Sediment Quality Monitoring Program (Saulteau EBA 2020), Peace River and Site C Reservoir Fish Food Organisms Monitoring Program (Schleppe et al. 2019) and the Peace River Water Level Fluctuation Monitoring Program (ESSA and Golder 2019).

METHODS

Methods to Synthesize Information

For the 2019 Synthesis Review, the key method for assessing the FAHMFP was the quality and completeness of data collection. For the 2019 Synthesis Review, qualitative descriptions of changes are used to point out potential trends in the indicator species that may be worth noting at this stage of implementing the FAHMFP.

The Diagnostic Tools are logical frameworks that adopt a weight-of-evidence approach to assess the capability of the metrics monitored in the FAHMFP to detect and diagnose causes of observed changes to indicator species. The use of the Diagnostic Tools resulted in a few changes in the monitoring of indicator species. These changes are discussed below in the species-specific subsections of the Results. The Diagnostic Tools served an important role in refining and communicating the robustness of the FAHMFP. As part of the Synthesis Review, a simplified version of the Diagnostic Tools called the Diagnostic Tool Synthesis was developed to ensure that the data collected from 2015 to 2019 were complete and of high quality. The Diagnostic Tool Synthesis assisted in summarizing the monitoring conducted as part of the FAHMFP over the last five years. Information is broadly summarized below in the Results.

Annual Sampling Consistency

Consistent sampling and methods facilitate the interpretation of results in long term monitoring programs. The importance of sampling consistency is described in the FAHMFP, including the section on the principles used in developing and implementing the FAHMFP (e.g., "Any revisions to the monitoring will need to be balanced with the interest in a consistent sampling approach through time."). Two components of consistency are reviewed. One component of consistency represents the adjustments to the monitoring programs (relative to those described in the FAHFMP [BC Hydro 2015]) that were made between 2015 and 2019. These adjustments are described for each indicator species and often include additional locations or seasons sampled. A second component of consistency is the methods used for monitoring that began prior to the FAHMFP (prior to 2015) and continued under the FAHFMP. This second component is described in the annual monitoring reports (e.g., Golder and Gazey 2019) and is not detailed in the Synthesis Review.

Using the Diagnostic Tool Synthesis

In the Diagnostic Tool Synthesis, the following questions were asked for each of the 124 observations or 'pieces of data' tied to each of the indicator species:

- Important Observations
    - What are the relevant observations (and indicators)?
    - How important is the observation in diagnosing change?
- Data Quality and Completeness
    - Were the data collected as planned?
    - What was the sampling approach?
    - How long is the sampling time series?
    - Where were the data collected?
    - Is the data quality as expected?
- Adjustments
    - Were adjustments made?
    - Were these (1) adjustments to existing monitoring, (2) introduction of new planned monitoring, and/or (3) introduction of new unplanned monitoring?

The Diagnostic Tool Synthesis – a filterable Microsoft Excel spreadsheet – has been structured with the following tabs:

1. Instructions: How to use the Diagnostic Tool Synthesis.
2. Observations: Observations for all indicator species that BC Hydro committed to collecting from 2015 to 2019 under the FAHMFP.
3. Sampling Map: Spatial extent of sampling that occurred from 2015 to 2019.
4. Data, Pathways and Life History: Key data, impact pathways and a description of the life history of each indicator species.

The Observations tab consists of the following columns:

Column	Name	Description
A	Diagnostic tool or grouping	Indicator species
B	Observation no.	Unique number that is linked to the Diagnostic Tools

Column	Name	Description
C	Category	Category of the observation
D	Monitoring program	FAHMFP monitoring program and task
E	Observation	Short title describing the observed measurement
F	Data type	Type of data
G	Sampling approach	Brief description of the data collection method(s) or approach(es)
H	Sampling year(s)	Year(s) in which sampling occurred
I	Spatial extent of sampling	Name of waterbody(ies) where sampling occurred
J	Observation importance	Linked to the impact pathways of the Diagnostic Tools. Observations tied to abundance, distribution, population structure and age structure – all key indicators of MOE – were assigned an importance of 'High'.
K	Were data collected as planned?	Were the data collected as described in the FAHMFP?
L	Is the quality of the data as expected?	Data quality (i.e., estimates, error, variation) relative to the quality of the data collected prior to 2015. For example, sampling prior to 2015 captured very few Goldeye in the Peace River. Low capture rates for Goldeye were observed from 2015 to 2019, and as such, the quality of the data is consistent expectations. As another example, catch rates of Arctic Grayling in the Moberly River were lower than expected from 2016 to 2019, relative to catch rates prior to 2015.
M	Were adjustments made?	Were there any unexpected or unplanned data gaps or data quality concerns?
N	Contact	Contractor responsible for collecting data
O	Reference	Most recent annual report

Members of the Committee can filter the observations using any of the columns described above; however, the information presented in Columns J to M is likely of utmost importance to the Committee. Information presented in the Diagnostic Tool Synthesis is distilled into sections on each indicator species below. The Diagnostic Tool Synthesis allows the Committee to review the individual observations for the purposes of potentially refining the sampling approaches and effort in the FAHMFP.

RESULTS

A combination of life-history, key findings, and a report card style summary were used to address the questions outlined in the Methods. Sections for each indicator species are presented below with the following headings: Rationale for Monitoring, Important Observations, Data Quality and Completeness, Adjustments, and Status Update.

In the summaries, important observations are the species-specific measures of abundance, size and age distribution, species distribution, and population structure. Generally, the performance metrics used to assess each of these measures depended on the available data. The measures used to determine changes for each indicator species before and during operation of the Project are outlined in Appendix C.

Estimates of abundance can be generated using mark-recapture, catch-per-unit-effort[12] (CPUE), and other measures. For some indicator species in specific sections of the Peace River (e.g., Figure 8), abundance estimates are generated through a Bayes sequential model. These estimates can be generated when sufficient mark-recapture data are collected from the Peace River Large Fish Indexing Survey (Golder and Gazey 2018). For some indicator species like Bull Trout, other indicators are used such as redd counts as an index of spawner abundance. When mark-recapture data are not sufficient to generate a population estimate for a given species, section and year, measures of relative changes in abundance like CPUE are also included to help assess trends in abundance. The number of fish captured in surveys was used when the captures were limited (e.g., Goldeye).

Estimates of age- and size-distribution were calculated using data collected from the Peace River Large Fish Indexing Survey (Golder and Gazey 2018) but are not presented in this report.

Species distribution is discussed for each indicator species, starting with the known sightings in the LAA and surrounding area, based on the 'Known BC Fish Observations and BC Fish Distributions' (British Columbia Data Catalogue), followed by specific monitoring actions for understanding species distribution. Generally, this is determined using radio and PIT telemetry.

Population structure is estimated using otolith and fin ray microchemistry for Bull Trout, Rainbow Trout, Arctic Grayling, Goldeye, Walleye, and Mountain Whitefish. However, these results are not included in the Synthesis Review because the reporting is not finalized. An exception is microchemistry results Goldeye, which are presented because the results are more straightforward to interpret. Population structure is also estimated using genetics for Bull Trout, Rainbow Trout, and Arctic Grayling. Genetics results are shown for Bull Trout, preliminary results for Arctic Grayling are referenced, and the status of the analyses for Rainbow Trout are provided.

The Rationale for Monitoring section describes why an indicator species is monitored, including a list of key uncertainties. Important Observations are monitoring tasks that are deemed “high” importance in the Diagnostic Tool Synthesis that support the resolution of a key uncertainty, and directly address species-specific measures of abundance, size and age distribution, species distribution, and population structure. Observations tied to abundance, distribution, population structure and age structure – all key indicators (MOE 2011) – were assigned an importance of ‘High’. Other observations were assigned an importance of ‘Medium’ or ‘Low’ because they do not measure indicator species status directly.

[12] All CPUE values reported in the Synthesis Review exclude within-year recaptures. That is, if an individual fish is captured more than once in a given year, it is only listed as a single captured fish in the CPUE values.

Bull Trout

Life History

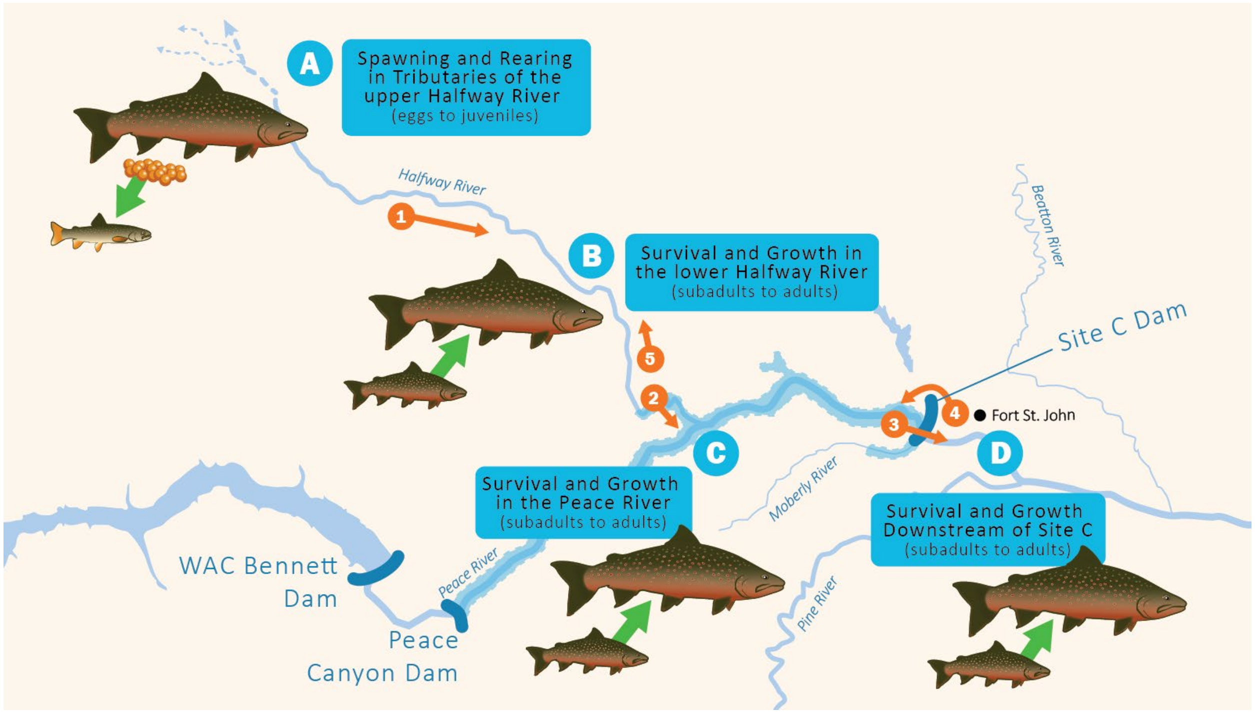

Figure 5: Life history of Bull Trout in the LAA. The Site C Reservoir is indicated by the semi-transparent blue polygon with dashed outline.

In the LAA, almost all Bull Trout reproduce in tributaries of the Halfway River (**Location A**) (EIS Vol. 2, App Q3). Juveniles rear in these tributaries for two to three years before moving downstream as sub-adults (**Arrow 1**) to either the lower reaches of the Halfway River (**Location B)** or the Peace River (**Arrow 2**) (**Locations C & D**) (EIS Vol. 2, App Q3; McPhail 2007). Subadults mature into adults in the lower reaches of the Halfway River and Peace River (EIS Vol. 2, App Q3). Currently, Bull Trout that migrate to the Peace River use habitat above (**Location C**) and below (**Location D**) the Project. One key uncertainty is whether Bull Trout will continue to migrate downstream of the Project (**Arrow 3**) into the Peace River because Bull Trout are known to thrive in reservoirs and lakes (EIS Vol. 2, App Q3). Bull Trout that attempt to move upstream of the Project will be assisted through the temporary and permanent upstream fish passage facilities (**Arrow 4**) (EIS Vol. 2, App Q3; BC Hydro 2019). Adult Bull Trout migrate upstream during the spring and summer to tributaries of the Halfway River (**Arrow 5, Location A**) and spawn in September (EIS Vol. 2, App Q3). Bull Trout also spawn in tributaries of the Pine River; their downstream migration rarely includes the Peace River (EIS Vol. 2, App Q3, Taylor and Yau 2012).

Rationale for Monitoring

Bull Trout are an indicator species because they are (MOE 2011):

- A high value target for anglers;
- Relatively well studied within the LAA and elsewhere;
- Representative of coldwater fauna; highly migratory; noteworthy headwater populations; not tolerant of high turbidity; global level conservation concerns; top predators; and

- Representative of Pacific origin species.

Bull Trout are found throughout the LAA as far downstream as Many Islands, Alberta (Figure 6) but are less abundant in the Peace River downstream of the Project (Figure 9). Bull Trout are considered by MFLNRO and MOE to be a fish passage sensitive species because they undertake long feeding and spawning migrations past the Project (EIS, Vol 2, App Q2).

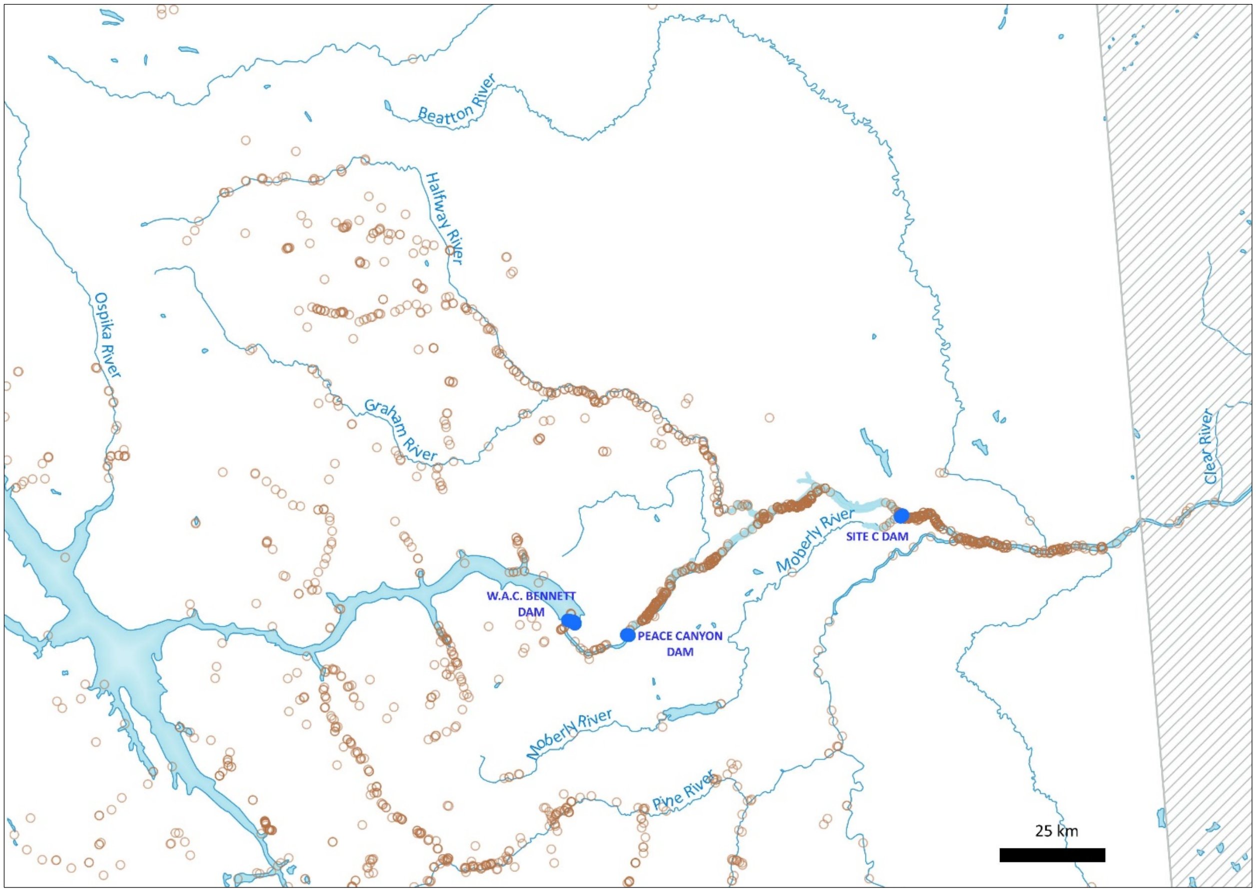

Figure 6: Bull Trout distribution in the Peace Region in BC and Alberta. Each brown circle represents a confirmed observation in British Columbia and Alberta. Data source: 'Known BC Fish Observations and BC Fish Distributions' (British Columbia Data Catalogue).

In the Site C Reservoir, Bull Trout are expected to be an important component of the fish community and angler catches. Bull Trout are a specialist piscivore that feed on a variety of fish species but seem to prefer Kokanee when this species is present (Beauchamp and Tassell 2001).

Bull Trout present distinct sampling challenges for assessing population status. The Site C EIS (App Q3) notes the following:

> *"Complex migratory patterns are common in Bull Trout (McPhail 2007). The current Halfway/Peace population follows a fluvial life-history where sub-adult and adult fish inhabit different parts of the same river system... Following reservoir construction, part of the population would be expected to follow an adfluvial life-history, where adults reside in a lake or reservoir but spawning and sub-adult rearing takes place in tributary streams"*

Migration past the Project is an integral part of the life history of a component of this population; the Site C EIS (Vol 2, Appendix Q2) highlighted “Bull Trout as being the priority species for detailed evaluation of fish passage technologies, since there is high certainty that fish passage could serve to meet management objectives.”

The FAHMFP monitoring tasks for Bull Trout are based on performance measures related to abundance, size structure, age structure, distribution, and population structure that are designed to meet management objectives at the species level (MOE 2011).

Additional performance measures include “Bull Trout (passage) mortality (adults and juveniles)” and “total Bull Trout angler days”.

Key uncertainties for Bull Trout include the following:

1. Whether Bull Trout will continue to move into Site C Reservoir and downstream past the Project;
2. Whether entrainment through the Project will reduce Bull Trout abundance in Site C Reservoir;
3. Whether Bull Trout can be effectively moved upstream from downstream of the Project;
4. Whether there will be sufficient prey in Site C Reservoir to maintain high condition Bull Trout;
5. Whether Bull Trout will be the top predator in Site C Reservoir (vs. Lake Trout); and
6. Whether Bull Trout overharvest will threaten the population.

Important Observations

Bull Trout are sampled in the Peace River through annual repetitive boat electroshocking surveys from Peace Canyon Dam to Many Islands, Alberta, and tributaries of the Halfway River through redd surveys, resistivity counters, PIT arrays and backpack electrofishing.

The key indicator for Bull Trout is spawner abundance in the Halfway Watershed. The Peace River Bull Trout Spawning Assessment estimates spawner abundance through redd counts. Based on peak redd counts (the index collected prior to 2016), there may have been an increase in Bull Trout spawner abundance from 2002 to 2010, and a decline following 2010 (Ramos-Espinoza et al. 2019). Resistivity counters in two spawning tributaries (Chowade River, Cypress Creek) provide an estimate of kelt abundance, which represent independent estimates of Bull Trout spawner abundance. PIT arrays at these same locations provide additional information, such as the presence or absence of resident populations, the timing of both pre- and post-spawn movements by adults, the residence time of immature life stages, the timing of downstream immature dispersal, and the extent of skip-spawning by adults. Such information can feed into the Bull Trout Integrated Population Model (BTIPM) that is described below and in Appendix B.

The Peace River Bull Trout Spawning Assessment also estimates the size of spawning Bull Trout using two methods: measuring the size of redds during redd surveys, and from video validation of resistivity counter data (Ramos-Espinoza et al. 2019). Fecundity is largely dependent on fish size (Kindsvater et al. 2016), and thus monitoring the size of spawning Bull Trout under the Peace River Bull Trout Spawning Assessment provides a direct link to the juveniles monitored under the Site C Reservoir Tributaries Fish Population Indexing Survey (Ramos-Espinoza et al. 2019).

Population estimates of subadults and non-spawning adults are calculated using captures from the Peace River Large Fish Indexing Survey when there were sufficient captures (Golder and

Gazey 2018) (Figure 8). However, population estimates cannot be calculated in all years and river sections. CPUE can be generated across all years and sections and is, therefore, a metric available in all sampled years to assess potential trends in the relative abundance of Bull Trout. In contrast to the trends in the number of redds over time, CPUE has remained stable in the Peace River (Figure 9). Possible causes of this discrepancy could be skip spawning behaviour leading to higher variability in redd counts, a sudden change to higher angler harvest rates of fish migrating to spawn (i.e., poaching), changes in observation error, or high natural variation in population abundance. Ma et al. (2015) detected high natural variation in redd counts and estimated that the error structure in Bull Trout redds was 1.38- to 3.28-fold higher than observation error standard deviation. This result was consistent with other studies (Al-Chokhachy et al. 2009).

Several key uncertainties for Bull Trout are related to the future movement patterns in the Peace River and its tributaries. BC Hydro implemented the Site C Fish Movement Assessment in 2019 to help reduce these uncertainties and help answer the management questions of several monitoring programs. Seventy-five adult and 63 juvenile Bull Trout were radio-tagged in the Peace River and tributaries of the Halfway River in 2019 (LGL 2020). Spatial stratification of tag releases in 2019 intended to strike a balance among the objectives of several monitoring programs requiring the data (Burnett et al. 2019). Radio-tagged fish will be tracked in the Peace River from Peace Canyon Dam to Many Islands, Alberta as well as movements in and out of all major tributaries (Figure 10). Information from radio tagged fish also helps to examine assumptions for the mark-recapture estimates in sections of the Peace River (e.g., the estimates in Golder and Gazey 2018).

Population structure was assessed using genetic analyses. Recent genetic analyses confirmed the findings of Taylor and Yau (2012), whereby the vast majority (92%, 436 of 473) of Bull Trout sampled in the Peace River from 2016 to 2018 originated from the Halfway River (Figure 12, Geraldes and Taylor 2020). Such information is critical to understand the population structure of Bull Trout in the LAA during baseline conditions and may help inform long-term decisions related to fish passage management (BC Hydro 2020).

The BTIPM is being developed to integrate information collected from the different monitoring tasks and generate population estimates using all data sources (Appendix B). This model will help integrate information from spawning surveys, relative abundance measures (i.e., CPUE), and radio and PIT telemetry data to help understand changes in Halfway River Bull Trout. The BTIPM can take advantage of the information from the increasing number of Bull Trout that are PIT tagged and redetected in the Peace River and Halfway River (Figure 11).

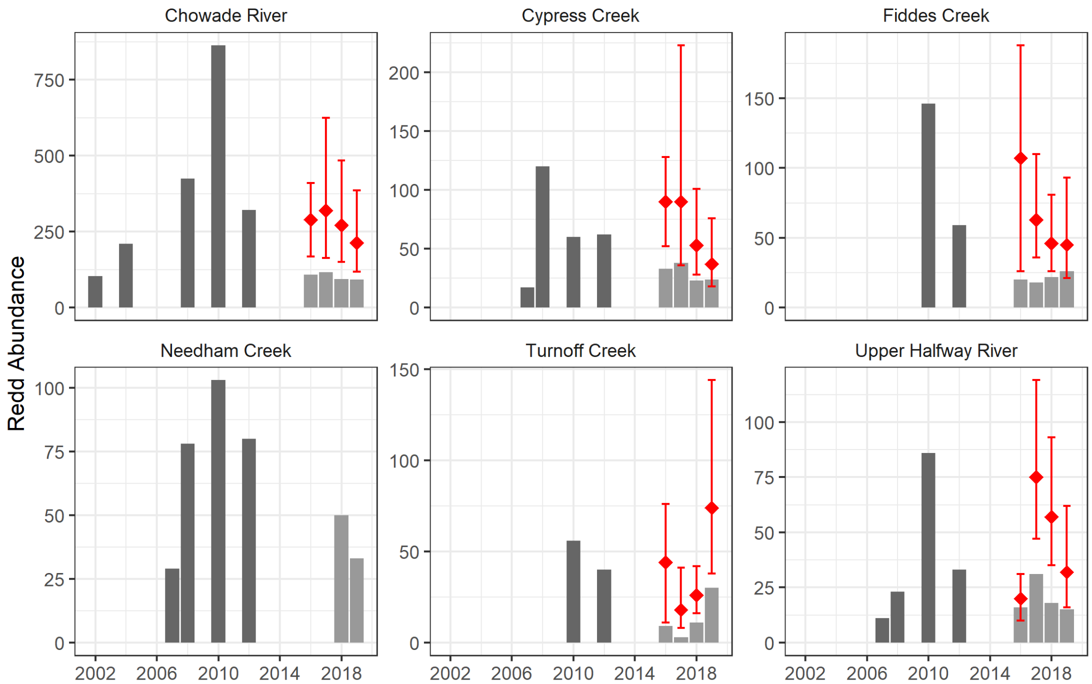

Figure 7: Peak and AUC count estimates of redd abundance for Bull Trout from 2002 to 2019 in tributaries of the Halfway River. The red points are the AUC estimates with 95% confidence intervals, dark grey bars are historic peak counts, and the light grey bars are recent peak counts conducted as part of the FAHMFP. Note that the y-axis scales are different.

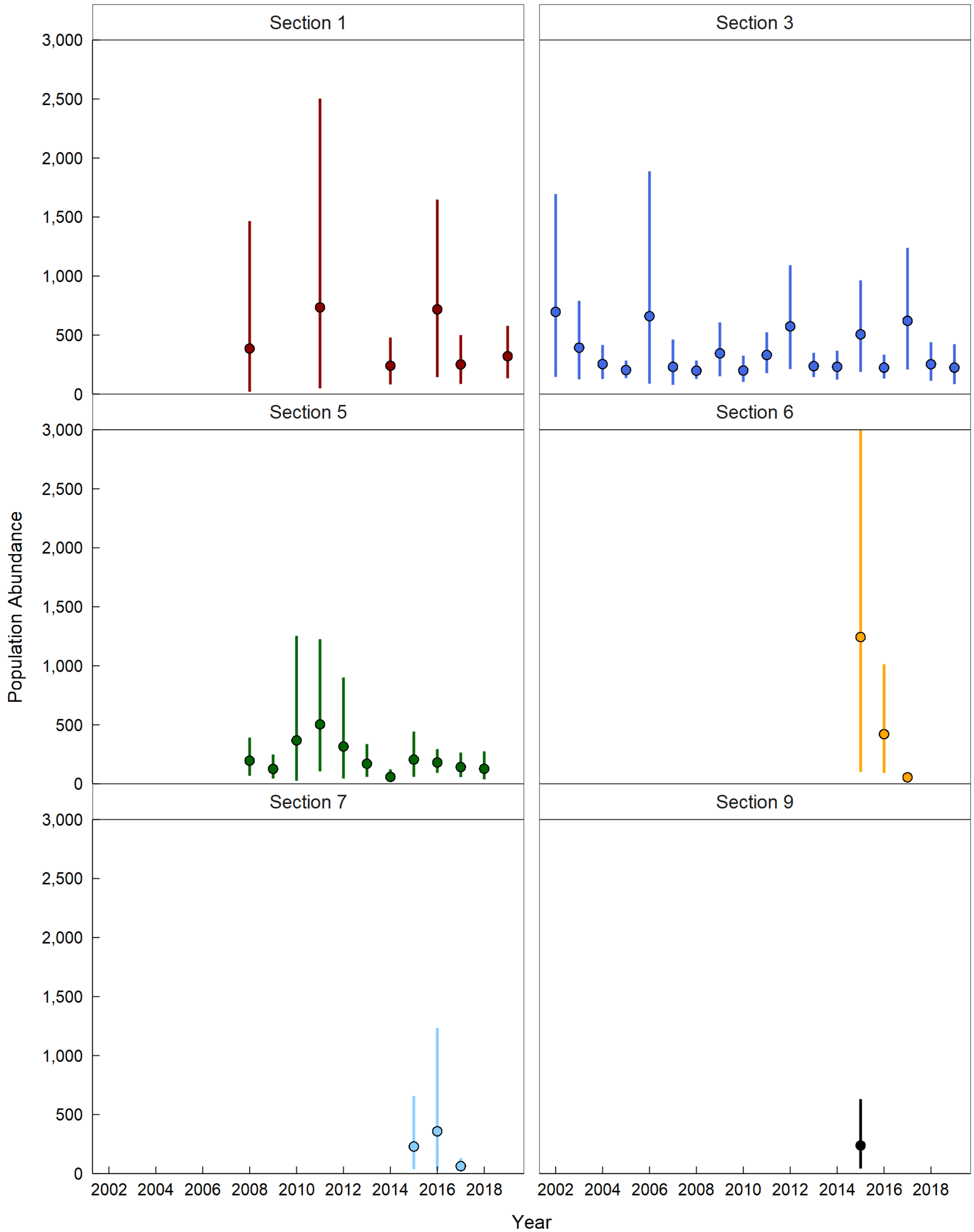

Figure 8: Population abundance estimates (with 95% credibility intervals) generated using the Bayes sequential model for Bull Trout captured by boat electroshocking in Sections 1, 3, 5, 6, 7, and 9 of the Peace River, 2002 to 2019.

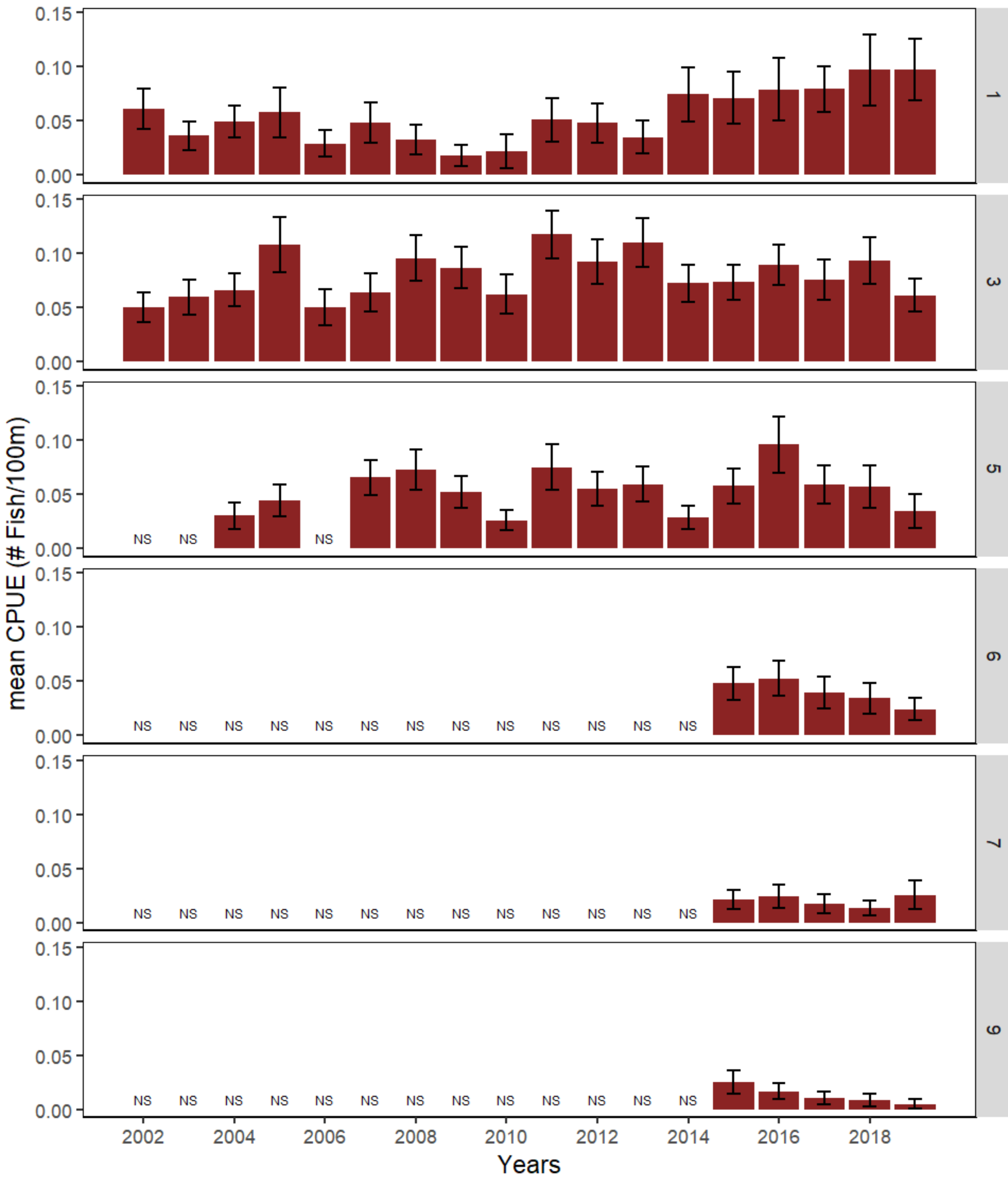

Figure 9: CPUE of Bull Trout captured by boat electroshocking in Sections 1, 3, 5, 6, 7 and 9 of the Peace River from 2002 to 2019. Error bars represent 1.96xSE. Analysis included captured fish only and all size cohorts. Data Source: Peace River Large Fish Indexing Survey Database. NS indicates a section not sampled in a given year.

BC Hydro
Power smart

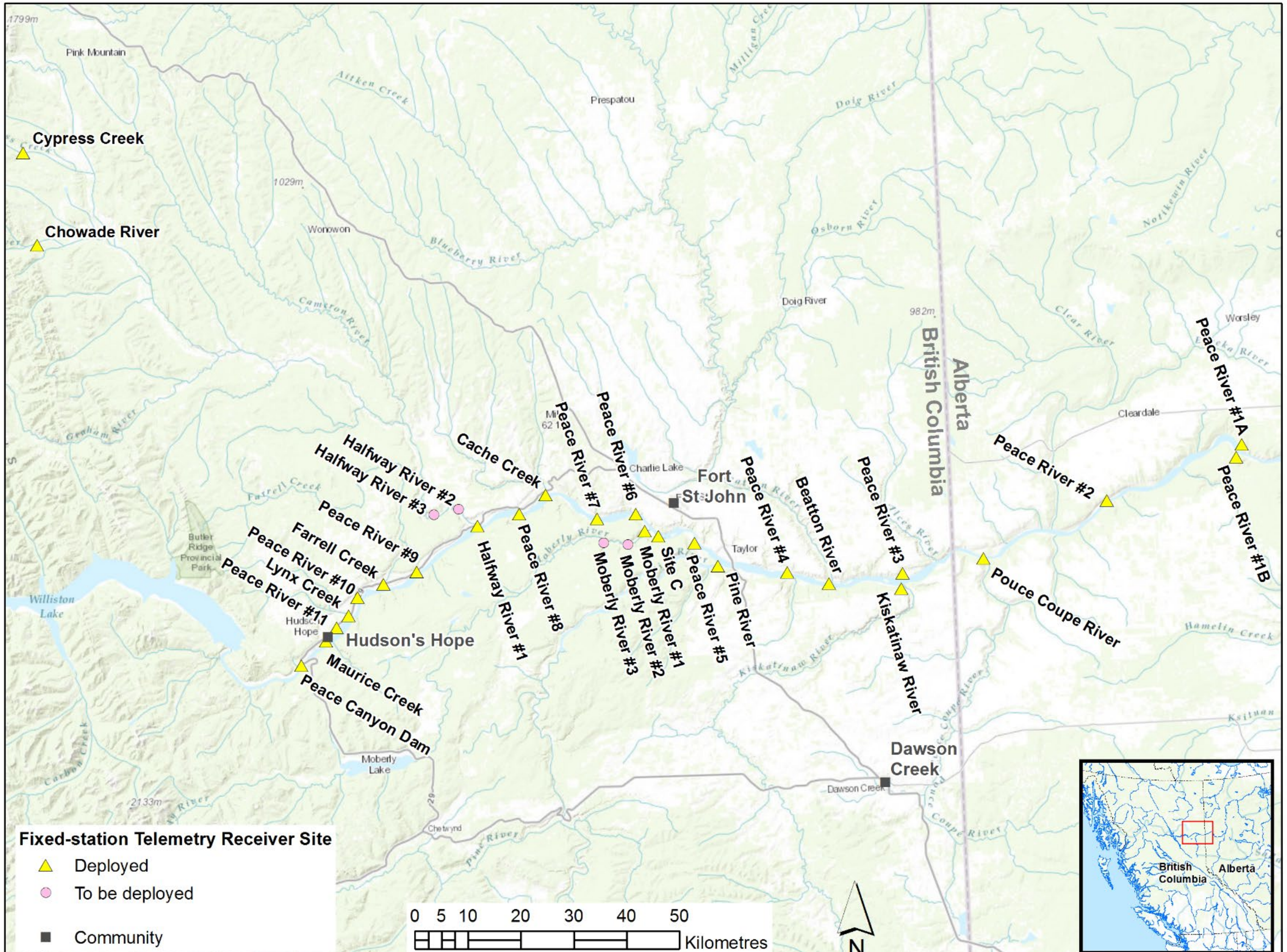

Figure 10: Location of fixed radio telemetry stations for the Site C Fish Movement Assessment. Stations that were deployed in 2019 are shown as yellow triangles. Four of the 30 originally proposed stations (pink circles) will be deployed in spring 2020.

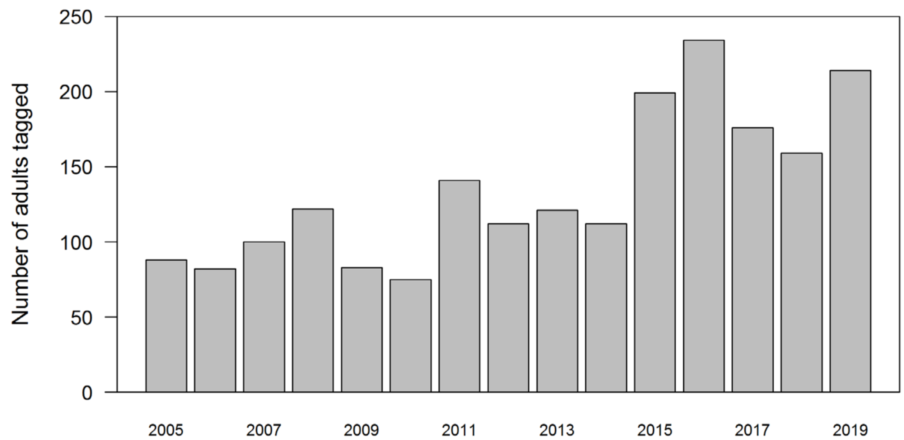

Figure 11: Number of subadult and adult Bull Trout PIT-tagged in the Peace River from 2005 to 2019.

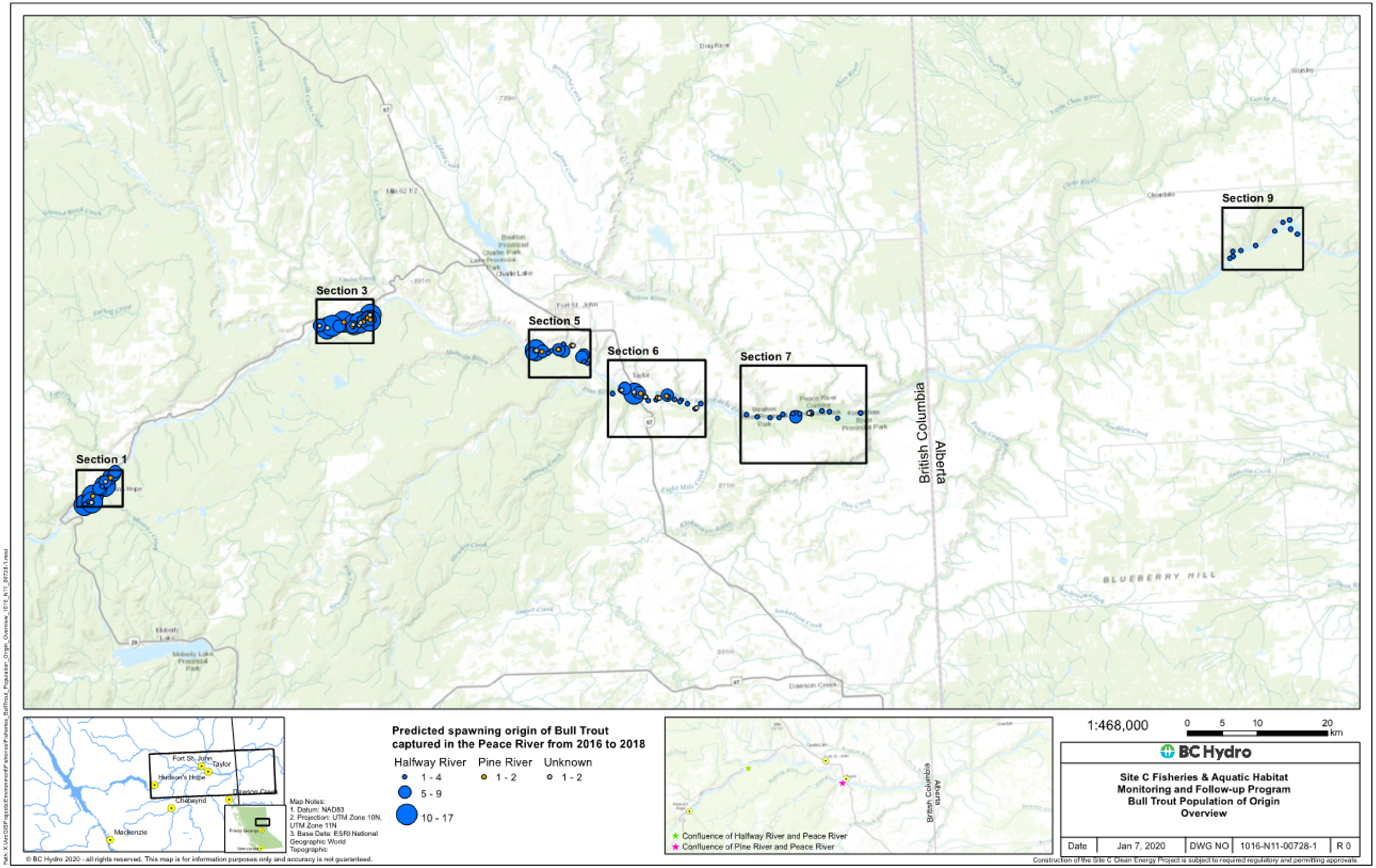

Figure 12: Predicted population of origin based on genetic analysis (blue: Halfway River, Pine River: orange) of subadult and non-spawning adult Bull Trout captured in Sections 1, 3, 5, 6, 7, and 9 of the Peace River from 2016 to 2018. Circles are proportional to frequency. Samples that could not be assigned to either group are shown in gray.

Data Completeness and Quality

Data collected to monitor Bull Trout is considered complete and of high quality. Twenty-two of the 22 observations (100%) for Bull Trout were collected as planned, which include two high importance observations, 10 medium importance observations and 10 low importance observations.

Two observations where the quality was not as expected were for juvenile density estimates as collected by backpack electrofishing in the tributaries of the Halfway River (Site C Reservoir Tributaries Fish Population Indexing Survey). The sampling design for juveniles in tributaries of the Halfway River involved tradeoffs between the objectives to increase the number of juvenile Bull Trout PIT tagged (to ultimately estimate juvenile-to-adult survival) and estimate juvenile density in all habitats (Mossop et al. 2017). Since 2017, sampling focused on high quality habitat and achieved the tagging objective. As a result, juvenile density estimates will be based on high quality habitat

Were Adjustments Made?

For redd surveys, BC Hydro adopted area-under-the-curve (AUC) field and analysis methods for estimating redd abundance alongside the peak redd count methods used during baseline studies (Ramos-Espinoza et al. 2019). AUC methods will increase the accuracy and precision of estimates and will help to generate estimates of uncertainty. AUC methods are superior to peak redd count methods because they account for observation error and redd survey life (Millar et al. 2012), while peak redd count methods may fail to account for variability in migration timing and spawning behaviour (Ramos-Espinoza et al. 2019).

BC Hydro adjusted the monitoring of juvenile Bull Trout in tributaries of the Halfway River as part of the Site C Reservoir Tributaries Fish Population Indexing Survey since it began in 2016. In 2016, Bull Trout catch was lower than anticipated (Figure 13; Golder 2017). As a result, the program was modified in 2017 to increase the juvenile Bull Trout catch. These modifications included limiting the capture method exclusively to backpack electrofishing, as this method had the highest catch rate in 2016, focusing effort in the upper reaches of each stream, as juvenile Bull trout densities were higher in these areas, and focusing effort in the upper reaches at locations expected to yield higher Bull Trout catches (e.g., locations with abundant large woody debris, side channel habitats). In 2017, the upper Halfway River was removed in favor of sampling Fiddes Creek, which flows into the upper Halfway River. These adjustments to sampling increased the number of juvenile Bull Trout tagged in 2017, 2018 and 2019 (Golder 2018, 2019a; Figure 13). The higher number of PIT tags should allow BC Hydro to estimate juvenile-to-adult survival and juvenile abundance using the BTIPM rather than a crude estimate of juvenile density in high quality habitats (Appendix B). The shift in the sampling frame to upper stream reaches and smaller tributaries came at the cost of fewer Arctic Grayling and Rainbow Trout captured and tagged in tributaries of the Halfway River.

The adjustment to monitoring of Bull Trout diet from stomach content sampling to stable isotope analysis was over concern of causing undue harm to Bull Trout. Further, the effective and complete removal of stomach contents from large piscivores through gastric lavage is difficult. Stable isotope analysis, however, will only give general information of the trophic level of prey items (e.g., zooplankton, benthos, or fish) and cannot provide information on the volume and species of prey. For example, stable isotopes can determine whether the major diet items of Bull Trout in the tailrace of Peace Canyon Dam are fish. However, the analysis may not have the resolution to determine whether they are feeding primarily on Kokanee or other fish species.

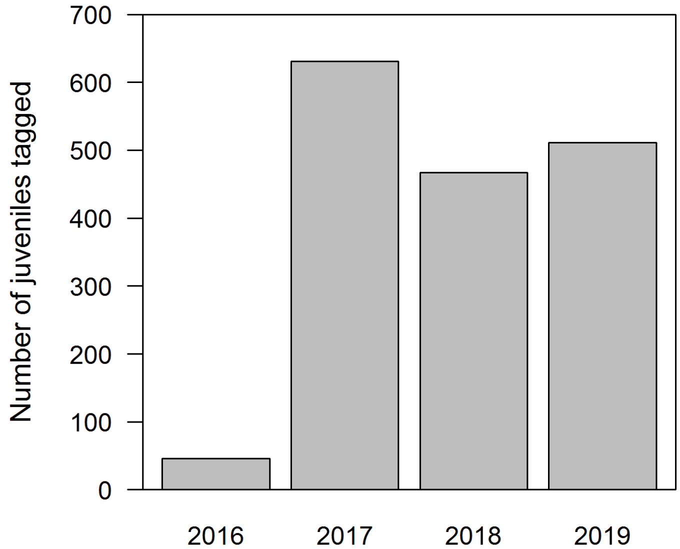

Figure 13: Number of juvenile Bull Trout PIT-tagged in the Halfway Watershed from 2016 to 2019.

Status Update

Monitoring to date is for baseline data, which continues to be collected. Overall, the understanding of the Bull Trout population has improved since the Site C EIS because of an increased level of monitoring of Halfway River Bull Trout. Several adjustments to sampling protocols and the ongoing development of the BTIPM have improved the ability to track and interpret changes in Bull Trout performance measures. The AUC estimate of total redds improves spawner count accuracy, while peak counts continue to be collected to align with baseline data. Juvenile tagging will be integrated into the BTIPM to provide an estimate of juvenile to sub-adult survival and, therefore, a retrospective estimate of juvenile abundance. Although peak redd counts from 2016 onward are lower than those observed during some prior years, Bull Trout population estimates in the Peace River do not suggest any directional changes in abundance. This discrepancy could be attributed to high natural variation and observation error in the redd count data, differences in Bull Trout spawning behaviour from year-to-year, or a sudden increase in sub-adult to adult survival. The contrasting evidence from the important observations emphasizes the need for integrating multiple data sources into a single assessment of the Bull Trout population through the BTIPM (Appendix B).

Rainbow Trout

Life History

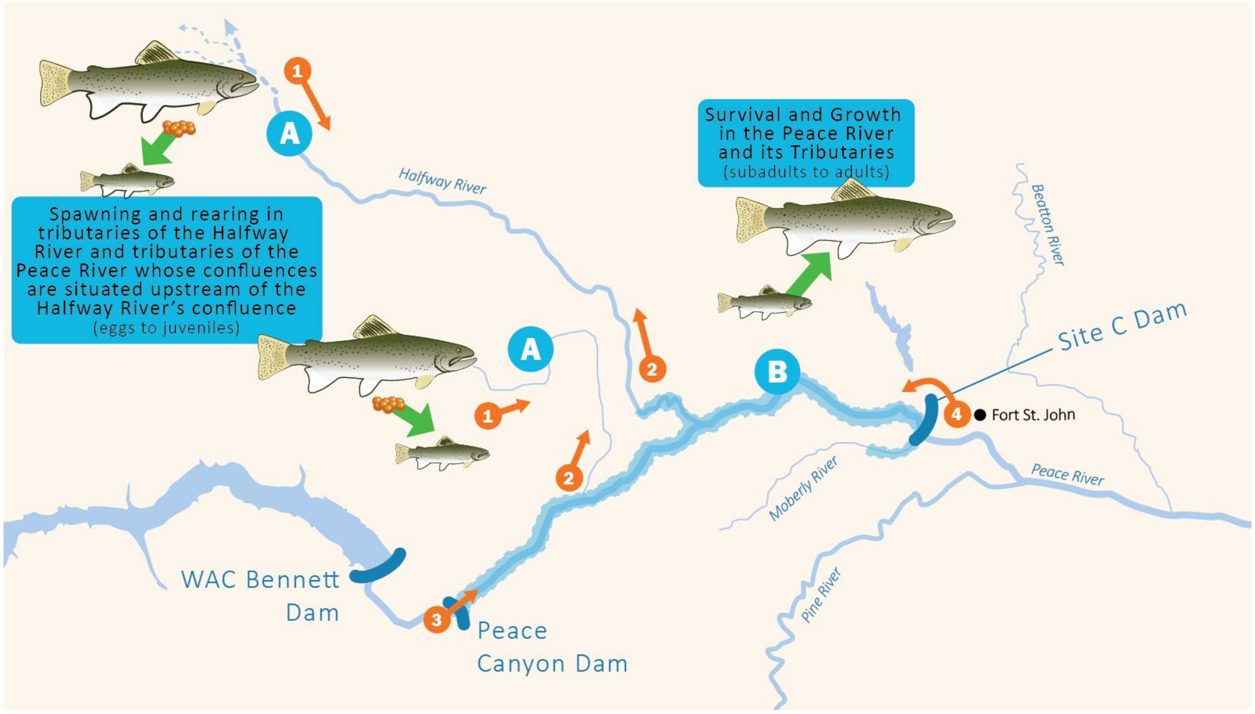

Figure 14: Life history of Rainbow Trout in the LAA. The Site C Reservoir is indicated by the semi-transparent blue polygon with dashed outline.

Rainbow Trout are present in the Peace River from Peace Canyon Dam to Many Islands, Alberta (Figure 15) but are more abundant in reaches upstream of the Project. Although age-0 fry are present in the mainstem Peace River, most Peace River Rainbow Trout are thought to spawn in tributaries of the Halfway River and tributaries of the Peace River whose confluences are situated upstream of the Halfway River's confluence (**Location A**) (EIS Vol. 2, App O). Rainbow Trout are also common in the headwaters of the Moberly, Pine and Kiskatinaw rivers, but few fish from the Pine River are thought to move into the Peace River (EIS Vol 2, Table 12.8). Age-0 and age-1 (juvenile) fish typically remain in smaller tributaries before migrating downstream (**Arrow 1**) to larger tributaries of the Peace River (e.g., Halfway, Graham, and Chowade rivers), or into the Peace River itself, where they grow from sub-adults to adults (**Location B**) (R.L. & L. 1995, EIS App O). Starting at age-2, Rainbow Trout mature and migrate (**Arrow 2**) to spawning tributaries each spring (**Location A**). Entrainment through Peace Canyon Dam also contributes to Rainbow Trout recruitment in the Peace River (**Arrow 3**) (EIS Vol. 2, Section 12.3.2.4).

The reservoir habitat is expected to be suitable for Rainbow Trout (EIS, Vol. 2, Section 12). Seasonally colder temperatures are expected to increase habitat suitability for Rainbow Trout between the Project and the Pine River, but the presence of Rainbow Trout downstream of the Project will depend on recruitment through entrainment, reproduction in the dam tailrace or additional recruitment from the Pine River (EIS, Vol. 2, Section 12.4.2.2). Low rates of entrainment are expected through the Project (EIS, Vol. 2, Section 12.4.4.2). Rainbow Trout that approach, enter and pass the temporary and permanent upstream fish passage facilities will be moved upstream past the Project through trap and haul (**Arrow 4**) (EIS Vol. 2, App Q3; BC Hydro 2019).

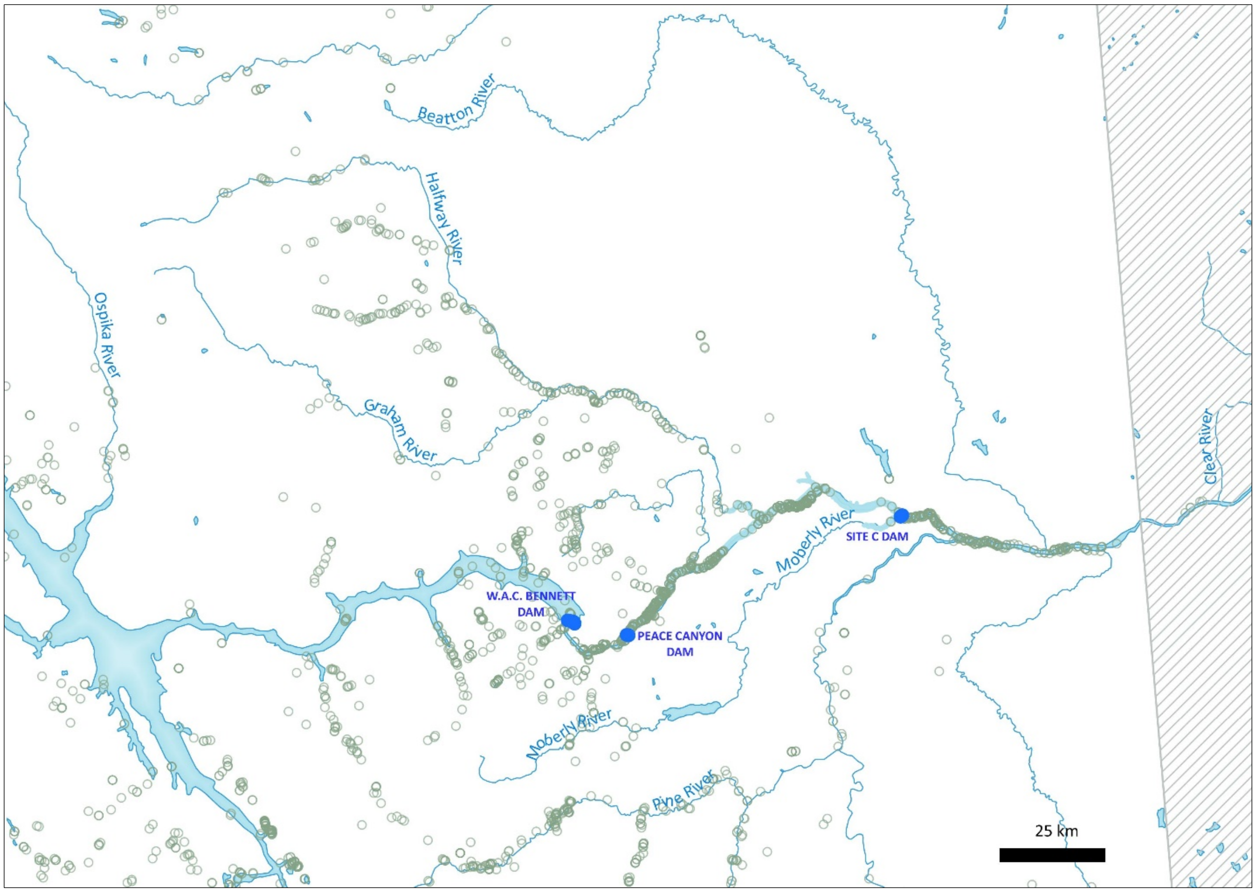

Figure 15: Rainbow Trout distribution in the Peace Region in BC and Alberta. Each green circle represents a confirmed observation in British Columbia and Alberta. Data source: 'Known BC Fish Observations and BC Fish Distributions' (British Columbia Data Catalogue).

Rationale for Monitoring

Rainbow Trout are an indicator species because they are (MOE 2011):

- A high value target for anglers;
- Relatively well-studied within the LAA and elsewhere;
- Representative of cool/coldwater fauna;
- Not tolerant of turbidity; and
- Are representative of Pacific and Beringia origins.

Within the LAA, Rainbow Trout are present in the Peace River and many of its tributaries (Figure 15) but are much less common downstream of the Project. With respect to passage sensitivity, Rainbow Trout "were considered by MFLNRO and MOE to have uncertainty as to their degree of sensitivity to fish passage technology alternatives, yet remained a high priority for assessment" (EIS, Appendix Q2, Section 2.1.2).

In the Site C Reservoir, Rainbow Trout are expected to be an important component of the fish community and angler catches (EIS, Vol 2, App P3). In Dinosaur Reservoir, Rainbow Trout were the second most common species in gillnet catches and were the most common species captured by anglers (Euchner 2011). Rainbow Trout are a generalist species and occupy a wide range of habitats but typically spawn in smaller streams. There are three potential sources of Rainbow Trout recruitment to the current Peace River and future Site C Reservoir: known juvenile rearing locations in Maurice, Lynx, and Farrell creeks, entrainment through Peace Canyon Dam, and tributaries of the Halfway River (MOE 1997, EIS App O Section 6.4.1.1, Golder 2019a).

Monitoring for Rainbow Trout is based on performance measures related to abundance, size structure, age structure, distribution, and population structure that are designed to meet management objectives at the species level (MOE 2011).

Sustainable use measures are stated in terms of the First Nations harvest (to be determined) and recreational fishery objective:

> *"Optimize recreational angling opportunities, participation and local benefits — this sub-objective reflects the higher-level MOE objective related to resource use. The sub-objective addresses three topics: angler effort, regional catch rates and local participation rates. The primary measures in support of the sub-objectives are fairly typical for use of the fisheries resource: angler days, catch per unit effort (CPUE), and number of fishing licences sold in the region. The proposed targets in support of the sub-objectives are derived from MOE fisheries management analyses described in Johnston et al. (2002a, 2002b)."*

In the LAA, Rainbow Trout are at the eastern edge of their native range[13], with the exception of the upper Athabasca system east of the Rocky Mountains (Alberta Athabasca Rainbow Trout Recovery Team 2014). Observations of Rainbow Trout and Bull Trout in the Peace Region (Figure 16) are consistent with the habitat segregation observed in southern BC, where Bull Trout reproduce in colder headwaters, and Rainbow Trout reproduce in warmer, lower elevation streams (Parkinson and Haas 1996). This segregation was observed in the Halfway Watershed (Golder 2017). As adults, both Bull Trout and Rainbow Trout can make extensive migrations in fluvial systems, but the inter-specific segregation is most pronounced in juvenile fish.

[13] https://www.canadiangeographic.ca/article/animal-facts-rainbow-trout

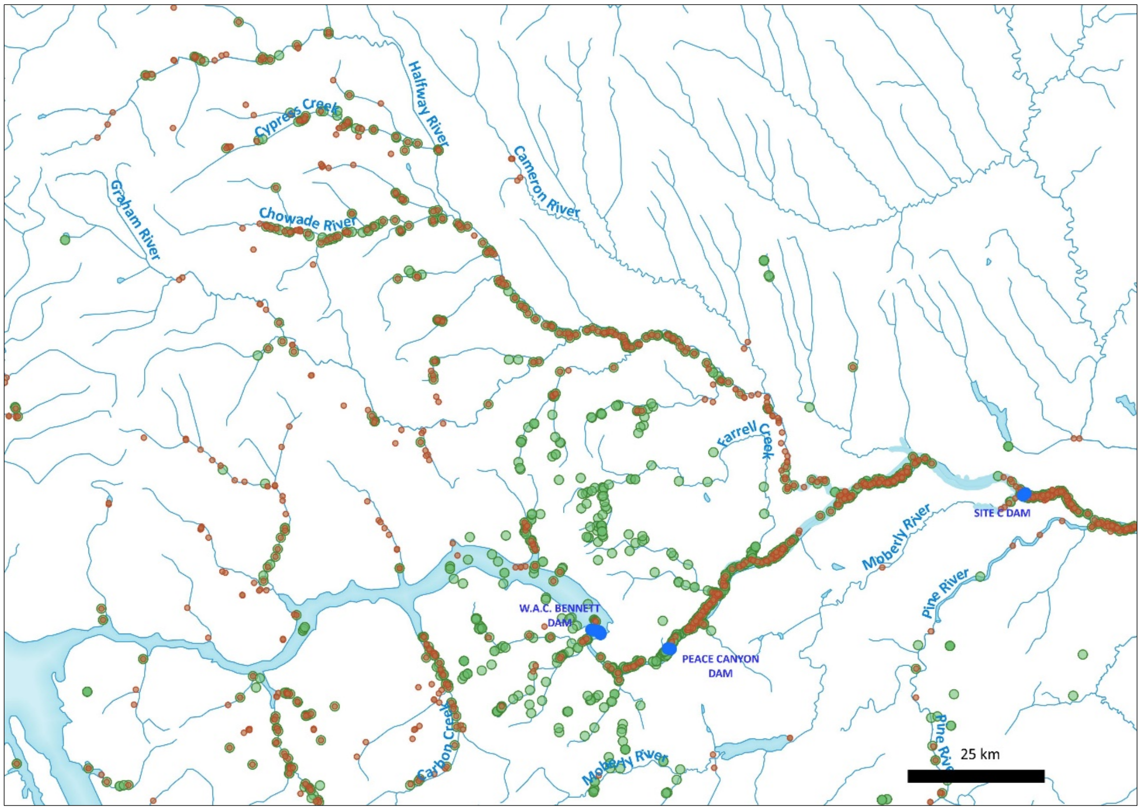

Figure 16: Observed occurrences of Rainbow Trout (green) and Bull Trout (brown) in the Peace River and adjacent drainages. In the Peace River, Bull Trout tend to occupy colder headwaters while Rainbow Trout tend to occupy warmer and lower elevation streams (e.g., Farrell Creek).

Key uncertainties for the Rainbow Trout population include the following:

1. The proportional contribution of each potential recruitment source;
2. Whether the food resources in the Site C Reservoir will sustain good growth and survival;
3. Whether Rainbow Trout will successfully colonize the Peace River downstream of the Project;
4. Whether Rainbow Trout can be effectively moved upstream from downstream of the Project; and
5. Whether overharvest will threaten the population.

Important Observations

Rainbow Trout are sampled in the Peace River through annual repetitive boat electroshocking surveys from Peace Canyon Dam to Many Islands, Alberta, and tributaries of the Peace River through backpack electrofishing.

The key indicators of the Rainbow Trout population are population abundance, age structure, and spatial distribution. These data are collected through annual repetitive boat electroshocking surveys in Sections 1, 3, 5, 6, 7, and 9 of the Peace River.

Rainbow Trout population abundance estimates for Sections 1, 3, 5, and 6 of the Peace River are presented in Figure 17 based on PIT tag data in 2016, 2017 and 2018 (Golder and Gazey 2018). However, the time series is short, and low catches of Rainbow Trout prevented the generation of estimates in Sections 7 and 9. Therefore, we also include the CPUE of Rainbow Trout through boat electroshocking in the Peace River from 2002 to 2019 (Figure 18) which shows abundance is lower further downstream of Peace Canyon Dam but does not demonstrate any year-to-year trend in data. During the operations phase of the Project, Rainbow Trout are expected to be present in Site C Reservoir. If sufficient recruitment occurs, population abundance should increase downstream of Section 5 as the coldwater fish community shifts downstream.

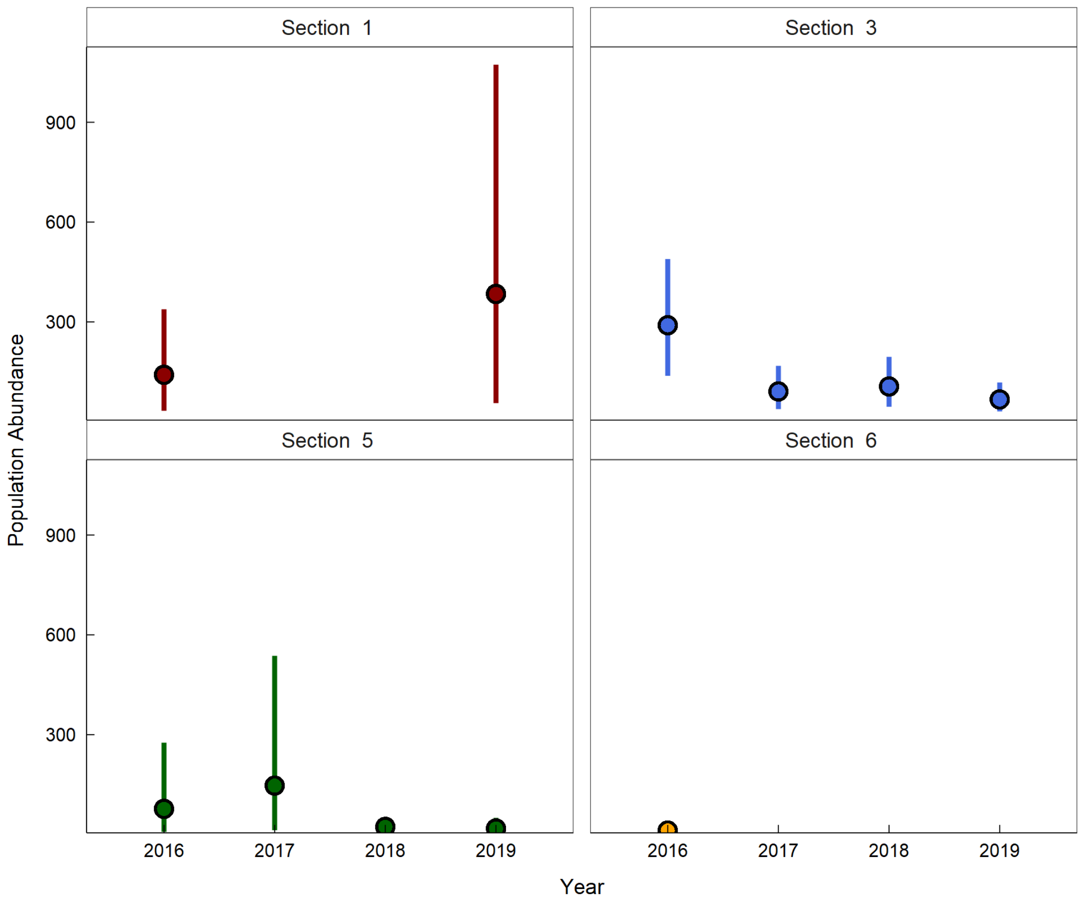

Figure 17: Population abundance estimates (with 95% credibility intervals) generated using the Bayes sequential model for Rainbow Trout captured by boat electroshocking in Sections 1, 3, 5 and 6 of the Peace River, 2016 to 2019. Low Rainbow Trout catch prevented the generation of abundance estimates in Sections 7 and 9.

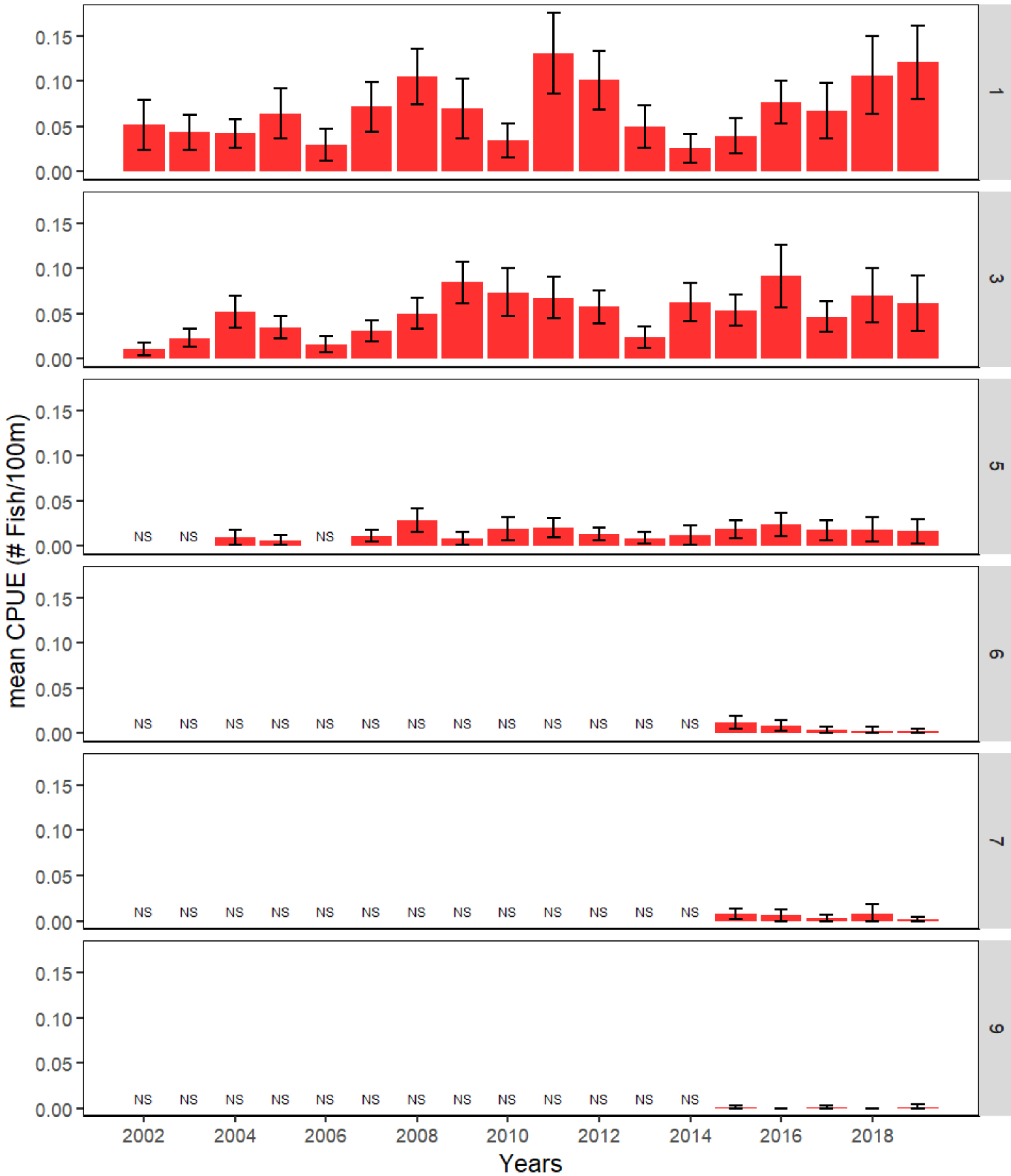

Figure 18: CPUE of Rainbow Trout captured by boat electroshocking in Sections 1, 3, 5, 6, 7 and 9 of the Peace River from 2002 to 2019. Error bars represent 1.96xSE. Analysis included captured fish only and all size cohorts. Data Source: Peace River Large Fish Indexing Survey Database. NS indicates a section not sampled in a given year.

Several of the key uncertainties for Rainbow Trout are related to future movement patterns in the Peace River and its tributaries. In 2019, as part of the Site C Fish Movement Assessment, Rainbow Trout were captured and radio-tagged in the Peace River (40 adults, 16 immature) and tributaries of the Halfway River (15 immature) to monitor their movements in the LAA (LGL 2020) (Figure 10). PIT tags were also applied to juvenile Rainbow Trout in Colt, Kobes and Farrell creeks (Golder 2019a). PIT tag recoveries in the Peace River will be used to link Rainbow Trout recaptured in the Peace River to recruitment sites in these tributaries.

Data Completeness and Quality

Data collected to monitor Rainbow Trout is considered complete and of high quality. Nineteen of the 19 observations (100%) for Rainbow Trout were collected as planned, which include two high importance observations, 13 medium importance observations and four low importance observations.

To date, the only uncertainty that has been actively monitored is the proportional contribution of recruitment sources through the Site C Reservoir Tributaries Fish Population Indexing Survey. Other uncertainties are related to conditions during operation of the Project.

Were Adjustments Made?

Adjustments to the Site C Reservoir Tributaries Fish Population Indexing Survey (Golder 2019a) were made to increase juvenile Rainbow Trout catch. In 2016, the Chowade and upper Halfway rivers and Cypress Creek were sampled. In 2017, to increase the number of Rainbow Trout encountered, new sampling locations were established in Kobes, Colt, and Farrell creeks (Golder 2019a) and sampled consistently through 2019. From 2017 onwards, sampling in the Chowade and upper Halfway rivers and Cypress Creek targeted juvenile Bull Trout in upper reaches, resulting in lower catch rates of Rainbow Trout.

Status Update

Monitoring to date is for baseline data, which continues to be collected. Baseline data collection will be sufficient to monitor changes in the Rainbow Trout population, and the findings from the monitoring data from the FAHMFP are consistent with the findings documented in the Site C EIS. The last five years of data confirm that there is a high level of variance in estimates of adult abundance from year-to-year. There do not appear to be any strong trends and therefore the causes of variation have not been explored at this point. Given logistical difficulties in direct assessment of spawner abundance, this method was not included in the FAHMFP. Trends in population abundance are inferred from a combination of adult catch rates in the Peace River Large Fish Indexing Survey and juvenile catch rates from the Site C Reservoir Tributaries Fish Population Indexing Survey. Radio telemetry, genetic and microchemistry data will continue to be collected over the coming years and used to link the two catch rate data sets into a single assessment of abundance.

BC Hydro
Power smart

Arctic Grayling

Life History

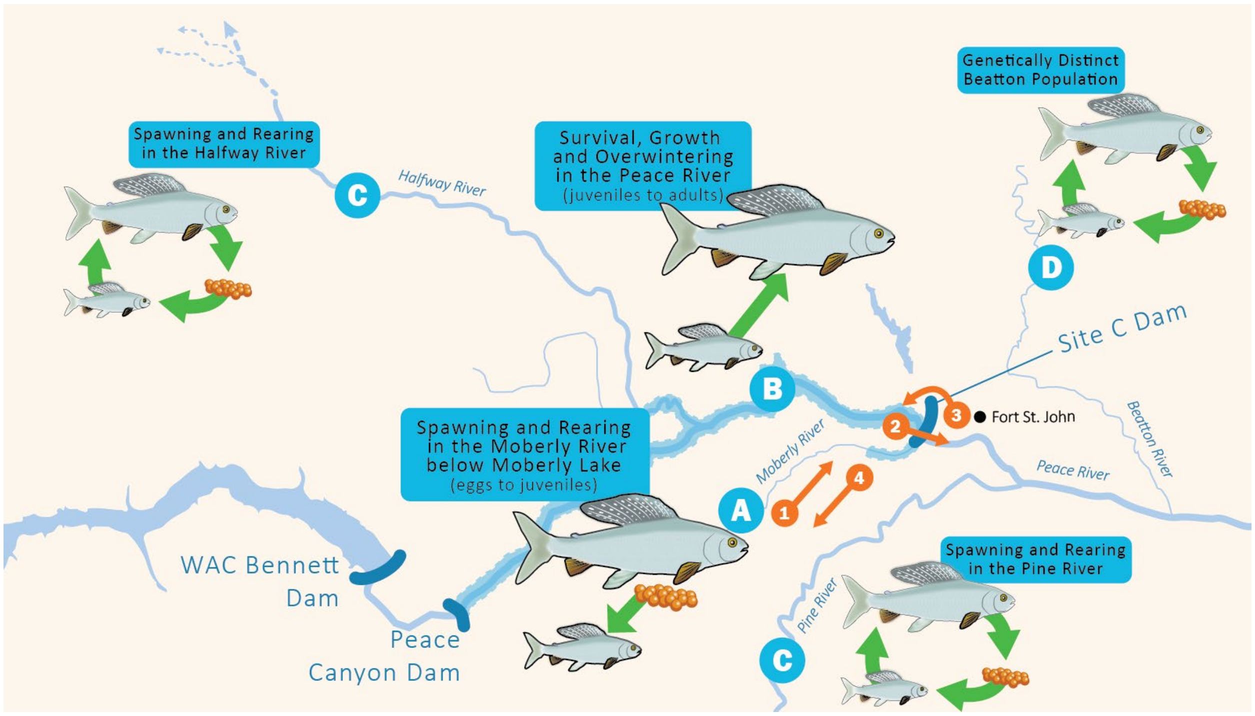

Figure 19: Life history of Arctic Grayling in the LAA. The Site C Reservoir is indicated by the semi-transparent blue polygon with dashed outline.

Arctic Grayling are common in the Peace River and major tributaries (Moberly, Halfway, Pine and Beatton rivers) but are absent from smaller tributaries and do not reproduce in the mainstem Peace River (see Figure 20) (Mainstream Aquatics Ltd. 2012). Approximately 95% of Arctic Grayling captured in the Peace River spawn in the Moberly River downstream of Moberly Lake (**Location A**) and migrate to the Peace River (**Location B**) as age-0 and age-1 juveniles (**Arrow 1**) (Taylor and Yau 2012; Earth Tone and Mainstream 2013). In the Peace River, both adults and juveniles make irregular upstream and downstream movements, including movements past the Project (**Arrow 2 and 3**) (EIS, Vol. 2, App Q3). Mature adults migrate into the Moberly River in early spring (**Arrow 4**) and migrate back downstream (**Arrow 1**) to feed and overwinter in the Peace River (**Location B**).

Arctic Grayling in the LAA cluster into three genetically distinguishable groups: Peace-Moberly, Pine-Halfway (**Location C**) and Beatton (**Location D**) based on previous genetic analyses (Taylor and Yau 2012). Genetic analyses under the FAHMFP provide the ability to distinguish Halfway River Arctic Grayling from those in the Pine River (Geraldes and Taylor, In Prep).. Spawning, feeding and overwintering migrations are common within each watershed, but the amount of movement between the Peace, Halfway and Pine rivers is uncertain (EIS, Vol. 2, App Q3). Beatton River Arctic Grayling appear to remain in the Beatton River as a genetically distinct, resident population.

It is unclear how Arctic Grayling movement patterns will be affected by the Project:

- Will Arctic Grayling use the fish passage facilities at the Project?; and

- Will Arctic Grayling use the Site C Reservoir as a movement corridor between spawning and adult habitats (studies suggest that reservoir habitats are unsuitable for Arctic Grayling)?

If the answer to the questions above is "yes," Arctic Grayling life history is expected to continue as depicted in Figure 19 (Beaudrie et al. 2017).

If the answer to the questions above is "no," then juveniles and adults may persist within the Moberly River, but will depend on the ability of Arctic Grayling to grow and survive in the Moberly River and completely fulfill all of this species' life cycle requirements. Persistence in the Peace River downstream of the Project will depend on the extent to which recruitment from the Pine River, the mainstem Peace River, and the Beatton River can replace recruitment from the Moberly River (Beaudrie et al. 2017).

Adult Arctic Grayling abundance is expected to be lower under all operational scenarios because of the conversion of large river habitat to reservoir habitat (Beaudrie et al. 2017).

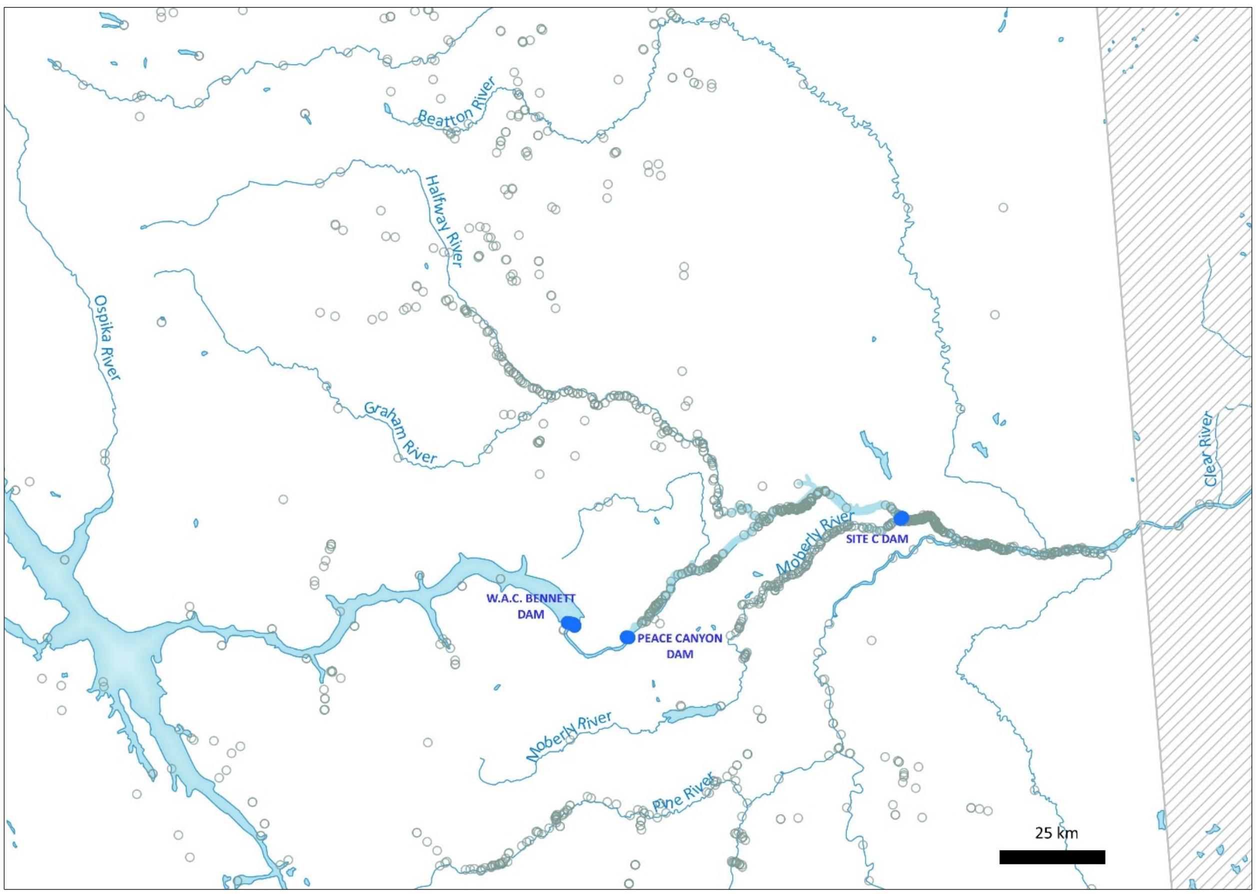

Figure 20: Arctic Grayling distribution in the Peace Region in BC and Alberta. Each grey circle represents a confirmed observation in British Columbia and Alberta. Data source: 'Known BC Fish Observations and BC Fish Distributions' (British Columbia Data Catalogue).

Rationale for Monitoring

Arctic Grayling are an indicator species because they are (MOE 2011):

- A high value target for anglers; sensitive to harvest pressure;
- Relatively well-studied within the LAA and elsewhere;
- Representative of cool/coldwater fauna;
- Very sensitive to habitat degradation; and
- Representative of Beringia origin.

The FAHMFP monitoring tasks for Arctic Grayling are based on performance measures related to abundance, size structure, age structure, distribution, and population structure that are designed to meet management objectives at the species level (MOE 2011).

Key uncertainties include:

1. Whether Arctic Grayling will continue to move into Site C Reservoir and downstream past the Project;
2. Whether some juvenile Arctic Grayling will remain in the Moberly River and survive to adulthood;
3. Whether recruitment from other sources can replace the expected decline in recruitment from the Moberly River to the Peace River downstream of Site C; and
4. The effect of habitat changes in the Peace River below the Project on Arctic Grayling survival.

Important Observations

Arctic Grayling are sampled in the Peace River through annual repetitive boat electroshocking surveys from Peace Canyon Dam to Many Islands, Alberta, and in the Moberly and Beatton rivers through backpack electrofishing and other methods.

The key indicator of the Arctic Grayling population is adult abundance in the Peace River. These data are collected through annual repetitive boat electroshocking surveys, conducted in Sections 1, 3, 5, 6, 7, and 9 of the Peace River. Population estimates of adult abundance are estimated through a Bayes sequential model where sufficient mark-recapture data are collected. The population estimates are only generated for Sections 3 and 5 in some years and have relatively high error (Figure 21) (Golder and Gazey 2018). Relative changes in abundance can be inferred using CPUE (Figure 22). Overall, the data suggest that Arctic Grayling have declined in abundance over the last decade, particularly in Sections 3 and 5, though no formal statistical trend analysis was performed. Arctic Grayling are more abundant in Sections 3 and 5 (Figure 22).

In 2019, as part of the Site C Fish Movement Assessment, Arctic Grayling were captured and radio-tagged in the Peace River (32 adults, 6 immature) to monitor their movements in the LAA (LGL 2020) (Figure 10). Such information will add to the current understanding of the life history and movement patterns of Arctic Grayling in the Peace Region.

Population structure was assessed using genetic analyses. Preliminary genetic analyses provide further resolution to previous analyses (Taylor and Yau 2012), where there are four genetically distinguishable groups of Arctic Grayling: Halfway River, Moberly River, Pine River and Beatton River (Geraldes and Taylor, In Prep).

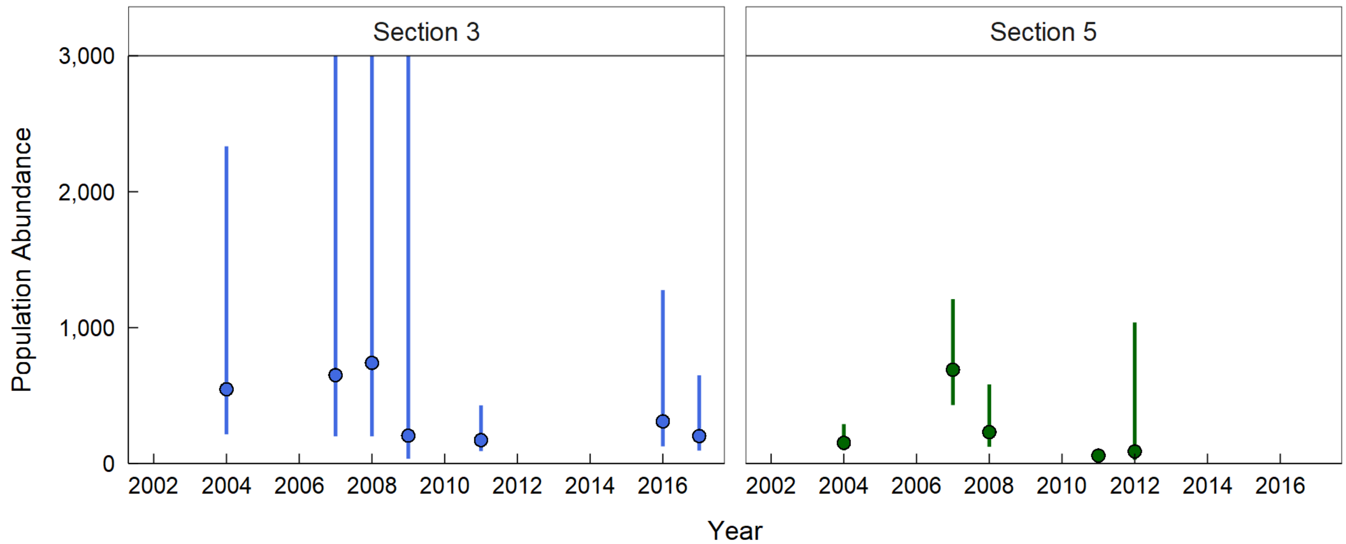

Figure 21: Population abundance estimates (with 95% credibility intervals) generated using the Bayes sequential model for Arctic Grayling captured by boat electroshocking in sections 3 and 5 of the Peace River, 2002 to 2019. Insufficient recaptures prevented the generation of population abundance estimates for Sections 1, 6, 7, and 9. Data are from Golder and Gazey (2018).

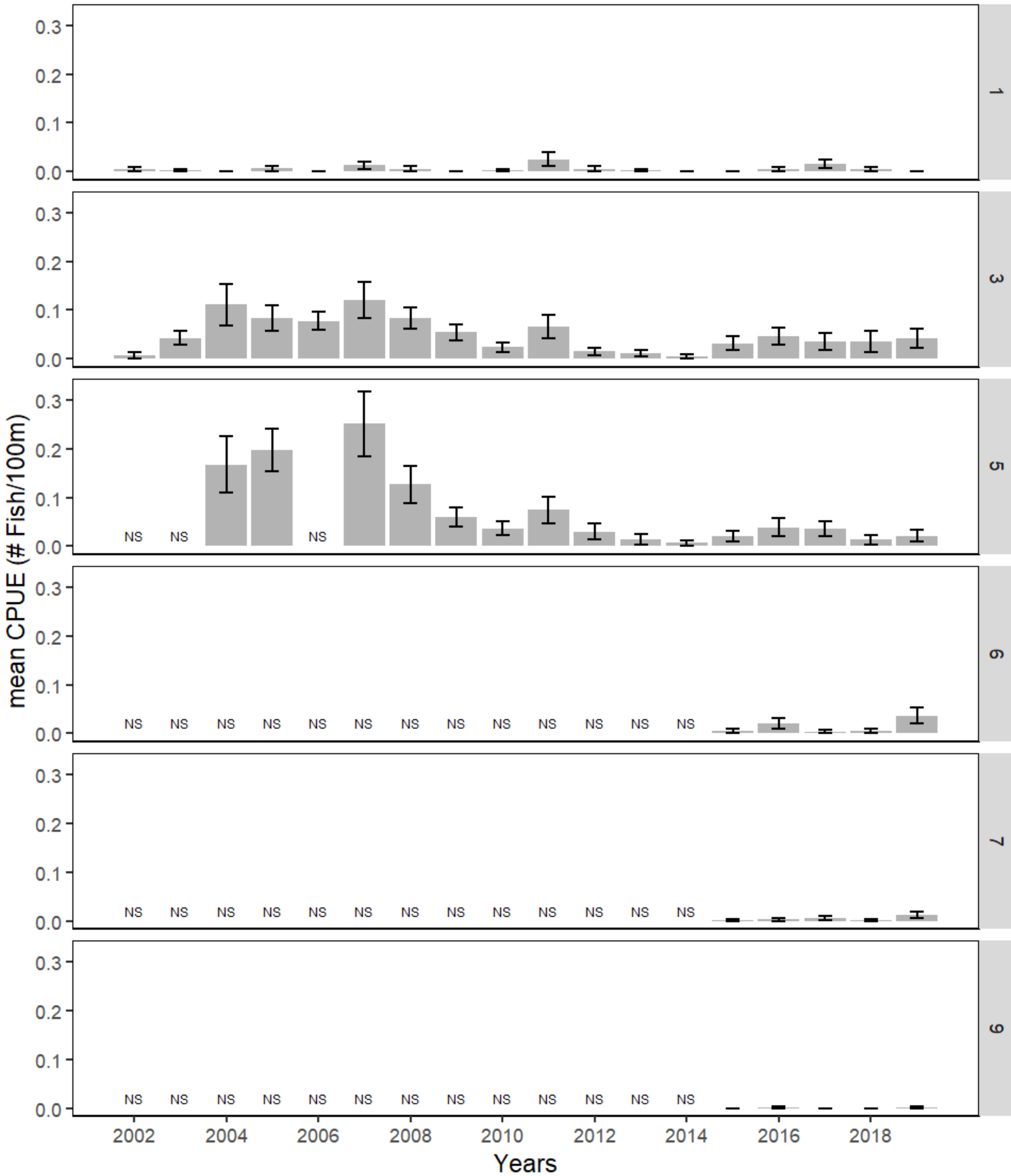

Figure 22: CPUE of Arctic Grayling captured by boat electroshocking in Sections 1, 3, 5, 6, 7 and 9 of the Peace River from 2002 to 2019. Error bars represent 1.96xSE. Analysis included captured fish only and all size cohorts. Data Source: Peace River Large Fish Indexing Survey Database.

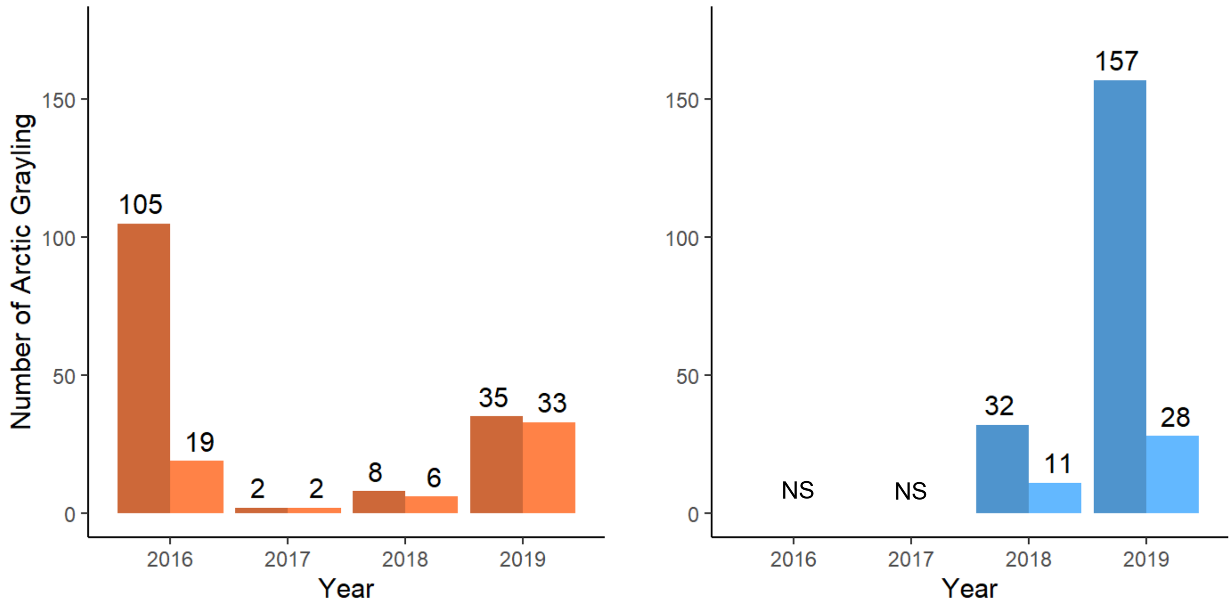

Figure 23: Number of Arctic Grayling captured and PIT-tagged in the Moberly River (left panel; dark brown – captured, light brown – tagged) and Beatton River (right panel; blue – Captured, light blue – tagged) from 2016 to 2019. Data from Golder (2019a, b).

Data Completeness and Quality

Data collected to monitor Arctic Grayling is considered complete. Twenty-five of the 25 observations (100%) for Arctic Grayling were collected as planned, which include one high importance observation, 14 medium importance observations and 10 low importance observations.

Data quality was as expected for monitoring abundance in the Peace River and refining the understanding of the population structure in tributaries. The quality of the data was lower than expected for measures of abundance in tributaries (14 of 25 observations) because of low catch rates during most study years (Figure 23). The assessment of trends in abundance is more complex when catch rates are low. Increased sampling effort and changes in the timing of sampling have resulted in increased encounter and tagging rates of Arctic Grayling in tributaries in recent years (Figure 23).

Were Adjustments Made?

Catch rates were low in the Moberly River in 2016 (Golder 2017). In 2017, sample locations were accessed by inflatable boat, and crews camped by the side of the river, which reduced daily travel time, allowing for increased effort (Golder 2018). In each subsequent year, sampling was conducted earlier than the year prior to increase the likelihood of capturing fish before they migrated downstream (Golder 2019a).

The Beatton River Arctic Grayling Status Assessment provides information on Arctic Grayling that are not expected to be affected by the Project. Sampling in 2019 occurred earlier in the year to sample at higher water levels and to increase the likelihood of encountering Arctic Grayling before they migrated downstream (Golder 2019b). Closed-site electrofishing was proposed in the FAHMFP; however, open-site electrofishing was employed to allow for comparison with data from other watersheds (Halfway and Moberly rivers) and to increase sampling effort (i.e., less time installing and removing block nets).

Status Update

Monitoring to date is for baseline data, which continues to be collected. Baseline data collection will be sufficient to monitor changes in the Arctic Grayling population, and the findings from the monitoring data from the FAHMFP are consistent with the findings documented in the Site C EIS. There is some evidence that Arctic Grayling abundance may be declining during baseline conditions based on a general decline in CPUE. This may make it difficult to isolate the effects of the Project on this species in the future. However, the decline in Arctic Grayling is not surprising because the species exhibits an unusual vulnerability to overharvest and is sensitive to a wide variety of environmental impacts, including hydropower development, which in combination have led to widespread declines across their range (Northcote 1995).

Goldeye

Life History

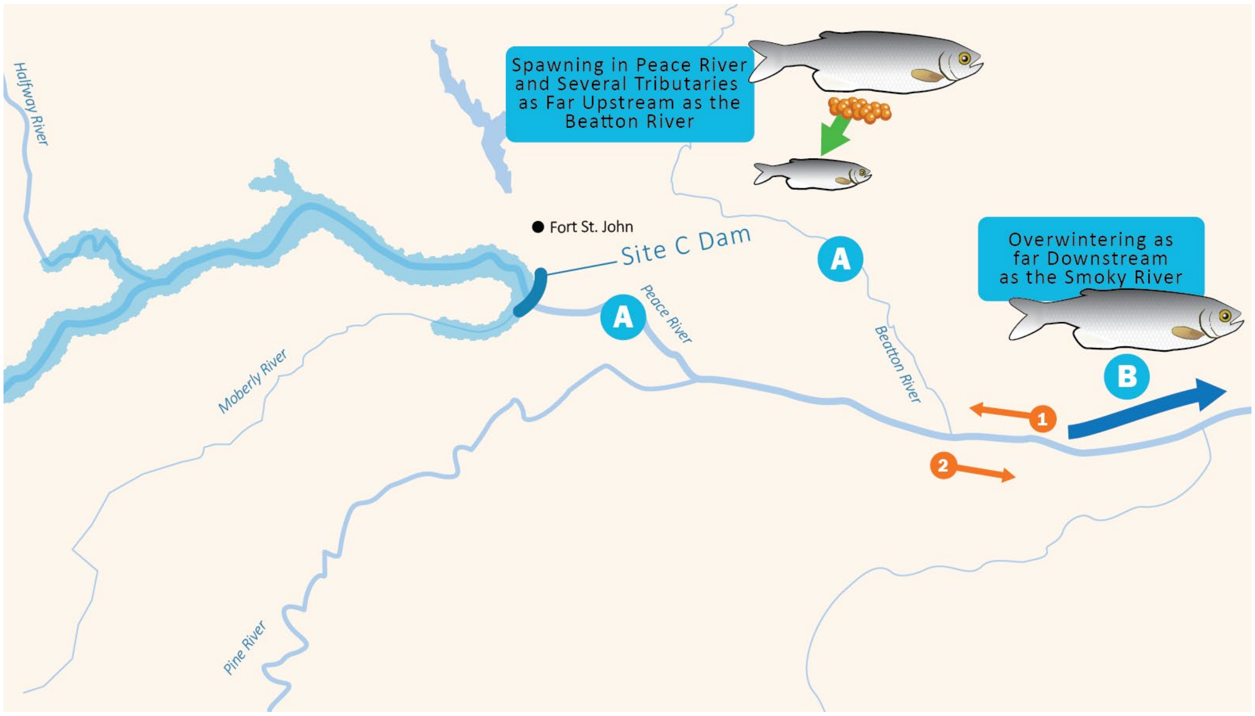

Figure 24: Life history of Goldeye in the LAA. The Site C Reservoir is indicated by the semi-transparent blue polygon with dashed outline.

Goldeye are generally found in warm, turbid, and slow-moving waters of large rivers, quiet shallow lakes, ponds, marshes and muddy shallows of large lakes. Goldeye can exhibit riverine and adfluvial life history types (McPhail 2007).

In the LAA, Goldeye are at the western edge of their range and are found exclusively downstream of the Project in the Peace River (Figure 25). Goldeye use the Peace River as a movement corridor, migrating approximately 500 km from downstream of the Smoky River (near the town of Peace River, Alberta) to as far upstream as the Pine River, and possibly even the Moberly River (**Location A**, **Arrow 1**) (Mainstream Aquatics Ltd. 2012; Figure 25).

Goldeye are listed as "blue" (special concern) in BC by the Conservation Data Centre[14] and are classified as "secure" in Alberta (Mainstream Aquatics Ltd. 2012).

Goldeye reach maturity at age-6 to 7 (McPhail 2007). Mature Goldeye spawn between May and July in pools and backwaters of large turbid rivers and lakes (McPhail 2007). Spawning occurs in the Peace River and several of its tributaries between the BC / AB border and the Town of Peace River (Glacier Power 2006) and is thought to also occur in the Beatton River, based on the capture of a single age-0 Goldeye captured directly downstream of the Beatton River (Mainstream Aquatics Ltd. 2011). Goldeye eggs are semi-buoyant (Battle and Sprules 1960) and would be

[14] Available at: https://www2.gov.bc.ca/gov/content/environment/plants-animals-ecosystems/conservation-data-centre

expected to float downstream before hatching (McPhail 2007). Downstream migration (**Arrow 2**) to overwintering habitat occurs between August and October (Mainstream Aquatics Ltd. 2012).

After reservoir filling, Goldeye are expected to decline in abundance immediately downstream of the Project due to the altered flow regime (cooler summer temperatures and reduced sediment load) (Mainstream Aquatics Ltd. 2012). Goldeye are not expected to establish in the Site C Reservoir. Any Goldeye captured in the temporary and permanent upstream fish passage facilities will be released downstream in the Peace River.

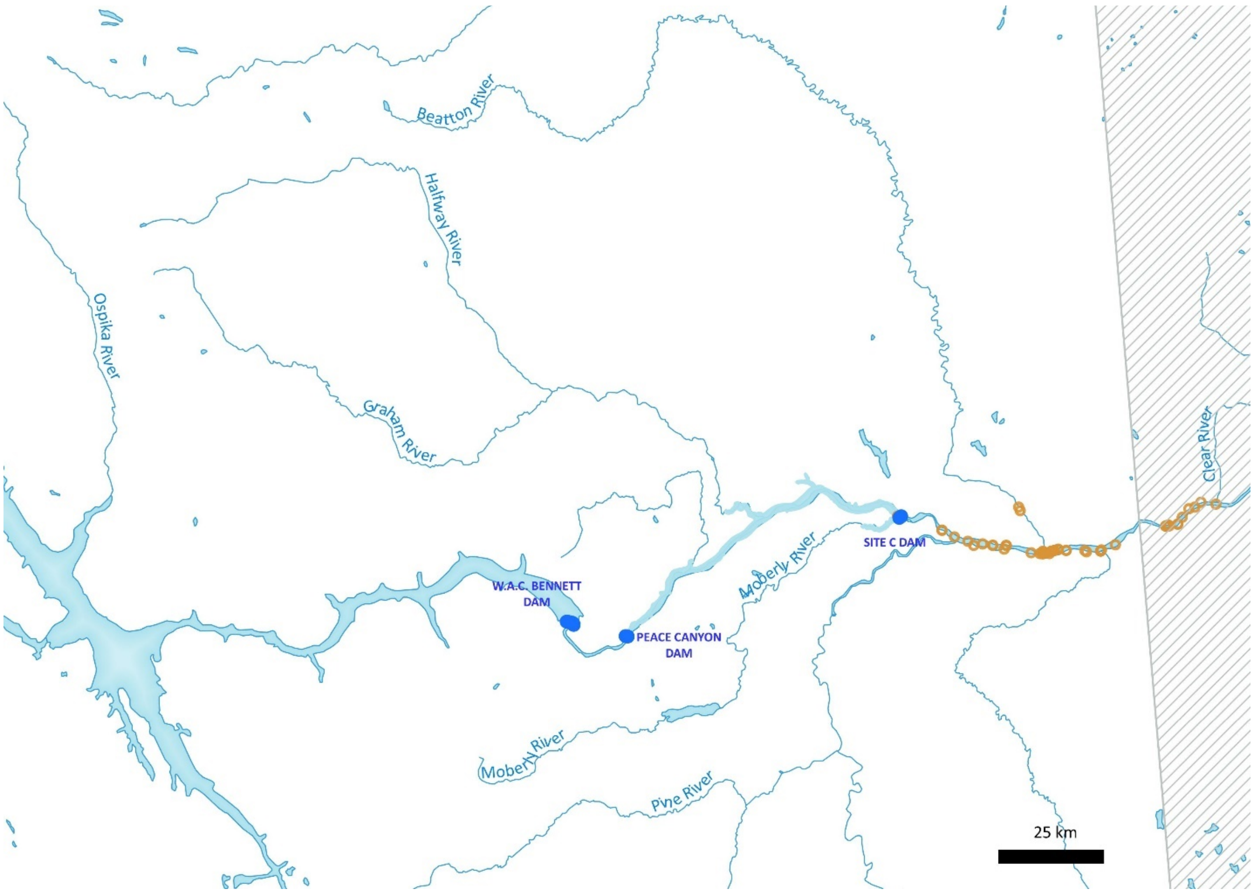

Figure 25: Goldeye distribution in the Peace Region in BC and Alberta. Each orange circle represents a confirmed observation in British Columbia and Alberta. Data source: 'Known BC Fish Observations and BC Fish Distributions' (British Columbia Data Catalogue).

Rationale for Monitoring

Goldeye are an indicator species because they are (MOE 2011):

- Goldeye are not well studied within the LAA and elsewhere;
- Representative of coolwater fauna, tolerant of turbidity, and highly migratory; and
- Representative of Great Plains origin.

With respect to the Project, the most important characteristic of Peace River Goldeye is their migratory behavior, which is described in the following summaries from the Site C EIS (Section 12):

> *"Radio-tagged Goldeye moved long distances and the total range of movement encompassed approximately 700 km of river from Vermillion Chutes to the Pine River confluence in British Columbia. Although the majority of Goldeye were highly migratory, not all fish moved past the Dunvegan site during annual migrations. A portion of the sample population remained downstream (of Dunvegan). Peak upstream migrations were most likely to occur between May and July. Downstream (migrations) were most likely to occur between August and October when fish returned to wintering habitats.*
>
> *Radio-tagged Goldeye frequented confluence areas of several tributaries, generally were not recorded moving upstream into the tributary. Exceptions include upstream migrations by Goldeye into the Smoky River near the Town of Peace River, Alberta, as well as the Clear River and Beatton River near the B.C./Alberta boundary. The presence of Goldeye in (Peace River) tributaries during the spawning period suggested that tributaries may be used for spawning by Goldeye."*

The life history of Peace River Goldeye will not be directly affected by the physical presence of the Project and the Site C Reservoir as their current distribution is restricted to the Peace River downstream of the Pine River (EIS, Vol. 2, App O).

The Site C EIS predicts changes to Goldeye abundance downstream of the Project. Goldeye abundance is expected to decrease because:

> "Spawning migration is cued by temperature. Lower temperatures, less turbid water, and flow fluctuations will make conditions less preferable for Goldeye."

Monitoring programs under the FAHMFP provide some ability to distinguish between changes in Goldeye abundance caused by factors within the LAA versus factors outside of the LAA.

The life history of Goldeye implies that if the population does decline, key uncertainties include the following:

1. Whether changes in conditions inside the LAA will result in changes in Goldeye survival and migration into the LAA;
2. Whether changes in conditions outside the LAA downstream in Alberta will result in changes in Goldeye survival and migration into the LAA; and
3. Whether Goldeye spawn in the LAA.

Important Observations

Goldeye are sampled in the Peace River through annual repetitive boat electroshocking surveys from Peace Canyon Dam to Many Islands, Alberta.

The key indicators for the Goldeye population are adult abundance and distribution. Catch rates to date have been low and fish have only been present in Sections 6, 7 and 9 (Figure 26; Golder and Gazey 2018). Population estimates using mark-recapture cannot be calculated given the low number of recaptured fish. Monitoring trends in abundance are more challenging when CPUE is low. Limited data collected to date suggest that Goldeye remain in the lower reaches of the LAA.

Population structure and species distribution are measured using fin ray microchemistry data. Fin ray microchemistry data from 2016 to 2018 suggest that Goldeye captured by boat electroshocking (n = 13) in the Peace River originated from and spent their first summer in the Smoky River in Alberta (Figure 27), providing evidence that most Goldeye captured by boat electroshocking in the BC portion of the Peace River likely spawned and reared in Alberta outside of the LAA (TrichAnalytics 2020). Goldeye are suspected seasonal residents in the BC portion of the Peace River, migrating upstream into the LAA in the spring to feed and potentially spawn (Figure 27). The Peace River Large Fish Indexing Survey encounters Goldeye from August to October during their downstream migrations to more turbid areas outside of the LAA. The information from fin ray microchemistry is consistent with the previous understanding from other data sources.

One key uncertainty is related to how the changes in conditions in the LAA will affect Goldeye adult abundance and distribution. With low catch rates, it will be difficult for the FAHMFP to detect changes in adult abundance statistically. BC Hydro may only be able to evaluate whether Goldeye distributions in the LAA are being maintained or the distribution is changing through monitoring the occurrence of Goldeye in boat electroshocking catches.

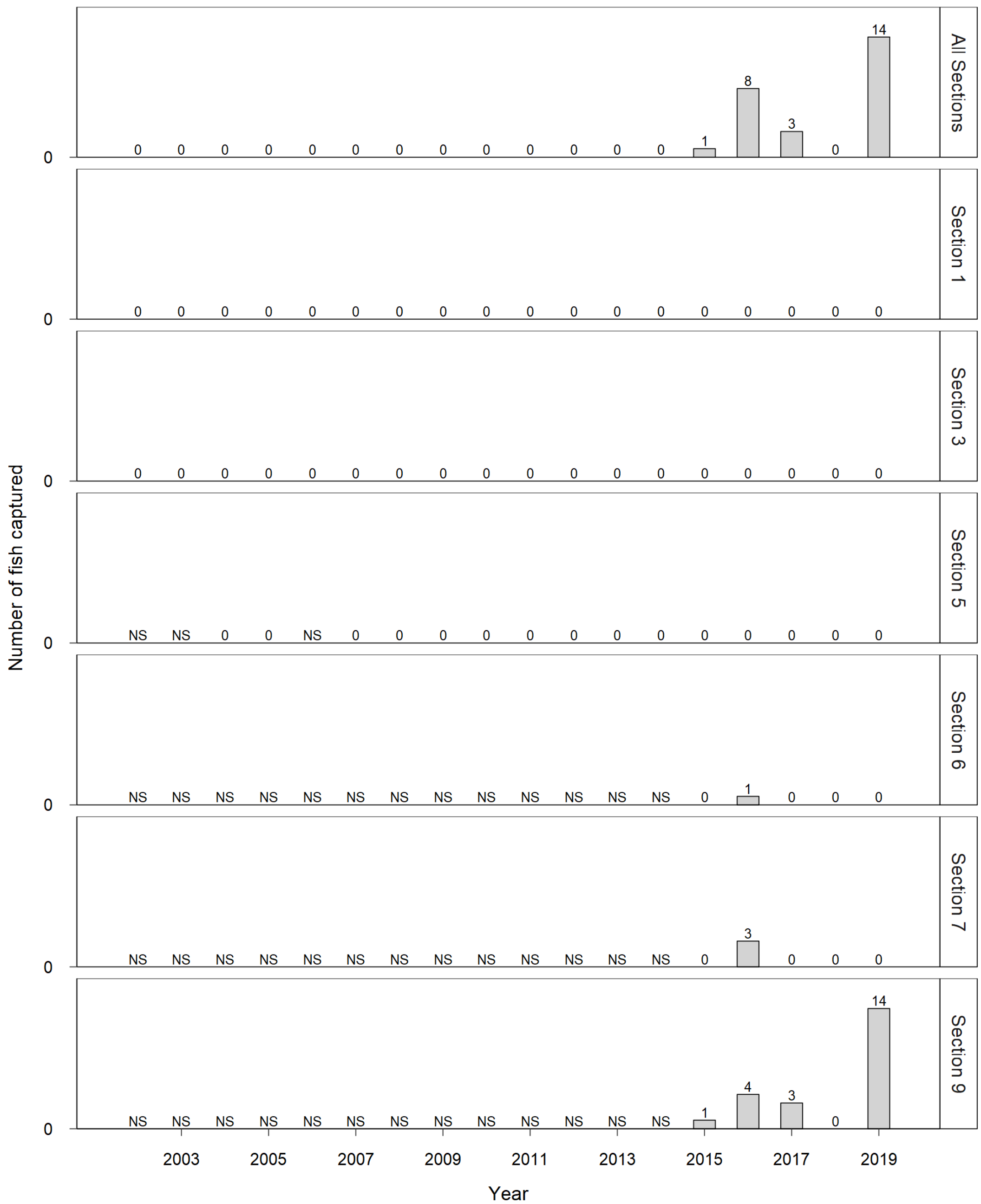

Figure 26: Number of Goldeye captured by boat electroshocking in Sections 1, 3, 5, 6, 7 and 9 of the Peace River from 2002 to 2019. Sample sizes are listed above each bar. NS denotes years in which no surveys occurred.

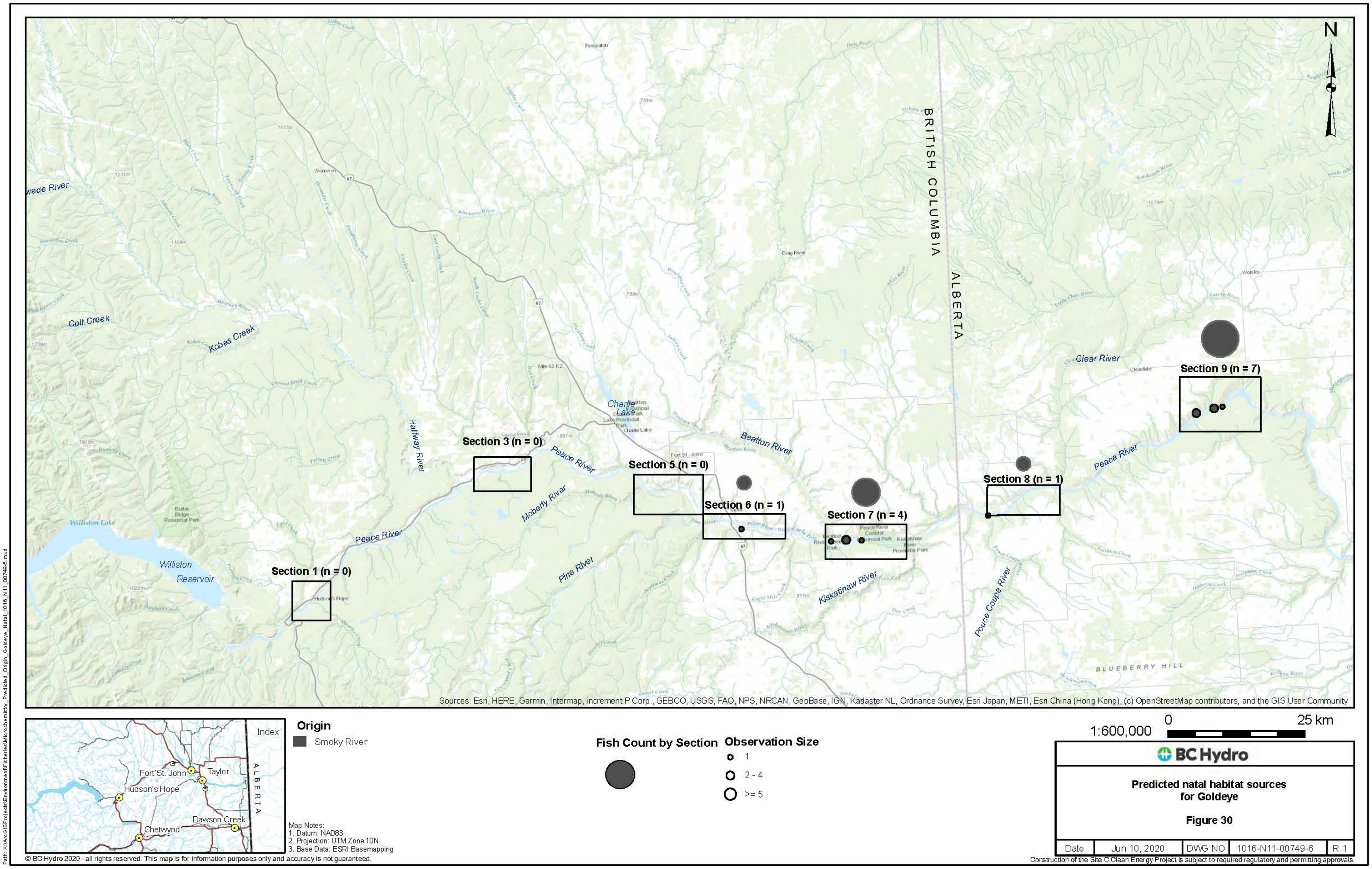

Figure 27: Predicted natal origin of Goldeye captured in the Peace River based on fin ray microchemistry (TrichAnalytics 2020).

Data Completeness and Quality

Data collected to monitor Goldeye is considered complete and of high quality. Seven of the 7 observations (100%) for Goldeye were collected as planned, which include one high importance observation, five medium importance observations and one low importance observation.

Similar to predictions in the Site C EIS (EIS, App P3), Goldeye were only encountered downstream of the Pine River and catch rates were low. Microchemistry data collected during the FAHMFP were consistent with baseline studies (Earth Tone and Mainstream 2013), which show that most captured Goldeye likely spawned and reared in Alberta outside of the LAA (TrichAnalytics 2020).

Were Adjustments Made?

Catches of Goldeye during the Peace River Large Fish Indexing Survey in August and September of each year are consistently low. To increase catch rates, BC Hydro conducted dedicated boat electroshocking surveys from mid-May to late June in 2018 and 2019 near the confluences of major tributaries (Beatton, Alces, Kiskatinaw, Pouce Coupe and Clear rivers and Mile Six and Mile Eight creeks) downstream of the Project. Spring surveys were successful in capturing additional Goldeye, however catch rates were low in both years (n = 2 in 2018, n = 5 in 2019).

Status Update

Monitoring to date is for baseline data, which continues to be collected. Baseline data collection will be sufficient to monitor changes in the Goldeye population, and the findings from the monitoring data from the FAHMFP are consistent with the findings documented in the Site C EIS. The increased baseline sampling in the Peace River Large Fish Indexing Program in Sections 6, 7, and 9 produced data that are consistent with the previous understanding that Goldeye are more abundant in the downstream reaches of the LAA. Data are consistent with the current understanding that the LAA represents the western edge of the Goldeye range. Future analyses on Goldeye will likely need to be based on an occupancy (i.e., presence/absence) framework, as the total number of Goldeye captured are expected to remain low.

Walleye

Life History

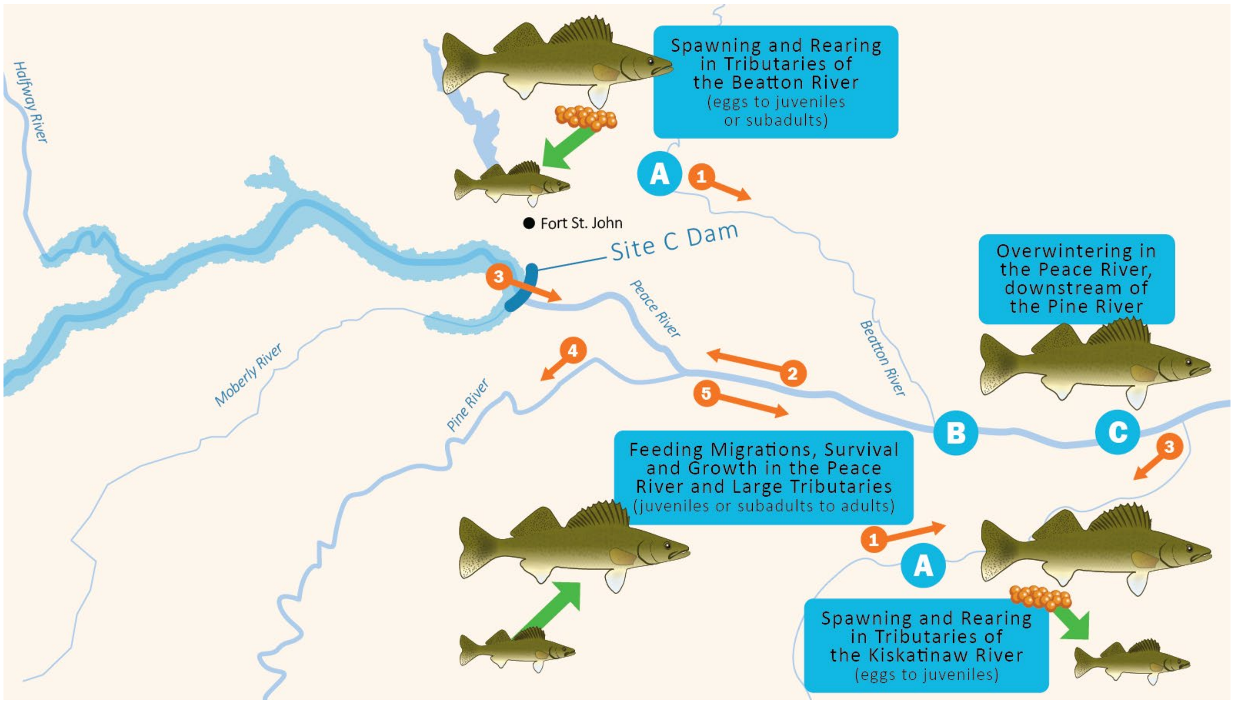

Figure 28: Life history of Walleye in the LAA. The Site C Reservoir is indicated by the semi-transparent blue polygon with dashed outline.

Walleye in the LAA are at the western edge of their range (see Figure 29) and do not appear to reproduce upstream of the confluence of the Peace and Pine rivers (McPhail 2007; Mainstream Aquatics Ltd. 2012). Adults in the LAA spawn in the spring in tributary streams, mainly in the Beatton River, but including various other downstream tributaries (e.g., Kiskatinaw River) (**Location A**). Most adults appear to move back to the Peace River following spawning (EIS Volume 2, App P3). Juvenile Walleye can rear in tributaries or migrate downstream to the Peace River (**Arrow 1**) (Mainstream Aquatics Ltd. 2012). Juveniles are rarely found in the Peace River upstream of the Beatton River (Mainstream Aquatics Ltd. 2012).

During the summer, subabult and adult Walleye typically move upstream on a feeding migration before migrating back downstream to overwinter (Mainstream Aquatics Ltd. 2012). Feeding migrations (**Location B**) are mainly within the Peace River (**Arrow 2**) and include movement past the Project (**Arrow 3**) and into larger tributaries including the Pine River (**Arrow 4**) (BC Hydro 2013). In the fall, Walleye move back downstream (**Arrow 5**). Overwintering takes place in the Peace River downstream of the Pine River (**Arrow 5, Location C**) (Mainstream Aquatics Ltd. 2012).

After reservoir filling, Walleye are expected to decline in abundance immediately downstream of the Project due to the altered flow regime (cooler summer temperatures and reduced sediment load) (Mainstream Aquatics Ltd. 2012). If Walleye attempt to move upstream past the Project through the temporary and permanent upstream fish passage facilities, all individuals are planned to be released in the Peace River downstream of the Project. The establishment of a Walleye population upstream of the Project (i.e., in the Site C Reservoir) is thought to be unlikely because all adults appear to move downstream of the Project each fall and would not have upstream migratory access after river diversion in the fall of 2020 (BC Hydro 2013).

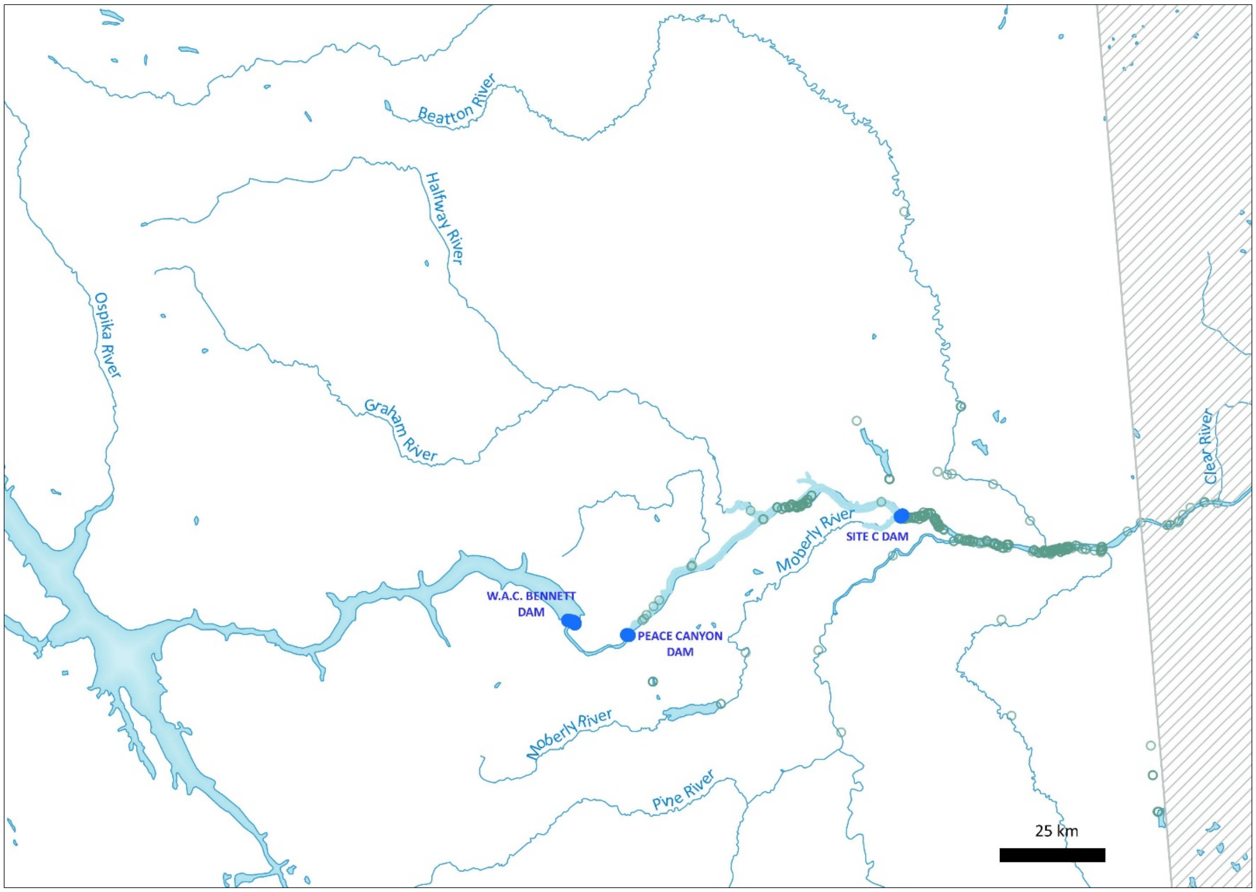

Figure 29: Walleye distribution in the Peace Region in BC and Alberta. Each green circle represents a confirmed observation in British Columbia and Alberta. Data source: 'Known BC Fish Observations and BC Fish Distributions' (British Columbia Data Catalogue).

Rationale for Monitoring

Walleye are an indicator species because they are (MOE 2011):

- A high value target for anglers;
- Well studied within the LAA and elsewhere;
- Representative of warm/coolwater fauna, tolerant of turbidity, and are highly migratory; and
- Representative of Great Plains origin.

The FAHMFP monitoring tasks for Walleye are based on performance measures related to abundance, size structure, age structure, distribution, and population structure that are designed to meet management objectives at the species level (MOE 2011).

Walleye are common in turbid lakes, reservoirs, and large rivers (McMahon et al. 2984). Adult Walleye generally feed on small fish but they are known to ingest other organisms such as amphipods, crayfish, insects, and worms (Little et al. 1998). Cannibalism is common in Walleye populations and has been known to affect population structure. Walleye avoid high light intensity (e.g., daylight) when possible by remaining in dark, turbid or deep waters, generally feeding in shallow water at dawn and dusk (Lester et al. 2004, Barton 2011).

A key uncertainty relating to Walleye will be their response to the changes in physical conditions downstream of the Project. For example, whether the upstream feeding migration will change in response to changes in water temperature or turbidity.

Important Observations

Walleye are sampled in the Peace River through annual repetitive boat electroshocking surveys from Peace Canyon Dam to Many Islands, Alberta.

The key indicators for the Walleye population are catch rate and life history. These data are collected under the Peace River Large Fish Indexing Survey. Surveys consist of annual repetitive boat electroshocking, as well as some targeted boat electroshocking surveys during the spring. Walleye were captured predominantly downstream of the Pine River in Sections 6, 7, and 9 (Figure 30), which were not sampled consistently prior to 2015 (Golder and Gazey 2018). Data collected to date demonstrate that Walleye are found in higher numbers in the downstream sections of the LAA, but that they can be found upstream (as far as Section 1) during what is understood to be ‘summer’ feeding migrations.

In 2019, as part of the Site C Fish Movement Assessment, Walleye were captured and radio-tagged in the Peace River (63 adults, 1 immature) to monitor their movements in the LAA (LGL 2020) (Figure 10). Such information will add to the current understanding of the life history and movement patterns of Walleye in the Peace Region.

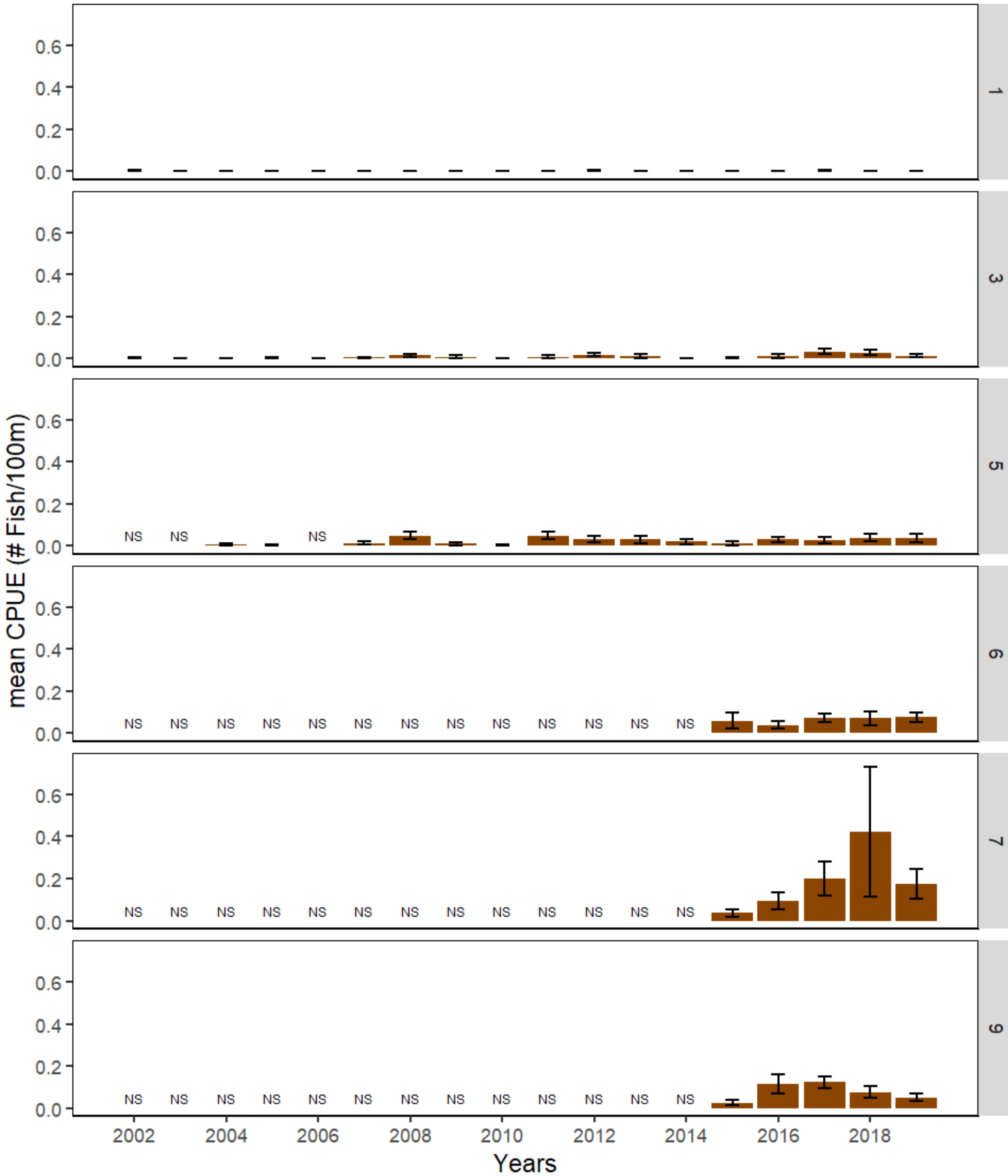

Figure 30: CPUE of Walleye captured by boat electroshocking in Sections 1, 3, 5, 6, 7 and 9 of the Peace River from 2002 to 2019. Error bars represent 1.96xSE. Analysis included captured fish only and all size cohorts. Data Source: Peace River Large Fish Indexing Survey Database.

Data Completeness and Quality

Data collected to monitor Walleye is considered complete and of high quality. Nine of the 9 observations (100%) for Walleye were collected as planned, which include two high importance observations, six medium importance observations and one low importance observation.

Were Adjustments Made?

Boat electroshocking surveys for Walleye and Goldeye during the spring for Walleye were implemented in 2018 and 2019, with the aim of increasing catch rates. While additional Walleye can be captured during these spring surveys, the surveys were implemented to increase catch rates of Goldeye. Walleye catch rates during the Peace River Large Fish Indexing Survey (during September and October) have met the targets listed in the FAHMFP.

Status Update

Monitoring to date is for baseline data, which continues to be collected. Baseline data collection will be sufficient to monitor changes in the Walleye population, and the findings from the monitoring data from the FAHMFP are consistent with the findings documented in the Site C EIS.

Sampling Walleye upstream and downstream of the Project serve different purposes. Walleye catches downstream of the Project (Section 5, 6, 7 and 9), together with supporting information on Walleye movement (from radio telemetry and otolith and fin ray microchemistry), will be important to understand the response of the Walleye to the Project. The information from upstream of the Project provide information to understand whether Walleye may establish in the Site C Reservoir. Walleye catch rates in Section 3 (upstream of the Project) appear qualitatively higher in 2017 and 2018 than years prior and in 2019 (Figure 30). This potential trend was noted, because it could affect the likelihood that Walleye are present (i.e., at least one male and one female) and successfully reproduce and establish upstream of the Project following river diversion. Despite observing higher catch rates in some years, given the downstream movements of Walleye for overwintering as well as other factors, it is unlikely that Walleye will establish in the Site C Reservoir.

Mountain Whitefish

Life History

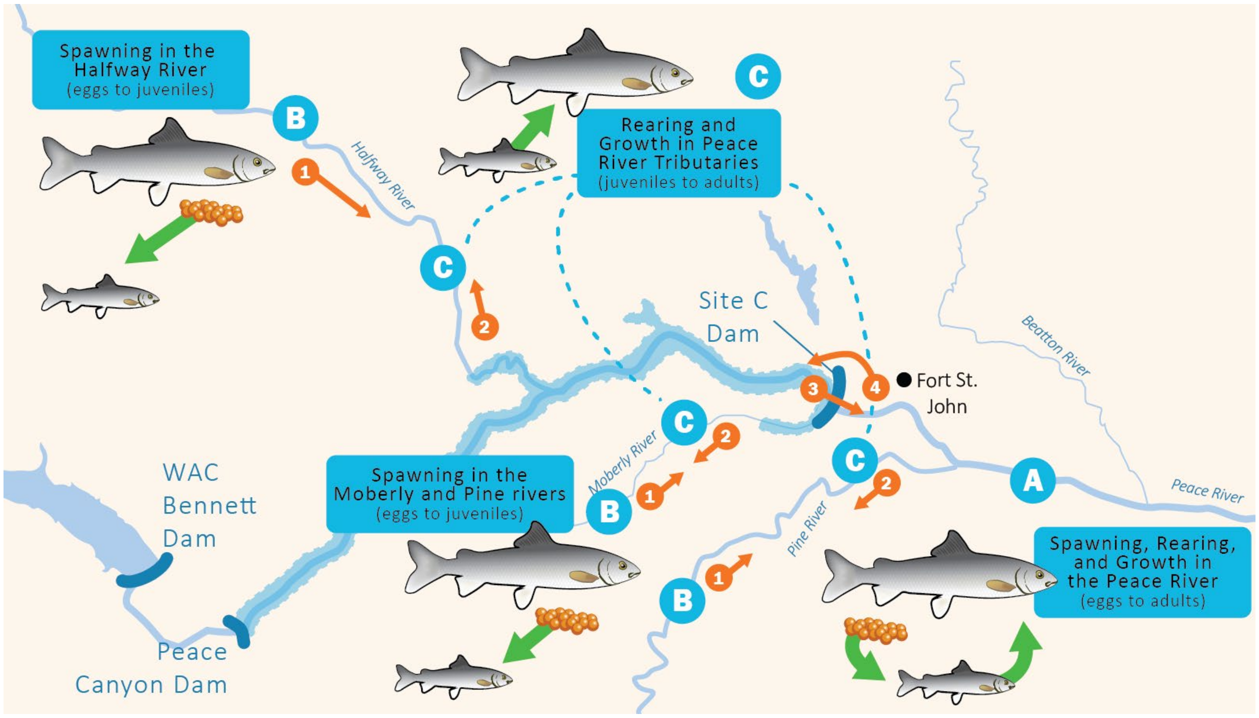

Figure 31: Life history of Mountain Whitefish in the LAA. The Site C Reservoir is indicated by the semi-transparent blue polygon with dashed outline.

Upstream of the Beatton River, Mountain Whitefish are the most abundant and widely distributed fish species in the Peace River (Mainstream Aquatics Ltd. 2012). Movement patterns are highly variable with no well-defined seasonal pattern. Mountain Whitefish may complete all life history activities within a 1 or 2 km section of the Peace River or move many kilometres (from upstream and downstream) to access tributary spawning habitats in the Pine, Moberly, and Halfway rivers (Mainstream Aquatics Ltd. 2012). Spawning, feeding and overwintering areas are dispersed over most of the species' distribution within the LAA (Mainstream Aquatics Ltd. 2012).

Mountain Whitefish first mature at age-4 to 6 and typically move upstream to spawn in the fall, both in the Peace River (**Location A**) and its tributaries including the Halfway, Moberly, and Pine rivers (**Location B**) (McPhail 2007; Mainstream Aquatics Ltd. 2012). Fry emerge in the spring, and tend to move downstream (**Arrow 1**), rearing in lower segments of Peace River tributaries (**Location C**) and the mainstem Peace River (**Location A**) (McPhail 2007; Mainstream Aquatics Ltd. 2012). In the spring, age-0 fish are most often recorded in Peace River side channels, while in the summer and fall they are most often recorded in the main channel (Mainstream Aquatics Ltd. 2012). Adult Mountain Whitefish are found in all sections of the Peace River and in all habitat areas, although they primarily occupy the main channel (Mainstream Aquatics Ltd. 2012).

Mountain Whitefish are expected to pass downstream of the Project (**Arrow 3**) and will be assisted upstream of the Project (**Arrow 4**) through the temporary and permanent fish passage facilities (EIS, Vol. 2, App Q3). However, the Project is expected to hinder both upstream and downstream passage, which is likely to split the Mountain Whitefish population into an upstream population and a downstream population (EIS, Vol. 2, App Q3).

Rationale for Monitoring

Mountain Whitefish are an indicator species because they are (MOE 2011):

- Relatively well-studied within the LAA and elsewhere;
- Representative of coldwater fauna, not tolerant of turbidity;
- An important insectivore prey species for piscivorous fish; and
- Representative of Pacific origins.

Mountain Whitefish are the numerically dominant large-fish species in the LAA. For example, Mountain Whitefish represented 52% of the total catch in the Peace River Large Fish Indexing Survey in 2017 (Golder and Gazey 2018). Mountain Whitefish's core population within the LAA ranges from Peace Canyon Dam to the Beatton River (Figure 32). Mountain Whitefish are present in low abundance downstream of the Beatton River (Golder and Gazey 2018). Mountain Whitefish spawn in the Peace, Halfway, Moberly, and Pine rivers (Mainstream Aquatics Ltd. 2012).

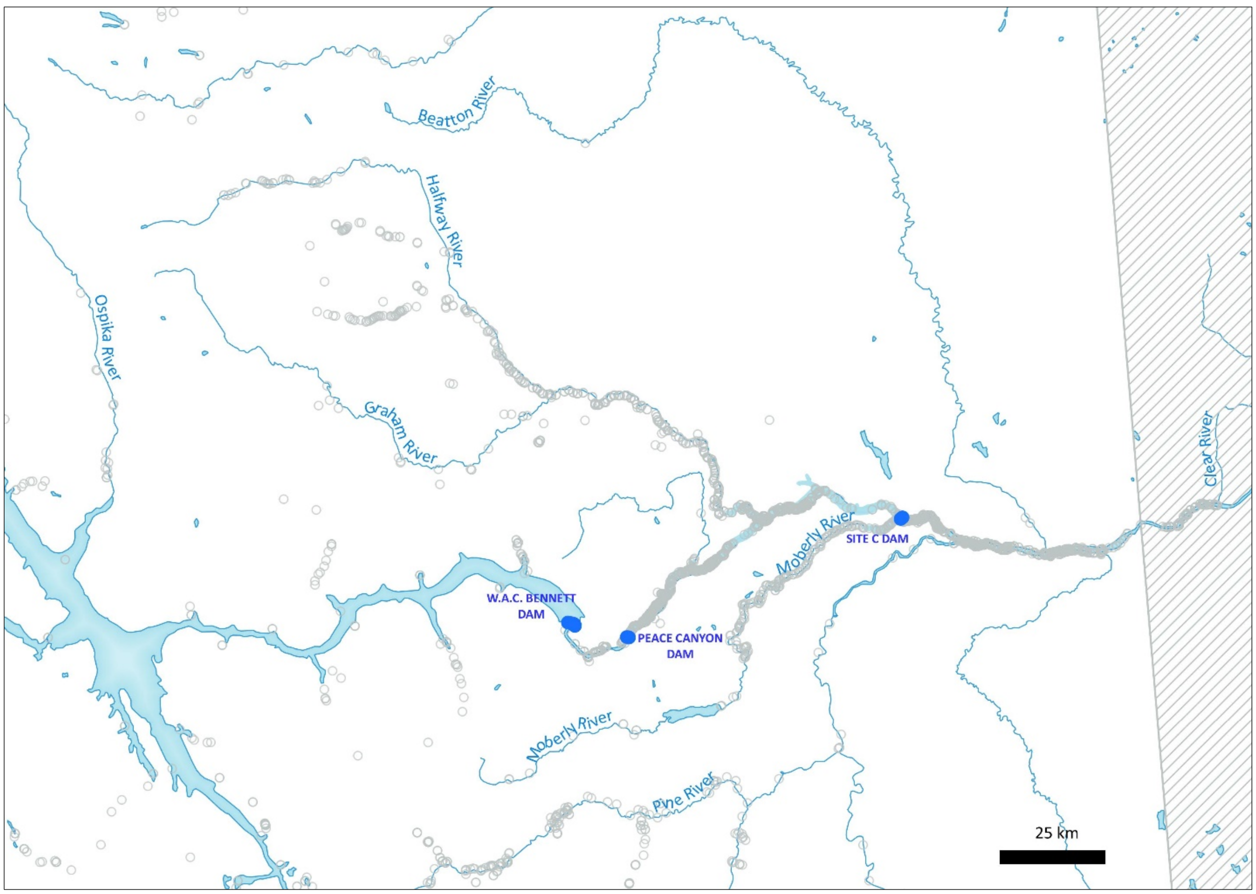

Figure 32: Mountain Whitefish distribution in the Peace Region in BC and Alberta. Each grey circle represents a confirmed observation in British Columbia and Alberta. Data source: 'Known BC Fish Observations and BC Fish Distributions' (British Columbia Data Catalogue).

Mountain Whitefish are considered secure in both British Columbia and Alberta. Although Mountain Whitefish are found in both lakes and rivers, they are only dominant in rivers. Following construction of the Project and inundation of the Site C Reservoir, Mountain Whitefish biomass is predicted to decline within the Site C Reservoir (EIS, Volume 3, Appendix P3). They are expected to be a much smaller component of the reservoir fish community after reservoir inundation (EIS, Vol. 2, App Q3). However, Mountain Whitefish biomass is predicted to increase two-fold downstream of the Project (EIS, Vol. 2, App P3).

Mountain Whitefish do not have a Diagnostic Tool because the effects of the Project are well understood. Mountain Whitefish are expected to remain abundant in the Peace River and its tributaries. The key uncertainty for Mountain Whitefish is the nature and extent of any changes to habitat due to inundation. Mountain Whitefish are not expected to be a dominant species in the Site C Reservoir but will still be locally abundant within the reservoir.

Important Observations

Mountain Whitefish are sampled in the Peace River through annual repetitive boat electroshocking surveys from Peace Canyon Dam to Many Islands, Alberta.

The key indicators for Mountain Whitefish population are abundance (Figure 33), biomass, distribution, growth and age structure. Mountain Whitefish have the most reliable abundance and age-structure estimates because of the large sample sizes. This is valuable for examining interactions between fish capture and environmental covariates. These data are collected under the Peace River Large Fish Indexing Survey.

Abundance estimates by river section and year are calculated using two methods: a Bayes sequential model and a synthesis model. These models and the assumptions in each model are described in annual reports (e.g., Golder and Gazey 2019). The following summary of the synthesis model is provided for reference (Golder and Gazey 2019):

> "The Mountain Whitefish age-structured stochastic model that was developed by Gazey and Korman (2016) was updated to include 2018 data in addition to historical data collected between 2002 and 2017. The model synthesised length-at-age, incremental growth from release-recapture occurrences, length-frequency, and mark-recapture data.
>
> The synthesis model evaluates the consistency of assumed population dynamics with historical data. Demographic parameter estimates are expected to be more accurate and precise than separate analyses (e.g., separate analyses of growth and abundance) because appropriate population dynamics and all available information are used by the model. A synthesis model can also provide an effective mechanism for monitoring a population. New data may require alterations to the model to improve the fit to the data, which enhances knowledge of population dynamics. Additionally, a synthesis model can assist impact assessment through identification of quantities that can be reliably predicted or identify additional data required to obtain reliable predictions."

Abundance estimates are generated each year in Sections 1, 3 and 5[15] that have large numbers of within-year recaptures (i.e., recaptured fish that were tagged during an earlier session in that year).

The amount of year-to-year variation in Mountain Whitefish abundance is difficult to explain, given the tight confidence limits on each estimate and the presence of multiple age classes in catches

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[15] Mark recapture estimates for Sections 6, 7 and 9, starting in 2015, are described in the annual reports (e.g., Golder and Gazey 2019).

from the Peace River Large Fish Indexing Survey (Figure 33; Golder and Gazey 2018). Precision on each estimate is high because of the large number of PIT tags deployed and recovered, combined with multiple recaptures of individually marked fish.

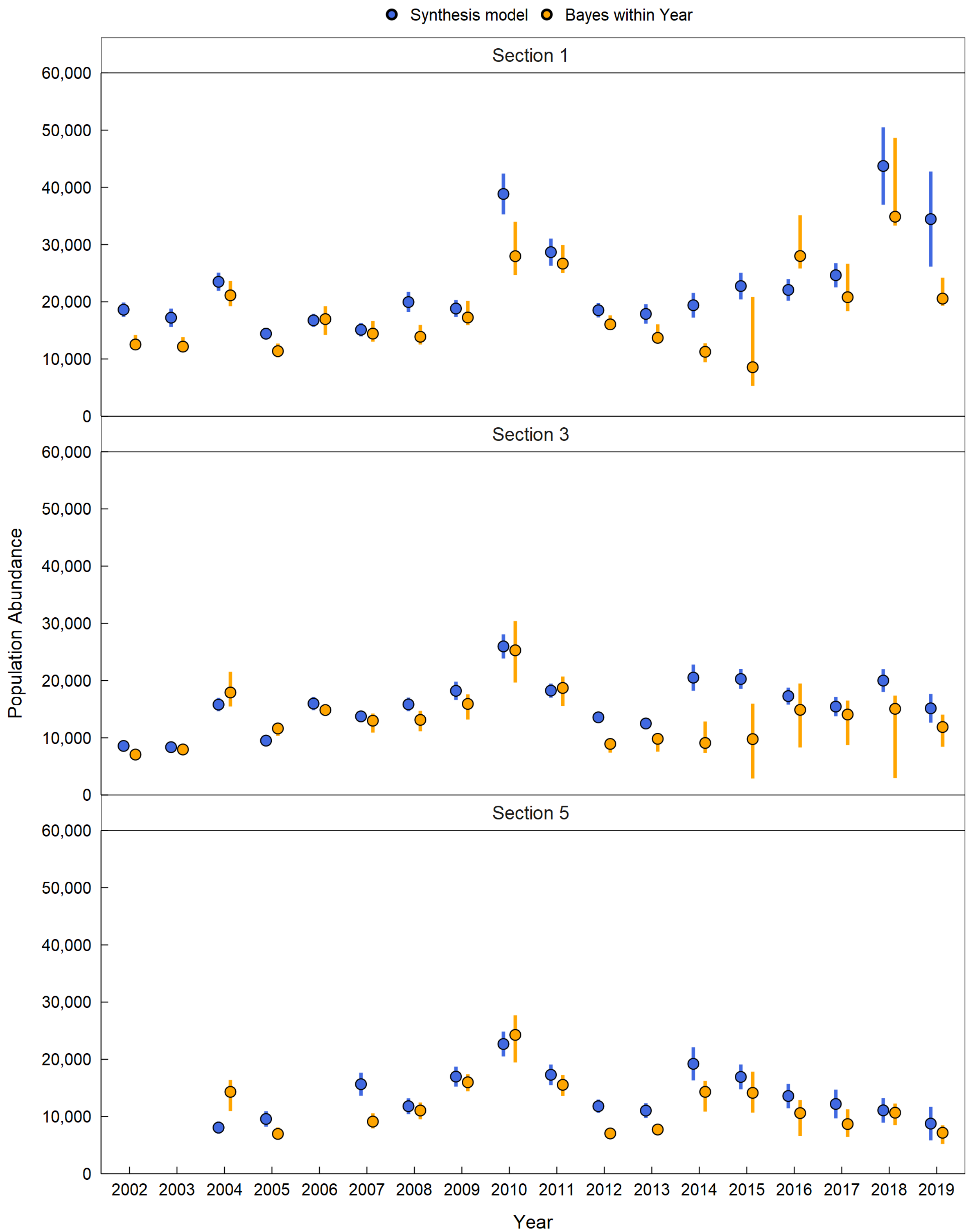

Figure 33: Estimated Mountain Whitefish abundance in the Peace River Sections 1, 3, and 5 based on the Synthesis model and Bayes within year estimation methods. Section 5 was not sampled in 2002, 2003 and 2006.

The high quality of Mountain Whitefish data plays a key role in evaluating catchability and recruitment processes associated with large fish species. Analysis of interactions between fish capture and environmental covariates has been used to identify factors that may generate significant variation in catchability at the daily to annual time scales. In the longer term, associations between Mountain Whitefish year class strength and environmental variation will help identify environmental conditions that negatively affect recruitment at the annual and decadal time scales. These challenges are explored by the Peace River Water Level Fluctuation Monitoring Program (e.g., ESSA and Golder 2019).

Data Completeness and Quality

Data collected to monitor Mountain Whitefish is considered complete and of high quality. Because Mountain Whitefish represent the most abundant large fish species in the LAA, BC Hydro has used this species as an indicator species for examining some uncertainties such as the impact of environmental covariates on catchability (ESSA and Golder 2019).

Were Adjustments Made?

No adjustments were made.

The stock synthesis model (Golder and Gazey 2019) was being developed during the initial years of implementing the FAHMFP. The model has been a helpful tool to make use of the large quantity of data for Mountain Whitefish.

Status Update

Monitoring to date is for baseline data, which continues to be collected. Baseline data collection will be sufficient to monitor changes in the Mountain Whitefish population, and the findings from the monitoring data from the FAHMFP are consistent with the findings documented in the Site C EIS.

Mountain Whitefish continue to be the most abundant fish species in the Peace River Large Fish Indexing Survey upstream of the Beatton River. Monitoring to date is for baseline data collection and is sufficient to diagnose changes in the Mountain Whitefish population. Natural variation in population abundance continues to be higher than expected but this challenge is balanced by the long, relatively precise, time series of population estimates.

Fish Community

Rationale for Monitoring

Monitoring the status of the fish community focuses on high-level objectives that are in addition to the status of indicator species. MOE provides ecosystem objectives regarding the fish community (MOE 2009, Table 3, p11):

1. Ecosystem Integrity and Productivity:
   a. Zoogeography of fish fauna;
   b. Productive capacity of the native fish community; and
   c. Structure and function of aquatic community.
2. Sustainable Use:
   a. Sustain an adequate fisheries resource to support First Nations' traditional uses and treaty rights; and
   b. Optimize recreational angling opportunities, participation and local benefits.

More specifically, ecosystem values associated with the fish community in the LAA are high because:

> "It [the Lower Peace Region] is unique in that species and sub-species of Pacific, Beringia and Great Plains origin come into contact with one another. Different terms are used to describe this zone of contact and mixing; this report uses the term interface zone.
>
> For fish, the interface zone is an area of contact and mixing between species and sub-species from three glacial refugia, the Pacific, Beringia and Great Plains (McPhail 2007). The zone includes contact and mixing between separate species, and also between different lineages within species (i.e., different sub-species or populations). It has only been lightly studied to date, but continues to be investigated. The key features of the interface zone in relation to MOE[16] objectives are: total productivity, diversity of the east and west faunas, and the structure and function of the community assemblages (e.g., competition and predator-prey interactions, meta-population dynamics)."[17]

Monitoring the fish community aims to address uncertainties regarding the effects of the Project on aquatic ecosystem values that are not captured by metrics for single indicator species. The largest uncertainty for the fish community is how the species abundance and composition will change during operation of the Project. The distribution and relative abundance of the fish community in the Peace River is predicted to change downstream of the Project. For example, seasonal differences in water temperature and turbidity may affect the seasonal distribution of Walleye and Goldeye, and potential effects of fish movement upstream and downstream at the Projecy may affect the distribution and abundance of Bull Trout (EIS Vol 2, Section 12).

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[16] BC Ministry of Environment
[17] MOE 2009, p5

The spatial scope of the Fish Community metrics is limited to the Peace River and does not include tributaries of the Peace River. Information from sampling in tributaries (via fish capture, telemetry, genetics, and microchemistry) provide supporting information for the metrics measured in the fish community of the Peace River.

Important Observations

Several monitoring tasks are grouped to represent the Fish Community. The key indicators of the Fish Community are fish biomass and diversity, which are estimated from the abundance and distribution of individual species. No obvious shifts in species-specific abundance or distribution were noted during the last five years, and the findings are consistent with the results documented in the Site C EIS. One exception is the decline in Arctic Grayling abundance in recent years as demonstrated by lower CPUE across sections of the Peace River (Figure 22). Coolwater indicator species (Walleye, Goldeye) still occur mainly in areas downstream of the Project. Coldwater species (Bull Trout, Arctic Grayling, Rainbow Trout, Mountain Whitefish) are common in the Peace River and its tributaries upstream of the Project. There were no changes in the understanding of the distribution of other species.

Fish species diversity and relative abundance is assessed using diversity profiles. Diversity profiles account for both the number of species observed in the community and the relative abundance of those species by describing the relationship between the ‘effective number of species’ (i.e., the number of equally common species required to get a particular value of an index) and the degree to which species abundance is represented (q) (Leinster and Cobbold 2012; Jost 2013). Figure 5 represents a comparison of the effective number of species in baseline conditions, using data collected from the Peace River Fish Inventory (Mainstream 2010, 2011, and 2013), and the conditions during operation of the Project, using the predicted changes in biomass from the Site C EIS (Vol. 2, App P3). The variable q represents the strength of relative abundance in estimating the effective number of species; as q increases, relative abundance has a stronger impact. The ability to detect changes in fish community composition in the Peace River is anticipated to be high based on power analyses (Ma et al. 2015). Diversity profiles are also generated from River Large Fish Indexing Survey and reported annually (e.g., Golder and Gazey 2018).

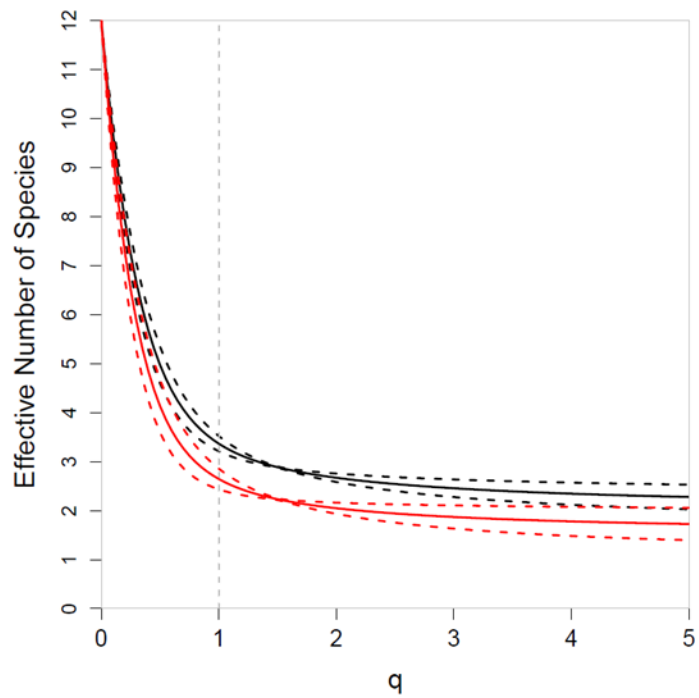

Figure 34: Diversity profiles illustrating potential changes in metrics of fish species diversity in the Peace River downstream of Site C. Black lines display means (solid) and upper and lower confidence limits (dashed) for baseline data (using fish inventory data targeting small fish species, Mainstream 2010, 2011, 2013). Red lines display effective number of species (solid) and upper and lower confidence limits (dashed) predicted during operation of the Project (EIS, Vol. 2, App P3). Dashed grey lines indicates q=1 (Ma et al. 2015).

Data Completeness and Quality

Data collected to monitor fish community is considered complete and of high quality. Forty of the 42 observations (95%) for fish community were collected as planned, which include six medium importance observations and 36 low importance observations.

Stomach content samples of Bull Trout (two medium importance observations) to examine food volume and species composition (diet) were not completed because of concerns from the Committee of causing undue harm during gastric lavage. Stable isotope analysis has been undertaken to understand the diet of Bull Trout in the LAA.

Were Adjustments Made?

Adjustments were made to two observations: annual index fish stranding and expanded fish stranding assessments (both are a component of the Site C Fish Stranding Monitoring Program). In 2016, surveys were limited to high risk sites through targeted sampling, which does not provide information on sites with lower stranding risk. Surveys conducted in 2017, 2018 and 2019 consisted of both targeted and random sampling (including high and low risk sites; Patterson and Hawker 2020). Fish stranding is included in the Fish Community section as it may provide supporting information for any observed changes in the Fish Community.

Status Update

Monitoring to date is for baseline data, which continues to be collected. Overall, the understanding of the Fish Community has not changed since the Site C EIS. Increased boat electroshocking in Sections 6, 7 and 9 since 2015 and in future years will increase the understanding of potential changes downstream of the Project.

Data from the Peace River Large Fish Indexing Survey indicates that the abundance of some indicator species (e.g., Arctic Grayling, as described above) may have changed over the course of the time series of data collected (since 2002). Such changes would be indicative of fish community changes that are unrelated to the Project. If so, such changes under baseline conditions may reduce the statistical significance and alter the biological interpretation of any changes in the overall fish community that are observed post-diversion and post-impoundment.

DISCUSSION

The Synthesis Review evaluates whether the understanding of fish and aquatic habitat has changed during the five-year period leading up to the review. Further, the review assesses whether the FAHMFP is on track to meet its objectives to (1) monitor fish and aquatic habitat during the construction and operation of the Project; (2) understand the effects of the Project and the effectiveness of mitigation measures; and (3) evaluate and implement future mitigation and compensation options. Prior to river diversion, the focus of the FAHMFP was on collecting sufficient baseline information to ensure that the changes to fish and aquatic habitat can be evaluated when the Project is complete and does not change the understanding of baseline conditions. Therefore, the 2019 Synthesis Review focuses on the expected ability of the FAHMFP to monitor fish and aquatic habitat, diagnose causal mechanisms, and the completeness and quality of the data collected. Future iterations of the Synthesis Review (2024 onward) will begin to assess the changes in the fish and aquatic habitat associated with the Project.

Overall, the Synthesis Review indicates that the information collected during the first five years of the FAHMFP is consistent with the understanding of fish and aquatic habitat documented in the Site C EIS. Data collected to date were found to be complete and of high quality, and sufficient to characterize baseline conditions and to understand potential mechanisms for changes in fish and aquatic habitat metrics during operation of the Project and to address key uncertainties. Currently, most of the key uncertainties associated with the changes from the Project cannot be addressed because they require data following Project operations and a before-after comparison of conditions. Ultimately the monitoring tasks of the FAHMFP are designed to address these uncertainties.

Over the last five years, several changes were made to monitoring tasks of the FAHMFP in consultation with the Committee. These changes were all adjustments to existing monitoring, rather than the introduction of new monitoring. Table 1 presents a list of these adjustments. Generally, the monitoring tasks have not deviated far from what was planned when the FAHMFP was first developed in 2015 (BC Hydro 2015).

Table 1: Summary of the changes to the FAHMFP by indicator species. All changes are considered adjustments to current monitoring.

Component	Year	Activity	Change	Rationale / Outcome
Bull Trout	2016	Redd counts (abundance estimate) (Mon-1b, Task 2b)	Added area under the curve (AUC) methods to complement peak counts; estimating redd and fish size; estimating survey life and observer efficiency.	Increase the accuracy and precision of estimates; estimate uncertainty
		Stomach content of Bull Trout (Mon-2, Task 2a)	Stomach contents - gastric lavage replaced by stable isotope analysis	Lower mortality risk to piscivores; however, diet composition limited to trophic level
	2017	Juvenile Bull Trout monitoring (Mon-1b, Task 2c)	Focus on reaches and high quality habitats for juvenile Bull Trout to increase PIT tag deployment	More PIT tags deployed; the BTIPM provides a better estimate of juvenile density and survival. However, focused sampling biases CPUE estimates of juvenile Bull Trout.
		Juvenile Bull Trout monitoring (Mon-1b, Task 2c)	Juvenile sampling expanded to include Fiddes Creek (in addition to Chowade River, Cypress Creek, and upper Halfway River)	
Rainbow Trout	2016	Choice of sites for juvenile Rainbow Trout monitoring (Mon-1b, Task 2c)	Added upper Halfway River, Cypress Creek and Chowade River (in addition to Maurice and Lynx creeks)	Abandon inaccessible (Maurice Creek) and poor habitat (Lynx Creek) locations
	2017	Choice of sites for juvenile Rainbow Trout monitoring (Mon-1b, Task 2c)	Kobes, Colt, and Farrell creeks; 2016 locations (upper Halfway River, Cypress Creek, and Chowade River) no longer sampled.	Focus on more likely recruitment locations for the Peace River
Arctic Grayling	2017	PIT tagging in Moberly River (Mon-1b, Task 2c)	Extensive reaches sampled, whereas previously only short reaches were sampled. Added angling as a method	Increase Arctic Grayling captures and number of PIT tags deployed
	2018 and 2019	PIT tagging in Moberly River (Mon-1b, Task 2c)	Sampling occurred earlier in the season.	Increase number of Arctic Grayling captured
		Beatton River Arctic Grayling Assessment (Mon-2, Task 2f)	Open site sampling (vs. closed site sampling)	Allow for comparison with data from other watersheds
			Add angling as a capture technique in addition to backpack electroshocking	Increase the likelihood of encountering adults and increase the number of PIT tags deployed
			Sampling occurred earlier in the season.	Increase the likelihood of encountering adults prior to downstream migration
Goldeye	2018	Goldeye electroshocking survey (Mon-2, Task 2a)	Added spring sampling in addition to late summer / fall sampling	Increase catches

Component	Year	Activity	Change	Rationale / Outcome
Walleye	2018	Walleye electroshocking survey (Mon-2, Task 2a)	Added spring sampling in addition to late summer / fall sampling	Increase catches
Mountain Whitefish	No Adjustments			
Fish Community	2017	Index of Fish Stranding (Mon-12, Task 2b)	Random sampling of both high and low risk sites, instead of only high risk sites	Reduce bias in estimate

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APPENDIX A: MONITORING PROGRAMS AND DATA COLLECTION TASKS

Monitoring Program	Data Collection Task
Mon-1a: Site C Reservoir Fish Community Monitoring Program – Monitor the effects of river to reservoir transformation on the fish community in Site C Reservoir and associated tributaries.	**2a:** Site C Reservoir Hydroacoustic, Trawl, and Gillnet Survey
	2b: Site C Reservoir Summer Profundal Index Netting (SPIN) Survey
	2c: Site C Reservoir Creel Survey
	2d: Williston Reservoir Hydroacoustic, Trawl, and Gillnet Survey
Mon-1b: Site C Reservoir Tributaries Fish Community and Spawning Monitoring Program – Monitor fish populations in Peace River and Site C Reservoir that migrate to tributaries to determine effects of the Project and the effectiveness of mitigation measures for fish and fish habitat.	**2a:** Peace River Arctic Grayling and Bull Trout Movement Assessment
	2b: Peace River Bull Trout Spawning Assessment
	2c: Site C Reservoir Tributaries Fish Population Indexing Survey
	2d: Site C Fish Movement Assessment
Mon-2: Peace River Fish Community Monitoring Program – Monitor fish populations in the Peace River to determine effects of the Project and the effectiveness of mitigation measures for fish and fish habitat.	**2a:** Peace River Large Fish Indexing Survey
	2b: Peace River Fish Composition and Abundance Survey
	2c: Peace River Creel Survey
	2d: Offset Effectiveness Monitoring Program
	2e: Peace River Tributaries Walleye Spawning and Rearing Use Survey
	2f: Beatton River Arctic Grayling Status Assessment
Mon-3: Peace River Physical Habitat Monitoring Program – Monitor the effects of the Project on physical habitat.	**2a:** Channel Morphology
	2b: Substrate size
	2c: Offset Effectiveness Monitoring Program
Mon-4: Site C Reservoir Riparian Vegetation Monitoring Program – Monitor the effectiveness of planned riparian planting adjacent to the Site C Reservoir.	**2a:** Vegetation Survey and Bank Stability Assessment
Mon-5: Peace River Riparian Vegetation Monitoring Program – Monitor how the construction and operation of the Project affects the quality and quantity (species composition, biological productivity, spatial area) of riparian vegetation along the Peace River downstream of Site C.	**2a:** Aerial Imagery Interpretation
	2b: Vegetation Surveys / Ground Truthing
Mon-6: Site C Reservoir Fish Food Organisms Monitoring Program – Monitor the effects of Site C Reservoir formation on the production of fish food organisms.	**2a:** Biomass and Production of Fish Food Organisms
	2b: Ecosystem Attributes
Mon-7: Peace River Fish Food Organisms Monitoring Program – Monitor the effects of Project construction and operations on the biomass of invertebrates and the availability of fish food organisms downstream of Site C.	**2a:** Biomass and Production of Fish Food Organisms
	2b: Ecosystem Attributes
Mon-8: Site C Reservoir Water and Sediment Quality Monitoring Program – Monitor the effects of reservoir formation on water and sediment quality.	**2a:** General Water and Sediment Quality Monitoring
	2b: Temperature Monitoring
	2c: Turbidity Monitoring
Mon-9: Peace River Water and Sediment Quality Monitoring Program – Monitor the effects of the Project on water and sediment quality downstream of Site C.	**2a:** General Water and Sediment Quality Monitoring
	2b: Temperature Monitoring
	2c: Turbidity Monitoring
Mon-10: Site C Fish Entrainment Monitoring Program – Monitor entrainment rates and	**2a:** Monitoring of Entrainment Rates
	2b: Monitoring Survival Rates of Entrained Fish

Monitoring Program	Data Collection Task
survival rates of entrained fish during the operation of Site C.	
Mon-11: Site C TDG Monitoring Program – Monitor Total Dissolved Gas (TDG) supersaturation and potential effects to downstream fish populations resulting from Gas Bubble Disease (GBD) during Site C Project construction and operation.	**2a:** TDG Monitoring **2b:** TDG Effects on Fish
Mon-12: Site C Fish Stranding Monitoring Program – Monitor Project construction and operation effects associated with flow fluctuations and fish stranding on the Peace River fish community.	**2a:** Identification of Monitoring Sites **2b:** Monitoring Stranding Sites
Mon-13: Site C Fishway Effectiveness Monitoring Program – Monitor the performance of the temporary and permanent fishways at the Project.	**2a:** Site C Tailrace and Fishway Telemetry Assessment **2b:** Attraction Efficiency and Entrance Accessibility Assessment **2c:** Contingent Radio Telemetry Surveys in Site C Tailrace
Mon-14: Site C Trap and Haul Fish Release Location Monitoring Program – Monitor the movements following release of fish collected at Site C fishways and transported and released at several upstream release locations.	**2a:** Data Collection - Monitor tagged fish
Mon-15: Site C Small Fish Species Translocation Monitoring Program – Monitor small fish species populations in the Peace River to determine effects of the project on genetic structure, movement, and genetic exchange.	**2a:** Data Collection - Tissue Sample Collection for Genetic Analysis
Mon-16: Site C Reservoir Constructed Shallow Water Habitat Areas Sediment and Vegetation Monitoring Program – Monitor the suitability of benthic substrates in constructed shallow water habitats of Site C Reservoir for aquatic plants and monitor the natural colonization of aquatic plants in these habitats.	**2a:** Substrate Monitoring **2b:** Aquatic Plant Monitoring
Mon-17: Peace River Water Level Fluctuation Monitoring Program – Investigate the effects of water level fluctuations on the catchability of Peace River fish and the biomass and production of periphyton, downstream of Site C.	**2a:** Supplementary Sampling of Benthos and Periphyton **2b:** Supplementary Sampling of Small Fish **2c:** Supplementary Sampling of Large Fish **2d:** Supplementary Sampling of Fish
Follow-up Program 1: Site C Tributary Mitigation Opportunities Evaluation Program – Identify enhancement opportunities for stream dependent indicator species described in the EIS including Arctic Grayling, Bull Trout, Burbot, Goldeye, Mountain Whitefish, Rainbow Trout and Walleye.	**2a:** Initial Mitigation Project Identification **2b:** WSEP Tier 1 Assessments **2c:** Identification of Additional Candidate Watersheds

APPENDIX B: BULL TROUT INTEGRATED POPULATION MODEL

A Bull Trout Integrated Population Model (BTIPM) is being developed to integrate information collected from the different monitoring tasks and generate population estimates using all data sources. This model will use information from spawning surveys, mark-recapture data from surveys in the Peace River and its tributaries, and telemetry data from radio- and PIT-tagged fish to help understand changes in Halfway River Bull Trout.

Integrated population models integrate the joint analysis of population abundance data and demographic data (e.g. survival, ontogenetic development, fecundity, spawning probability/success, and movement) into a single framework (Schaub & Abadi 2011). At the core of an integrated population model is a population dynamics model that describes how abundance in a structured (e.g. by age, stage, sex, etc.) population changes over time as a function of various demographic parameters. Data on the various demographic parameters are often available from monitoring programs and lend themselves to analysis with capture-recapture models and generalized linear (mixed) models. In the integrated population model framework, one or more parameters are common in the population dynamics model and the models used to analyze the demographic data, so that a joint likelihood can be created by multiplying the likelihoods of each data set (Schaub & Abadi 2011).

Integrated population models, particularly the core population dynamics models, are typically fitted using a state-space formulation (Schaub & Abadi 2011). In the state-space formulation, the population dynamics model represents the state (e.g. abundance and structure) model and is linked to the abundance data via an observation model. By enabling the population dynamics and observation processes to be modeled separately, the state-space formulation leads to unbiased and more precise estimates of density-dependence effects on animal populations (Lebreton & Gimenez 2013).

The joint analysis of population abundance and demographic data with an integrated population model has a few other major advantages over the traditional piecemeal approach (i.e., an approach where a population dynamics model is parameterized with values extracted from the literature or with parameter estimates extracted from models fitted to demographic data in isolation). First, the integrated population model automatically propagates uncertainty across related parameters and accounts for correlations that may exist between parameters. Second, the integrated population model framework often enables the estimation of parameters for which no explicit data are available. Finally, the efficient use of all available data within the integrated population model framework leads to more precise estimates of model parameters (Schaub & Abadi 2011).

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APPENDIX C: DETERMINING CHANGES IN PERFORMANCE MEASURES FOR EACH INDICATOR SPECIES

Species-specific performance measures for each indicator species, including the primary method of assessment and metric used. Where available, direct links are provided to the figures in the Synthesis Review.

Indicator Species	Species-Specific Measure	Location	Primary Method of Assessment	Metric	Monitoring Task Name	Monitoring Task	Reference in Synthesis Review
Bull Trout	Abundance	Peace River	Fish captures from large boat electrofishing	Population estimate using a Bayes sequential model of mark-recapture data; CPUE	Peace River Large Fish Indexing Survey	Mon-2, Task 2a	Figure 8; Figure 9
		Reservoir	Gillnet survey	CPUE	Site C Reservoir Hydroacoustic, Trawl, and Gillnet Survey	Mon-1a, Task 2a	Not Shown
		Tributaries	Redd counts	Number of redds	Peace River Bull Trout Spawning Assessment	Mon-1b, Task 2b	Figure 7
	Size and Age Distribution	Peace River	Fish captures from large boat electrofishing	Frequency of catch per size class; Length-at-age	Peace River Large Fish Indexing Survey	Mon-2, Task 2a	Not Shown
		Reservoir	Gillnet survey	Frequency of catch per size class; Length-at-age	Site C Reservoir Hydroacoustic, Trawl, and Gillnet Survey	Mon-1a, Task 2a	Not Shown
		Tributaries	Fish captures from backpack electrofishing	Frequency of catch per size class; Length-at-age	Site C Reservoir Tributaries Fish Population Indexing Survey	Mon-1b, Task 2c	Not Shown
	Species Distribution	All	Bull Trout movement through tributaries, Site C reservoir, and the Peace River downstream of the Project	Radio telemetry; microchemistry sampling; encounters	Peace River Adult Arctic Grayling and Bull Trout Movement Assessment	Mon-1b, Task 2a	Figure 10; Not Shown; Figure 6
		Tributaries	Bull Trout movement to and from tributary spawning locations	Resistivity counters; PIT tag arrays	Peace River Bull Trout Spawning Assessment	Mon-1b, Task 2b	Not Shown
	Population Structure	All	Otolith, fin ray, and tissue collection and analysis	Natal origin from otolith and fin ray microchemistry and genetic analysis	Peace River Large Fish Indexing Survey	Mon-2, Task 2a	Figure 12
Rainbow Trout	Abundance	Peace River	Fish captures from large boat electrofishing	Population estimate using a Bayes sequential model of mark-recapture data; CPUE	Peace River Large Fish Indexing Survey	Mon-2, Task 2a	Figure 17; Figure 18
		Reservoir	Gillnet survey	CPUE	Site C Reservoir Hydroacoustic, Trawl, and Gillnet Survey	Mon-1a, Task 2a	Not Shown
		Tributaries	Fish captures from backpack electrofishing	CPUE	Site C Reservoir Tributaries Fish Population Indexing Survey	Mon-1b, Task 2c	Not Shown
	Size and Age Distribution	Peace River	Fish captures from large boat electrofishing	Frequency of catch per size class; Length-at-age	Peace River Large Fish Indexing Survey	Mon-2, Task 2a	Not Shown
		Reservoir	Gillnet survey	Frequency of catch per size class; Length-at-age	Site C Reservoir Hydroacoustic, Trawl, and Gillnet Survey	Mon-1a, Task 2a	Not Shown
		Tributaries	Fish captures from backpack electrofishing	Frequency of catch per size class; Length-at-age	Site C Reservoir Tributaries Fish Population Indexing Survey	Mon-1b, Task 2c	Not Shown
	Species Distribution	All	Rainbow Trout movement through tributaries, Site C reservoir, and the Peace River downstream of the Project	Radio telemetry; encounters	Peace River Adult Arctic Grayling and Bull Trout Movement Assessment	Mon-1b, Task 2a	Figure 10; Figure 15
	Population Structure	All	Otolith, fin ray, and tissue collection and analysis	Natal origin from otolith and fin ray microchemistry and genetic analysis	Peace River Large Fish Indexing Survey	Mon-2, Task 2a	Not Shown
Arctic Grayling	Abundance	Peace River	Fish captures from large boat electrofishing	Population estimate using a Bayes sequential model of mark-recapture data; CPUE	Peace River Large Fish Indexing Survey	Mon-2, Task 2a	Figure 21; Figure 22
		Reservoir	N/A	N/A	N/A	N/A	Not Shown
		Tributaries	Fish captures from backpack electrofishing	CPUE	Site C Reservoir Tributaries Fish Population Indexing Survey	Mon-1b, Task 2c	Not Shown

Indicator Species	Species-Specific Measure	Location	Primary Method of Assessment	Metric	Monitoring Task Name	Monitoring Task	Reference in Synthesis Review
	Size and Age Distribution	Peace River	Fish captures from large boat electrofishing	Frequency of catch per size class; Length-at-age	Peace River Large Fish Indexing Survey	Mon-2, Task 2a	Not Shown
		Tributaries	Fish captures from backpack electrofishing	Frequency of catch per size class; Length-at-age	Site C Reservoir Tributaries Fish Population Indexing Survey	Mon-1b, Task 2c	Not Shown
	Species Distribution	All	Arctic Grayling movement through tributaries, Site C reservoir, and the Peace River downstream of the Project	Radio telemetry; encounters	Peace River Adult Arctic Grayling and Bull Trout Movement Assessment	Mon-1b, Task 2a	Figure 10; Figure 20
	Population Structure	All	Otolith, fin ray, and tissue collection and analysis	Natal origin from otolith and fin ray microchemistry and genetic analysis	Peace River Large Fish Indexing Survey	Mon-2, Task 2a	Not Shown
Goldeye	Abundance	Peace River	Fish captures from large boat electrofishing	Number captured	Peace River Large Fish Indexing Survey	Mon-2, Task 2a	Figure 26
		Reservoir	N/A	N/A	N/A	N/A	Not Shown
	Size and Age Distribution	Peace River	Fish captures from large boat electrofishing	Frequency of catch per size class; Length-at-age	Peace River Large Fish Indexing Survey	Mon-2, Task 2a	Not Shown
	Species Distribution	Peace River	Fish captures from large boat electrofishing	Microchemistry sampling; encounters	Peace River Large Fish Indexing Survey	Mon-2, Task 2a	Figure 27; Figure 25
	Population Structure	All	Otolith and fin ray collection and analysis	Natal origin from otolith and fin ray microchemistry	Peace River Large Fish Indexing Survey	Mon-2, Task 2a	Figure 27
Walleye	Abundance	Peace River	Fish captures from large boat electrofishing	CPUE	Peace River Large Fish Indexing Survey	Mon-2, Task 2a	Figure 30
		Reservoir	Gillnet survey (but not expected to be in the reservoir)	CPUE	Site C Reservoir Hydroacoustic, Trawl, and Gillnet Survey	Mon-1a, Task 2a	Not Shown
		Tributaries (Kiskatinaw River only)	Fish captures from backpack electrofishing	CPUE	Peace River Tributaries Walleye Spawning and Rearing Use Survey	Mon-2, task 2e	Not Shown
	Size and Age Distribution	Peace River	Fish captures from large boat electrofishing	Frequency of catch per size class; Length-at-age	Peace River Large Fish Indexing Survey	Mon-2, Task 2a	Not Shown
	Species Distribution	Peace River	Fish captures from large boat electrofishing	Radio telemetry; encounters	Peace River Large Fish Indexing Survey	Mon-2, Task 2a	Figure 10; Figure 29
		Tributaries (Kiskatinaw River only)	Fish captures from backpack electrofishing	CPUE	Peace River Tributaries Walleye Spawning and Rearing Use Survey	Mon-2, task 2e	Not Shown
	Population Structure	All	Otolith and fin ray collection and analysis	Natal origin from otolith and fin ray microchemistry	Peace River Large Fish Indexing Survey	Mon-2, Task 2a	Not Shown
Mountain Whitefish	Abundance	Peace River	Fish captures from large boat electrofishing	Population estimate using a Bayes sequential model of mark-recapture data	Peace River Large Fish Indexing Survey	Mon-2, Task 2a	Figure 33
		Peace River	Fish captures from small fish boat electrofishing, minnow traps, hoop nets, backpack electrofishing	CPUE	Peace River Fish Composition and Abundance Survey	Mon-2, Task 2b	Not Shown
		Reservoir	Gillnet survey	CPUE	Site C Reservoir Hydroacoustic, Trawl, and Gillnet Survey	Mon-1a, Task 2a	Not Shown
	Size and Age Distribution	Peace River	Fish captures from large boat electrofishing	Frequency of catch per size class; Length-at-age	Peace River Large Fish Indexing Survey	Mon-2, Task 2a	Not Shown
		Reservoir	Hydroacoustic, Trawl, and Gillnet Survey	Frequency of catch per size class; Length-at-age	Site C Reservoir Hydroacoustic, Trawl, and Gillnet Survey	Mon-1a, Task 2a	Not Shown

Indicator Species	Species-Specific Measure	Location	Primary Method of Assessment	Metric	Monitoring Task Name	Monitoring Task	Reference in Synthesis Review
		Tributaries	Fish captures from small fish boat electrofishing, backpack electrofishing, and angling	Frequency of catch per size class; Length-at-age	Site C Reservoir Tributaries Fish Population Indexing Survey	Mon-1b, Task 2c	Not Shown
	Species Distribution	Peace River	Fish captures from large boat electrofishing	CPUE	Peace River Large Fish Indexing Survey	Mon-2, Task 2a	Not Shown
		Reservoir	Gillnet Survey	CPUE	Site C Reservoir Hydroacoustic, Trawl, and Gillnet Survey	Mon-1a, Task 2a	Not Shown
		Tributaries	Fish captures from small fish boat electrofishing, backpack electrofishing, and angling	CPUE	Site C Reservoir Tributaries Fish Population Indexing Survey	Mon-1b, Task 2c	Not Shown
		All	Various methods	Encounters	N/A	N/A	Figure 32
	Population Structure	All	Otolith collection and analysis	Natal origin from microchemistry	Peace River Large Fish Indexing Survey	Mon-2, Task 2a	Not Shown
Fish Community	Relative Abundance	Peace River	Fish captures from large boat electrofishing	Species diversity curves	Peace River Large Fish Indexing Survey	Mon-2, Task 2a	Figure 34
			Fish captures from small fish boat electrofishing, minnow traps, hoop nets, backpack electrofishing	Species diversity curves	Peace River Fish Composition and Abundance Survey	Mon-2, Task 2b	Figure 34
		Reservoir	Hydroacoustic, Trawl, and Gillnet Survey	Species diversity curves	Site C Reservoir Hydroacoustic, Trawl, and Gillnet Survey	Mon-1a, Task 2a	Figure 34