Roberts Bank Terminal 2 Follow-up Program

Juvenile Salmon Density Annual Data Report – 2020

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Executive Summary

The Roberts Bank Terminal 2 Project (RBT2 or project) is a proposed new marine container terminal on Canada's west coast led by the Vancouver Fraser Port Authority (port authority). RBT2 involves the construction of a new marine container terminal, a widened causeway and an expanded tug basin at Roberts Bank in Delta, British Columbia. If approved and built, Roberts Bank Terminal 2 would play a critical role in supporting Canadian exporters and consumers of goods who increasingly want to trade with economies around the world.

Should the project be approved, the RBT2 follow-up program (FUP) will be developed to meet the requirements of the *Canadian Environmental Assessment Act, 2012*, to develop "a program for verifying the accuracy of the environmental assessment of a designated project, and determining the effectiveness of any mitigation measures". At present, the RBT2 FUP is proposed to include 24 sub-programs referred to as FUP elements. The juvenile salmon FUP element has been designed to verify the accuracy of the assessment conclusions presented in the Environmental Impact Statement (EIS) that, with mitigation, project-related changes in the productivity of juvenile salmon, including Chinook and chum, will be negligible. The juvenile salmon FUP element uses density and distribution as measurable metrics of productivity. It also focuses on Chinook and chum salmon given that they are the two Pacific salmon species that are most estuarine-dependent when rearing and they are the two representative species selected for the assessment presented in the EIS. A before-after-control-impact (BACI) study has been designed to meet the objectives of the juvenile salmon FUP element.

The overall study design was informed by input received from Indigenous groups as part of the port authority's ongoing consultation program for the project. Results presented in this report describe current (2020) conditions of juvenile Chinook and chum salmon density and distribution in the study area. They also constitute the first year of a pre-project construction data set that will be used to evaluate post-project construction changes in juvenile salmon density and distribution in the study area to meet the objectives of the juvenile salmon FUP element.

The study area of the juvenile salmon FUP element is Roberts Bank and includes one impact area and one control area as part of the BACI study design. The impact area includes two intertidal shore-tied (i.e., along the shore) locations, the north and south shorelines of the Roberts Bank causeway. The impact area also includes subtidal locations north (in the eelgrass bed) and south of the existing Roberts Bank terminals. The control area encompasses the intertidal west shoreline of Westham Island and is spatially independent from the impact area given that it is located beyond the influence of predicted project-related effects. Twenty-four shore-tied permanent sampling sites were selected (eight each along the north and south sides of the Roberts Bank causeway and along Westham Island), and five spot sampling sites (one shore-tied site along the Roberts Bank dyke, selected based on the result of consultation on the study design with Tsawwassen First Nation, two shallow subtidal sites in the eelgrass bed north of the existing Roberts Bank terminals, and two subtidal offshore sites south of the existing Roberts Bank terminals).

Sampling was undertaken between April 23, 2020 and July 31, 2020. All shore-tied permanent and spot sites were sampled on foot with a beach seine net. All subtidal spot sites were sampled by boat using a beach seine net in the shallow subtidal eelgrass bed, and a purse seine net at the subtidal offshore sites. Permanent sites were visited four times in spring (April and May) and four times in summer (June and July). Shore-tied spot sampling off the Roberts Bank dyke was done once in spring and twice in summer, while subtidal spot sampling was done once in summer.

A total of 44,316 fish were caught belonging to 26 species and 18 families. Juvenile salmon comprised 22.6% of the total catch (i.e., 10,006 juvenile salmon out of 44,316 individuals). Juvenile pink salmon accounted for 57.1% of the juvenile salmon catch (5,718 out of 10,006 juvenile salmon), followed by Chinook (36.1%, 3,610 individuals) and chum (6.4%, 639 individuals). Only three juvenile coho and one juvenile sockeye salmon were caught during sampling in 2020. Thirty-five juvenile salmon could not be identified to the species level.

Analysis of juvenile Chinook data indicated that Chinook densities in spring 2020 were higher in the control area and north of the causeway than in the inter-causeway area. In summer, no difference in Chinook densities were detected north and south of the causeway, however, Chinook densities in the control area were higher than north and south of the causeway. Brackish marshes, which are distributed along the shorelines at and near the river mouth, are the first habitat encountered and the most used by outmigrating Chinook salmon. Brackish marshes offer less physiologically stressful and more sheltered habitat than the outer flats of the estuary and have been shown to provide rearing opportunities, including food and refuge, to juvenile Chinook salmon. Later in spring (May 2020), juvenile Chinook salmon south of the causeway were found to be larger than north of the causeway and in the control area. As they grow, Chinook adapt physiologically to higher salinities and are capable of transitioning later in spring to rearing habitats away from the river mouth, including in the inter-causeway area.

Analysis of juvenile chum data presented in this report detected no difference in juvenile chum densities in spring 2020 between the two locations of the impact area, i.e., north and south of the causeway. Due to low chum salmon catches in the control area, data from the control area were excluded from the analysis as the models could not run. Also, very few juvenile chum salmon were caught in summer 2020 and were excluded from the analysis. Juvenile chum salmon generally acclimatize to higher salinities faster than juvenile Chinook salmon, which allows them to disperse readily from brackish habitats at the river mouth onto the more saline outer flats of the estuary during outmigration. Later in spring (May 2020), juvenile chum salmon south of the causeway were found to be larger than north of the causeway and in the control area. This is likely indicative of estuarine growth, consistent with patterns observed in previous studies conducted in the early 1980s in the inter-causeway area. Caution should be applied when interpreting analysis results for juvenile chum salmon, due to variability in abundance, spatial distribution across habitats, movements, and behaviour that are characteristic of juvenile chum salmon during estuarine residency.

Overall, the objectives of the juvenile salmon FUP element for 2020 were achieved. Results presented in this report describe current (2020) conditions of juvenile Chinook and chum salmon density and distribution in the study area. They also constitute the first year of a pre-project construction data set that will be used, if the project is approved to be built, to evaluate post-project construction changes in juvenile salmon densities and distribution north and south of the causeway and in the control area. The data set will ultimately be used to verify whether or not project changes in the productivity of juvenile salmon, including Chinook and chum, are negligible, as predicted in the EIS for RBT2.

Based on the 2020 study, six recommendations have been put forward for the juvenile salmon FUP element, and are summarized below. These recommendations are intended to improve the study design and data analysis and will be discussed with Indigenous groups as part of the port authority's ongoing consultation activities to help inform the 2021 study design.

- **Recommendation 1:** Sampling in 2021 and future years is recommended to start on April 1 to capture the greater length of the spring outmigration period of juvenile Chinook and chum salmon.
- **Recommendation 2:** It is recommended that the 2013 dataset (collected by Archipelago 2014a) not be considered as a pre-project construction year in the data analyses moving forward, to minimize the large number of zeros (i.e., hauls with no juvenile salmon in the catch) in future data analyses and between year comparisons. It is noted that data in 2013 were collected using a different study design and to meet a set of objectives that differed from those of the juvenile salmon FUP element.
- **Recommendation 3:** It is recommended that a minimum of two additional years of sampling be added to the 2020 dataset for a total of three years before project construction, as confirmed by the results of the 2020 power analysis.
- **Recommendation 4:** It is recommended that the 2020 power analysis be re-run each year following data collection to confirm or refine the study design, including number of sampling years required before and after project construction as well as sampling design.

- **Recommendation 5:** It is recommended that the efficacy of Westham Island as a control area for juvenile chum salmon in the BACI study be further evaluated with additional years of data. It is also proposed that the use of other sources of information (e.g., chum smolt index that may be available by Fisheries and Oceans Canada (DFO) be evaluated as a potential control for year to year variability in the Fraser River population of juvenile chum salmon.
- **Recommendation 6:** It is recommended that the influence of environmental factors, such as salinity and temperature, on the density and distribution of juvenile Chinook and chum salmon in the study area be investigated with additional years of pre-construction data.

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Abbreviations

B.C.	British Columbia
BACI	before-after-control-impact
°C	degrees Centigrade
CEAA	*Canadian Environmental Assessment Act*
CI	confidence interval
CIAR	Canadian Impact Assessment Registry
CN	causeway north
CS	causeway south
DFO	Fisheries and Oceans Canada
EIS	Environmental impact statement
FUP	Follow-up program
g/kg	grams per kilogram
GLMMs	generalized linear mixed-effects models
ha	hectares
IR	information request
km	kilometres
µS/cm	microSiemens per centimetre
m	metres
m^3	cubic metre
MDD	minimum detectable difference
mg/L	milligram per litre
mm	millimetres
PSU	practical salinity units
RBT2	Roberts Bank Terminal 2
SD	standard deviation
SE	standard error
TFN	Tsawwassen First Nation
UTM	Universal Transverse Mercator
VFPA	Vancouver Fraser Port Authority
WI	Westham Island

Glossary of terms

Term	Definition
Action plan	A plan for a defined course of action, developed if an action threshold is exceeded as a result of project related activities. It identifies the actions that will be taken, along with the time frame, to address the action threshold exceedance.
Action threshold	The specific value or level (expressed as a unit of measurement or category) of an indicator parameter above/beyond which the adaptive management process is triggered (e.g., 25% decrease in density relative to baseline). There can be more than one action threshold for a FUP element (e.g., associated with different indicator parameters).
Adaptive management measure	Corrective action (e.g., modification of existing mitigation or implementing new mitigation) taken to address adverse effects identified through the adaptive management process.
Control area	A defined geographical area that will not be impacted by the project or specific activity to be evaluated (e.g., area where project related effects will not occur), selected to serve as a comparative reference for evaluation of negative or positive effects.
FUP element	A sub-program of the project's overall follow-up program (FUP) that has been selected to verify the accuracy of the assessment of project effects or mitigation effectiveness.
Impact area	A defined geographical area, within the broader study area, that is the zone of potential impact by a project component or activity, where monitoring for potential adverse effects takes place.
Indicator parameter	The specific monitoring parameter (e.g., juvenile crab density) that is used to evaluate the condition(s) of the monitoring component that are linked to the action thresholds. Specific values, levels, or degrees of change in the indicator parameter in comparison to the action threshold are considered indicative of a potential adverse effect or indicative of project mitigation effectiveness. There may be more than one indicator parameter for a FUP element.
Monitoring component	A characteristic of the physical, biophysical, or human environment that is being monitored by a FUP element (e.g., intertidal marsh vegetation establishment, Great Blue Heron abundance).
Monitoring parameter	A metric associated with a monitoring component, that is measured during monitoring (or as part of another program) and is anticipated to be used for analysis of monitoring results (e.g., intertidal marsh percent cover, stem density and length, species diversity index).
Monitoring period	The period of time within a reporting year when data collection takes place (e.g., spring monitoring period, defined as March through June)
Ocean-type life history	Chinook salmon with ocean-type life history outmigrate to sea during their first year of life; they are also referred to as subyearlings
Sampling site	A specific point in space where data collection occurs (e.g., multiple sampling sites along a transect).
Study area	The geographical area where all aspects of the study take place. The study area encompasses all sub-areas including control areas, impact areas and sampling sites, and other defined areas as applicable.

1. Introduction

At the request of the Vancouver Fraser Port Authority (port authority), Hemmera Envirochem Inc. (Hemmera) is pleased to provide the 2020 annual data report of the Roberts Bank Terminal 2 (RBT2 or project) follow-up program (FUP) element for juvenile salmon. The objectives of this report are to: (i) summarize methods deployed in the field in spring and summer 2020 to collect juvenile salmon data that will form part of a pre-project construction dataset, (ii) describe the approach to the data analysis, (iii) summarize and interpret the results of the data analysis, and (iv) put forward recommendations related to aspects of the study for the juvenile salmon FUP element, including recommendations to modify the study design and data analysis, if required.

1.1. Background

The RBT2 is a proposed new container terminal at Roberts Bank in Delta, British Columbia (B.C.) and is located adjacent to Tsawwassen First Nation (**Appendix A**, **Figure A1**). The project includes the following components:

- A new marine container terminal with capacity for 2.4 million twenty-foot equivalent containers annually
- A widened causeway to accommodate additional road and rail infrastructure to link existing road and rail networks to the new marine container terminal
- An expanded existing tug basin to accommodate additional tugs and a second tug operations contractor

A FUP is required for the project under the *Canadian Environmental Assessment Act* (*CEAA*)*, 2012*. A FUP is "a program for *verifying the accuracy* of the environmental assessment of a designated project, and determining the *effectiveness* of any mitigation measures" (emphasis added). The FUP consists of a number of FUP elements, each of which is focused on a specific topic identified during the environmental assessment process.

Each project FUP element involves implementing a monitoring study or program focused on a specific monitoring target (or multiple targets), the results of which are used to verify project effects predictions or monitor the effectiveness of mitigation measure(s). Where monitoring results indicate an exceedance of an action threshold, an adaptive management approach is employed that aims to: (a) confirm the monitoring results; (b) evaluate whether the exceedance is project-related; and (c) develop an action plan that may include new or modified adaptive management measures.

1.2. Study overview

As part of the assessment of potential project effects on juvenile salmon (described in the Environmental Impact Statement (EIS; VFPA 2015) and expanded on in the response to information requests (IR) 5-18 and 5-22 in Canadian Impact Assessment Registry (CIAR) Document #1153 (VFPA 2018a)), placement of the marine terminal in subtidal waters was predicted to potentially disrupt outmigration of juvenile Chinook and chum salmon when rearing at Roberts Bank and potentially limit or impede access to rearing habitats in the inter-causeway area (this effect mechanism is henceforth referred to as disruption to outmigration). Disruption to outmigration would result in potential losses in juvenile salmon productivity. To mitigate such losses in productivity the port authority committed to the creation of offsetting habitats, including intertidal marsh and native eelgrass. With mitigation, including offsetting, potential project-related changes in the productivity of juvenile salmon were predicted to be negligible[1] (VFPA 2015). There is uncertainty in the understanding of existing conditions that relate to movement patterns of juvenile Chinook and chum salmon

[1] In the EIS, productivity change was characterized according to the following categories: negligible = 0% to 5% change; minor = 6% to 30% change; moderate = 31% to 60% change; and high = 61% to 100% change (VFPA 2015).

that rear at Roberts Bank and the influence of existing infrastructure on the patterns of juvenile salmon distribution. This uncertainty stems from the absence of empirical data predating the construction of causeways at Roberts Bank and the limited empirical data post-causeway construction (VFPA 2018a). Given this uncertainty, the port authority committed to a FUP element for juvenile salmon to verify assessment predictions.

The purpose of the FUP element for juvenile salmon is to verify whether or not project-related changes in the productivity of juvenile salmon, including Chinook and chum, are negligible, as predicted in the EIS (VFPA 2015). To this end, a before-after-control-impact (BACI) study was designed to evaluate changes in the density of juvenile salmon within one impact area and one control area before and after project construction. Data of juvenile salmon that will be collected before and after project construction will also be used to evaluate shifts in the distribution of juvenile salmon at Roberts Bank that may be causally linked to the project. Density and distribution were selected as monitoring parameters as they constitute measurable metrics of juvenile salmon productivity. This annual data report describes methods and results of the analysis of juvenile salmon data collected in spring and summer 2020 in support of the FUP element for juvenile salmon.

1.3. Connections with other FUP elements

No connections are identified within this reporting period between other project FUP elements and the juvenile salmon FUP element. Data that will be acquired for other FUP elements on physical (e.g., temperature, salinity) and biological (e.g., marine food sources) attributes of the marine environment at Roberts Bank may inform data analysis for this FUP element in subsequent years of sampling before or after project construction. The results of the juvenile salmon FUP element, including those of the 2020 reporting year, will inform the Current Use and Cultural Heritage FUP elements in subsequent years, when those elements have been developed and implemented in consultation with Indigenous groups. At that time, opportunities for the Current Use and Cultural Heritage FUP elements to inform other FUP elements, including the juvenile salmon FUP element, will also be sought.

2. Methods

This section describes the spatial and temporal boundaries of the BACI study, and the methods used to obtain and analyze data on juvenile Chinook and chum salmon collected in spring and summer 2020 as part of pre-project construction monitoring for the juvenile salmon FUP element. Methods used to update, using the 2020 data, the power analysis that was undertaken in 2019 to inform the BACI study design, are also described in this section. Study design, including spatial boundaries of the study, sampling methods frequency, and timing, were informed by input from Indigenous groups solicited during virtual meetings as part of the port authority's ongoing consultation activities for the project. The approach to the data analysis, as well as preliminary and final analysis results, were presented to Indigenous groups during a ground-truthing workshop facilitated by the port authority on October 6, 2020. The ground-truthing workshop was held to provide an opportunity to discuss the data collected, to collaboratively interpret the findings in relation to Indigenous knowledge about juvenile salmon, and to explore next steps for the 2021 sampling program for this FUP element. The workshop and follow up consultation supported the port authority's efforts to integrate Indigenous knowledge and ways of knowing with scientific approaches to enhance the work and support planning and approach decisions about the juvenile salmon FUP element. Input received by Indigenous groups during ongoing consultation activities has been incorporated in relevant sections of this report.

2.1. Study area

The study area of the juvenile salmon FUP element is Roberts Bank and includes one impact area and one control area as part of the BACI study design (**Appendix A**, **Figure A2**). The impact area was selected to include those locations at Roberts Bank where project-related effects to juvenile salmon, such as disruption to outmigration, are predicted to occur. The impact area encompasses the intertidal zone (extending from the high-water mark seaward to zero metre (m) depth Chart Datum) north and south of the Roberts Bank causeway, as well as the subtidal zone adjacent to the seaward end of the existing Roberts Bank terminals (**Appendix A**, **Figure A2**). Within the impact area, two intertidal shore-tied locations were selected, the north (Causeway North) and south (Causeway South) shorelines of the Roberts Bank causeway, to evaluate project-related changes in the density of juvenile salmon. Also, within the impact area, an intertidal location off the Roberts Bank dyke, and two subtidal locations north and south of the existing Roberts Bank terminals were selected to evaluate project-related shifts in the distribution of juvenile salmon.

The control area encompasses the intertidal zone seaward of Westham Island, approximately nine kilometres (km) north of the impact area (**Appendix A**, **Figure A2**). The control area was selected to enable comparison of density of juvenile Chinook and chum salmon in the impact area to an area not affected by the project, and thereby evaluate project effects. The control area forms part of Roberts Bank and is subject to freshwater flows from the main arm of the Fraser River and tidal flushing from the Strait of Georgia. Thus, it possesses similar physical attributes and is subject to similar fluctuations in environmental conditions as the impact area. The control area is also spatially independent from the impact area given that it is located beyond the influence of predicted project-related effects. Also, this control area will not be subjected to major positive or negative changes in land use (e.g., restoration programs, shoreline developments) during the period of implementing this FUP element.

2.1.1. Sampling sites

A total of 24 permanent sampling sites were established to collect juvenile salmon data for the purpose of evaluating project-related changes in density of juvenile Chinook and chum salmon. Five spot sampling sites were also established for the purpose of evaluating project-related shifts in the distribution of juvenile Chinook and chum salmon. For this technical report, data collected at permanent sampling sites were used to compare densities of juvenile Chinook and chum salmon in spring and summer 2020 from north and south of the Roberts Bank causeway to those in the control area. Moreover, data collected within spot sampling sites were used to report on occurrence (i.e., distribution) of juvenile Chinook and chum salmon within areas at Roberts Bank that are not shore-tied.

Eight permanent sampling sites were established along each of the north shoreline (CN: Causeway North) and the south shoreline (CS: Causeway South) of the Roberts Bank causeway. Eight sites were also established in the control area (WI: Westham Island; **Appendix A**, **Figure A2**). Permanent sampling sites represent shore-tied intertidal habitats that are located alongshore the Roberts Bank causeway and Westham Island and are easily accessible by foot. Their locations were selected randomly using a grid made up of 100 m × 100 m cells. The space within each cell was considered discrete, thus a sampling site within a cell was assumed to be representative of the entire cell. Slight shifting of five of the randomly selected sites was deemed necessary following field reconnaissance to facilitate access and allow for effective sampling; these modifications are described in detail below.

The locations of five permanent sampling sites were modified during the first month of the sampling program. The two easternmost sites on the north and the south sides of the causeway (i.e., CN1, CN2, CS1 and CS2) were shifted west to avoid higher elevation along the landward section of the Roberts Bank causeway and short duration of flooding tides resulting in shallow depths that hampered effective sampling. CN1 was shifted west by approximately 500 m, while CN2, CS1 and CS2 were shifted west by approximately 250 m. Additionally, CN7 was shifted north by approximately 400 m to allow for easier access on foot through the property of Westshore Terminals.

Spot sampling sites included two shallow subtidal sites within the eelgrass bed north of the Roberts Bank causeway (i.e., EG1 and EG2 in **Appendix A**, **Figure A2**, also sampled during the project's 2012 and 2013 field surveys; Archipelago 2014a,b) and two subtidal sites in the inter-causeway area south of the existing Roberts Bank terminals (i.e., OS7 and OS8 in **Appendix A**, **Figure A2**, also sampled during the project's 2012 and 2013 field surveys; Archipelago 2014a).

Following consultation on the study design, additional sampling was requested by Tsawwassen First Nation (TFN) to be undertaken off the Roberts Bank dyke to incorporate shore-tied habitats in the impact area that are similar in physical (e.g., exposure) and biological (i.e., presence of intertidal marsh) conditions to the Westham Island foreshore. The port authority undertook a desktop exercise to examine the feasibility of additional sampling along the Roberts Bank dyke as proposed by TFN, and determined that high tides in spring 2020 would likely not yield sufficient depths for deploying the beach seine effectively. To address

TFN's input, the port authority proposed a sandflat site in proximity to the Roberts Bank dyke (i.e., SF1 shown in Figure 3 of Archipelago 2014a, sampled during the project's 2012 and 2013 field surveys) with similar characteristics as the permanent sites off Westham Island. Field reconnaissance in early May 2020 revealed that tides during the second half of May 2020 would be sufficient to beach seine effectively along the Roberts Bank dyke. The port authority selected a spot sampling site adjacent to the Roberts Bank dyke consistent with TFN's original request (SF1 shown in **Appendix A**, **Figure A2**). During the ground-truthing workshop on October 6, 2020, TFN contributed that there was a big empty pass that was not proposed to be sampled between Canoe Passage and the Roberts Bank causeway, as well as the two spot sampling sites in the eelgrass bed north of the existing Roberts Bank terminals (**Appendix A**, **Figure A2**). The addition of SF1 proposed by TFN addressed that gap and will help in understanding the distribution of juvenile salmon across the Roberts Bank tidal flats.

2.2. Temporal scope

Sampling was undertaken in spring and summer 2020. Each permanent sampling site (**Appendix A**, **Figure A2**) was visited on foot four times in spring (April and May) and four times in summer (June and July) of 2020. Spot sampling sites were sampled at a reduced level of effort. EG1, EG2, OS7 and OS8 (**Appendix A**, **Figure A2**) were visited by boat once in summer (June); sampling by boat in spring 2020 was not possible due to restrictions associated with the COVID-19 pandemic. SF1 was sampled on foot once in spring (May) and twice in summer (June and July).

Spring sampling coincided with the outmigration of juvenile Chinook salmon that belong to the ocean-type Fall Chinook stock aggregate. Fall Chinook juveniles arrive at Roberts Bank from the Harrison River in early March and reside until late July, with outmigration peaking between late April and early May (Scott et al. 2019). Spring sampling also coincided with the outmigration of juvenile chum salmon, which occurs between February and June, and peaks between mid-March and late April (Beacham and Starr 1982, Chalifour et al. 2019).

Summer sampling coincided with the outmigration of juvenile Chinook salmon that belong to the ocean-type Summer 4_1[2] Chinook stock aggregate, which arrive at Roberts Bank from the Lower and South Thompson rivers in late May to early June and reside until late August (VFPA 2018c, Scott et al. 2019). Juvenile Chinook and chum salmon have been shown to rear at Roberts Bank predominantly (e.g., Archipelago 2014a, Chalifour et al. 2019). Juvenile Chinook salmon that rear at Roberts Bank have been shown to exhibit an ocean-type life history and originate from the Harrison and Thompson River systems (VFPA 2018c, Scott et al. 2019).

2.3. Data collection

Sampling to support the juvenile salmon FUP element was undertaken in spring and summer 2020 under the authority of the following licenses and authorizations:

- DFO license XHAB 68 2020 issued by DFO on April 22, 2020 for scientific purposes, and amended on May 15, 2020
- *Wildlife Act* section 4(4) authorization 39580-20 to enter and conduct juvenile salmon sampling within the Roberts Bank Wildlife Management Area issued by the B.C. Ministry of Forests, Lands, Natural Resource Operations and Rural Development on April 15, 2020

Permanent sites (i.e., all CN, CS, and WI sites; **Appendix A**, **Figure A2**) and SF1 were sampled using a 20 m long x 2 m deep beach seine net with a mesh size of 6 millimetres (mm). Sampling was undertaken during the daytime and three net sets were conducted during each sampling event: set 2 sampled a location adjacent to set 1, and set 3 sampled a location adjacent to set 2. Beach seines were deployed on foot from the shoreline and the volume of water sampled depended on water depth along the shoreline. For each of

[2] Chinook age and life history type are expressed as a group of numbers. In the Gilbert and Rich (G-R) format (e.g., 4_1), the large number (i.e., 4) represents the age of the salmon on its next birthday. The subscript number (i.e., $_1$) represents the year in which the fish migrated to the ocean (i.e., it migrated as a 1-year-old in its second year of life).

the three sets, the net was set perpendicular to shore and pulled manually along the beach at a constant speed (15 m per minute) toward the shore for the length of the net. After the net was pulled over the entire distance, the seaward end of the net was brought to shore by pivoting it around the onshore end, and the entire net was pulled onto the beach ensuring that the lead line was in contact with the seabed, such that fish would not escape under the net. After each tow, the catch was transferred immediately and with care to aerated containers (one per set). Fish were processed, including identification to the lowest taxonomic level (species to the extent feasible), and enumerated. Length-weight measurements were taken of juvenile salmon caught. All processed fish were live released near the point of capture. Photos representative of sampling efforts and salmon species caught in spring and summer 2020 are included in **Appendix C**.

Subtidal spot sampling sites were accessed by boat during high tide, and sampling was conducted without disembarking the vessel. EG1 and EG2 (**Appendix A**, **Figure A2**) were sampled using a 20 m long x 2 m deep beach seine net with a mesh size of 6 mm. OS7 and OS8 (**Appendix A**, **Figure A2**) were sampled using a 32 m long x 4.5 m deep purse seine net with mesh size of 6 mm. Both beach and purse seine nets were deployed from a boat, which was used to bring the net around the site. The net was then cinched up and slowly hauled aboard the boat. Three net sets were conducted during each sampling event. Fish were carefully transferred into aerated containers and processed as described above.

Field data was collected using waterproof iPad devices containing preloaded, formatted data forms. Universal Transverse Mercator (UTM) coordinates at each sampling site were taken using a handheld GPS. Digital video cameras, part of the iPad device, were used to document representative species. Electronic back-ups were conducted at the end of each field day onto a laptop computer.

Detailed information collected by the field crew for each net tow included the following:

- Date and time of sampling by sampling site.
- Water temperature (degrees Centigrade; °C), conductivity (microSiemens per centimetre (µS/cm); a proxy of salinity (practical salinity units; PSU), dissolved oxygen (milligrams per litre; mg/L), and water depth at time of sampling using a YSI ProDSS multiparameter water quality meter.
- Digital photo numbers
- Tidal state (i.e., ebb, flood)
- Tow duration (start and end tow time), direction (with or against current), and distance covered
- Identity of all fish captured to the lowest taxonomic level (species to the extent feasible)
- Number of fish
- Measurement (mm; fork length) and weight (g) recorded of all juvenile salmon, or a sub-sample of 30 fish per species if large numbers were captured
- Life history stage (i.e., juvenile, adult), sex (if possible) and condition (e.g., fin erosion, injury, lesions, mortality, pregnant, or physical abnormality) through visual inspection

Data from the field sheets were transcribed into Excel tables.

During sampling in spring and summer 2020, DNA tissue from juvenile Chinook salmon was collected following DFO's DNA sampling protocol (DFO 2009). During sampling events that yielded more than 15 juvenile Chinook salmon, fin clips were taken from ten juvenile Chinook salmon. An attempt was made to collect equal amounts of DNA samples from north and south of the causeway and from Westham Island. Fin clips were stored in vials containing 95% non-denatured ethanol solution (at a ratio of one-quarter tissue and three-quarters ethanol). Vials were numbered, accompanied by a standard reporting (Excel) sheet, and will be submitted in the future to a molecular genetics lab, not determined yet, for processing. The genetics analysis results will be used to inform the stock composition of juvenile Chinook salmon rearing at Roberts Bank, and results will be presented in an addendum to this report.

Video footage of fieldwork activities was taken and shared with Indigenous groups to facilitate remote Indigenous involvement due to restrictions associated with the COVID-19 pandemic. Video footage was taken during surveys on May 21, June 22, June 25, and July 6, 2020, using a GoPro Hero 7. The objective of the video footage was to capture key aspects of sampling during a typical day of fieldwork. Such key aspects included the health and safety pre-start meeting, water quality measurements, seine net cast and haul, fish identification and processing, and the live release of captured fish. Moreover, updates on sampling activities, including a breakdown of the catch composition, was provided to Indigenous groups on a weekly basis during the study period.

2.4. Data management and analysis

This section describes data management procedures that were followed as well as the methods used to analyze the data collected in spring and summer 2020 as part of the juvenile salmon FUP element.

2.4.1. Data management

The following measures were employed to ensure data were collected, stored and processed in a consistent and rigorous manner:

- Data were auto-synchronized directly from iPad to a master database (arcSDE)
- The field crew lead completed detailed quality checks and electronic back-ups after each day of sampling to ensure consistency in the data collected and to resolve immediately any outliers
- Datasheets on waterproof paper were available in case of failure of electronic devices during data collection

2.4.2. Data analysis

Methods used to analyze data collected in spring and summer 2020 on juvenile salmon abundance and density (**Section 2.4.2.1**), distribution (**Section 2.4.2.2**), body size (i.e., fork length) (**Section 2.4.2.3**), and water quality (**Section 2.4.2.5**) are described in this section. Methods to update the power analyses that were undertaken in 2019 to inform the BACI study design are described in **Section 2.4.2.4**.

2.4.2.1. Abundance and density

Mean abundance (with standard deviation (SD)) was estimated using descriptive statistical analysis of juvenile salmon raw data collected during sampling in spring and summer 2020 at permanent sites in the impact and control areas. For each sampling site, the three net sets were summed for a total juvenile salmon count per sampling event at each site. Mean abundance was calculated across sampling events by location and season.

Marginal mean density (number of fish caught per cubic metre (m^3) of sampled water) was also calculated from abundance after accounting for the following factors: sampling location (north and south of the causeway and Westham Island), season (spring: April, May; summer: June, July), tidal stage (ebb and flood tide) and time of day (morning: 6 am – 10 am; midday: 10 am – 2 pm; afternoon: 2 pm – 6 pm: night: 6 pm – 10 pm). Marginal mean density is the metric used in this report to report on differences in juvenile salmon density north and south of the causeway and in the control area and is henceforth referred to as density. Differences in the density of juvenile salmon north and south of the Roberts Bank causeway and in the control area were evaluated using generalized linear mixed-effects models (GLMMs or models).

Data analysis focused on juvenile Chinook and chum salmon as they are the two Pacific salmon species that are most estuarine-dependent when rearing (Thorpe 1994, Archipelago 2014a, Moore et al. 2016, Chalifour et al. 2019). They are also the two representative species selected for the assessment presented in the EIS (VFPA 2015).

The GLMMs were fit using the statistical computing software R (R Core Team 2020) to the following data classes: (1) Chinook salmon (spring and summer), (2) Chinook salmon (spring), (3) Chinook salmon (summer), and (4) chum salmon (spring). Data classes of juvenile Chinook salmon were examined for spring and summer combined (item 1 of the above list) as well as separately for spring and for summer (items 2 and 3 of the above list) to investigate potential differences in densities north and south of the causeway and in the control area that are specific to juvenile Fall Chinook (Harrison) in spring and juvenile Summer 4_1 Chinook (South Thompson) in the summer. Except for three individuals caught in June, juvenile chum salmon were caught predominantly during spring sampling.

Models were fit to all data classes of salmon using a negative binomial distribution to account for the number of zeros in the data set (i.e., the number of seine hauls that yielded no juvenile salmon). A GLMM with a negative binomial distribution was selected after checking the data for overdispersion, a condition whereby the variation in the data is greater than expected based on the statistical model selected. A GLMM with a poisson distribution was first investigated and in turn rejected, as the data were found to be over dispersed, likely due to the number of zeros in the data sets.

Variation in the volume of sampled water (i.e., seine net volume) was considered in the analysis by incorporating this factor as an offset[3] in the models. Volume of water sampled at each sampling site was calculated by multiplying the surface area sampled by the beach seine with water depth measured at the site.

The following models were constructed to investigate differences in mean density of juvenile salmon north and south of the causeway and in the control area in a manner that is robust to sampling location, season, tidal stage and time of day:

1. Chinook (spring and summer):

   Chinook density = data class + location + season + tide + time of day + (1|site); offset = log(sampled volume)

2. Chinook (spring):

   Chinook density = data class + location + tide + time of day + (1|site); offset = log(sampled volume)

3. Chinook (summer):

   Chinook density = data class + location + tide + time of day + (1|site); offset = log(sampled volume)

4. Chum (spring):

   Chum density = data class + location + tide + time of day + (1|site); offset = log(sampled volume)

Juvenile salmon densities (with standard error (SE) and confidence intervals (CIs)) in the impact and control areas were estimated using the emmeans[4] package (Lenth et al. 2018) in R. A pairwise comparison was performed using the cld[5] package (Piepho 2004) in R to investigate whether there were statistically significant differences in juvenile salmon densities north and south of the causeway and in the control area (alpha = 0.05).

For those instances where a statistically significant difference in density was not detected, a post-hoc power analysis was performed to investigate whether the data had sufficient statistical power to detect a significant difference. This was achieved by calculating the minimum detectable difference (MDD). A post-hoc power analysis was performed for chum (spring).

2.4.2.2. Distribution

Raw counts were used to report on the numbers of juvenile salmon caught at spot sampling sites in spring and summer 2020. Comparisons between years and among spot sampling sites will be explored in future

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[3] An offset is a model variable that was used to adjust fish count data for the volume of sampled water.

[4] emmeans – estimated marginal means

[5] cld – compact letter display

reports to investigate project-related shifts in juvenile salmon distribution. Further analysis of the 2020 data was not possible due to the small number of sampling events in 2020, truncated due to COVID-19 restrictions (EG1, EG2, OS7 and OS8 were sampled once during summer, and SF1 once in spring and twice in summer).

2.4.2.3. Body size

Descriptive statistical analysis was undertaken to determine the distribution of body size (in terms of mean fork length with SD) of juvenile Chinook and chum salmon caught along the north and south shorelines of the Roberts Bank causeway and along Westham Island. GLMMs were also used to test for differences in mean fork length of juvenile salmon in the impact area (north and south of the Roberts Bank causeway) and in the control area. Analysis of fork length data is intended to inform how increases in body size (and by inference in age) of juvenile Chinook and chum salmon may influence their distribution when rearing at Roberts Bank.

The following factors were accounted for in the data analysis: sampling location (north and south of the causeway and Westham Island) and month (April and May). Only spring data were used in the analysis of juvenile salmon fork length due to the paucity of summer catch and length measurements in the data set. The following GLMM was constructed and applied to Chinook (spring) and chum (spring) data classes to investigate differences in mean fork length of juvenile salmon north and south of the causeway and at Westham Island after accounting for sampling location and month in spring:

Fork length = data class + location + month + location*month; offset = log(sampled volume)

A pairwise comparison was performed to investigate whether there were statistically significant differences in juvenile salmon mean fork length between north and south of the causeway and in the control area (alpha = 0.05).

2.4.2.4. 2020 power analysis

This section describes the methodology used to update the power analysis that was undertaken in 2019 (henceforth referred to as the 2019 power analysis) to evaluate if a juvenile salmon FUP element would be feasible to detect changes in juvenile salmon densities within an impact and a control area, before and after project construction, consistent with the port authority's updated project commitment #81 (VFPA 2019). In 2019, a power analysis was completed to inform the BACI study design by exploring the feasibility of various design and sampling scenarios (i.e., number of sampling sites, number of visits per sampling site, number of net sets per visit, and number of years of sampling) that would achieve 80% power to detect a 50% change in juvenile salmon density due to the project. The 2019 power analysis used juvenile salmon data collected in 2013 during empirical field surveys undertaken for the project (Archipelago 2014a,b). The 2013 dataset included a large number of zeros (i.e., beach seine hauls that yielded no juvenile salmon catches). Thus, it was supplemented with juvenile salmon data collected in 2016 and 2017 by Chalifour et al. (2019[6]) so that variance for the power analysis could be estimated. An optimal BACI study design was developed and implemented in 2020. The 2019 power analysis was updated in 2020 by incorporating data collected in spring and summer 2020. This minimized the influence of the large number of zeros in the datasets and accounted for data collected in 2020 in the control area. The updated power analysis is henceforth referred to as the 2020 power analysis.

The 2020 power analysis considered the following two effects pathways as part of the BACI study design developed in 2019 for the juvenile salmon FUP element: (i) a project-related change in juvenile salmon densities between the impact area (i.e., north and south of the Roberts Bank causeway combined) and the control area, and (ii) a project-related change in juvenile salmon densities separately between the north and south of the Roberts Bank causeway and the control area (i.e., between north and south of the causeway; between north of the causeway and the control area; and between south of the causeway and

[6] Chalifour et al. (2019) juvenile salmon data open access at https://zenodo.org/record/4290894#.X85mK_ZFw2x.

the control area). The following model, used in the 2020 power analysis, describes project-related changes in juvenile salmon density (*D*) as a function of area and time:

$$\mathrm{g}(D) \sim Location + Period + Location \times Period,$$

where *Location* represents areas of sampling north and south of the Roberts Bank causeway and along Westham Island, and *Period* represents the "before and after project construction" time component. This was assumed to be zero in 2020 as the project has not been constructed yet. The interaction term *Location* x *Period* represents the project effect.

The 2020 power analysis was completed using the following linear mixed model to estimate the variance of a BACI study design to inform the 2020 power analysis:

$$\log(\bar{D} + 1/3) = X\boldsymbol{\beta} + u_l + v_t + z_{l:t} + \epsilon.$$

Mean juvenile salmon density ($\bar{D}$) was modelled as a function of the fixed effects ($X\boldsymbol{\beta}$). Random effects are represented by terms for repeated visits to sampling sites (u), years (v), and within location and year ($z_{l:t}$). Because a linear model was used, the observed density was log transformed to improve fit and a term of 1/3 was added to avoid the log of zero. Models were fit in the statistical computing software R (R Core Team 2020) using glmmTMB (Brooks et al. 2017) or lme4 (Bates et al. 2015). Power was calculated using methods described in Stroup (1999) and Schwarz (2019) for power analysis using linear mixed models.

The 2019 power analysis method was updated in 2020 to include the control area and allow for power of a pooled estimate (i.e., north and south of the Roberts Bank causeway combined) versus the control area. The 2020 power analysis used data collected by the port authority in 2013 (Archipelago 2014a,b) and in 2020. Data collected in 2016 and 2017 by Chalifour et al. (2019) were not incorporated into the 2020 power analysis, as sampling methods differed from those deployed by the port authority in 2013 and 2020, and also the dataset by Chalifour et al. (2019) contained many zeros.

As was done in 2019, the 2020 power analysis was undertaken separately for the following groups of juvenile Chinook and chum salmon: (i) juvenile Chinook salmon (spring), and (ii) juvenile Chinook salmon (summer), to account for the difference in outmigration timing that characterizes various stocks of ocean-type Chinook salmon (see also **Section 2.2**), and (iii) juvenile chum.

The 2020 power analysis assumed that the study design developed and used during sampling in 2020 would also be employed in future years. Thus, frequency of visits, number of net sets, and number of sampling sites were kept unchanged in the 2020 power analysis. Power was tested using the linear mixed effect model approach by combining these three study design features and a combination of numbers of sampling years before and after project construction as follows:

- Net sets per sampling site: 3
- Visits per sampling site per season: 4
- Sampling sites (north of causeway; south of causeway; Westham Island): 8
- Sampling years: 3-4 before and 4-10 after project construction

2.4.2.5. Water quality

Water conductivity was converted to salinity using a formula by Fofonoff and Millard (1983) and setting water temperature at the reference point of 25°C. Descriptive statistical analysis was then undertaken to determine mean (with SD), minimum and maximum water temperature, salinity, and dissolved oxygen for permanent sampling sites. Similar statistical analysis was not possible for water quality measurements taken at spot sampling sites, due to the small number of sampling events and lack of repeat measurements. Water quality was measured once in summer at all spot sampling sites except for SF1, which was visited once in spring and twice in summer. Analysis of water quality information is intended to inform how environmental parameters may influence the distribution of juvenile Chinook and chum salmon when rearing at Roberts Bank.

3. Results

This section presents the analysis results of the juvenile salmon data collected in spring and summer 2020 as part of the juvenile salmon FUP element. **Section 3.1** describes the composition (in terms of fish species caught) of the overall seine catch. Analysis results on density, distribution and body size are described specifically for Chinook salmon (spring and summer – **Section 3.2.1**; spring – **Section 3.2.2**; summer – **Section 3.2.3**), and for chum salmon (spring – **Section 3.2.4**). Results of the 2020 power analysis are presented in **Section 3.2.5**. Water quality in the impact and control areas is described in **Section 3.2.6**. Lastly, gaps and limitations encountered during the data analysis are described in **Section 3.3**.

3.1. Catch composition

Sampling was undertaken during 199 sampling events as described in **Section 2.2**. Overall, 594 of the anticipated 597 net sets were completed. Three net sets could not be completed on April 23, 2020 at CS3 (one net set due to technical issues when deploying the beach seine) and at CN8 (two net sets due to a large seine haul of juvenile pink salmon caught in the first net set that took too long to process during a fast receding tide).

A total of 44,316 fish were caught at Roberts Bank from April 23, 2020 to July 31, 2020, belonging to 26 species and 18 families (**Table 3-1**). The number of fish by species and sampling site caught during permanent and spot sampling in spring and summer 2020 is provided in **Appendix B**. Juvenile salmon comprised 22.6% of the total catch (i.e., 10,006 juvenile salmon out of 44,316 individuals). Juvenile pink accounted for 57.1% of the juvenile salmon catch (5,718 out of 10,006 juvenile salmon), followed by Chinook (36.1%, 3,610 individuals) and chum (6.4%, 639 individuals). Only three juvenile coho (*Oncorhynchus kisutch*) and one juvenile sockeye (*Oncorhynchus nerka*) salmon were caught during sampling in 2020. Thirty-five juvenile salmon could not be identified to the species level.

Of the non-salmonid fish species, shiner perch (*Cymatogaster aggregata*) accounted for 36.9% (12,654 of 34,310 individuals; **Table 3-1**), followed by sculpins (Cottidae; 25.7%, 8,816 individuals), threespine stickleback (*Gasterosteus aculeatus*; 16.7%, 5,724 individuals), and peamouth chub (*Mylocheilus caurinus*; 10.7%, 3,658 individuals). Eighty fish and 145 larval fish caught could not be identified to the species or family level. Thirty two fish suffered mortality, of which 21 were juvenile pink salmon (**Table 3-2**). In total, 347 fin clippings were collected from juvenile Chinook salmon.

Table 3-1 Number of marine fish species caught at Roberts Bank from April 23, 2020 to July 31, 2020

Species	Scientific name	Family	Count
Pacific salmon			
Chinook salmon	*Oncorhynchus tshawytscha*	Salmonidae	3,610
Chum salmon	*Oncorhynchus keta*		639
Coho salmon	*Oncorhynchus kisutch*		3
Pink salmon	*Oncorhynchus gorbuscha*		5,718
Sockeye salmon	*Oncorhynchus nerka*		1
Unidentified salmon	*Oncorhynchus* sp.		35
Total Pacific salmon			*10,006*
Other species			
Bay goby	*Lepidogobius lepidus*	Gobiidae	111
Bay pipefish	*Syngnathus leptorhynchus*	Syngnathidae	17
English sole	*Parophrys vetulus*	Pleuronectidae	4

Species	Scientific name	Family	Count
Kelp greenling	*Hexagrammos decagrammus*	Hexagrammidae	1
Pacific herring	*Clupea pallasii pallasii*	Clupeidae	456
Pacific sandlance	*Ammodytes personatus*	Ammodytidae	230
Pacific snake prickleback	*Lumpenus sagitta*	Stichaeidae	54
Pacific staghorn sculpin	*Leptocottus armatus*	Cottidae	2,110
Peamouth chub	*Mylocheilus caurinus*	Cyprinidae	3,658
Penpoint gunnel	*Apodichthys flavidus*	Pholidae	2
Saddleback gunnel	*Pholis ornata*	Pholidae	1
Shiner perch	*Cymatogaster aggregata*	Embioticidae	12,654
Smoothhead sculpin	*Artedius lateralis*	Cottidae	597
Speckled sanddab	*Citharichthys stigmaeus*	Paralichthyidae	12
Starry flounder	*Platichthys stellatus*	Pleuronectidae	1,221
Surf smelt	*Hypomesus pretiosus*	Osmeridae	217
Tadpole sculpin	*Psychrolutes paradoxus*	Psychrolutidae	1
Threespine stickleback	*Gasterosteus aculeatus*	Gasterosteidae	5,724
Tidepool sculpin	*Oligocottus maculosus*	Cottidae	9
Tube-snout	*Aulorhynchus flavidus*	Aulorhynchidae	14
Whitespotted greenling	*Hexagrammos stelleri*	Hexagrammidae	1
Unidentified flatfish	N/A	Pleuronectidae	871
Unidentified greenling	N/A	Hexagrammidae	8
Unidentified gunnel	N/A	Pholidae	11
Unidentified kelpfish	N/A	Clinidae	1
Unidentified larval fish	N/A	N/A	145
Unidentified sculpin	N/A	Cottidae	6,100
Unknown	N/A	N/A	80
Total other species			*34,310*
Total all fish			**44,316**

Table 3-2 Number of marine fish mortalities associated with sampling at Roberts Bank from April 23, 2020 to July 31, 2020

Species	Scientific name	Family	Mortality count
Pacific salmon			
Pink salmon	*Oncorhynchus gorbuscha*	Salmonidae	21
Chum salmon	*Oncorhynchus keta*		1
Chinook salmon	*Oncorhynchus tshawytscha*		4
Total Pacific salmon			*26*
Other species			
Bay goby	*Lepidogobius lepidus*	Gobiidae	1
Pacific herring	*Clupea pallasii pallasii*	Clupeidae	2
Shiner perch	*Cymatogaster aggregata*	Embiotocidae	1
Staghorn sculpin	*Leptocottus armatus*	Cottidae	1
Threespine stickleback	*Gasterosteus aculeatus*	Gasterosteidae	1
Total other species			*6*
Total all fish			**32**

3.2. Data analysis results

This section summarizes results of descriptive statistical analysis of mean abundances (with SE and CIs) for the juvenile Chinook, chum and pink salmon data classes based on data collected during sampling at permanent (north and south of the Roberts Bank causeway and Westham island) and spot sites. Tabular and graphical representations of GLMM applications are also described below regarding differences in the density of juvenile Chinook and chum salmon north and south of the causeway and in the control area that account for sampling location, season, tidal stage and diel differences. Mean fork length and SD for juvenile Chinook and chum salmon caught north and south of the causeway and along Westham Island are also reported on by sampling season. Data analysis results are described below for Chinook salmon (spring and summer – **Section 3.2.1**; spring – **Section 3.2.2**; and summer – **Section 3.2.3**), and for chum salmon (spring – **Section 3.2.4**).

3.2.1. Chinook salmon (spring and summer)

This section presents results for juvenile Chinook salmon caught in spring and summer 2020. Results on abundance and density are presented in **Section 3.2.1.1**, on distribution in **Section 3.2.1.2**, and on body size in **Section 3.2.1.3**.

3.2.1.1. Abundance and density

Mean abundance (with SE and CI) of juvenile Chinook salmon caught in beach seines north and south of the Roberts Bank causeway and along Westham Island in spring and summer 2020 are shown in **Table** 3-3. During spring and summer 2020, 1,664 and 643 juvenile Chinook were caught respectively north and south of the Roberts Bank causeway, and 1,185 individuals along Westham Island, for a total catch of 3,492 juvenile Chinook salmon. Mean abundance of juvenile Chinook salmon north of the causeway was 26 individuals (± 63 SD), south of the causeway 10 individuals (± 39 SD), and along Westham Island 19 individuals (± 22 SD).

When sampling location, season, tidal stage and time of day were considered, density of juvenile Chinook salmon was found to be higher (different groupings of 1 and 2 shown in **Table 3-3**; see also **Figure 3-1**) north of the causeway and at Westham Island (0.04 ± 0.01 SE for both locations) than south of the causeway (0.01 ± 0.00 SE).

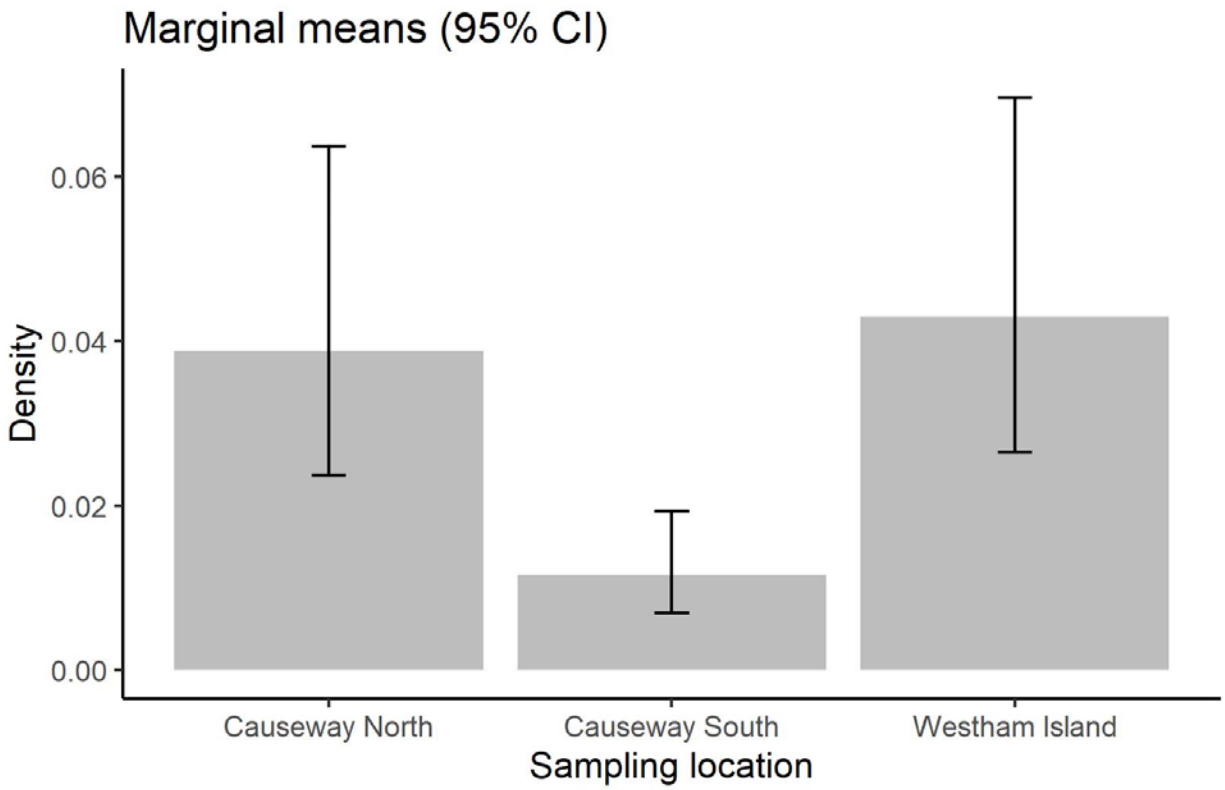
Table 3-3 Mean abundance (with standard deviation) and density (with standard error and confidence intervals) of juvenile Chinook salmon caught in beach seines in the impact area (north and south of the Roberts Bank causeway) and in the control area in spring and summer 2020

Parameter	Impact area		Control area
	Causeway North	Causeway South	Westham Island
Number of sampling events	64	64	64
Number of fish caught	1,664	643	1,185
Mean abundance (raw data)	26	10	19
Standard deviation	63	39	22
Density	0.04	0.01	0.04
Standard error	0.01	0.00	0.01
Lower confidence interval	0.02	0.01	0.03
Upper confidence interval	0.06	0.02	0.07
Grouping	1	2	1

Notes:

- Impact area: Causeway North – CN1-8 and Causeway South – CS1-8; Control area: Westham Island – WI1-8 (see **Appendix A**, **Figure A2**)
- Mean abundance (raw data) – mean abundance of juvenile Chinook salmon (spring and summer) calculated using raw data counts
- Density – mean abundance of juvenile Chinook salmon (spring and summer) per cubic metre of sampled water, after accounting for sampling location, season, tidal stage and time of day (calculated using the emmeans package in R)
- Confidence intervals – 95% of the samples with densities within the range defined by the lower and upper confidence limits
- Grouping – data classes that share group symbols (i.e., 1, 2) are not significantly different in terms of density of juvenile Chinook salmon caught in beach seines in spring and summer 2020 (based on pairwise comparisons using the cld package in R)

Figure 3-1 Density of juvenile Chinook salmon caught in beach seines in the impact area (north and south of the Roberts Bank causeway) and in the control area in spring and summer 2020



Notes:

- Impact area: Causeway North – CN1-8 and Causeway South – CS1-8; Control area: Westham Island – WI1-8 (see **Appendix A**, **Figure A2**)
- Density – mean abundance of juvenile Chinook salmon (spring and summer) per cubic metre of sampled water, after accounting for sampling location, season, tidal stage and time of day (calculated using the emmeans package in R)
- Bars – upper and lower (95%) confidence intervals.
- Confidence intervals – 95% of the samples with densities within the range defined by the lower and upper confidence limits

3.2.1.2. Distribution

Spot sampling in spring and summer 2020 yielded 38 juvenile Chinook salmon. Of these, 32 were caught during a single spot sampling event at SF1 (**Appendix A**, **Figure A2**) in spring (May 23, 2020). Spot sampling at SF1 in summer 2020 yielded no juvenile Chinook salmon catches. Six juvenile Chinook salmon were caught during spot sampling in the subtidal zone. Five and one juvenile Chinook salmon were caught at EG1 and EG2 (**Appendix A**, **Figure A2**), respectively, while no juvenile Chinook salmon were caught at OS7 and OS8 (**Appendix A**, **Figure A2**).

3.2.1.3. Body size

Fork length recorded for juvenile Chinook salmon caught at permanent sampling sites in spring and summer 2020 ranged from 29 mm to 122 mm with a mean of 49.8 mm ± 8.5 SD (number of individuals measured (n) = 2,680). North of the causeway, fork length ranged from 32 mm to 122 mm with a mean of 48.1 mm ± 8.8 SD (n = 1,102), while south of the causeway, fork length ranged from 37 mm to 95 mm with a mean of 54.6 mm ± 10.1 SD (n = 393). Along Westham Island, fork length ranged from 29 mm to 108 mm with a mean of 49.7 mm ± 6.9 SD (n = 1,185).

Fork length of juvenile Chinook salmon caught during spot sampling ranged from 41 mm to 107 mm with a mean of 56.6 mm ± 14.8 SD (n = 38).

3.2.2. Chinook salmon (spring)

This section presents results for juvenile Chinook salmon caught in spring 2020. Results on abundance and density are presented in **Section 3.2.2.1**, on distribution in **Section 3.2.2.2**, and on body size in **Section 3.2.2.3**.

3.2.2.1. Abundance and density

Mean abundance (with SD) of juvenile Chinook salmon caught in beach seines north and south of the Roberts Bank causeway and along Westham Island in spring 2020 are shown in **Table 3-4**. During spring 2020, 1,632 and 627 juvenile Chinook salmon were caught respectively north and south of the Roberts Bank causeway, and 1,003 individuals along Westham Island, for a total of 3,262 juvenile Chinook salmon. Mean abundance of juvenile Chinook salmon north of the causeway was 51 individuals (± 82 SD), south of the causeway was 20 individuals (± 54 SD), and along Westham Island was 31 individuals (± 23 SD).

When sampling location, tidal stage and time of day were considered, there was evidence of higher densities (different groupings of 1 and 2 shown in **Table 3-4**; see also **Figure 3-2**) of juvenile Chinook salmon north of the causeway and along Westham Island (0.18 ± 0.05 SE and 0.11 ± 0.03 SE, respectively) than south of the causeway (density of 0.03 ± 0.01 SE).

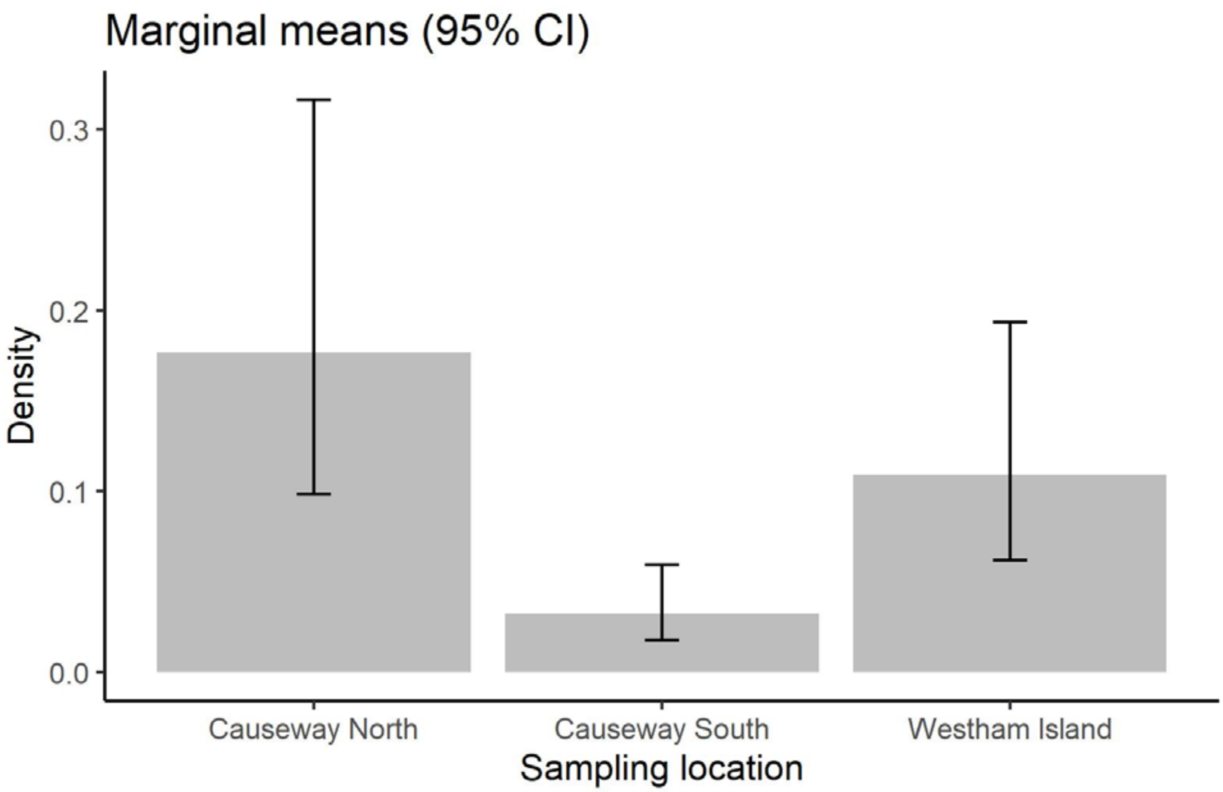
Table 3-4 Mean abundance (with standard deviation) and mean density (with standard error and confidence intervals) of juvenile Chinook salmon caught in beach seines in the impact area (north and south of the Roberts Bank causeway) and in the control area in spring 2020

Parameter	Impact area		Control area
	Causeway North	Causeway South	Westham Island
Number of sampling events	32	32	32
Number of fish caught	1,632	627	1,003
Mean abundance (raw data)	51	20	31
Standard deviation	82	54	23
Density	0.18	0.03	0.11
Standard error	0.05	0.01	0.03
Lower confidence limit	0.10	0.02	0.06
Upper confidence limit	0.32	0.06	0.19
Grouping	1	2	1

Notes:

- Impact area: Causeway North – CN1-8 and Causeway South – CS1-8; Control area: Westham Island – WI1-8 (see **Appendix A**, **Figure A2**)
- Mean abundance (raw data) – mean abundance of juvenile Chinook salmon (spring) calculated using raw data counts
- Density – mean abundance of juvenile Chinook salmon (spring) per cubic metre of sampled water, after accounting for sampling location, tidal stage and time of day (calculated using the emmeans package in R)
- Confidence intervals – 95% of the samples with densities within the range defined by the lower and upper confidence limits
- Grouping – data classes that share group symbols (i.e., 1, 2) are not significantly different in terms of density of juvenile Chinook salmon caught in beach seines in spring 2020 (based on pairwise comparisons using the cld package in R)

Figure 3-2 Density of juvenile Chinook salmon caught in beach seines in the impact area (north and south of the Roberts Bank causeway) and in the control area in spring 2020



Notes:

- Impact area: Causeway North – CN1-8 and Causeway South – CS1-8; Control area: Westham Island – WI1-8 (see **Appendix A**, **Figure A2**)
- Density – mean abundance of juvenile Chinook salmon (spring) per cubic metre of sampled water after accounting for sampling location, tidal stage and time of day (calculated using the emmeans package in R).
- Bars – upper and lower (95%) confidence intervals
- Confidence intervals – 95% of the samples with densities within the range defined by the lower and upper confidence limits

3.2.2.2. Distribution

Only one spot sampling event occurred in spring 2020 at SF1, which yielded 32 juvenile Chinook salmon.

3.2.2.3. Body size

Fork length recorded for juvenile Chinook salmon caught during sampling at permanent sites in spring 2020 ranged from 29 mm to 122 mm with a mean of 49.2 ± 8.4 SD (n = 2,388). North of the causeway, fork length ranged from 32 mm to 122 mm with a mean of 47.8 ± 8.5 SD (n = 1,032). South of the causeway, fork length ranged from 37 mm to 95 mm with a mean of 54.2 ± 10.1 SD (n = 368). Along Westham Island, fork length ranged from 29 mm to 108 mm with a mean of 48.8 ± 6.7 SD (n = 988). Mean fork length of juvenile Chinook caught in April and May 2020 is shown for north and south of the causeway and the control area in **Table 3-5** and **Figure 3-3**.

When the interaction between sampling location and month was considered, there was little evidence of a difference in mean fork length of juvenile Chinook salmon caught in April between north and south of the causeway (p = 0.245; **Table 3-6**) and the control area (north of causeway – Westham Island comparison:

p = 0.386; south of causeway – Westham Island comparison: *p* = 0.745; **Table 3-6**). Juvenile Chinook salmon caught in May 2020 south of the causeway were found to be larger than juvenile Chinook caught north of the causeway (*p* < 0.001; **Table 3-6**) and along the Westham island (*p* < 0.001; **Table 3-6**). Lastly, no difference was detected in mean fork length of juvenile Chinook salmon caught north of the causeway and along Westham Island (*p* = 0.750; **Table 3-6**).

Fork length of juvenile Chinook salmon caught during spot sampling at SF1 ranged from 41 mm to 64 mm with a mean of 51.1 ± 6.2 SD (n = 32).

Table 3-5 Mean fork length (with standard error and confidence intervals) of juvenile Chinook salmon caught in beach seines in the impact area (north and south of the Roberts Bank causeway) and in the control area in spring 2020

Parameter	Impact area				Control area	
	Causeway North		Causeway South		Westham Island	
	April	May	April	May	April	May
Number of sampling events	13	18	8	15	4	23
Number of fish measured	397	635	37	331	249	739
Mean fork length	44.1	49.0	46.1	54.2	45.2	49.6
Standard error	0.5	0.5	1.1	0.7	0.6	0.5
Lower confidence limit	43.1	48.0	43.9	52.8	44.0	48.5
Upper confidence limit	45.2	50.1	48.4	55.7	46.4	50.6

Notes:

- Impact area: Causeway North – CN1-8 and Causeway South – CS1-8; Control area: Westham Island – WI1-8 (see **Appendix A**, **Figure A2**)
- Mean fork length – calculated after accounting for sampling location and month and the interaction between the two (using the emmeans package in R)
- Confidence intervals – 95% of the samples with fork length within the range defined by the lower and upper confidence limits

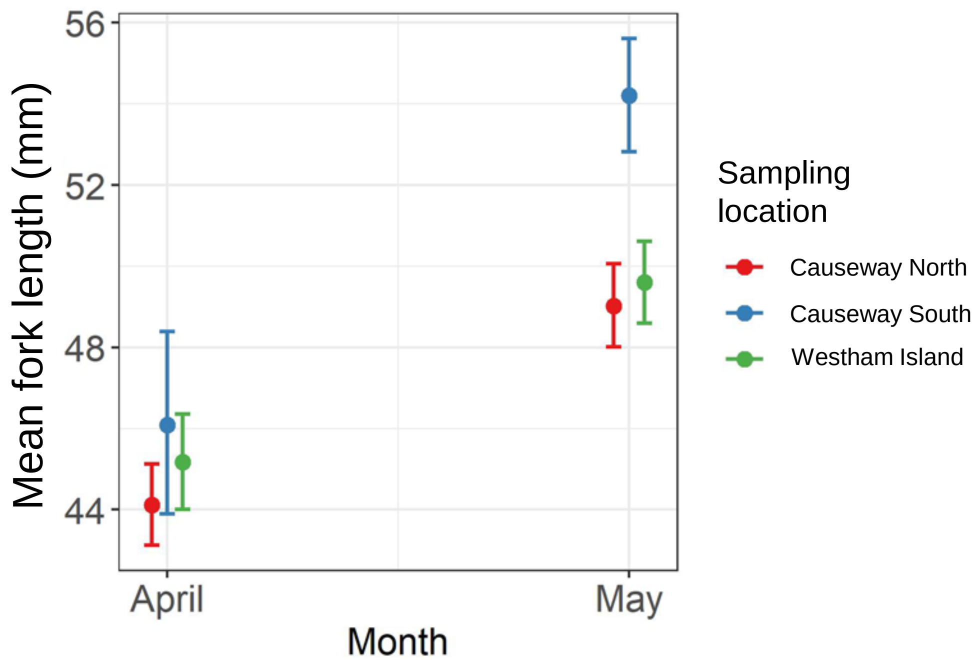
Table 3-6 Pairwise comparisons of fork length of juvenile Chinook salmon caught in spring 2020 in beach seines in the impact area (north and south of the Roberts Bank causeway) and in the control area by month with ratio, standard error and *p* value. Bold font indicates significant result

Month	Comparison	Ratio	Standard error	*p* value
April	Causeway North – Causeway South	0.957	0.026	0.245
	Causeway North – Westham Island	0.977	0.017	0.386
	Causeway South – Westham Island	1.021	0.028	0.745
May	Causeway North – Causeway South	0.905	0.015	**<0.001**
	Causeway North – Westham Island	0.989	0.015	0.750
	Causeway South – Westham Island	1.094	0.018	**<0.001**

Notes:

- Impact area: Causeway North – CN1-8 and Causeway South – CS1-8; Control area: Westham Island – WI1-8 (see **Appendix A**, **Figure A2**)

Figure 3-3 Mean fork length of juvenile Chinook salmon caught in beach seines in the impact area (north and south of the Roberts Bank causeway) and in the control area in spring 2020



Notes:

- Impact area: Causeway North – CN1-8 and Causeway South – CS1-8; Control area: Westham Island – WI1-8 (see **Appendix A**, **Figure A2**)

3.2.3. Chinook salmon (summer)

This section presents results for juvenile Chinook salmon caught in summer 2020. Results on abundance and density are presented in **Section 3.2.3.1**, on distribution in **Section 3.2.3.2**, and on body size in **Section 3.2.3.3**.

3.2.3.1. Abundance and density

Mean abundance (with SD) of juvenile Chinook salmon caught in beach seines north and south of the Roberts Bank causeway and along Westham Island in summer 2020 are shown in **Table 3-7**. During summer 2020, 32 juvenile Chinook salmon were caught north and 16 south of the causeway, and 182 along Westham Island, for a total of 230 juvenile Chinook salmon. Mean abundance of juvenile Chinook salmon north and south of the causeway was 1 individual (± 2 SD), and along Westham Island 6 individuals (± 11 SD).

After accounting for sampling location, tidal stage and time of day, no difference was detected in densities of juvenile Chinook north and south of the causeway (same grouping (i.e., 1); **Table 3-7** and **Figure 3-4**). However, mean density of juvenile Chinook salmon in the control area was found to be higher (0.02 ± 0.01 SE) than in the impact area (0.02 ± 0.01 SE; different groupings of 1 and 2 shown in **Table 3-7**; see also **Figure 3-4**).

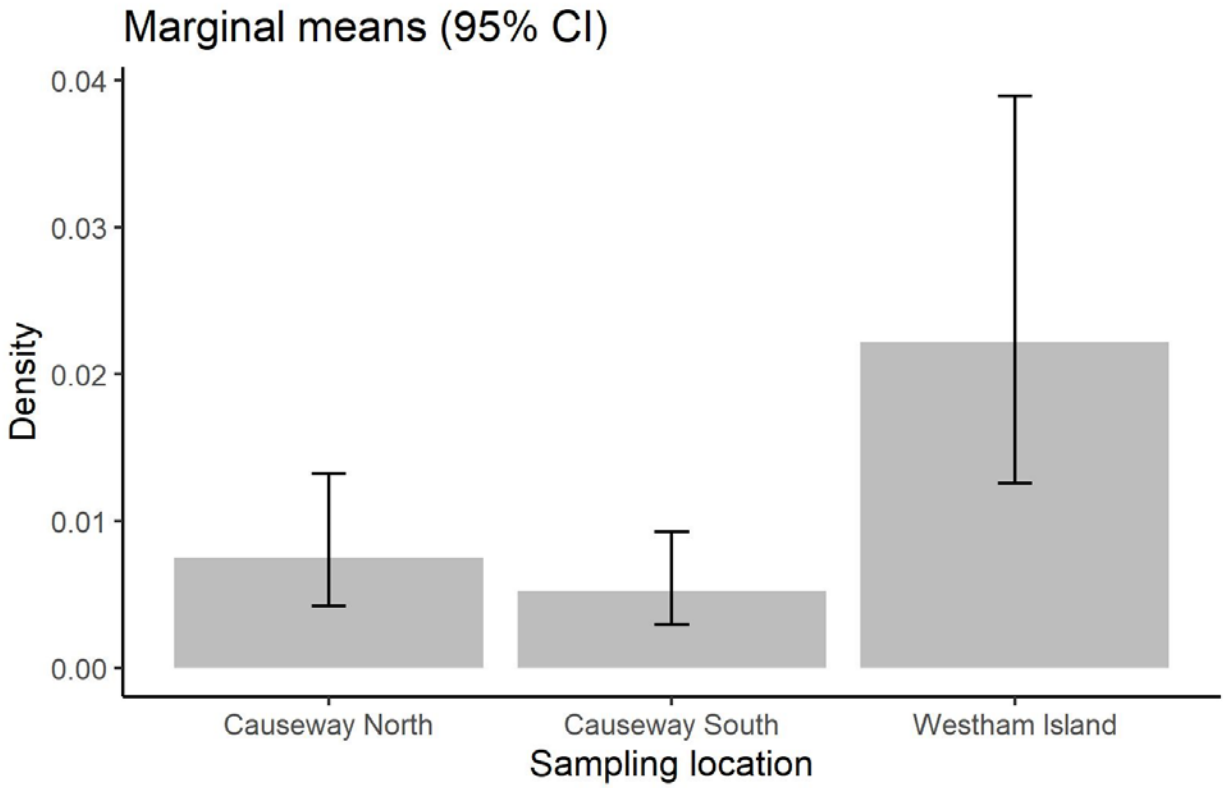
Table 3-7 Mean abundance (with standard deviation) and density (with standard error and confidence intervals) of juvenile Chinook salmon caught in beach seines in the impact area (north and south of the Roberts Bank causeway) and in the control area in summer 2020

Parameter	Impact area		Control area
	Causeway North	Causeway South	Westham Island
Number of sampling events	32	32	32
Number of fish caught	32	16	182
Mean abundance (raw data)	1	1	6
Standard deviation	2	2	11
Density	0.01	0.01	0.02
Standard error	0.00	0.00	0.01
Lower confidence limit	0.00	0.00	0.01
Upper confidence limit	0.01	0.01	0.04
Grouping	1	1	2

Notes:

- Impact area: Causeway North – CN1-8 and Causeway South – CS1-8; Control area: Westham Island – WI1-8 (see **Appendix A**, **Figure A2**)
- Mean abundance (raw data) – mean abundance of juvenile Chinook salmon (summer) calculated using raw data counts
- Density – mean abundance of juvenile Chinook salmon (summer) per cubic metre of sampled water, after accounting for sampling location, tidal stage and time of day (calculated using the emmeans package in R)
- Confidence intervals – 95% of the samples with densities within the range defined by the lower and upper confidence limits
- Grouping – data classes that share group symbols (i.e., 1, 2) are not significantly different in terms of densities of juvenile Chinook salmon caught in beach seines in summer 2020 (based on pairwise comparisons using the cld package in R)

Figure 3-4 Density of juvenile Chinook salmon caught in beach seines in the impact area (north and south of the Roberts Bank causeway) and in the control area in summer 2020



Notes:

- Impact area: Causeway North – CN1-8 and Causeway South – CS1-8; Control area: Westham Island – WI1-8 (see **Appendix A**, **Figure A2**)
- Density – mean abundance of juvenile Chinook salmon (summer) per cubic metre of sampled water after accounting for sampling location, tidal stage and time of day (calculated using the emmeans package in R)
- Bars – upper and lower (95%) confidence intervals
- Confidence intervals – 95% of the samples with densities within the range defined by the lower and upper confidence limits

3.2.3.2. Distribution

Two spot sampling events at SF1 caught no juvenile Chinook salmon in summer 2020, while one spot sampling event in the subtidal yielded six individuals (five at EG1 and one at EG2). No juvenile Chinook salmon were caught at OS7 and OS8.

3.2.3.3. Body size

Fork length recorded for juvenile Chinook caught at permanent sampling sites in summer 2020 ranged from 40 mm to 92 mm with a mean of 56.1 mm ± 7.0 SD (n = 229). North of the causeway, fork length ranged from 49 mm to 92 mm with a mean of 60.4 mm ± 9.0 SD (n = 31), and south of the causeway, fork length ranged from 53 mm to 74 mm with a mean of 64.1 mm ± 5.2 SD (n = 16). Along Westham Island, fork length ranged from 40 mm to 85 mm with a mean of 54.6 mm ± 5.9 SD (n = 182).

At spot sampling sites, fork length ranged from 74 mm to 107 mm with a mean of 86.0 mm ± 12.0 SD (n = 6).

3.2.4. Chum salmon (spring)

This section presents results for juvenile chum salmon caught in spring 2020. Results on abundance and density are presented in **Section 3.2.4.1**, on distribution in **Section 3.2.4.2**, and on body size in **Section 3.2.4.3**.

3.2.4.1. Abundance and density

Mean abundance (with SD) of juvenile chum salmon caught in beach seines north and south of the Roberts Bank causeway and along Westham Island in spring 2020 are shown in **Table 3-8**. During spring 2020, 228 juvenile chum salmon were caught north and 388 south of the Roberts Bank causeway, and 19 along Westham Island, for a total of 635 juvenile chum salmon. Mean abundance of juvenile chum salmon north of the causeway was 7 individuals (± 14 SD), south of the causeway 12 individuals (± 26 SD), and along Westham Island 1 individual (± 2 SD).

Westham Island data were not considered in the density analysis for juvenile chum salmon using GLMMs due to low number of juvenile chum salmon caught. After accounting for sampling location, tidal stage and time of day, there was little evidence that densities of juvenile chum salmon differed between north (0.03 ± 0.01 SE) and south (0.02 ± 0.01 SE) of the causeway (same grouping of 1 shown in **Table 3-8**; see also **Figure 3-5**).

Post-hoc power analysis indicated that the juvenile chum beach seine data for spring 2020 had low statistical power to detect significant differences in abundance north and south of the Roberts Bank causeway. Specifically, the observed difference in mean abundance of five individuals between sampling sites north and south of the Roberts Bank causeway was lower than the minimum difference that could have been detected with sufficient statistical power (MDD = 15 individuals, using the benchmark power value of 0.8 and a significance value alpha of 0.05).

Table 3-8 Mean abundance (with standard deviation) and density (with standard error and confidence intervals) of juvenile chum salmon caught in beach seines in the impact area (north and south of the Roberts Bank causeway) and in the control area in spring 2020

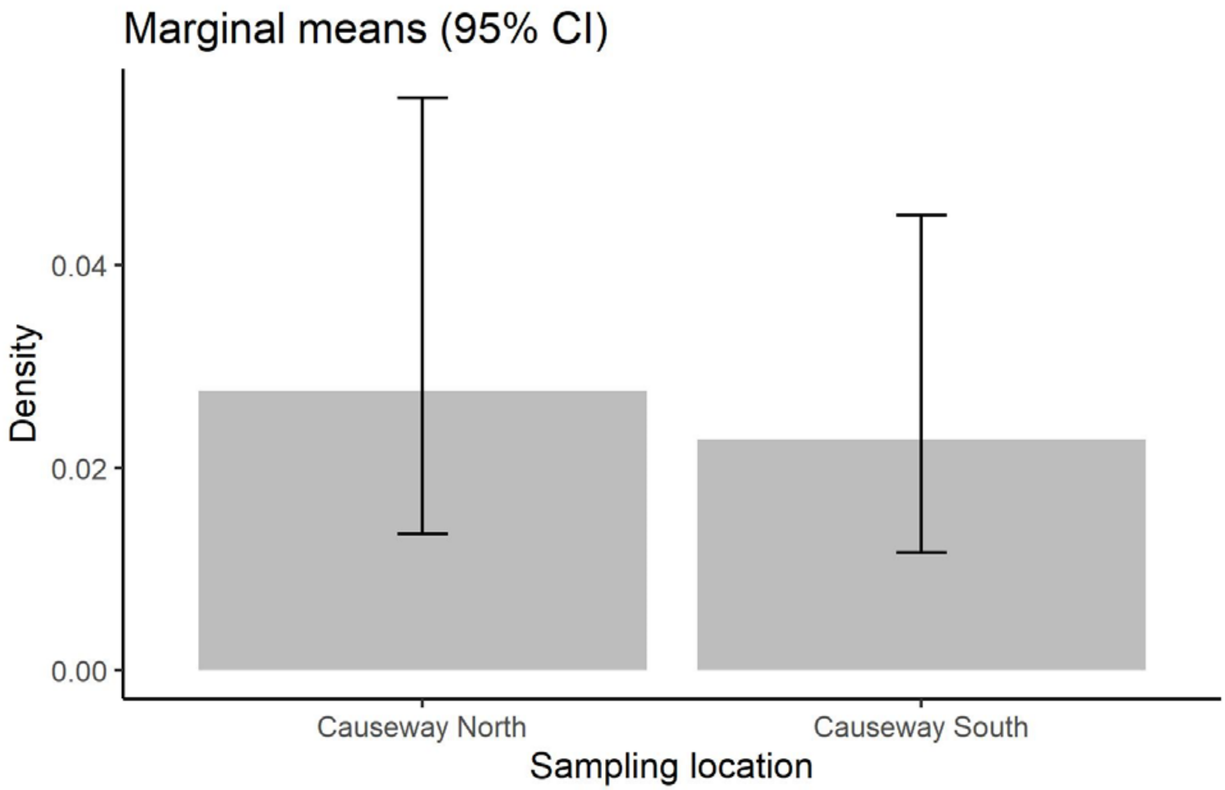
Parameter	Impact area		Control area
	Causeway North	Causeway South	Westham Island
Number of sampling events	32	32	32
Number of fish caught	228	388	19
Mean abundance (raw data)	7	12	1
Standard deviation	14	26	2
Density	0.03	0.02	N/A
Standard error	0.01	0.01	N/A
Lower confidence limit	0.01	0.01	N/A
Upper confidence limit	0.06	0.05	N/A
Grouping	1	1	N/A

Notes:

- Impact area: Causeway North – CN1-8 and Causeway South – CS1-8; Control area: Westham Island – WI1-8 (see **Appendix A**, **Figure A2**)
- Mean abundance (raw data) – mean abundance of juvenile chum salmon (spring) calculated using raw data counts
- Density – mean abundance of juvenile chum salmon (spring) per cubic metre of sampled water, after accounting for sampling location, tidal stage and time of day (calculated using the emmeans package in R)
- Confidence intervals – 95% of the samples with densities within the range defined by the lower and upper confidence limits

- Grouping – data classes that share group symbols (i.e., 1, 2) are not significantly different in terms of density of juvenile chum salmon caught in beach seines in spring 2020 (based on pairwise comparisons using the cld package in R)
- N/A – not applicable; Westham Island data were not considered in the analysis of densities using GLMMs due to low number of juvenile chum salmon caught

Figure 3-5 Density of juvenile chum salmon caught in beach seines in the impact area (north and south of the Roberts Bank causeway) in spring 2020



Notes:

- Impact area: Causeway North – CN1-8 and Causeway South – CS1-8 (see **Appendix A**, **Figure A2**). Data from the control area were not considered in the analysis of densities using GLMMs due to low number of juvenile chum salmon caught
- Density – mean abundance of juvenile chum salmon (spring) per cubic metre of sampled water after accounting for sampling location, tidal stage and time of day (calculated using the emmeans package in R)
- Bars – upper and lower (95%) confidence intervals
- Confidence intervals – 95% of the samples with densities within the range defined by the lower and upper confidence limits

3.2.4.2. Distribution

No juvenile chum salmon were caught during spot sampling in spring 2020.

3.2.4.3. Body size

Fork length recorded for juvenile chum salmon caught during sampling at permanent sites in spring 2020 ranged from 30 mm to 83 mm with a mean of 47.7 mm ± 8.3 SD (n = 514). North of the causeway, fork length ranged from 30 mm to 72 mm with a mean of 46.3 mm ± 7.2 SD (n = 184), while south of the causeway, fork length ranged from 34 mm to 83 mm with a mean of 48.9 mm ± 8.7 SD (n = 312). Along Westham Island, fork length ranged from 35 mm to 50 mm with a mean of 40.2 mm ± 4.0 SD (n = 18).

Mean fork length of juvenile chum salmon caught in April and May 2020 is shown for north and south of the causeway and the control area in **Table 3-9** and **Figure 3-6**.

When the interaction between sampling location and month was considered, no difference was detected in mean fork length of juvenile chum salmon caught in April between north and south of the causeway ($p = 0.871$; **Table 3-10**), and in the control area (north of causeway – Westham Island comparison: $p = 0.052$; south of causeway – Westham Island comparison: $p = 0.139$; **Table 3-10**). In May, there was evidence of larger juvenile chum salmon rearing south than north of the causeway ($p = 0.004$; **Table 3-10**), however, no difference in mean fork length was detected between south of the causeway and the control area ($p = 0.079$; **Table 3-10**). This result is likely due to only five fork lengths of juvenile chum recorded in the control area and the high variance in those samples (as indicated by the wide confidence intervals in **Figure 3-6**).

Table 3-9 Mean fork length (with standard error and confidence intervals) of juvenile chum salmon caught in beach seines in the impact area (north and south of the Roberts Bank causeway) and in the control area in spring 2020

Parameter	Impact area				Control area	
	Causeway North		Causeway South		Westham Island	
	April	May	April	May	April	May
Number of sampling events	10	10	5	10	3	3
Number of fish measured	133	51	44	268	13	5
Marginal mean fork length	45.8	41.7	44.8	48.9	39.4	41.1
Marginal mean standard error	1.2	1.4	1.6	1.3	2.2	3.1
Marginal mean lower confidence limit	43.2	38.9	41.7	46.2	35.3	35.4
Marginal mean upper confidence limit	48.5	44.6	48.1	51.9	44.1	47.7

Notes:

- Impact area: Causeway North – CN1-8 and Causeway South – CS1-8; Control area: Westham Island – WI1-8 (see **Appendix A**, **Figure A2**)
- Mean fork length – calculated after accounting for sampling location and month and the interaction between the two (using the emmeans package in R)
- Confidence intervals – 95% of the samples with fork length within the range defined by the lower and upper confidence limits

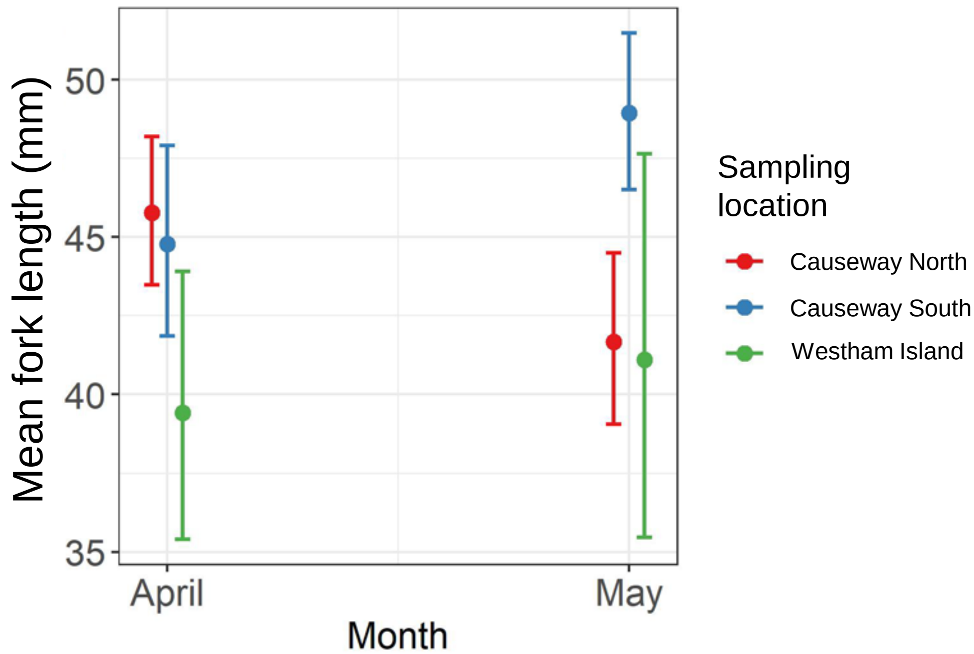
Table 3-10 Pairwise comparisons of fork length of juvenile chum salmon caught in spring 2020 in beach seines in the impact area (north and south of the Roberts Bank causeway) and in the control area by month with ratio, standard error and *p* value. Bold font indicates significant result

Month	Comparison	Ratio	Standard error	*p* value
April	Causeway North – Causeway South	1.022	0.045	0.871
	Causeway North – Westham Island	1.161	0.071	0.052
	Causeway South – Westham Island	1.136	0.074	0.139
May	Causeway North – Causeway South	0.852	0.036	**0.004**
	Causeway North – Westham Island	1.014	0.084	0.985
	Causeway South – Westham Island	1.191	0.095	0.079

Notes:

- Impact area: Causeway North – CN1-8 and Causeway South – CS1-8; Control area: Westham Island – WI1-8 (see **Appendix A**, **Figure A2**)

Figure 3-6 Mean fork length of juvenile chum salmon caught in beach seines in the impact area (north and south of the Roberts Bank causeway) and in the control area (Westham Island) in spring 2020



3.2.5. 2020 Power Analysis Results

This section describes the results of the 2020 power analysis undertaken as described in **Section 2.4.2.4**. Results of the 2020 power analysis are shown in **Table 3-11**, and in **Figure 3-7** and **Figure 3-8**, respectively, for the following two effects pathways: (i) a project-related change in juvenile salmon densities between the impact area (i.e., north and south of the Roberts Bank causeway combined) and the control area, and (ii) a project-related change in juvenile salmon densities separately between the north and south of the Roberts Bank causeway and within the impact area (i.e., between north and south of the causeway; between north of the causeway and the control area; and between south of the causeway and the control area).

For effects pathways (i) and (ii) above, results of the 2020 power analysis indicated that the current study design (in terms of number of sampling sites established, number of net sets per site, and frequency of visits; see also **Section 2.4.2.4**) is adequate to detect 50% change in the densities of juvenile Chinook and chum salmon. For both effects pathways, power to detect a 50% change was above 80% for each juvenile salmon group in the scenarios considered (**Figure 3-7**, **Figure 3-8**). Power was generally higher when data from north and south of the causeway combined, due in part to the larger sample size. Increasing the number of sampling years before project construction from 3 to 4 provided additional power than the addition of a sampling year after project construction (**Figure 3-7**, **Figure 3-8**).

Table 3-11 Estimated standard deviation for each random effects term in the linear mixed model for each season and salmon species of interest

Species	Season	Power analyses	Random effect term				
			Site	Year	Site:Year	Visit	Residual
Chinook salmon	Spring	2019	0.61	0.54	0.002	0.3	0.84
		2020	<0.001	0.86	0.1	-	1.4
	Summer	2019	0.09	0.19	0.002	0.4	0.56
		2020	0.31	1.07	<0.001	-	0.79
Chum salmon	Spring	2019	1.13	<0.01	0.85	1.07	1.47
		2020	0.35	<0.001	<0.001	-	1.14

Notes:

- Site – permanent sampling site (Impact area: Causeway North – CN1-8 and Causeway South – CS1-8; Control area: Westham Island – WI1-8 (see **Appendix A**, **Figure A2**))
- Year – sampling years before and after project construction
- Site: Year – interaction term which allows for differences in sampling sites over time (e.g., some sites may response differently during sampling years before the project)
- Residual – the variance within site-year, i.e., the visit-to-visit variance

Figure 3-7 2020 power analysis for comparisons between north and south of the Roberts Bank causeway (pooled) and the control area, with adding number of years after project construction, and sampling three or four years before project construction. The design is otherwise fixed at four visits per sampling site per season, eight sampling sites, and three net sets per sampling site. Power (80%; blue dashed line) is for a 50% change in the density of juvenile Chinook and chum salmon

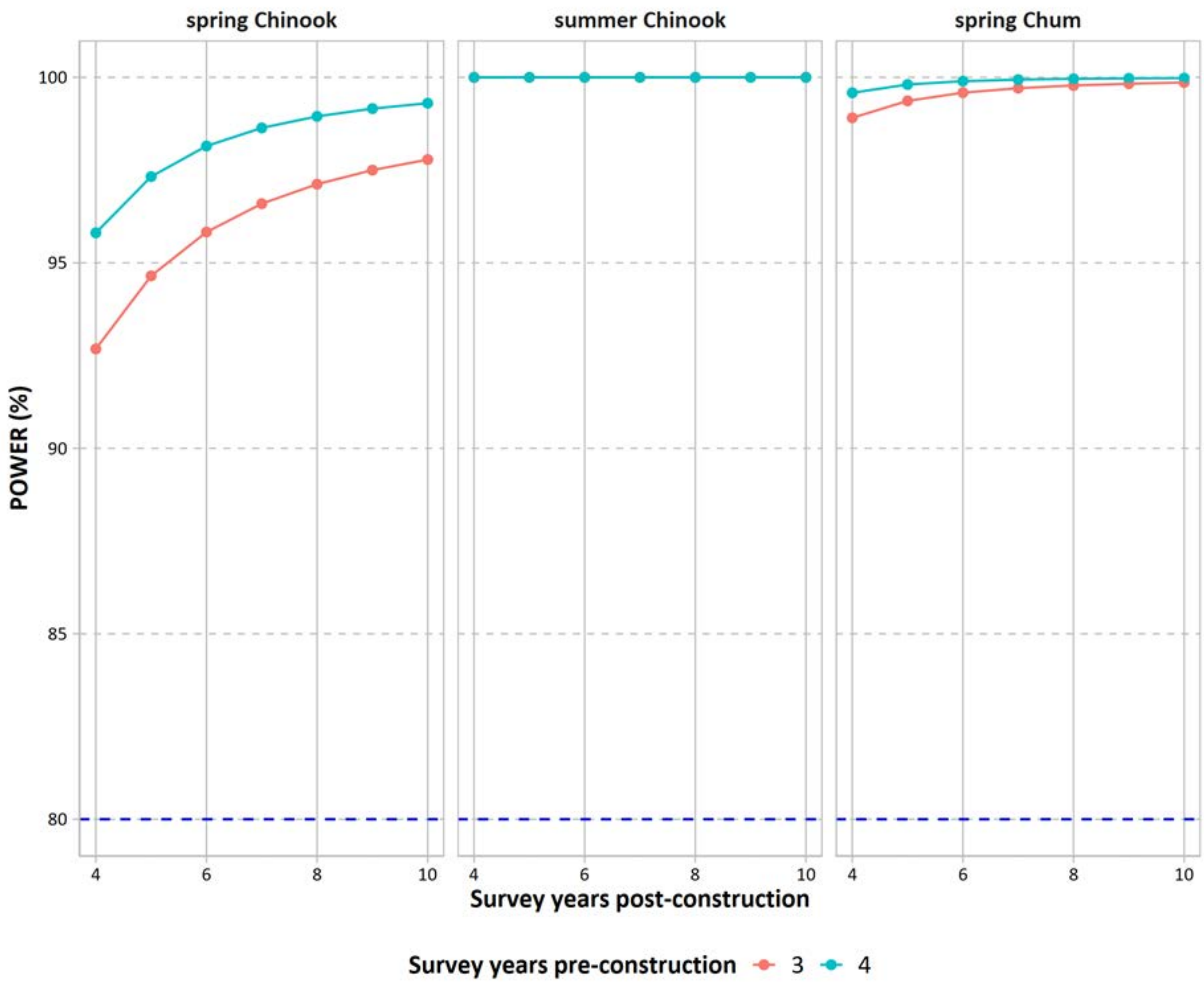
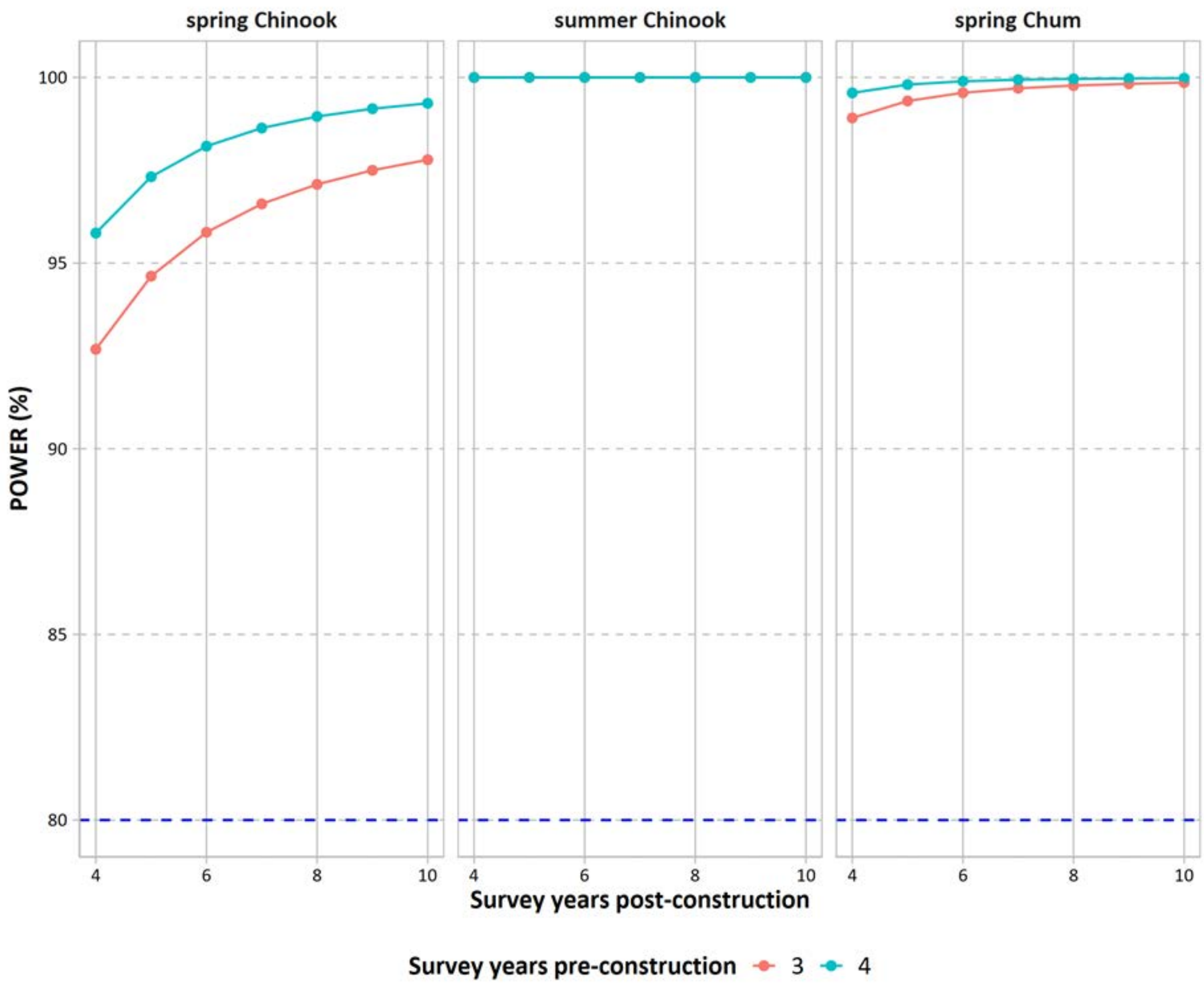


Figure 3-8 2020 power analysis for comparisons between north and south of the Roberts Bank causeway (considered separately) and the control area, with adding number of years after project construction, and sampling three or four years before project construction. The design is otherwise fixed at four visits per sampling site per season, eight sampling sites, and three net sets per sampling site. Power (80%; blue dashed line) is for a 50% change in the density of juvenile Chinook and chum salmon



3.2.6. Water quality

3.2.6.1. Permanent sampling sites

Water quality measured at permanent sampling sites in spring and summer 2020 is summarized in **Table 3-12**. Water temperature across sites and throughout the monitoring period ranged from 8.4°C to 33.6°C (mean 17.9°C ± 6.0°C SD). Water temperature in spring across sites was cooler (mean 14.7°C ± 4.2 SD) than in summer (mean 21.0°C ± 6.0 °C SD). In spring, water temperature was generally warmer (16.2°C ± 5.3°C SD) and more variable off Westham Island (**Figure 3-9**) than to the north (13.6°C ± 3.4°C SD) and south (14.2°C ± 3.3°C SD) of the causeway. During summer, waters off Westham Island were warmer (22.8°C ± 6.8°C SD) and more variable (**Figure 3-9**) than north (20.0°C ± 6.2°C SD) and south (20.4°C ± 4.5°C SD) of the causeway. Within the control area, cooler temperatures were recorded at the southernmost sites (WI6, WI7, and WI8; **Appendix A**, **Figure A2**) which are closer to freshwater flows from the Fraser River off Canoe Passage.

Salinity throughout the monitoring period ranged across sites from 0.1 to 29.2 PSU (mean 13.0 PSU ± 10.0 SD; **Table 3-12**). During spring, waters south of the causeway were consistently more saline (26.7 PSU ± 2.4 SD) than north of the causeway (17.1 PSU ± 6.7 SD) and Westham Island (2.8 PSU ± 2.7 SD), given the influence by freshwater flows from the Fraser River. Salinity north of the causeway showed greater variability (**Figure 3-10**). During summer, salinity across sites in both the impact and control areas were slightly less saline compared to spring (**Figure 3-10**), likely due to the freshet that peaked on July 6, 2020, in Hope (WSC 2020).

Dissolved oxygen throughout the monitoring period ranged across sites from 5.5 mg/L to 18.4 mg/L (mean 9.7 mg/L ± 2.2 SD; **Table 3-12**). Dissolved oxygen was generally more variable in summer than spring (**Figure 3-11**).

Table 3-12 Water quality parameters (water temperature, salinity, dissolved oxygen) measured at permanent sampling sites in the impact and control areas in spring and summer 2020

Parameter (unit)	All permanent sampling sites		Impact area				Control area	
			Causeway North		Causeway South		Westham Island	
	Spring	Summer	Spring	Summer	Spring	Summer	Spring	Summer
Number of sampling events	96	96	32	32	32	32	32	32
Minimum temperature (°C)	8.4	13.3	8.8	13.3	10.5	13.9	8.4	14.1
Maximum temperature (°C)	28.2	33.6	21.0	32.1	23.8	28.8	28.2	33.6
Mean temperature (°C)	14.7	21.0	13.6	20.0	14.2	20.4	16.2	22.8
Standard deviation (°C)	4.2	6.0	3.4	6.2	3.3	4.5	5.3	6.8
Minimum salinity (PSU)	0.2	0.1	6.1	5.4	19.9	10.7	0.2	0.1
Maximum salinity (PSU)	29.2	26.5	27.6	25.1	29.2	26.5	15.2	1.9
Mean salinity (PSU)	15.5	11.8	17.1	14.8	26.7	20.0	2.8	0.6
Standard deviation (PSU)	10.8	9.1	6.7	4.6	2.4	5.2	2.7	0.5
Minimum dissolved oxygen (mg/L)	5.6	5.5	7.8	6.2	5.6	5.5	5.8	5.6
Maximum dissolved oxygen (mg/L)	18.4	17.7	11.2	16.4	18.4	17.7	12.2	13.0
Mean dissolved oxygen (mg/L)	9.7	9.7	9.3	9.7	10.6	10.3	9.2	9.2
Standard deviation (mg/L)	2.2	2.3	0.9	2.5	3.4	2.3	1.3	1.9

Notes:

- °C – degrees Centigrade
- PSU – practical salinity units
- mg/L – milligram per litre

Figure 3-9 **Water temperature (ºC) measured at permanent sampling sites in the impact area (Causeway North – CN (red), Causeway South – CS (green)) and in the control area (Westham Island – WI (blue)) in spring and summer 2020**

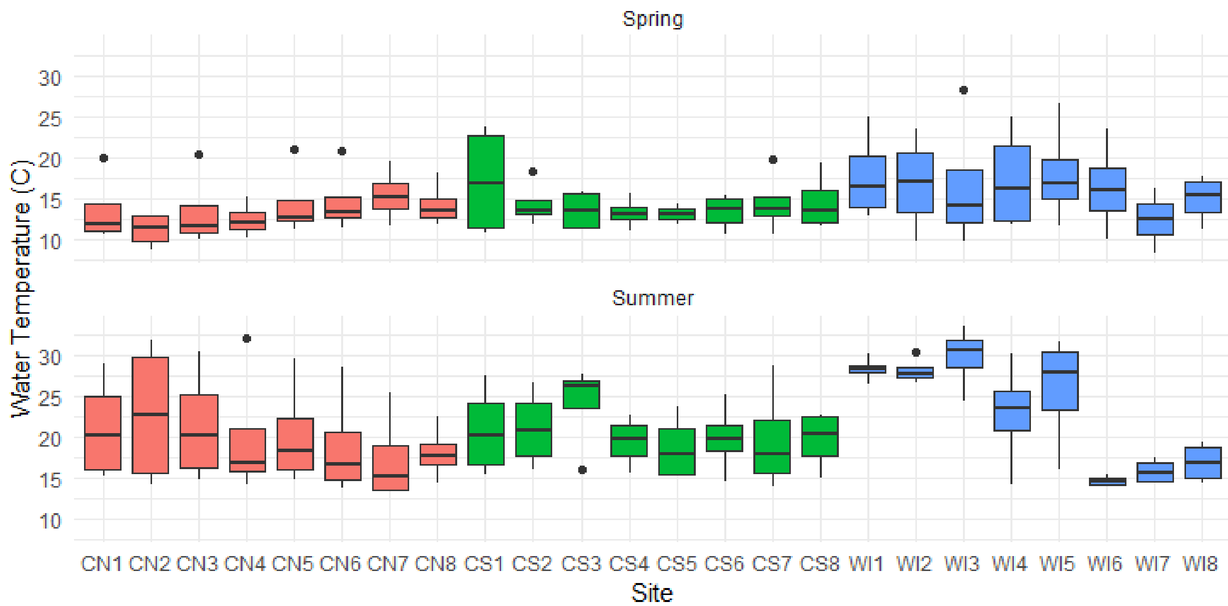


Figure 3-10 **Salinity (practical salinity units; PSU) measured at permanent sampling sites in the impact area (Causeway North – CN (red), Causeway South – CS (green)) and in the control area (Westham Island – WI (blue)) in spring and summer 2020**

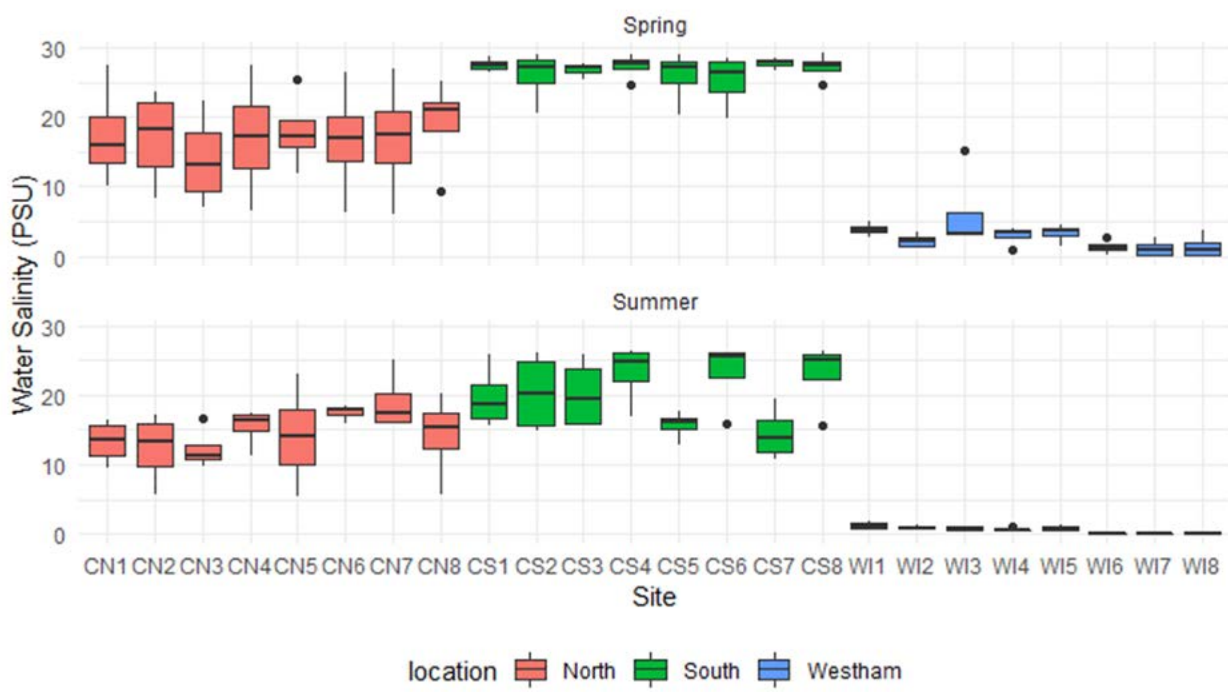
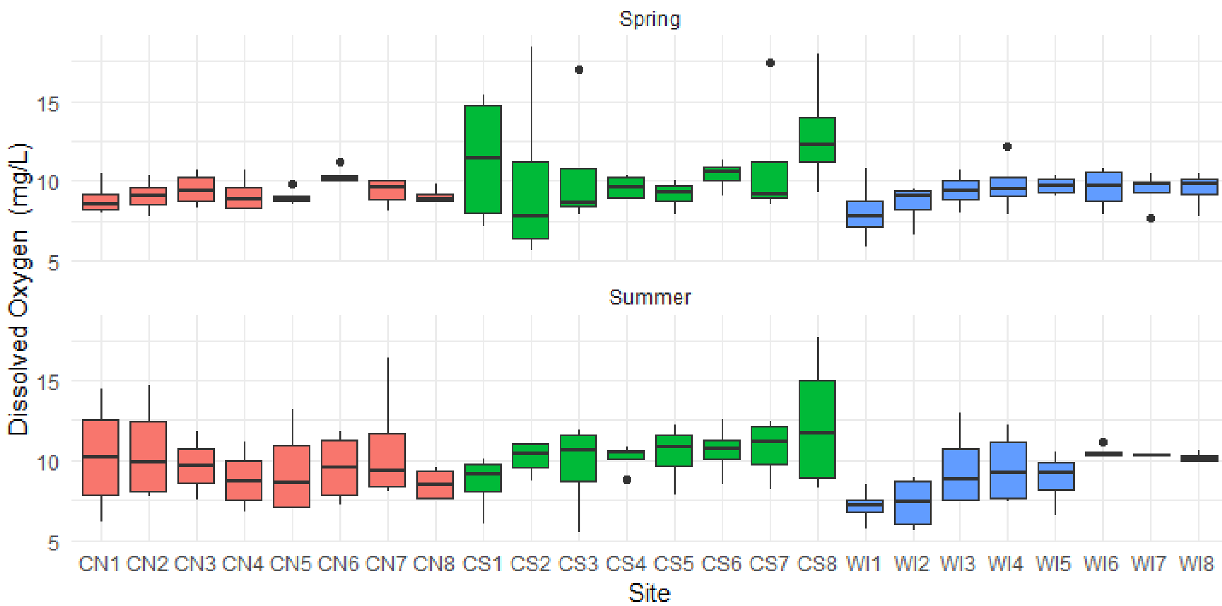


Figure 3-11 Dissolved oxygen (milligrams per litre; mg/L) measured at permanent sampling sites in the impact area (Causeway North – CN (red), Causeway South – CS (green)) and in the control area (Westham Island – WI (blue)) in spring and summer 2020



3.2.6.2. Spot sampling sites

Water quality measurements taken during spot sampling are summarized in **Table 3-13**.

Water temperature at subtidal spot sampling sites ranged in the summer from 14.5°C at OS sites to 15.5°C at EG sites. At SF1, water temperature recorded in spring was 21.9°C and in summer 24.2°C (June) and 26.2°C (July).

Salinity was higher at OS sites than at EG sites. At SF1, salinity in spring was 5.3 PSU, and in summer 6.3 PSU (June) and 15.1 PSU (July).

Across OS and EG sites, dissolved oxygen was 7.6-7.7 mg/L in summer. At SF1, dissolved oxygen was higher than in the subtidal zone, measuring 12.3 mg/L in spring, and in summer 13.4 mg/L (June) and 9.3 mg/L (July).

Table 3-13 Water quality parameters (water temperature, salinity, dissolved oxygen) measured at spot sampling sites (EG1, EG2, OS7, OS8, SF1) in spring and summer 2020

Water quality parameter (unit)	Spot sampling sites						
	EG1	EG2	OS7	OS8	SF1		
	Summer	Summer	Summer	Summer	Spring	Summer (June)	Summer (July)
Temperature (°C)	15.5	15.5	14.6	14.5	21.9	26.2	24.2
Salinity (PSU)	20.8	21.1	22.2	23.5	5.3	6.3	15.1
Dissolved oxygen (mg/L)	7.6	7.7	7.6	7.6	12.3	13.4	9.3

Notes:

- °C – degrees Centigrade
- PSU – practical salinity units
- mg/L – milligrams per litre

3.3. Data gaps and limitations

Data described in this report represent the first year of pre-project construction information collected using a BACI study design and at a level of sampling effort described in **Section 2.2**. There is little overlap with sites sampled previously in 2013 along the north and south shorelines of the Roberts Bank causeway by Archipelago (2014a). This is largely due to a different study design and reduced sampling effort employed in 2013 to meet a different set of objectives (i.e., describe seasonal use and abundance of different habitat types in support of the project's effects assessment presented in the EIS (VFPA 2015)) from those of the juvenile salmon FUP element (outlined in **Section 1.2**). Moreover, Westham Island was sampled in 2020 for the first time. Given the lack of spatial overlap between the two studies and the large number of hauls in 2013 that yielded no juvenile Chinook and chum salmon, between-year (i.e., 2013 and 2020) comparisons of juvenile Chinook and chum salmon densities were not possible using methods described in **Section 2.4.2**.

Caution should be applied when interpreting analysis results from one year of data that pertain to the density of juvenile chum salmon in the impact area (both north and south of the Roberts Bank causeway) and in the control area. Abundance of Fraser River chum salmon outmigrating to the Strait of Georgia is highly variable year to year, and juvenile chum also exhibit high variability in spatial distribution, movements, and behaviour when rearing at Roberts Bank. Results of the 2019 power analysis indicated that the BACI study design selected for the juvenile salmon FUP element could not achieve adequate power in detecting a 50% change in juvenile chum density with 80% statistical power. It is anticipated that additional years of pre-project construction sampling will increase power of the data to detect significant differences in juvenile chum densities using the selected BACI study design.

Timing of peak abundance of juvenile Chinook and chum salmon are variable, and dependent on the outmigration timing of different Fraser River stocks. Outmigration of juvenile Chinook salmon occurs over an extended period of time given the multitude of stocks and different life histories, with abundance peaking between late April and early May (Scott et al. 2019) (see **Section 2.2**). Sampling undertaken from April 23 to July 31, 2020 likely adequately sampled across the stocks of juvenile Chinook salmon known to pause during their outmigration and rear at Roberts Bank. On the other hand, outmigration of juvenile chum salmon may begin as early as late February and peaks between mid-March and late April (Beacham and Starr 1982, Chalifour et al. 2019). Moreover, residency of juvenile chum salmon in the estuary, including at Roberts Bank, is short; juvenile chum salmon have been documented rearing in the estuary for up to a couple of weeks (Levy and Northcote 1981, 1982). As such, beginning sampling in 2020 during the last week of April may have missed a portion of the juvenile chum salmon population that may have outmigrated in March and early April and may have already transitioned to nearshore coastal rearing habitats of the Strait of Georgia.

Lastly, the juvenile chum salmon catch from the control area was small with only 19 individuals caught throughout the 2020 monitoring period. As a result, chum data from the control area could not be analyzed using GLMMs and existing conditions regarding density and distribution of juvenile chum in the control area could not be described for 2020. Compared to juvenile Chinook salmon, juvenile chum salmon have been reported to rely less on brackish intertidal marsh habitats and to disperse readily from the river mouth onto the outer flats of the estuary during outmigration (Levy and Northcote 1981, 1982, Macdonald 1984, Chalifour et al. 2019). Consequently, the west shoreline of Westham Island may not be frequented by outmigrating juvenile chum at the same extent as by juvenile Chinook salmon. The efficacy of Westham Island as a control area for juvenile chum salmon in the BACI study will be further evaluated with additional years of data. Moreover, and to meet the objectives of this FUP element for juvenile chum salmon, the potential will also be evaluated for use of other sources of information (e.g., chum smolt index developed by DFO) to control for year to year natural variability in the Fraser River population of juvenile chum salmon.

4. Discussion

This section provides a summary and interpretation of key findings of the analysis of juvenile Chinook and chum salmon data collected in spring and summer 2020 as part of pre-project construction sampling for the juvenile salmon FUP element.

4.1. Summary and interpretation of key findings

Data collected in spring and summer 2020 as part of pre-project construction sampling for the juvenile salmon FUP element were analyzed to estimate densities of juvenile Chinook and chum salmon for the two locations in the impact area (north and south of the Roberts Bank causeway), and in the control area. Densities of juvenile Chinook and chum salmon were estimated after accounting for the effects of season, tidal stage, and time of day. Differences in densities of juvenile Chinook and chum salmon were also investigated between north and south of the causeway, between north of the causeway and the control area, as well as between south of the causeway and the control area. A discussion of patterns that emerged from this analysis is provided below for Chinook (**Section 4.1.1**) and chum salmon (**Section 4.1.2**). Differences in body size were also investigated to explore how the distribution of Chinook and chum juveniles in the study area may be influenced by increases in body size. Lastly, environmental parameters, such as temperature and salinity, are also considered below in the context of juvenile Chinook and chum distribution in the study area during the outmigration period. Results presented in this report describe current (2020) conditions of juvenile Chinook and chum salmon density and distribution in the study area. They also constitute the first year of a pre-project construction data set that will be used to evaluate in the long-term, following project construction, project-related changes in juvenile salmon density and distribution to meet the objectives of this FUP element.

4.1.1. Chinook salmon

Analysis of juvenile Chinook salmon data collected in 2020 revealed that densities in the control area and north of the causeway were consistently higher than south of the causeway in both spring and summer. In spring, juvenile Chinook densities were greater in the control area and north of the causeway than further away from the river mouth (i.e., south of the Roberts Bank causeway). As the seasons progressed, juvenile Chinook densities were found to be evenly distributed north and south of the causeway, but remained consistently higher in the control area.

Specifically, when spring and summer were considered together, four times more juvenile Chinook salmon were caught north of the causeway and in the control area than south of the causeway (**Table 3-3**). Most of juvenile Chinook salmon (93% of the juvenile Chinook catch) was caught in spring 2020, of which 60% was caught in May, likely indicative of an influx of Fall Chinook from the Harrison River. As indicated in **Section 2.2**, outmigration of Fall Chinook (Harrison) extends over two to three months, with abundance of juveniles peaking between late April and early May (Scott et al. 2019). When spring was considered separately, juvenile Chinook salmon densities were found to be six times higher north than south of the causeway, and three and half times higher in the control area than south of the causeway (**Table 3-4**). Chinook densities in spring did not differ between the control area and north of the causeway (**Table 3-4**).

Juvenile Chinook densities were also analyzed separately for summer to investigate differences between north and south of the causeway and the control area. Chinook densities were found two times higher in the control area than north and south of the causeway (**Table 3-7**). Most (96%) of the juvenile Chinook salmon summer catch was caught in June. Higher catches in June compared to July could be indicative of an influx of ocean-type juvenile Chinook salmon originating from the Lower and South Thompson rivers; their outmigration has been documented to peak in June (Scott et al. 2019; see also **Section 2.2**). It is also probable that Chinook juveniles from the Harrison River outmigrating later in spring formed part of the June catch. The composition of Chinook stocks in the 2020 catch will be confirmed at a later date as genetic analysis of fin clippings collected in 2020 is pending. In the impact area, no difference was detected in Chinook densities north and south of the causeway (**Table 3-7**).

Estuarine distribution of juvenile Chinook salmon is largely influenced by the availability and distribution of habitats that provide rearing opportunities, including food and refuge. The west shoreline of Westham Island, as well as the shoreline along Brunswick Point, the Roberts Bank dyke and north of the Roberts

Bank causeway, are characterized by brackish marsh vegetation, which has been documented in the literature to provide refuge during flood tides and to increase food availability for juvenile Chinook salmon that rear in the estuary (Levy and Northcote 1981, 1982, Archipelago 2014a, Chalifour et al. 2019, 2020). Chalifour et al. (2019) suggest that brackish marsh is the first habitat encountered and the most used by outmigrating salmon. Chalifour et al. (2019) consistently caught salmon, including Chinook, in substantially higher numbers in marsh than eelgrass or sandflat during sampling in spring and summer 2016 and 2017. This report presents results that are consistent with these studies.

Analysis of Chinook body size presented in this report suggests that juvenile Chinook that enter Roberts Bank undergo a period of growth that allows them to transition to habitats away from the river mouth as the seasons progress. No differences were detected in mean body size of juvenile Chinook sampled in April in the control area, and north and south of the causeway. However, in May, juvenile Chinook sampled south of the causeway were found to be larger (by approximately 8 mm in mean fork length) than individuals north of the causeway and in the control area (**Table 3-5**). Juvenile Chinook become tolerant of higher salinities as they increase in body size (Taylor 1990, McCormick 2006, Wong et al. 2019). Brackish marshes, such as those distributed in the control area and north of the causeway, tend to offer smaller juvenile Chinook less osmotically stressful and more sheltered habitat than the outer flats, including south of the causeway (Taylor 1990, Gregory and Levings 1998, Chalifour et al. 2019, 2020). The inter-causeway area is predominantly influenced by tidal exchanges and is characterized by higher salinities as indicated by higher salinity values measured during sampling in spring and summer 2020 (**Table 3-12**). Larger juveniles that are physiologically adapted to higher salinities are capable of transitioning to habitats away from the river mouth including in the inter-causeway area later in spring.

Along with salinity, temperature is another environmental factor that influences the distribution of juvenile Chinook salmon in the estuary. Mean water temperature increased through the monitoring period; in the summer, mean water temperature north and south of the causeway and in the control area exceeded 20°C (**Table 3-12**). In general, juvenile Chinook catches decline as water temperatures increase, and juvenile Chinook tend to avoid waters with temperatures exceeding 22°C (Macdonald 1984). Although the influence of temperature was not investigated using GLMMs, higher temperatures in the summer 2020 could explain low or no juvenile Chinook catches across sampling sites in the impact and control areas.

4.1.2. Chum salmon

Analysis of juvenile chum salmon data collected in spring 2020 suggests that juvenile chum salmon are evenly distributed across the impact area as no difference in densities was detected between north and south of the causeway (**Table 3-8**). Sampling throughout the study area in summer 2020 caught only three individuals which were excluded from the analysis. Chum catches from the control area were also low (19 individuals) and were excluded from the analysis. Distribution of juvenile chum salmon at Roberts Bank is generally not constrained by large salinity fluctuations characteristic of the estuarine environment. This is likely due to the ability of juvenile chum to acclimatize to higher salinities faster than juvenile Chinook salmon (McCormick 2006, Wong et al. 2019). This allows them to disperse readily from the river mouth onto the outer flats of the estuary during outmigration (Levy and Northcote 1981, 1982, Macdonald 1984, Chalifour et al. 2019). Macdonald (1984) suggests that recruitment of chum in the length range of 38 to 41 mm within the Fraser River main arm, Sturgeon Bank and Roberts Bank, and the Fraser River plume is evidence that outmigrating juvenile chum immediately disperse throughout the entire estuary. Part of the juvenile chum population have been documented to pause in the marshes of the inner estuary (i.e., at the Woodward Island complex upriver of Westham Island) for up to 11 days; growth has been noted in the inner estuary to an average length of 46.2 mm by early June (Levy and Northcote 1982). At Roberts Bank, mean fork length estimated in spring 2020 was 47.7 mm ± 8.3 SD (**Section 3.2.4.3**), similar to that reported by Levy and Northcote (1982) from the inner estuary. This could suggest dispersion of juvenile chum on the outer flats early in spring.

Analysis of chum body size recorded in April 2020 revealed no difference in mean body size in the control area, and north and south of the causeway (**Table 3-10**). In May, juvenile chum sampled south of the causeway were found to be larger (by approximately 7 mm in mean fork length) than individuals north of the causeway and in the control area (**Table 3-10**). This is likely indicative of growth of juvenile chum salmon rearing at Roberts Bank. Macdonald (1984) has described estuarine growth of juvenile chum rearing in the inter-causeway area and has reported growth rates of 0.17 mm/day. It is also likely that influx of young (and by inference small in body size) chum fry that arrived at Roberts Bank later in spring influenced the body size analysis results presented in this report.

Caution should be applied when interpreting analysis results for juvenile chum salmon as high variation was noted in juvenile chum densities both north and south of the causeway (as indicated by the wide CIs shown in **Figure 3-5**). This is largely due to variability in abundance, spatial distribution across habitats, movements, and behaviour that are characteristic of juvenile chum salmon during estuarine residency (Archipelago 2014a, Chalifour et al. 2019). Moreover, juvenile chum may begin their outmigration as early as late February and peak between mid-March and late April (Beacham and Starr 1982, Chalifour et al. 2019). Given that estuarine residency is short (up to a couple of weeks; Levy and Northcote 1981, 1982), beginning sampling in 2020 during the last week of April may have missed a portion of the juvenile chum salmon population that may have outmigrated in March and early April and may have already transitioned to nearshore coastal rearing habitats of the Strait of Georgia.

5. Recommendations

Based on the 2020 study, six recommendations have been put forward for the juvenile salmon FUP element. These recommendations are intended to improve the study design and data analysis for the juvenile salmon FUP element and will be discussed with Indigenous groups as part of the port authority's ongoing consultation activities to help inform the 2021 study design.

- **Recommendation 1:** Sampling in 2021 and future years is recommended to start on April 1 to capture the greater length of the spring outmigration period of juvenile salmon. Juvenile Chinook and chum salmon have been documented outmigrating to the Fraser River estuary including Roberts Bank as early as February (chum; Beacham and Starr 1982, Chalifour et al. 2019) or March (Chinook; Levy and Northcote 1981, 1982, Levings 1985, Chalifour et al. 2019).
- **Recommendation 2:** It is recommended that the 2013 dataset (collected by Archipelago 2014a) not be considered as a pre-project construction year in the data analyses moving forward. This would minimize the large number of zeros (i.e., hauls with no juvenile salmon in the catch) in future data analyses and between year comparisons.
- **Recommendation 3:** It is recommended that a minimum of two additional years of sampling be added to the 2020 dataset for a total of three years before project construction, as confirmed by the results of the 2020 power analysis.
- **Recommendation 4:** It is recommended that the 2020 power analysis be re-run each year following data collection to confirm or refine the study design, including number of sampling years required before and after project construction as well as sampling design.
- **Recommendation 5:** It is recommended that the efficacy of Westham Island as a control area for juvenile chum salmon in the BACI study be further evaluated with additional years of data. In 2020, chum catches in the control area were low (only 19 individuals). Compared to juvenile Chinook salmon, juvenile chum salmon have been reported to rely less on brackish intertidal marsh habitats and to disperse readily from the river mouth onto the outer flats of the estuary during outmigration. Consequently, Westham Island may not be frequented by outmigrating juvenile chum at the same extent as by juvenile Chinook salmon. Moreover, and to meet the objectives of this FUP element, the use of other sources of information (e.g., chum smolt index developed by DFO) is proposed to be evaluated as a potential control for year-to-year variability in the Fraser River population of juvenile chum salmon.
- **Recommendation 6:** It is recommended that the influence of environmental factors, such as salinity and temperature, on the density and distribution of juvenile Chinook and chum salmon in the study area be investigated with additional years of data. Based on literature, salinity and temperature exert physiological stress on rearing juvenile salmon and likely influence their distribution and use of habitats during estuarine residency (Taylor 1990, Quinn 2018, Chalifour et al. 2019, 2020).

6. Conclusions

Overall, the objectives of the juvenile salmon FUP element for 2020 were achieved. Results presented in this report describe current (2020) conditions of juvenile Chinook and chum salmon density and distribution in the study area. They also constitute the first year of a pre-project construction data set that will be used to evaluate post-project construction changes in juvenile salmon densities and distribution north and south of the causeway and in the control area and ultimately verify whether or not project changes in the productivity of juvenile salmon, including Chinook and chum, are negligible, as predicted in the EIS.

Analysis of juvenile Chinook data presented in this report indicated that Chinook densities in spring 2020 were higher in the control area and north of the causeway than in the inter-causeway area. In summer, no difference in Chinook densities was detected north and south of the causeway, however, Chinook densities in the control area were higher than north and south of the causeway. Brackish marsh, which is distributed along the shorelines at and near the river mouth, is the first habitat encountered and the most used by outmigrating Chinook salmon. Later in spring (May 2020), juvenile Chinook salmon south of the causeway were found to be larger than north of the causeway and in the control area. Larger Chinook are physiologically adapted to higher salinities and are capable of transitioning to rearing habitats away from the river mouth, including in the inter-causeway area, later in spring.

Analysis of juvenile chum data presented in this report detected no difference in juvenile chum densities in spring 2020 north and south of the causeway. Due to low chum salmon catches, data from the control area were excluded from the analysis. Also, very few juvenile chum salmon were caught in summer 2020 and were excluded from the analysis. Juvenile chum salmon generally acclimatize to higher salinities faster than juvenile Chinook salmon, which allows them to disperse readily from the river mouth onto the outer flats of the estuary during outmigration. Later in spring (May 2020), juvenile chum salmon south of the causeway were found to be larger than north of the causeway and in the control area. This is likely indicative of estuarine growth, consistent with patterns observed in previous studies conducted in the early 1980s in the inter-causeway area. Caution should be applied when interpreting analysis results for juvenile chum salmon, due to variability in abundance, spatial distribution across habitats, movements, and behaviour that are characteristic of juvenile chum salmon during estuarine residency.

Six recommendations have been put forward related to aspects of the study for the juvenile salmon FUP element . These recommendations will be discussed with Indigenous groups as part of the port authority's ongoing consultation activities to help inform the 2021 study design. In summary, recommendations include sampling moving forward to start on April 1 to capture the greater length of the spring outmigration period of juvenile salmon, as well as re-running of the 2020 power analysis each year following data collection to confirm or refine the study design. The influence of environmental factors (i.e., salinity, temperature) on the density and distribution of juvenile Chinook and chum salmon in the study area is recommended to be investigated with additional years of data. Lastly, it is recommended that the efficacy of Westham Island as a control area for juvenile chum salmon in the BACI study be further evaluated with additional years of data, as well as the use of other sources of information (e.g., chum smolt index developed by DFO) as a potential control for year-to-year variability in the Fraser River population of juvenile chum salmon.

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8. Closure

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9. Statement of limitations

This work was performed in accordance with Contract No. 16-0087(02) between Hemmera Envirochem Inc. (Hemmera), a wholly owned subsidiary of Ausenco Engineering Canada Inc. (Ausenco), and Vancouver Fraser Port Authority (Client), dated July 4, 2019 (Contract). This report has been prepared by Hemmera, based on fieldwork conducted by Hemmera, for sole benefit and use by the Vancouver Fraser Port Authority. In performing this work, Hemmera has relied in good faith on information provided by others, and has assumed that the information provided by those individuals is both complete and accurate. This work was performed to current industry standard practice for similar environmental work, within the relevant jurisdiction and same locale. The findings presented herein should be considered within the context of the scope of work and project terms of reference; further, the findings are time sensitive and are considered valid only at the time the report was produced. The conclusions contained in this report are based upon the applicable guidelines, regulations, and legislation existing at the time the report was produced; any changes in the regulatory regime may alter the conclusions.

Appendix A

Appendix B

Supporting tables of number of fish caught by species and sampling location in spring and summer 2020

Table B1 Number of fish by species and sampling site caught during beach seining along the north shoreline of the Roberts Bank causeway (CN) in spring 2020

Common name	CN1	CN2	CN3	CN4	CN5	CN6	CN7	CN8	Total
Bay goby	-	6	1	-	1	6	2	-	16
Bay pipefish	-	-	-	-	1	-	-	-	1
Chinook salmon	109	489	133	155	130	155	240	221	1,632
Chum salmon	8	33	13	4	66	1	45	58	228
Coho salmon	-	-	-	-	-	-	2	-	2
English sole	-	-	-	-	-	-	2	2	4
Pacific herring	118	-	67	-	92	4	3	8	292
Pacific sandlance	-	-	-	-	2	-	-	16	18
Pacific staghorn sculpin	35	7	15	29	12	24	10	5	137
Penpoint gunnel	-	-	-	-	-	-	1	-	1
Pink salmon	20	20	3	1	137	2	70	3,534	3,787
Shiner perch	371	4	198	321	251	113	741	44	2,043
Smoothhead sculpin	34	90	35	6	79	5	21	1	271
Sockeye salmon	-	-	-	-	-	-	1	-	1
Starry flounder	16	26	20	10	30	24	12	12	150
Surf smelt	-	-	-	9	16	-	9	32	66
Threespine stickleback	34	15	9	8	60	23	23	34	206
Unidentified flatfish	-	15	-	15	6	3	15	112	166
Unidentified gunnel	-	-	-	-	-	-	-	3	3
Unidentified kelpfish	-	-	-	-	-	-	1	-	1
Unidentified larval fish	-	2	-	1	7	-	2	3	15
Unidentified sculpin	182	338	216	75	248	208	55	105	1,427
Unknown	1	2	-	1	1	28	5	9	47
Total	**928**	**1,047**	**710**	**635**	**1,139**	**596**	**1,260**	**4,199**	**10,514**

Table B2 **Number of fish by species and sampling site caught during beach seining along the north shoreline of the Roberts Bank causeway (CN) in summer 2020**

Common name	CN1	CN2	CN3	CN4	CN5	CN6	CN7	CN8	Total
Bay goby	2	1	6	-	13	18	-	-	40
Bay pipefish	1	-	-	-	-	-	-	1	2
Chinook salmon	2	11	1	2	-	1	12	3	32
Pacific herring	-	-	-	-	-	1	52	2	55
Pacific sandlance	1	-	-	1	-	1	48	137	188
Pink salmon	-	-	-	-	-	-	-	1	1
Saddleback gunnel	-	-	-	-	-	-	-	1	1
Shiner perch	67	988	268	1,062	283	1,535	359	263	4,825
Speckled sanddab	-	-	-	-	-	-	8	2	10
Pacific staghorn sculpin	146	41	63	91	50	71	61	116	639
Starry flounder	18	3	22	26	22	18	55	27	191
Surf smelt	-	-	-	-	-	-	1	-	1
Threespine stickleback	56	37	26	26	20	67	17	113	362
Unidentified flatfish	-	-	-	1	-	-	2	19	22
Unidentified sculpin	44	-	109	-	80	19	6	43	301
Unknown	-	2	-	2	-	-	-	2	6
Total	**337**	**1,083**	**495**	**1,211**	**468**	**1,731**	**621**	**730**	**6,676**

Table B3 **Number of fish by species and sampling site caught during beach seining along the south shoreline of the Roberts Bank causeway (CS) in spring 2020**

Common name	CS1	CS2	CS3	CS4	CS5	CS6	CS7	CS8	Total
Bay goby	-	2	1	-	-	2	-	7	12
Bay pipefish	-	-	-	1	-	1	1	1	4
Chinook salmon	4	5	3	46	332	68	75	94	627
Chum salmon	-	6	-	27	46	166	37	106	388
Coho salmon	-	-	-	-	-	1	-	-	1
Kelp greenling	-	-	-	-	-	-	-	1	1
Pacific herring	46	-	-	-	-	-	-	1	47
Pacific sandlance	-	1	1	-	-	-	-	-	2
Pacific staghorn sculpin	6	12	36	101	39	37	25	62	318
Penpoint gunnel	-	-	-	-	-	-	-	1	1
Pink salmon	3	15	13	201	611	512	78	495	1,928
Shiner perch	-	195	31	67	19	163	42	57	574
Smoothhead sculpin	18	12	11	50	56	42	46	16	251
Speckled sanddab	-	-	-	-	-	-	-	1	1
Starry flounder	1	1	-	3	5	9	2	5	26
Surf smelt	-	-	-	-	-	-	144	2	146
Tadpole sculpin	-	-	-	-	-	-	1	-	1
Threespine stickleback	12	7	11	6	12	117	13	197	375
Tidepool sculpin	-	-	-	-	-	2	6	1	9
Tube-snout	-	-	-	-	-	1	-	11	12
Unidentified flatfish	-	-	8	12	9	8	7	15	59
Unidentified greenling	-	-	-	-	-	-	-	8	8
Unidentified gunnel	-	-	-	-	-	-	-	8	8
Unidentified larval fish	-	-	-	-	-	1	1	-	2
Unidentified salmon	-	-	-	32	-	-	-	-	32
Unidentified sculpin	15	12	76	35	87	88	127	150	590
Unknown	4	1	2	1	-	-	1	2	11
Total	**109**	**269**	**193**	**582**	**1,216**	**1,218**	**606**	**1,241**	**5,434**

Table B4 **Number of fish by species and sampling site caught during beach seining along the south shoreline of the Roberts Bank causeway (CS) in summer 2020**

Common name	CN1	CN2	CN3	CN4	CN5	CN6	CN7	CN8	Total
Bay goby	-	-	-	-	1	-	-	-	1
Bay pipefish	-	-	-	1	1	1	7	-	10
Chinook salmon	-	-	-	-	4	1	11	-	16
Chum salmon	-	-	-	-	-	-	1	2	3
Pacific sandlance	-	-	-	-	18	-	-	-	18
Pacific snake prickleback	-	-	-	-	-	-	-	1	1
Pacific staghorn sculpin	25	52	24	30	82	89	65	103	470
Shiner perch	53	195	70	406	636	257	713	1,486	3,816
Smoothhead sculpin	5	2	-	-	1	-	4	-	12
Starry flounder	18	-	17	16	43	57	64	14	229
Threespine stickleback	18	62	42	81	141	23	652	681	1,700
Tube-snout	-	-	-	-	-	-	2	-	2
Unidentified flatfish	6	6	4	15	50	2	13	12	108
Unidentified larval fish	-	-	-	-	-	-	113	-	113
Unidentified sculpin	42	12	15	115	57	44	37	110	432
Unknown	-	-	1	-	-	-	-	-	1
Total	**167**	**329**	**173**	**664**	**1,034**	**474**	**1,682**	**2,409**	**6,932**

Table B5 **Number of fish by species and sampling site caught during beach seining along Westham Island (WI) in spring 2020**

Common name	WI1	WI2	WI3	WI4	WI5	WI6	WI7	WI8	Total
Bay goby	1	-	3	-	-	-	-	38	42
Chinook salmon	169	87	111	124	74	145	178	195	1,083
Chum salmon	1	2	8	6	-	-	2	-	19
Pacific herring	18	3	4	1	1	-	-	-	27
Pacific staghorn sculpin	16	43	20	19	54	6	8	38	204
Peamouth chub	151	171	263	128	223	54	92	243	1,325
Pink salmon	-	-	-	-	1	-	-	-	1
Shiner perch	18	28	34	3	18	9	8	21	139
Smoothhead sculpin	3	8	8	3	1	-	4	2	29
Starry flounder	156	169	61	3	41	43	39	42	554
Surf smelt	-	-	3	-	-	-	-	-	3
Threespine stickleback	66	99	83	139	92	101	129	157	866
Unidentified flatfish	6	2	87	-	205	58	93	12	463
Unidentified larval fish	12	-	-	-	1	-	-	-	13
Unidentified salmon	-	-	-	-	3	-	-	-	3
Unidentified sculpin	130	147	322	240	335	252	458	281	2,165
Unknown	4	-	4	-	-	-	1	-	9
Total	**751**	**759**	**1,011**	**666**	**1,049**	**668**	**1,012**	**1,029**	**6,945**

Table B6 **Number of fish by species and sampling site caught during beach seining along Westham Island (WI) in summer 2020**

Common name	WI1	WI2	WI3	WI4	WI5	WI6	WI7	WI8	Total
Chinook salmon	-	-	1	22	44	30	61	24	182
Chum salmon	-	-	-	-	1	-	-	-	1
Pacific herring	-	-	-	-	1	-	1	-	2
Pacific staghorn sculpin	50	38	86	6	-	16	1	21	218
Peamouth chub	600	326	606	117	622	47	2	13	2,333
Pink salmon	-	-	-	-	-	-	1	-	1
Shiner perch	-	-	-	-	3	1	1	-	5
Smoothhead sculpin	31	-	-	-	-	-	-	-	31
Starry flounder	3	-	-	56	8	1	-	1	69
Threespine stickleback	107	104	315	279	253	402	86	207	1,753
Unidentified flatfish	2	2	8	33	-	-	-	2	47
Unidentified sculpin	279	181	142	177	148	8	204	4	1,143
Unknown	-	-	-	-	3	1	-	2	6
Total	**1,072**	**651**	**1,158**	**690**	**1,083**	**506**	**357**	**274**	**5,791**

Table B7 **Number of fish by species caught during spot sampling using a beach seine at location SF1 off the Roberts Bank dyke in spring 2020**

Common name	SF1
Chinook salmon	32
Pacific herring	5
Pacific staghorn sculpin	59
Shiner perch	619
Starry flounder	1
Threespine stickleback	13
Unidentified larval fish	2
Unidentified sculpin	32
Total	**763**

Table B8 **Number of fish by species caught during spot sampling in summer 2020 using a beach seine at location SF1 off the Roberts Bank dyke and in the eelgrass bed (EG) north of the Roberts Bank causeway, and using a purse seine at subtidal locations (OS) south of the Westshore Terminal**

Common name	SF1	EG1	EG2	OS7	OS8	Total
Chinook salmon	-	5	1	-	-	6
Pacific herring	-	28	-	-	-	28
Pacific sandlance	-	-	-	-	4	4
Pacific snake prickleback	-	-	53	-	-	53
Pacific staghorn sculpin	65	-	-	-	-	65
Shiner perch	626	4	3	-	-	633
Smoothhead sculpin	3	-	-	-	-	3
Speckled sanddab	-	-	1	-	-	1
Starry flounder	-	-	1	-	-	1
Surf smelt	-	1	-	-	-	1
Threespine stickleback	416	29	3	-	1	449
Unidentified flatfish	5	-	1	-	-	6
Unidentified sculpin	10	-	-	-	-	10
Whitespotted greenling	-	-	1	-	-	1
Total	**1,125**	**67**	**64**	**-**	**5**	**1,261**

Appendix C

Supporting photos

Photo 1 Juvenile chum (left) and juvenile Chinook salmon (right) caught at CS5 (May 1, 2020)

Photo 2 Juvenile Chinook salmon caught at CS5 (May 1, 2020)

Photo 3 Juvenile Chinook salmon caught at CS5 (May 1, 2020)

Photo 4 Top down view of juvenile chum and Chinook salmon caught at CS6 (May 1, 2020)

Photo 5 Juvenile coho salmon caught at CS6 (May 1, 2020)

Photo 6 The single juvenile sockeye salmon caught at CN7 (May 6, 2020)

Photo 7 Processing fish at CN3 (May 8, 2020). Juvenile salmon were measured by a biologist (on the left) using a measuring board and weighed using a scale (seen in front of red bucket). Measurements were entered into iPad by a second biologist (on the right)

Photo 8 Typical aerated container set-up for catch processing; aerator seen on the right of container. Water level has been temporarily reduced for photo taking. Fish in container include threespine stickleback and Pacific staghorn sculpin

Photo 9 CN3 looking west from Roberts Bank causeway (June 30, 2020)

Photo 10 Pulling in the beach seine net at CN3, looking west from Roberts Bank causeway (May 8, 2020)

Photo 11 CS3 looking southwest towards existing Roberts Bank terminals (April 29, 2020)

Photo 12 Beach seining at CS4, looking east towards Tsawwassen (April 25, 2020)

Photo 13 Beach seining at WI6, looking west (May 9, 2020)

Photo 14 Beach seining at WI3, looking west (April 26, 2020)