Eulachon Status on the Ecstall and Lower Falls Rivers (COA-F19-F-2680)

Prepared for:

Prepared by:

Ciara Sharpe, MSc.
Katherine Butts, MSc.

Lax Kw'alaams Fisheries
100 1 Ave E
Prince Rupert, BC
V8J 1A6

Date: 31-03-2019

Prepared with financial support for Fish and Wildlife Compensation Program on behalf of its program partners BC Hydro, the Province of BC, Fisheries and Oceans Canada, First Nations and Public Stakeholders

EXECUTIVE SUMMARY

Eulachon are a prized species culturally and ecologically along the northeastern Pacific from northern California to Alaska. Supporting a diverse array of birds, mammals and fish during several life history stage in freshwater and marine environments, eulachon populations have significantly declined. Eulachon runs in central and southern BC populations have been designated as Endangered, while populations in northern BC (Nass and Skeena Rivers) have been designated as Special Concern under COSEWIC (COSEWIC 2013). Many factors are likely contributing factors to declining populations, from both freshwater and marine environments, including climate change, bycatch in marine fisheries, water quality and freshwater habitat loss.

Hydroelectric projects alter flow and sediment regimes, which ultimately result in changes for riverine habitat downstream. Controlled flows during hydroelectric operation create different flow regimes compared to watersheds without hydroelectric projects. These changes can influence available spawning substrate and spawning conditions of species such as eulachon and Pacific salmon. The Falls River hydroelectric project located 50km southeast of Prince Rupert, British Columbia, has resulted in changes to riparian habitat upstream and downstream of the constructed impoundment. Eulachon have been documented in the lower Falls River and further research is needed to determine if this region contains suitable spawning habitat that is being used by eulachon.

This project addresses the FLS.RLR.RI.08.01 Priority Action of FWCP Falls River Watershed Action Plan, to assess eulachon population status and habitat use of the lower Falls River. As this research project furthers the understanding of a culturally and ecologically important and threatened fish species (a COSEWIC listed species) in relation to the Falls River Dam, it falls under the mandate of FWCP. The objectives of this study were to assess a) the availability of suitable eulachon spawning habitat below the Falls River dam, and b) determine if eulachon were spawning at this location. The outcomes of this project were used to evaluate the utility of future monitoring or restoration programs in the lower Falls River

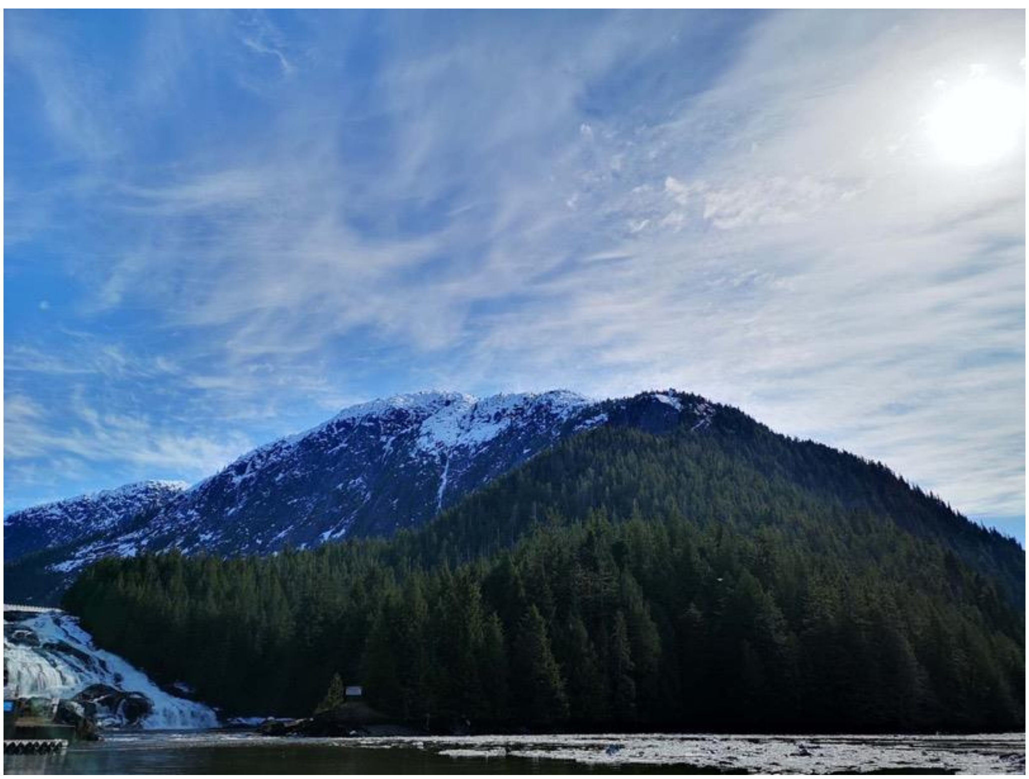
The results of this study suggest that eulachon are using the Falls River during their freshwater migration, however may only be spawning at the study locations in very low densities. Available spawning substrate was mainly comprised of fine sediment, which is known to be of lower value to spawning eulachon. A potential restoration project could be conducted to introduce additional coarse substrates (sand and gravel), which represents higher value habitat for spawning eulachon. However, maintaining a flow and sediment regime to support this type of restoration project may be challenging.

A restoration project in the lower Falls River would contribute to our understanding of enhancing streams in lake headed systems below impoundments. It would be an experiment that directly answers questions about the feasibility of enhancing spawning habitat for eulachon. As there is relatively limited research on eulachon in general, a restoration project would contribute to the overall understanding about eulachon spawning habitat.

Given the cultural and ecological importance of eulachon, conducting additional research will further our understanding of eulachon. Additional research, such as sampling for drifting larvae and eggs, in this region would strengthen our findings and provide supplementary information on the use of the Falls River by Eulachon

The results of this study led to the following recommendations for future restoration actions and research priorities:

- Conduct follow-up monitoring of gravels added to tail pond from earlier enhancement efforts. This will help determine if addition of sand or gravels to enhance eulachon spawning habitat downstream is feasible with the water and sediment regimes.
- Install temperature loggers at various locations in the Falls River to determine if temperature regimes remain suitable during the entire egg incubation period (March – May).
- Additional sampling in the Falls River to capture any drifting eggs and larval eulachon is needed to complete our understanding of eulachon that may be spawning in the Falls River area (including within the tail pond).
- If restoration activities are determined a priority to enhance spawning habitat for eulachon, a hydrology/ geomorphology expert should be consulted to assess the flow regime and available habitat to determine the feasibility of potential restoration activities.



Facing east towards the Falls River hydroelectric project in Falls River in March 2019 during eulachon sampling. (Photo by Jim Henry Jr.)

Table of Contents

LIST OF FIGURES

INTRODUCTION

Eulachon are a prized traditional food source with a distribution along the northeastern Pacific from northern California to Alaska. Large spawning migrations and high lipid content (Payne et al. 1999; Moody 2000) make them an integral part of the food web in the northeastern Pacific, supporting birds, mammals and many species of fish including Pacific salmon. However, eulachon populations have declined significantly from historical levels and continue to decline in many populations (Moody 2000). Eulachon runs in central and southern BC populations have been designated as Endangered, while populations northern BC (Nass and Skeena Rivers) have been designated as Special Concern under COSEWIC (COSEWIC 2013). The eulachon runs from the Nass and Skeena Rivers are the largest remaining runs in British Columbia, and remain at stable catch levels compared to adjacent populations in central/ southern BC and Alaska, which are declining (COSEWIC 2013). Although population size estimates have not been quantified, it is estimated that current abundance of Nass and Skeena Rivers are most likely lower than historical abundance (100 – 200 years ago). For example, while annual Nass River catches from the last 100 years are estimated to be around 200 – 500 tons, the largest historical estimate catch was 2000 tons (1840s) (Moody 2000). Many factors are likely contributing factors to declining populations, from both freshwater and marine environments including climate change, bycatch in marine fisheries and water quality (Pickard & Marmorek 2007; NOAA 2011; Gustafson et al. 2012; Schweigert et al. 2012; COSEWIC 2013).

Eulachon are an anadromous fish species, returning to freshwater from marine habitats to spawn in the spring, around the age of 3. They are found mainly in coastal rivers associated with glaciers and snow dominated basins that have strong spring freshets (Hay & McCarter 2000). In the spring (prior to peak flows), they generally spawn on sand or gravel substrates in tidally influenced river reaches (Langer et al. 1977), where eggs lightly attach to the substrate. The egg incubation period is temperature dependant and typically lasts for 2 – 8 weeks (Howell 2001), before the larvae hatch and are rapidly carried downstream to estuaries and nearshore coastal environments by spring freshwater flows. Once juvenile eulachon arrive in the marine environment they reside in nearshore waters and estuaries before moving to offshore waters, where they are found in deep waters of 20 – 150m deep (Hay & McCarter 2000). As larvae and juveniles they feed on phytoplankton and zooplankton, while adult eulachon primarily feed on zooplankton, particular crustaceans such as copepods and euphausiids (Hay 2002). Thus, impacts to marine and freshwater habitats and environmental conditions have the potential to influence eulachon populations.

Large hydroelectric projects alter flow regimes which may result in changes for riverine habitat downstream. Controlled flows during hydroelectric operation create different flow regimes compared to watersheds without hydroelectric projects (NOAA 2011). Potential changes include reduced or increased peak flows, sediment loads and timing of peak river discharges. Reservoirs created by dams trap coarse sediment (sand, gravel, cobble) and debris limiting the establishment as downstream bed material (Shaffer et al. 2007). In addition, in-stream modifications related to hydroelectric projects dykes, rip rap or bank armouring also cause changes to flow regime and available habitat. These changes can influence available spawning substrate and spawning conditions of species such as eulachon and Pacific salmon (NOAA 2011).

The Falls River located 50km southeast of Prince Rupert, British Columbia, is the location of the Falls River hydroelectric project. Created in 1930, Big Falls creek was dammed above a natural waterfall (natural fish barrier) to create the Big Falls reservoir (FWCP 2017). This lake (340 ha) is fed by Big Falls Creek, Hayward Creek and Carthew Creek and was not present before impoundment. Dam construction and resulting changes to the hydrologic regime have resulted in changes to habitat upstream and downstream of the Falls River dam (Miller et al. 2002). These changes include loss of 38 ha of riparian habitat and 6km of riverine habitat upstream of the impoundment (FWCP 2017). In addition, changes in flow regime has also resulting in the loss of downstream sedge habitat and recruitment of large woody debris and gravel (Miller et al. 2002; FWCP 2017). Changes in flow regimes include high flushing flows resulting in scarification and low recruitment of gravels and extremely low flows during shut down periods (FWCP 2017). Eulachon have been documented in the lower Falls River, however all individuals were adult males, and no eggs or larvae have been observed (FWCP 2017). It is unknown whether the lower falls region is used by eulachon for spawning.

GOALS AND OBJECTVIES

Falls River hydroelectric project is operated by BC Hydro and is a partner of The Fish and Wildlife Compensation Program (FWCP) along with the Province of BC, Fisheries and Oceans Canada, First Nations and Public Stakeholders. This program aims to conserve and enhance fish and wildlife impacted by BC Hydro dams (FWCP 2017).

The goal of this project is to conduct research to assess the eulachon population status and habitat use in the lower Falls River in relation to the Ecstall River (Action #8, Rivers, Lakes & Reservoirs, FLS.RLR.RI.08.01 (FWCP 2017). This project has been identified as priority action 2 for FWCP (Action Table, FWCP 2017). As this research project furthers the understanding of a culturally and ecology important fish species (COSEWIC listed species), in relation to the Falls River Dam, it falls under the mandate of FWCP.

This project aims to collect information necessary to evaluate the potential of subsequent conservation and restoration actions in relation to eulachon on the Falls River. By determining: a) the availability of suitable eulachon spawning habitat below the Falls River dam, and b) if eulachon are spawning in this region, we can evaluate future actions relation to eulachon conservation. The outcomes of this study will be used to evaluate the utility of future monitoring or restoration programs.

STUDY AREA

The Falls River watershed has an area of approximately 264 km^2 and is located 25km upstream of the confluence of the Ecstall and Skeena River. As a tributary of the Ecstall, the Falls River comprises approximately 23% of water flowing in the Ecstall River (Miller et al. 2002). Riverine habitat below the dam is tidally influenced and comprised of two reaches separated by a smaller 4.5m falls, which is a fish barrier at low tide (Figure 1). Upstream of the 4.5m falls is the tail pond of the dam. Because of the larger size of the boat used in this study and the lower tide heights during the study period, all sampling occurred below the tail pond and set of smaller falls.

Figure 1. Illustrating the 4.5 m falls at low tide that is a fish barrier. Our survey was conducted downstream of this smaller set of falls due the large size of the boat used during this study.

Skeena River Eulachon Population

The size of the Skeena River eulachon run is unknown, as it has been less documented than the Nass River. However, it is known to be smaller than the Nass River eulachon population and spawning of eulachon in smaller Skeena River tributaries, such as the Ecstall River and Kyex River have been previously documented (Kelson 2010; Rolston 2010). The COSEWIC report (2011, p41-22) summarizes the limited knowledge of the Skeena River eulachon that has been made publicly available. In this reference, it is recorded that the Skeena River run was historically small, with eulachon harvested on the Ecstall River by the Tsimshian First Nations for eulachon grease of high quality. The Skeena River eulachon historically returned during the first week of March, however are noted to be returning earlier in recent years during mid- to late February (Moody 2000; COSEWIC 2013). Local knowledge has indicated that eulachon runs declined sustainably by the mid-1990s and have had variable sizes since, with some years representing very low years (COSEWIC 2013). In addition, it is thought that spawning distribution has decreased, as fish are known to have historically spawned higher up in the Skeena River then present day (COSEWIC 2013). Given the lack of information on run size, timing and in-river habitat utilization of the Skeena River, further research is needed on the Skeena River eulachon.

METHODS

Sediment Sampling

To determine the extent of suitable eulachon spawning habitat, sediment samples were taken from the lower Falls River. Sampling sediment below the Falls River dam occurred several times in 2019. First, sediment samples were collected on April 16 -20 2018 and February 18-22, 2019. A 50 m^2 grid was placed over a 1:3000 scale map and sediment samples were taken as close to the cross hairs of each grid for a total of 27 sediment samples on each sampling date (Figure 2). Sediment samples were taken with a Wildco Standard Ekman sediment sampler and sediment was classified (fine, sand, gravels, bedrock). Sediment samples were also collected on March 20 and 21, 2019 during benthic sampling for eulachon eggs. These samples were collected at locations deep enough to sample with boat as the tide height was low during these sample dates. Sediment samples were taken randomly within the remaining habitat for a total for 28 samples (Figure 3). March sediment samples were classified using the same categories (fine, sand, gravels, bedrock) and were sampled with a Wildco Petite Ponar Grab.

Egg Sampling

Ponar grab samples were used to investigate the presence of eulachon eggs in the sediment of Falls River. Surface sediments from each ponar grab were strained through a 0.35mm sieve to filter out fine particle and make it possible to search for eulachon eggs (approximately 1.1 mm in diameter (Matarese et al. 1989)). Any water collected in sediment grab were also strained and searched for eulachon eggs. The samples were then collected, and the presence/absence of eggs was verified with a dissecting scope in the laboratory.

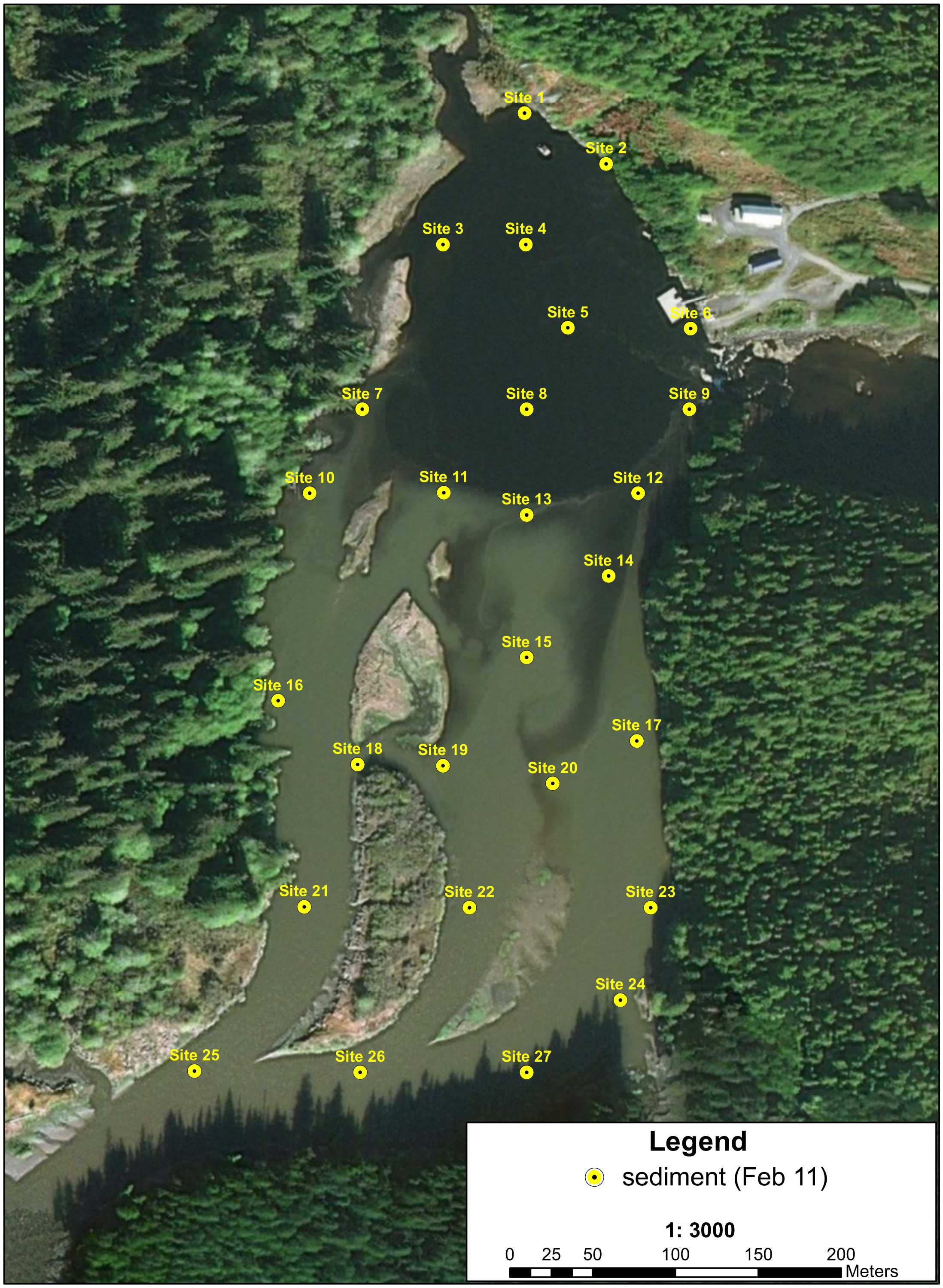


Figure 2. Locations of sediment sampling in 2018- 2019. (Map by John Latimer, Lax Kw'alaams)

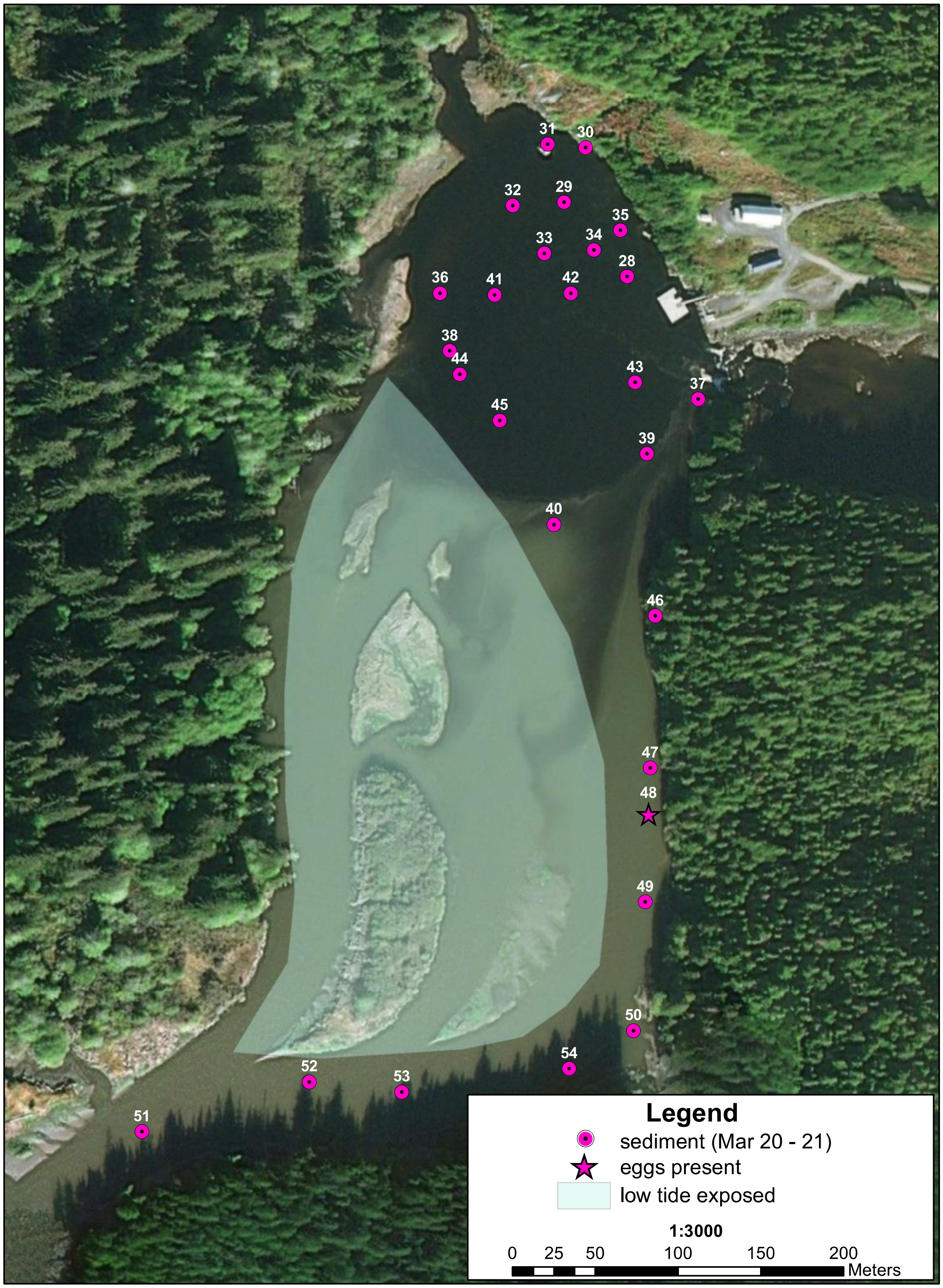


Figure 3. Locations of sediment and egg sampling using ponar benthic grab sampler on March 20 and 21, 2019. Region exposed at low tide is shaded in green. (Map by John Latimer, Lax Kw'alaams Fisheries)

Eulachon Sampling

Although there is no scientific data on the Skeena River eulachon run timing, members of the Lax Kw'alaams community and other Skeena River First Nations track the timing of the eulachon run using the abundance of marine birds as an indicator (COSEWIC 2011). In 2019, we used marine birds as an indicator to determine the start of the eulachon Skeena River eulachon run. Run timing was earlier than usual (Wade Helin, Lax Kw'alaams First Nation, pers. comm.) with catch recorded as early as February 16, 2019 (Katelyn Cooper, Lax Kw'alaams First Nation, pers. comm.). Upon completion of the project (March 21), marine mammals and birds were still abundant on the Ecstall and lower Skeena river suggesting that the 2019 eulachon run continued into late-March.

Sampling conditions during this study were challenging due to the high prevalence of moving ice (Figure 4 and 5). These challenging conditions influenced the accessibility, travel times and available net locations for the duration of the study. Given that safety was the primary priority, sampling was conducted only when possible. This led to a lower frequency of sampling events and a smaller geographic extent (limited Ecstall River sampling) then planned. On February 23, Lax Kw'alaams Fisheries technicians attempted to access to the study site but were stopped at the confluence of the Skeena and Ecstall Rivers by solid surface ice. The team returned on March 6 and March 8, 2019, findings the majority of the Ecstall and Falls Rivers completely iced over but were able to access a small portion of open water at the mouth of the Falls River. On these dates, three gillnets were set for short durations due to ice movement and alternative sampling methods (throw nets, dip nets and cone nets) were attempted. During subsequent sampling dates (March 6, 12, March 18 – 21), ice flow was lower and gill net sampling was more successful.

Figure 4. Illustrating the high volume of surface ice in Falls River (left picture, viewing east towards BC Hydro facility) and the Ecstall River (right picture, viewing west across the Ecstall River from the mouth of Falls River) resulted in challenging sampling conditions during the 2019 eulachon run.

Figure 5. Setting a successful gillnet set at Falls River (left picture) and retrieving an unsuccessful gillnet tangled in ice (right picture).

A total of 31 sinking gillnets were set during this project, with 28 gillnets set in Falls River and three gillnets set at one location on the Ecstall River (Figure 6). This location was the only location that was both deep enough to set a gill net and not subjected to high ice movement. Gillnets were left from 1 – 24 hours (Appendix Table 1), with soak time and location influenced by accessibility. Two sizes of gillnets were used with the following dimensions: small nets were 7.5m long x 1.8 m deep x 1 ½ inch mesh, and a large net was 100m long x 5m wide x 1 ½ inch mesh. Due to the limited size of the ice-free gillnet location on the Ecstall River, only the smaller gillnets were used.

Cath per unit effort (CPUE) was calculated for each net size separately by standardizing for 2-hour net sets. Mean CPUE from Falls River and Ecstall River for small net sets were compared with a Welsch t-test to account for unequal variance (different sample sizes) with log transformed CPUE values.

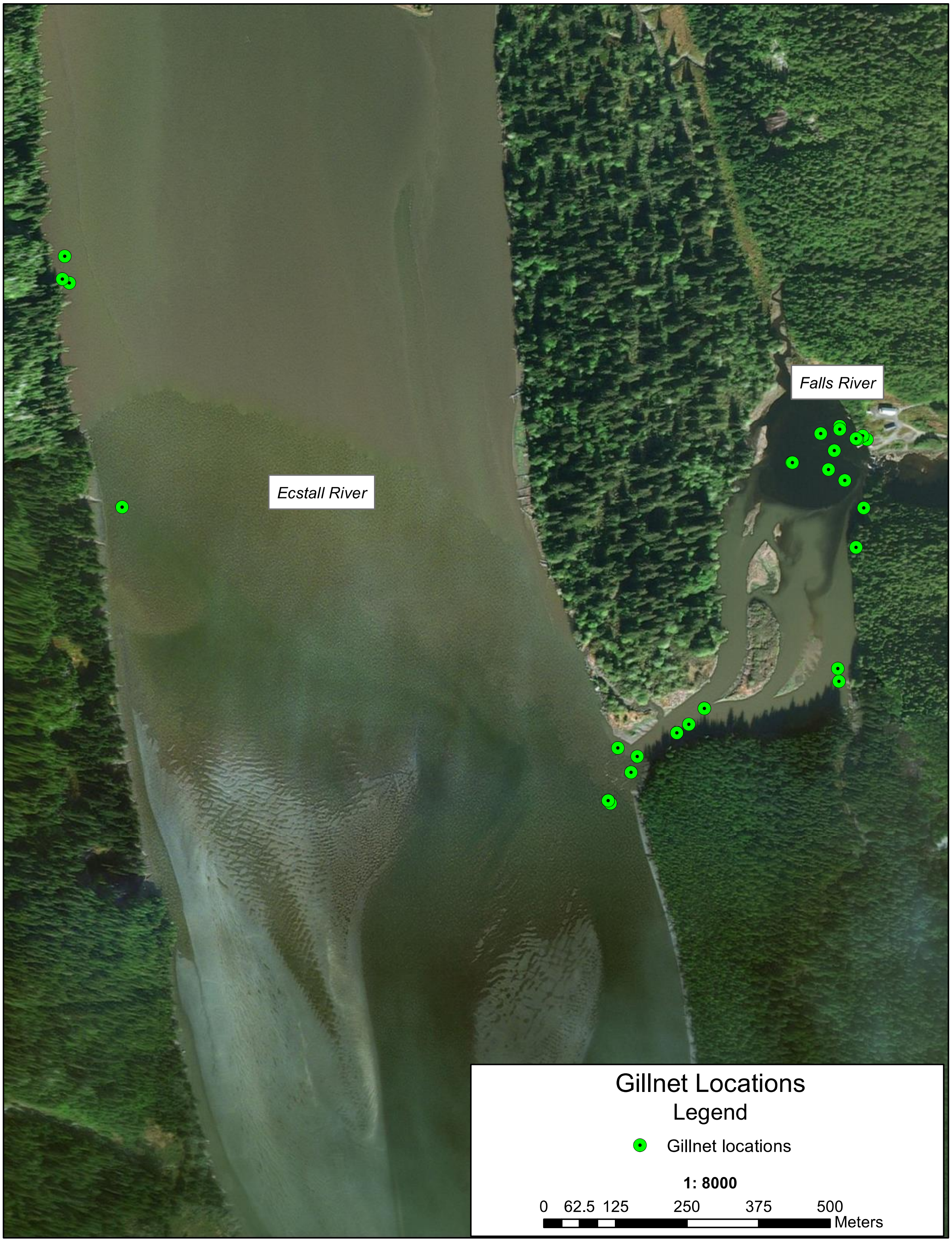


Figure 6. Locations of gillnet sets in the Falls River and Ecstall River. (Map by John Latimer, Lax Kw'alaams Fisheries)

Water Quality Parameters

Information on environmental parameters was collected in Falls River at various tide heights, locations and water depths. Water temperature, salinity and dissolved oxygen measurements were taken with a YSI (Pro2030) and turbidity was measured with a secchi disk.

RESULTS AND OUTCOMES

Eulachon Sampling

We caught 242 adult eulachon with 31 gillnet sets, sampling on the following 7 sampling dates: March 6, March 8, March 12 and March 18 – 21 (Figure 7, Appendix Table 1). On the Ecstall River we caught 83 eulachon in three successful gillnets sets and 160 eulachon from 28 successful gill nets sets on the Falls River (Figure 6 and 7). Gillnets that were tangled by ice were removed from analysis (Figure 5b). In addition to eulachon, four surf smelt (*Hypomesus pretiosus*), two sculpin (Cottus asper) and two capelins (*Mallotus villosus*) were also caught in gill nets in Falls River. During all sampling days, wildlife activity was high (abundant gulls dipping into the river) along the Ecstall River and within the lower Falls River, and crew members watched gulls successfully catch eulachon at both locations (Figure 8 and 9). Bird activity in Falls River was lowest on March 21 compared to earlier sampling dates but remained high on the Ecstall River. Seals, sealions and eagles were abundant in the lower stretches of the Ecstall River and the confluence of the Skeena on all trips in March.

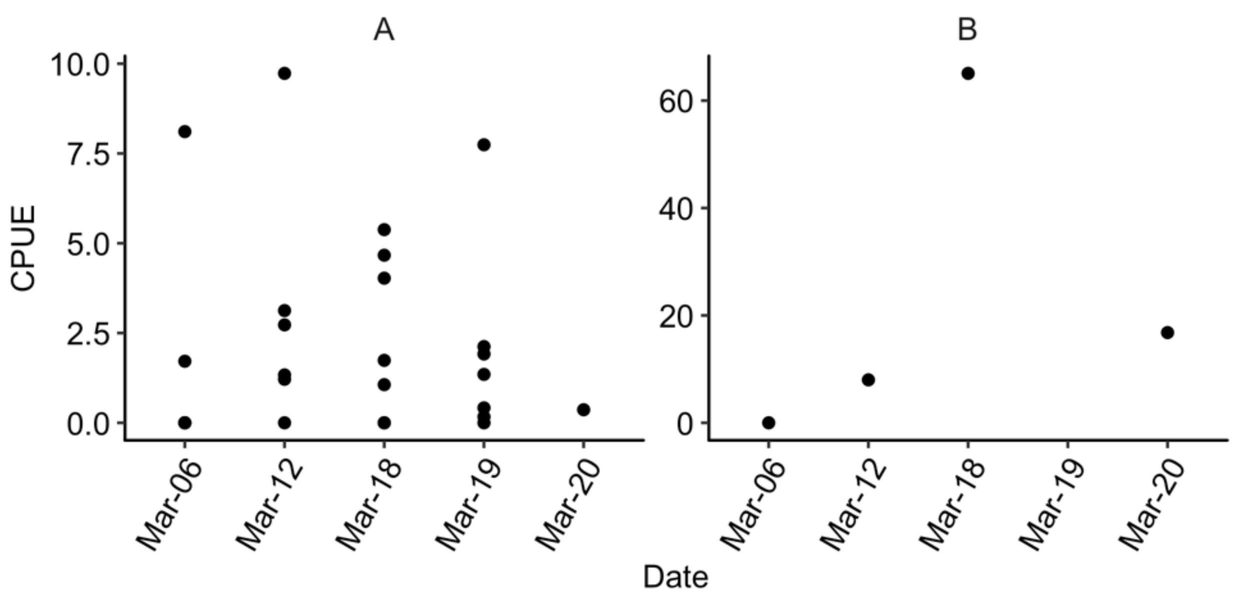


Figure 7. CPUE of eulachon from 7.5m gillnet (A) and 100m gillnet (B) across sampling dates from all locations on the Ecstall and Falls Rivers.

We caught substantially less female (5%) then male (95%) eulachon during gill net sampling, resulting in a male to female ratio of 19:1 (Figure 10). Of the 11 females captured, 6 were determined to be pre-spawn. Most males were determined to be post-spawn, with only 25 of the 229 males measured determined to be pre-spawn**.** Both pre-spawn males and females were caught in the lower Falls River (Figure 10 and 11)

Adult eulachon fork length ranged from 155 mm – 215 mm with a mean size of 178mm (Figure 12a). Mean fork length of males and females was 178 mm and 187 mm, respectively. There was no difference in size between eulachon caught at sites in Falls River or Ecstall River (Figure 12b).

Average CPUE from gillnet sets in Falls River were lower (2.34 ± 1.3 95%CI) when compared with average CPUE from the location sampled on the Ecstall River (4.06 ± 1.9 95%CI) (Figure 13). This difference was weakly statistically significant ($t(4.9) = -2.64$, $p = 0.045$).

Figure 8. Abundant gull foraging on eulachon in the Falls Rive below the tail pond during March sampling dates. Illustrating high wildlife activity and surface ice in proximity to BC Hydro dock.

Figure 9. Setting a gillnet in the Falls River downstream of the dam with abundant marine birds foraging for eulachon.

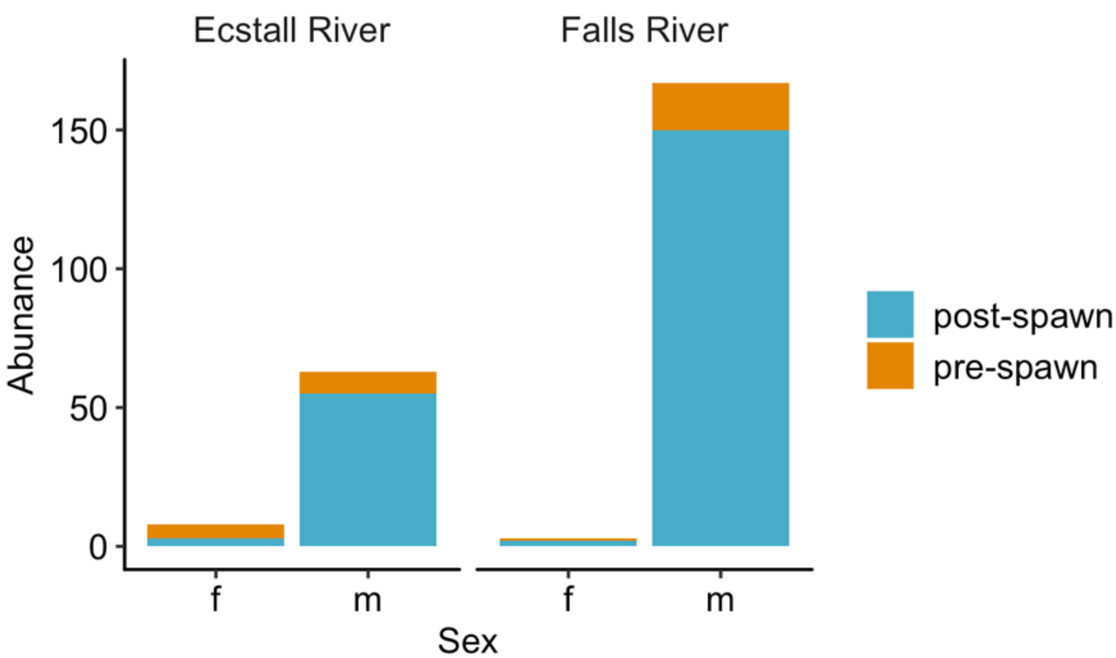


Figure 10. Abundance and spawning condition of males and females in the Ecstall River and Falls River

Figure 11. Eulachon found in the lower Falls River: top fish is a female pre-spawn eulachon and bottom in a male post-spawn eulachon.

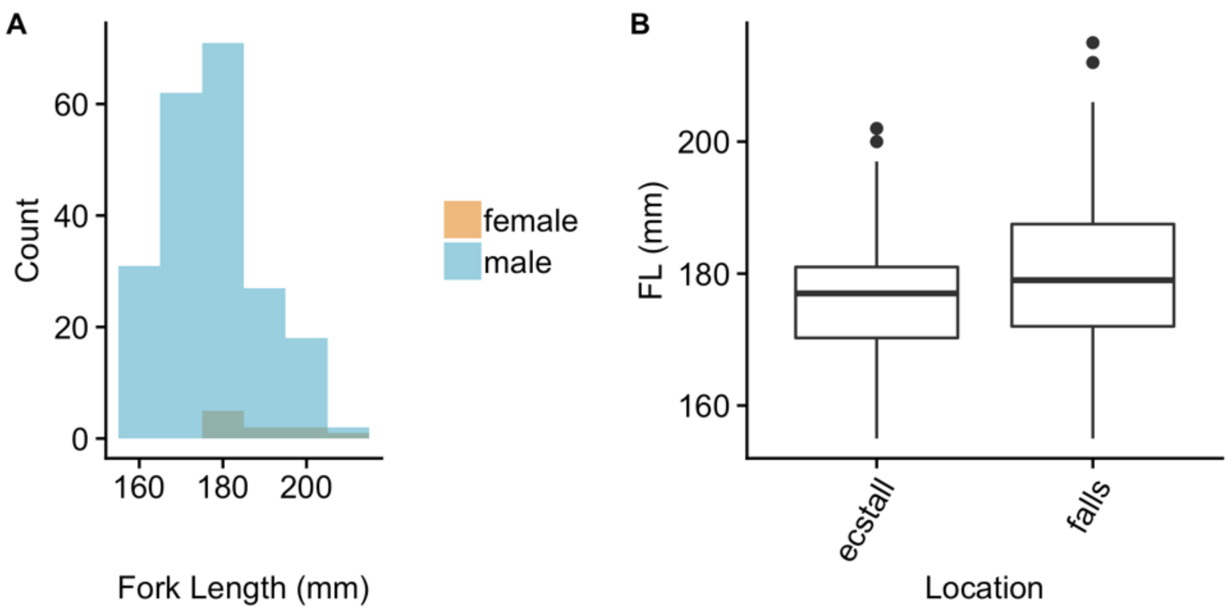


Figure 12. Distribution of eulachon fork length (male = blue, female = blue) caught during March 2019 (A). Eulachon fork length divided by Ecstall River and Falls River is shown in panel B. In panel B the solid black lines indicate median fork length for each location, while box boundaries indicate first, and third quantiles and whiskers indicate the highest and lowest values of fork length. Points outside the whiskers represent possible outliers.

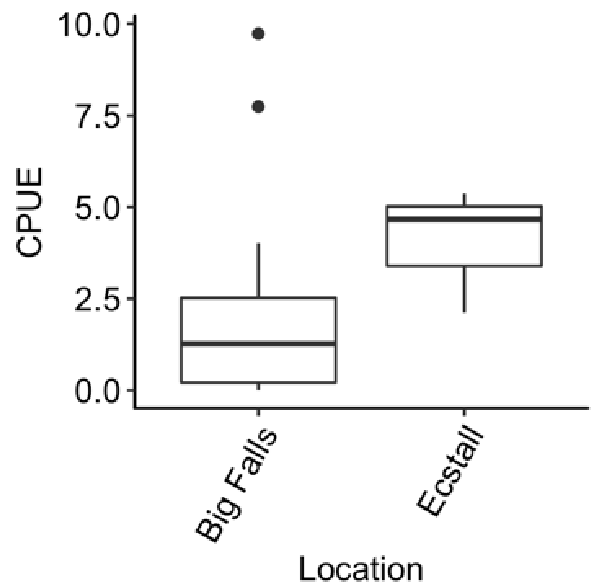


Figure 13. CPUE of eulachon caught in gillnets in Falls River and Ecstall River. The solid black lines indicate median CPUE of eulachon for each location, while box boundaries indicate first, and third quantiles and whiskers indicate the highest and lowest values of CPUE. Points outside the whiskers represent possible outliers.

Egg Deposition

We searched sediment from 28 sample locations (Figure 3) for eulachon eggs and found low abundance of eulachon eggs present in only one sample (Appendix Table 3). At site 48, five eggs were identified, while no eggs were found in other samples, including samples adjacent to site 48 (Figure 3).

Sediment Sampling

All substrate samples from April 2018 and February 2019 (27 samples, Appendix Table 2) and March 2019(28 sample, Appendix Table 3) were mainly composed of fine sediment (clay and silt). At several locations, there were traces of fine sand and organics mixed within the fine sediment, including the only location where five eulachon eggs were found (Appendix Table 3). Two locations (site 40 and 52) had a higher proportion of sand or gravel but samples were still mainly composed of fine sediment.

Water Quality

Measurements of salinity, temperature and dissolved oxygen varied across location, tidal stage and depth within Falls River (Appendix Table 4). Across all sampling dates, water visibility was low with secchi depth measurements ranging from 0.1 m to 0.5 m. Temperature and salinity values ranged from 0 ˚C – 2.6 ˚C and 0 ppt – 2.10 ppt, while dissolved oxygen ranged from 6.9 ppm - 29.10 ppm (Appendix Table 4).

Figure 14. Illustrating low tide in the Falls River with exposed banks comprised of fine sediment.

DISCUSSION

Utilization of Falls River by Eulachon

Adult eulachon were caught during most sampling days in the lower section of the Falls River. Average catch was slightly lower in the Falls River compared to the average catch of eulachon in a location in the adjacent Ecstall River. However, CPUE in both locations was significantly lower than that observed on the lower Skeena River in 2010 (Rolston 2010). Lower density of adult spawners and eggs have been documented in the Ecstall River compared to the Skeena River previously (Kelson 2010; Rolston 2010). Difficult sampling conditions caused by large quantities of flowing ice influenced the location and duration of gillnet sets. In addition, highly turbid water during the sampling period made detection of spawning eulachon difficult. Previous studies had success using underwater video to determine spawning locations (Kelson 2010; Rolston 2010). These challenges resulted in low replication and geographical area sampled on the Ecstall River, ultimately preventing further comparisons of adult eulachon caught in both locations.

Fork length and sex ratio of eulachon are typical of other eulachon spawning populations in BC (Willson et al. 2006). Given that male eulachon reside in freshwater for longer periods than females, the sex ratios are skewed highly towards male eulachon (Lewis 1997).

Although we found adult eulachon using the Falls River during this study, we did not find significant evidence to suggest that eulachon were spawning within the Falls River. Previous studies have used the presence of eggs (in the water column and substrate), larval eulachon

(Pederson et al. 1995; Lewis 1997) and high densities of eulachon adult spawners as an indication of a utilized spawning location (HDR Inc. & LGL 2014). High densities of adult eulachon at locations can be identified with a fish viewer, visually in clear waters and with methods such as dip nets and with technology such as radio telemetry (Rolston 2010; HDR Inc. & LGL 2014). Low water clarity during this study prevented our team for using this method to determine spawning locations. This study used egg abundance from substrate samples to determine if eulachon are spawning within the lower Falls River. We found low densities of eulachon eggs at only one location in the Falls River, after sampling sediment at 28 locations within the Falls River. Given the low density of eggs present during sampling, eulachon are not likely spawning in high densities within the lower Falls River. Addition research conducting larval and egg sampling in the water column would provide further information on eulachon habitat use.

Available Spawning Habitat and Environmental Conditions

Suitable eulachon spawning habitat is influenced by a variety of factors including substrate, flow, depth, temperature and salinity. These parameters are known to influence the incubation and survival of eulachon eggs.

Although eulachon have been known to spawn on a variety of substrates (silt, sand, gravel, cobble and detritus) (Barrett et al. 1984; Willson et al. 2006), spawning in coarse sand or small gravels sediments is preferred (Smith & Saalfeld 1955; Langer et al. 1977; Willson et al. 2006). Eggs adhere to sand and small gravels, anchoring them during incubation and ensuring they are not washed downstream into more saline conditions. Egg mortality is generally higher on sand or gravel sediments when compared to silt or organic sediments (Langer et al. 1977). We found most sediment samples in the Falls River to be comprised of fine sediment (silt and clay). This suggests that available spawning sediments in the lower Falls River is likely of low value for spawning eulachon.

Eulachon are known to spawn in moderate flow conditions (Smith & Saalfeld 1955) and in relatively shallow waters (Smith & Saalfeld 1955; Langer et al. 1977; Hay 2002). Flow was not measured in the Falls River during our study, although it was noted to be slow moving in most of the available habitat. Moderate flows were noted at the outflow of the first reach. In addition, suitable depths are present at Falls River with gillnets set across a range of depths from 1.5 m – 10m, with shallower and deeper habitat available. Eulachon spawning locations occur within this depth range in the Skeena River (Rolston 2010) and in other watersheds (Willson et al. 2006).

Both temperature and salinity conditions the Falls River were suitable for incubation of eulachon eggs. Eulachon are known to spawn in tidally influenced portions of the river (Lewis et al. 2002), (sometimes upstream of tidally influenced sections), but exposure to higher levels of salinity causes mortality in incubating eggs. However, eulachon eggs are thought to tolerate low- to mid- range salinities during incubation (Lewis et al. 2002). The Falls River is tidally influenced but remains at low levels of salinity. Although salinity values varied according to depth and tidal stage, the maximum recorded salinity was 2.10 ppt (Appendix Table 4). This is significantly below values demonstrated to cause egg mortality — past salinities of 16 ppt (Farara 1996). In addition, eulachon eggs are known to incubate across a variety of temperatures depending on location (Hay & McCarter 2000). Temperatures recorded at the Falls River ranged from 0°C – 2.6 °C, which are consistent with the temperatures recorded on the Skeena and Nass Rivers during egg incubation (Langer et al. 1977; Willson et al. 2006). Similar water quality values were also obtained in Falls River in the fall of 2002 (Miller et al. 2002). Given that egg incubation periods range from 2 – 8 weeks (Howell 2001), monitoring temperature for longer time periods (into April) will be necessary as drastic temperature changes are known to negatively influence egg survival (Willson et al. 2006). Installing temperature loggers at various locations will further determine if falls river is suitable habitat for egg incubation.

Overall, the environmental conditions recorded in the Falls River during March 2019 are adequate for incubation of eulachon eggs, but available substrate for adult spawning and egg adhesion is of lower value. Further sampling should be conducted to determine if temperatures and salinity regimes remain suitable for the duration of the egg incubation periods (March – May).

Potential Enhancement of Spawning Habitat

Hydroelectric projects such as the Falls River project influence flow and sediment regimes. Since construction in 1930, there have been changes to the bed material in the Falls River below the dam. Evidence of abundant sand and gravels (small and medium) along the banks of the Falls River can be seen in a historical photo taken prior to dam construction (Figure 15). In comparison, Figure 16 illustrates the current banks of the falls river which are mostly composed of fine-grained bed material. Sand and gravel particles sink and become entrained in reservoirs upstream of dams, decreasing recruitment of this coarse size of bed material downstream (Shaffer et al. 2007). This has been shown to significantly reduce the transport of coarse sediments downstream from dams (Shaffer et al. 2007). Other potential concerns in flow regime at Falls River Hydroelectric project include high flushing resulting in scarification and low flow periods (FWCP 2017).

Figure 15. Historical photo, circa 1914, viewing east at the falls prior to construction of the Falls River hydroelectric project. Abundant coarse sand and gravels on the exposed banks indicates that the bed material of the Falls River has changed over time. Photo courtesy of the Prince Rupert City & Regional Archives, Reginald Harold Greaves (2006 – 012 -0 24).

Figure 16. Photos taken during 2019 eulachon project, viewing east in the Falls River. When compared to Figure 15, it is evident that the bed material present in Falls River has changed over time. Although an exact repeat photo of Figure 15 to directly compare bed material was not taken, these photos illustrate the representative fine bed material in the Falls River.

Potential methods to enhance eulachon spawning habitat downstream of the Falls River dam should be aimed at replacement of sand and gravel substrate. These include restoration techniques such as sand and gravel addition, as well as increasing channel complexity with large woody debris or boulders. Large woody debris or boulder addition can assist with maintaining coarser sediment in restored habitats. Addition of sand and gravels to the lower Falls River will provide higher quality substrate for spawning, which may increase the use of the Falls River for eulachon spawners. However, maintaining these higher quality habitats will likely be challenging in the tidally influenced lower Falls River, while the recruitment of sand and gravel from upstream remain low (settling above the dam). Restoration of habitat should account for suitable flow regimes for both eulachon egg incubation and maintaining restored sand and gravel habitat. Moderated flows (as seen with hydroelectric projects) during peak periods can be beneficially in maintaining coarse bed material, as it has less chance of being washed downstream. However, flows will need to be high enough year-round to wash fine sediments off coarse sand and gravels to prevent them being buried. Given that a very specific flow regime is needed for a successful restoration project, it is recommended that geomorphology/ hydrology experts are consulted when considering a future project. It may be possible to engineer suitable habitat by constructing side channels, ramps or controlling water flow to certain sections below the tail pond.

A previous restoration project added gravel to the tail pond below the Falls River hydro project in 2009 to enhance Chinook spawning habitat. In 2011, the presence of a Chinook redd, remains of a Chinook salmon and juvenile Chinook salmon were identified, suggesting that gravel addition may have contributed to suitable spawning habitat in this portion of the river (Beblow 2012). Unfortunately, it was not possible to sample this section of the river with the large boat used to access the study location during 2019 eulachon sampling. However, marine birds were not observed foraging in the tail pond during the duration of the study, with most of the activity occurring downstream. This suggests that although, eulachon may be spawning in the tail pond, they were not present there in high densities. Future studies should sample this habitat for spawning eulachon along with egg and larvae samples to determine if eulachon are using the restored gravels in the tail pond. Additional adult sampling with gillnets can be conducted from shore from the BC Hydro facilities or with a smaller boat in future. Gravels added to the tail pond in 2009 should be monitored again to determine the long-term success of this restoration project.

Lastly, the potential positive impacts of a successful restoration project on overall eulachon populations must be considered. Eulachon population declines are widespread, however the cause of widespread declines are unknown and thought to be cumulative over marine and freshwater environments (Pickard & Marmorek 2007; COSEWIC 2011; Schweigert et al. 2012). Given that Eulachon spend so little time in freshwater (95% in marine environments) and their decline has been so widespread across their distribution, including populations with pristine freshwater habitat (Skeena River, Nass River and other populations in Alaska), it is thought that any freshwater impacts were not significant factors contributing to general decline (Hay & McCarter 2000; Pickard & Marmorek 2007; Schweigert et al. 2012; COSEWIC 2013). However, they may be contributing to recovery of populations in some regions where larger impacts are present (Pickard & Marmorek 2007; Schweigert et al. 2012). Suitable spawning habitat is not likely a limiting factor to eulachon populations in wwatersheds such as the Skeena and the Nass watershed where freshwater eulachon spawning habitat remains intact. This is true for the Ecstall River watershed, which remains relatively undamaged by industrial activities. Given that freshwater habitat is not likely a limiting factor to eulachon populations in the north, the benefit of enhancing Falls Rivers spawning habitat for the greater eulachon population may be limited.

Although a restoration project in the lower Falls River may have limited impact on the eulachon population as a whole, a successful project would contribute positively to the overall diversity and productivity of the Falls River system. A restoration project in the lower Falls River would contribute greater understanding about enhancing streams in lake headed systems below impoundments. At the current time, there is no recorded evidence of an attempt to restore freshwater spawning habitat for eulachon. Thus, conducting a project on the Falls River would be an experiment that directly answers questions about the feasibility of enhancing spawning habitat for eulachon. As there is relatively limited research on eulachon in general, a restoration project would contribute to the overall understanding about eulachon spawning habitat. This would be particularly applicable to other geographic locations (more impacted systems) where spawning habitat may be a limiting factor.

CONCLUSIONS & RECOMMENDATIONS

The results of this study suggest that eulachon are using the Falls River during their freshwater migration, however may only be spawning at the study locations in very low densities. In addition, available spawning substrate was mainly comprised of fine sediment, which is known to be of lower value to spawning eulachon.

Potential methods to restore eulachon spawning habitat within the Falls River include addition of coarser sediments such as sand or gravels. It may be possible to engineer suitable habitat by constructing side channels, ramps or controlling water flow to certain sections below the tail pond. However, the feasibility of maintaining restored habitat (flow and sediment regimes) need to be considered before enhancement projects proceed. Maintaining a flow regime to support sand and gravel restoration may be challenging in the lower Falls River and it is recommended that a geomorphology/ hydrology expert be consulted before undertaking any restoration activities. Gravels added to the tail pond in 2009 should be monitored again to evaluate the long-term success of this previous restoration project.

A restoration project in the lower Falls River would contribute to the greater understanding of enhancing streams in lake headed systems below impoundments. It would be an experiment that directly answers questions about the feasibility of enhancing spawning habitat for eulachon. As there is relatively limited research on eulachon in general, a restoration project would contribute to the overall understanding about eulachon spawning habitat.

Additional research would strengthen our findings and provide supplementary information on the use of the Falls River by Eulachon. As spawning locations are known to vary from year to year, eulachon spawning in the Falls River may be present in some years and not others. Returning to capture eulachon during years with less ice and increased water clarity will also aid in determining if eulachon are spawning within Falls River and allow for stronger comparisons between the Ecstall and Falls River habitats. In addition, further research sampling for eggs and larvae within the water column will provide increased understanding of use of Falls River by eulachon captured during this study. There are significant gaps in our understanding of eulachon life history, especially for Skeena River eulachon population. Given the cultural and ecological importance of eulachon, conducting additional research will further our scientific understanding of eulachon.

In summary, the results of this study indicate that the Falls River environment is suitable to support eulachon adult spawners and egg incubation but does not currently contain extensive high value spawning habitat. We recommend the following research priorities and future restoration actions:

- Conduct follow-up monitoring of gravels added to the tail pond from earlier enhancement efforts. This will help determine if addition of sand or gravels to enhance eulachon spawning habitat downstream is feasible with the water and sediment regimes.
- Install temperature loggers at various locations in the Falls River to determine if temperature regimes remain suitable during the entire egg incubation period (March – May).
- Additional sampling in the Falls River to capture any drifting eggs and larval eulachon is needed to complete our understanding of eulachon that may be spawning in the Falls River area (including within the tail pond).
- If restoration activities are determined a priority to enhance spawning habitat for eulachon, a hydrology/ geomorphology expert should be consulted to assess the flow regime and available habitat to determine the feasibility of potential restoration activities.

ACKNOWLEGEMENTS

This research was financially supported by Fish and Wildlife Compensation Program and Lax Kw'alaams Fisheries. We would like to acknowledge the hard work and experience of Lax Kw'alaams Technicians, Wade Helin, Jim Henry Jr. and Brandon Ryan that made field work in 2019 a success. Without their breadth of experience navigating tidal environments, setting gillnets and traditional knowledge of eulachon, this project would not have been possible due to high volumes of surface ice in the Ecstall River in 2019. We also thank Bill Shepert and John Latimer from Lax Kw'alaams Fisheries Department for project, field and mapping assistance respectively. Thank you to John Kelson for providing advice on sampling eulachon in the Ecstall River, Julie Fournier from FWCP and Jason Scher at PRPA for support in making this project possible.

REFERENCES

Barrett, B.M., Thompson, F.M. & Wick, S.N. (1984). *Adult anadromous fish investigations, May - October 1983* (Susitna Hydro Aquatic Studies No. APA 1450). Anchorage: Alaska Department of Fish and Game.

Beblow, J. (2012). *Falls River Salmon Presence Monitoring at Gravel Enhancement Area* (FWCP Report No. 00061335). Cambria Gordan, Prince Rupert.

COSEWIC. (2011). *COSEWIC assessment and status report on the eulachon (Thaleichthys pacificus), Nass - Skeena Rivers population, Central Pacific Coast population, Fraser River population in Canada.* COSEWIC, Ottawa.

COSEWIC. (2013). *COSEWIC assessment and status report on the eulachon, Thaleichtys pacificus, Nass/Skeena population, in Canada.*

Farara, D. (1996). *The toxicity of pulp mill effluent on eulachon eggs and larvae in the Kitimat River*. Consultants report prepared by Beak International for Eurocan Pulp Mills Ltd., Kitimat, BC.

FWCP. (2017). *Falls River Watershed Action Plan*. The Fish and Wildlife Compensation Program.

Gustafson, R.G., Ford, M.J., Adams, P.B., Drake, J.S., Emmett, R.L., Fresh, K.L., Rowse, M., Spangler, E.A.K., Spangler, R.E., Teel, D.J. & Wilson, M.T. (2012). Conservation status of eulachon in the California Current: Status review of eulachon. *Fish and Fisheries*, 13, 121–138.

Hay, D. (2002). The eulachon in Northern British Columbia. In: *Information supporting past and present ecosystem models of Northern British Columbia and the Newfoundland Shelf*, Fisheries Centre Research Reports. University of British Columbia, p. 119.

Hay, D. & McCarter, P.B. (2000). *Status of the eulachon Thaleichthys pacificus in Canada* (Research Document No. 2000–145). Department of Fisheries and Oceans, Canadian Stock Assessment Secretariat.

HDR Inc. & LGL. (2014). *Eulachon Run Timing Distribution and Spawning in the Susitna River. Study Plan Section 9.16. Initial Study Report. Susitna- Watana Hydroelectric Project* (No. Part A: Sections 1-6 , 8-10). Susitna-Watana Hydro, Alaska Energy Authority.

Howell, M.D. (2001). *Characterization of Development in Columbia River Prolarval Eulachon, Thaleichthys pacificus, using selected morphometric characters.* Washing Department of Fish and Wildlife, Vancouver, WA.

Kelson, J. (2010). *Skeena Eulachon Habitat Use Study. Prepared for Fisheries and Oceans Canada*. Metlakatla Fisheries Program, Prince Rupert, BC.

Langer, E., Shepherd, B.G. & Vroom, P.R. (1977). *Biology of the Nass River Eulachon (Thaleichthys pacificus)* (Canadian Fisheries and Marine Service Technical Report No. 77–10).

Lewis, A.F.J. (1997). *Skeena Eulachon Study. Draft Report.* (Prepared for: The Tsimshian Tribal Council).

Lewis, A.F.J., McGurk, M.D. & Galesloot, M.G. (2002). *Alcan's Kemano River eulachon (*Thaleichthys pacificus*) monitoring program 1988 - 1998. Consultants report preapared by Ecofish Research Ltd. for Alcan Primary Metal Ltd.* Kitimat, BC.

Matarese, A.C., Arthur, A.W., Blood, D.M. & Vinter. (1989). *Laboratory Guide to Early Life History Stages of Northeast Pacific Fishes. NOAA Technical Report* (NOAA Technical Report No. NMFS 80).

Miller, L., Hjorth, D. & Van Tine, J. (2002). *Falls River Hydro Dam: Fisheries Restoration Feasibility Study*. Fisheries and Oceans Canada- North Coast Resource Restoration Unit.

Moody, M. (2000). *Eulachon past and present* (Master of Science).

NOAA. (2011). *Critical Habitat for the Southern District Population Segment of Eulachon*. National Marine Fisheries Service, Northwest Region, Protected Resources Division.

Payne, S.A., Johnson, B.A. & Otto, R.S. (1999). Proximate composition of some north-eastern Pacific forage fish species. *Fisheries Oceanography*, 8, 159–177.

Pederson, R.V.K., Orr, U.N. & Hay, D.E. (1995). *Distribution and preliminary stock assessment (1993) of the eulachon, Thaleichthys pacificus, in the lower Kitimat River, British Columbia.* (Can. Manuscr. Rep. Fish. Aquat. Sci. No. 2330).

Pickard, D. & Marmorek, D. (2007). *A workshop to determine research priorities for Eulachon Workshop Report. Workshop held February 20-22, 2007 in Richmond, BC.* ESSA Technologies Ltd., Vancouver BC for Fisheries and Oceans Canada.

Rolston, D. (2010). *Final report on 2010 survey of eulachon adult spawner and egg distribution in the Lower Skeena River and Tributaries.* Kitsumkalum Fisheries Department, Terrace, BC.

Schweigert, J., Wood, C., Hay, D., McAllister, M., Boldt, J., McCarter, B., Therriault, T.W. & Brekke, H. (2012). Recovery Potential Assessment of Eulachon (*Thaleichthys pacificus*) in Canada, 128.

Shaffer, J.A., Penttila, D., McHenry, M. & Vilella, D. (2007). Observations of Eulachon, (*Thaleichthys pacificus*), in the Elwha River, Olympic Peninsula Washington. *Northwest Science*, 81, 76–81.

Smith, W.E. & Saalfeld, R.W. (1955). *Studies on Columbia river smlet (Thaleichthys pacificus).* (No. 1(3)). Fisheries Research Papers. Washington Department of Fisheries, Olympia, WA.

Willson, M.F., Armstrong, R.H., Hermans, M.C. & Koski, K. (2006). Eulachon: A Review of Biology and an Annotated Bibliography, 243.

APPENDIX

Table 1. Data from gillnet sets during eulachon sampling from Falls River and Ecstall River from March 6 to March 21.

Date	Location	Time IN	Time OUT	Soak time	Eulachon Abund.	Net Size*	Easting	Northing
06-Mar	Falls River				0	A	451254	5981414
06-Mar	Falls River				0	A	451243	5981386
06-Mar	Falls River				0	A	451220	5981429
08-Mar	Falls River	13:31	15:51	2:20	0	A	451207	5981332
08-Mar	Falls River	14:37	15:51	1:14	0	A	451203	5981337
08-Mar	Falls River	14:59	15:51	0:52	0	B	451203	5981337
12-Mar	Falls River	9:12	12:30	3:18	2	A	451323	5981455
12-Mar	Falls River	9:18	12:30	3:12	5	A	451323	5981455
12-Mar	Falls River	9:34	10:18	0:44	1	A	451371	5981498
12-Mar	Falls River	10:23	11:00	0:37	3	A	451371	5981498
12-Mar	Falls River	11:00	12:30	1:30	6	B	451323	5981455
12-Mar	Falls River	11:00	12:30	1:30	1	A	451323	5981455
12-Mar	Falls River	11:00	12:30	1:30	0	A	451323	5981455
18-Mar	Ecstall River	9:03	15:00	5:57	16	A	450262	5982242
18-Mar	Ecstall River	9:10	9:30	> 24	56	A	450254	5982289
18-Mar	Falls River	10:12	12:41	2:29	5	A	451574	5981979
18-Mar	Falls River	10:24	12:51	2:27	0	A	451527	6981975
18-Mar	Falls River	10:27	12:45	2:18	2	A	451523	5981928
18-Mar	Falls River	10:35	12:57	2:22	0	A	451525	5981928
18-Mar	Falls River	10:44	14:30	3:46	2	A	451588	5981916
18-Mar	Falls River	11:23	13:45	2:22	77	B	451607	5981992
19-Mar	Ecstall River	9:15	14:26	5:11	11	A	450250	5982249
19-Mar	Falls River	10:18	12:15	> 24	23	A	451636	5981780
19-Mar	Falls River	10:23	12:15	> 24	2	A	451649	5981849
19-Mar	Falls River	10:30	12:30	> 24	5	A	451607	5981986
19-Mar	Falls River	10:30	11:01	0:31	2	A	451616	5981897
19-Mar	Falls River	12:11	13:40	1:29	1	A	451606	5981545
19-Mar	Falls River	12:30	13:50	1:20	0	A	451604	5981568
20-Mar	Falls River	12:45	15:30	2:45	1	A	451647	5981975
20-Mar	Falls River	13:00	15:30	2:30	21	B	451638	5981969
21-Mar	Falls River	9:39	12:11	2:32	1	B	451636	5981970

*Net A dimensions: 7.5m x 1.8m with 1 ½ inch mesh, Net B: 100m x 5m x 1 ½ inch mesh

Table 2. Sediment samples from Falls River from February 11, 2019

Date	Site No.	Sediment (primary)	Sediment (secondary)	Easting	Northing
11-Feb	1	fine		451549	5982080
11-Feb	2	fine		451598	5982049
11-Feb	3	fine	sand	451500	5982000
11-Feb	4	fine	sand	451550	5982000
11-Feb	5	fine		451575	5981950
11-Feb	6	fine		451451	5981950
11-Feb	7	fine		451550	5981901
11-Feb	8	fine	sand	451649	5981901
11-Feb	9	bedrock		451419	5981901
11-Feb	10	fine		451419	5981850
11-Feb	11	fine	sand	451500	5981850
11-Feb	12	fine	sand	451618	5981850
11-Feb	13	fine	sand	451550	5981837
11-Feb	14	fine		451600	5981800
11-Feb	15	fine		451550	5981751
11-Feb	16	fine		451400	5981725
11-Feb	17	fine	sand	451617	5981700
11-Feb	18	fine		451448	5981686
11-Feb	19	fine		451500	5981685
11-Feb	20	fine		451566	5981675
11-Feb	21	fine		451416	5981600
11-Feb	22	fine		451516	5981599
11-Feb	23	organics	fine	451625	5981599
11-Feb	24	fine		451607	5981544
11-Feb	25	fine		451350	5981501
11-Feb	26	fine		451450	5981500
11-Feb	27	fine		451550	5981500

Table 3. Sediment samples and egg counts from Falls River from March 20 and 21, 2019

Date	Site no.	Depth (ft)	Sediment (primary)	Sediment (secondary)	No. Eggs	Easting	Northing
20-Mar	28	25	fine		0	451611	5981981
20-Mar	29	10	bedrock		0	451573	5982026
20-Mar	30	20	bedrock		0	451586	5982059
20-Mar	31	13	fine		0	451563	5982061
20-Mar	32	11	fine		0	451542	5982024
20-Mar	33	14	fine		0	451561	5981995
20-Mar	34	14	fine		0	451591	5981997
20-Mar	35	25	fine	organics	0	451607	5982009
20-Mar	36	13	fine		0	451498	5981971
20-Mar	37	30	fine	organics, sand	0	451654	5981907
20-Mar	38	16	fine		0	451504	5981936
20-Mar	39	21	fine	sand, gravel	0	451623	5981874
20-Mar	40	16	fine		0	451567	5981831
21-Mar	41	7	fine	organics	0	451531	5981970
21-Mar	42	11	fine		0	451577	5981971
21-Mar	43	56	fine		0	451616	5981917
21-Mar	44	3	fine	sand	0	451510	5981922
21-Mar	45	6	fine		0	451534	5981894
21-Mar	46	13	fine		0	451628	5981776
21-Mar	47	10	fine	organics, sand	5	451625	5981684
21-Mar	48	11	fine	organics, sand	0	451624	5981656
21-Mar	49	14.4	fine	sand	0	451622	5981603
21-Mar	50	7	fine		0	451615	5981525
21-Mar	51	17	fine	fine sand, organics	0	451318	5981464
21-Mar	52	20	fine		0	451419	5981494
21-Mar	53	19	fine		0	451475	5981488
21-Mar	54	15	fine		0	451576	5981502
21-Mar	55	13	fine		0	457239	5974160

Table 4. Water sampling results from Falls River and Ecstall River locations during March sampling at various times and tide heights during the day.

Date	Location	Easting	Northing	YSI Depth	Temp (C)	Sal (ppt)	DO (%L)	DO (ppm)	Secchi (m)	Time	Tide
12-Mar	Falls River			0	0.10	1.50			0.25		
12-Mar	Falls River			1	0.00	1.50			0.50		
12-Mar	Falls River			3	0.00	1.90			0.30		
12-Mar	Falls River			5	0.00	2.10					
12-Mar	Falls River	451258	5981397	0	0.10	1.50			0.10	12:54	near low
12-Mar	Falls River	451258	5981397	1	0.10	1.50				12:54	near low
12-Mar	Falls River	451258	5981397	2	0.10	1.50				12:54	near low
12-Mar	Falls River	451258	5981397	3	0.10	1.60				12:54	near low
12-Mar	Falls River	451258	5981397	4	0.10	1.80				12:54	near low
12-Mar	Falls River	451258	5981397	5	0.10	1.90				12:54	near low
18-Mar	Falls River	450254	5982289	0	1.10	0.30			0.30	10:12	near low
18-Mar	Falls River	450254	5982289	1	1.10	0.40				10:12	near low
18-Mar	Falls River	450254	5982289	2	1.20	0.40				10:12	near low
18-Mar	Falls River	450254	5982289	3	1.20	0.40				10:12	near low
18-Mar	Falls River	450254	5982289	4	1.20	0.40				10:12	near low
18-Mar	Falls River	451622	5981797	0	0.40	0.10			0.20	9:54	near low
18-Mar	Falls River	451622	5981797	1	0.40	0.10				9:54	near low
18-Mar	Falls River	451622	5981797	2	0.50	0.20				9:54	near low
18-Mar	Falls River	451622	5981797	3	0.60	0.20				9:54	near low
18-Mar	Falls River	451622	5981797	4	1.10	0.40				9:54	near low
18-Mar	Falls River			0	0.40	0.10	199.0	29.1		10:54	rising
18-Mar	Falls River			1	0.40	0.10				10:54	rising
18-Mar	Falls River			2	0.60	0.20	180.0	26.2		10:54	rising
18-Mar	Falls River			3	0.60	0.20				10:54	rising
18-Mar	Falls River			4	1.00	0.30	166.0	24.2		10:54	rising
18-Mar	Falls River			5	1.00	0.30				10:54	rising
18-Mar	Falls River			6	1.00	0.30	91.0	13.0		10:54	rising
18-Mar	Falls River	451564	5981963	0	0.60	0.10	182.0	26.7	0.20	11:54	rising

18-Mar	Falls River	451564	5981963	1	0.50	0.10			11:54	rising
18-Mar	Falls River	451564	5981963	2	0.60	0.20	175.0	25.6	11:54	rising
18-Mar	Falls River	451564	5981963	3	0.70	0.20			11:54	rising
18-Mar	Falls River	451564	5981963	4	0.80	0.20	166.0	24.0	11:54	rising
18-Mar	Falls River	451564	5981963	5	0.80	0.20			11:54	rising
18-Mar	Falls River	451564	5981963	6	0.80	0.20	161.0	23.3	11:54	rising
18-Mar	Falls River	451564	5981963	7	0.80	0.20			11:54	rising
18-Mar	Falls River	451564	5981963	8	1.20	0.30	164.0	23.5	11:54	rising
18-Mar	Falls River	451564	5981963	9	1.20	0.40			11:54	rising
18-Mar	Falls River	451564	5981963	10	1.30	0.70	113.0	16.1	11:54	rising
18-Mar	Falls River			0	0.90	0.20			13:23	near high
18-Mar	Falls River			1	0.80	0.20			13:23	near high
18-Mar	Falls River			2	0.80	0.20			13:23	near high
18-Mar	Falls River			3	0.80	0.20			13:23	near high
18-Mar	Falls River			4	0.80	0.20			13:23	near high
18-Mar	Falls River			5	0.80	0.20			13:23	near high
18-Mar	Falls River	450250	5982618	0	2.60	14.00			14:00	high tide
18-Mar	Falls River	450250	5982618	1	2.50	1.50			14:00	high tide
18-Mar	Falls River	450250	5982618	2	2.50	1.50			14:00	high tide
18-Mar	Falls River	450250	5982618	3	2.50	1.60			14:00	high tide
18-Mar	Falls River	450250	5982618	4	2.50	1.60			14:00	high tide
18-Mar	Falls River	450250	5982618	5	2.50	1.60			14:00	high tide
18-Mar	Falls River	450250	5982618	6	2.50	1.70			14:00	high tide
18-Mar	Falls River	450250	5982618	7	2.50	1.70			14:00	high tide
18-Mar	Falls River	450250	5982618	8	2.50	1.70			15:30	near high
18-Mar	Ecstall River	445358	5988104	0	2.70	3.40			15:30	near high
18-Mar	Ecstall River	445358	5988104	1	2.70	3.40			15:30	near high
18-Mar	Ecstall River	445358	5988104	2	2.70	3.40			15:30	near high
18-Mar	Ecstall River	445358	5988104	3	2.70	3.40			15:30	near high
18-Mar	Ecstall River	445358	5988104	4	2.70	3.40			15:30	near high
18-Mar	Ecstall River	445358	5988104	5	2.70	3.40			15:30	near high
18-Mar	Ecstall River	445358	5988104	6	2.70	3.40			15:30	near high
18-Mar	Ecstall River	445358	5988104	7	2.70	3.40			15:30	near high

18-Mar	Ecstall River	445358	5988104	8	2.70	3.40			15:30	near high
19-Mar	Ecstall River	450250	5982249	0	0.20	0.00			8:54	near high
19-Mar	Ecstall River	450250	5982249	1	0.20	0.00			8:54	near high
19-Mar	Ecstall River	450250	5982249	2	0.20	0.00			8:54	near high
19-Mar	Falls River			0	1.30	0.00			9:56	low
19-Mar	Falls River			1	1.30	0.00	129.0	18.4	9:56	low
19-Mar	Falls River			2	1.20	0.00			9:56	low
19-Mar	Falls River			3	1.20	0.00	122.0	17.5	9:56	low
19-Mar	Falls River			4	1.20	0.00			9:56	low
19-Mar	Falls River			5	1.20	0.00	85.0	12.1	9:56	low
19-Mar	Falls River			6	1.20	0.00			9:56	low
19-Mar	Falls River			7	1.20	0.00			9:56	low
19-Mar	Falls River	451605	5981569	0	0.60	0.10	127.0	18.5	12:13	rising
19-Mar	Falls River	451605	5981569	1	0.60	0.10			12:13	rising
19-Mar	Falls River	451605	5981569	2	0.60	0.10	124.0	18.1	12:13	rising
19-Mar	Falls River	451605	5981569	3	0.60	0.10			12:13	rising
19-Mar	Falls River	451468	5981502	0	1.30	0.30			13:43	near high
19-Mar	Falls River	451468	5981502	1	1.20	0.30			13:43	near high
19-Mar	Falls River	451468	5981502	2	1.20	0.40			13:43	near high
19-Mar	Falls River	451468	5981502	3	1.40	0.40			13:43	near high
19-Mar	Falls River	451468	5981502	4	1.50	0.60			13:43	near high
19-Mar	Falls River	451468	5981502	5	1.60	0.60			13:43	near high
19-Mar	Falls River	451468	5981502	6	1.60	0.60			13:43	near high
21-Mar	Falls River	451531	5981970	0	2.00	0.00	50.0	6.9	10:15	near low
21-Mar	Falls River	451531	5981970	1	1.90	0.00			10:15	near low
21-Mar	Falls River			0	2.00	0.00			11:30	low
21-Mar	Falls River			1	2.00	0.00			11:30	low
21-Mar	Falls River			3	2.00	0.00			11:30	low
21-Mar	Falls River			5	2.00	0.00			11:30	low
21-Mar	Falls River			7	1.90	0.00			11:30	low
21-Mar	Falls River			9	1.90	0.00			11:30	low
21-Mar	Falls River			11	1.90	0.00			11:30	low