
# Marine Survival Rates (Black Creek)

year 2

Prepared for Pacific Salmon Commission – South Fund

Andrew Pereboom
Fisheries & Oceans Canada
Campbell River, BC
May 2020

A-Tlegay Fisheries Society & Fisheries and Oceans Canada Pêches et Océans Canada

## Introduction:

Black Creek (fence) is the Department of Fisheries & Oceans (DFO) only wild coho indicator system for the Strait of Georgia (SOG) The enumeration fence is located in Miracle Beach Provincial Park, South of Campbell River, B.C., and is approximately 100 meters upstream of the high tide mark (Figure 1). Since 1985, an uninterrupted data set has been compiled under the present program and is considered one of the longest time series of coho smolt and adult returns in the Pacific Region. Marine survivals are currently being evaluated using Coded Wire Tags (CWT) on wild, non-adipose marked coho (~20-40% of smolts). Based on lower than expected ratio of CWT fish returning with the current program, A-Tlegay Fisheries Society and DFO conducted this Pacific Salmon Commission (PSC) funded Passive Integrated Transponder (PIT) tag program as a concurrent method to evaluate marine survival, and investigate if there is a difference in survivals based on two separate tag methodologies. The PIT tagging program was implemented in 2018 with tags being applied to a portion of the out-migrating smolts. The advantage of using PIT tags is that every returning fish to Black Creek would be autonomously scanned at the enumeration fence for the presence of a PIT tag, while the CWT component relies on handling each fish and scanning by hand. Also, a PIT array will scan all adults, even if the fence is topped, while the current CWT program is unable to sample fish when the fence is topped, as fish bypass the trap box. As an end result, DFO is seeking an alternative approach to evaluate wild Coho marine survival rates in the SOG.

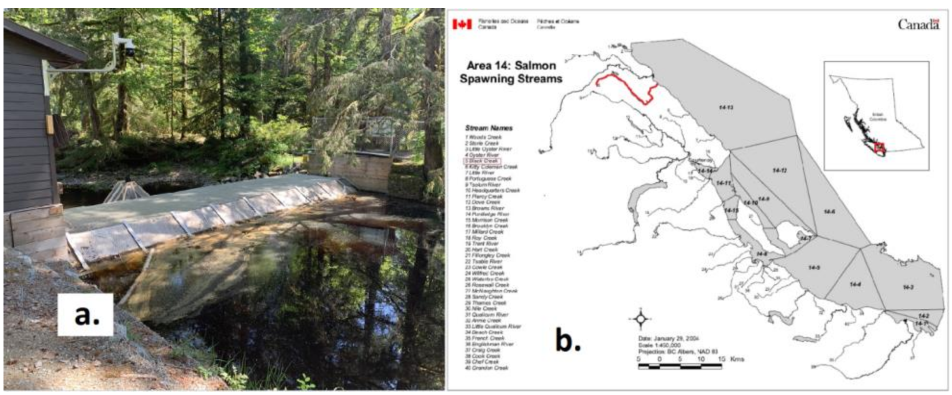


*Figure 1a. Black Creek Fence Structure* *b. Location of Black Creek in red (DFO Area 14)*

Since the early 2000's, DFO in partnership with the A-Tlegay Fisheries Society have continued to deliver the juvenile and adult Black Creek programs. The application of PIT tags in juveniles and monitoring of adults in the following year(s) at the fence is a slight augmentation to the current program, without any major labour or infrastructure costs, just tags, antenna arrays, application and reporting.

Figure 2. PIT tag for reference

PIT tags operate on Radio Frequency Identification (RFID) technology and do not have a battery. They can be read at short distances (~0.5 m) with an antenna that both charges the tag with a magnetic field and listens for the response in the form of a unique 16 digit number (Figure 2).

A CWT is a magnetized piece of stainless steel wire about 1.1 mm long that has etched codes into the wire. CWT's do not transmit a code, and therefore need to be extracted from the fish to be read. CWT presence can be detected with an electronic scanner, but requires fish capture and physical scanning of each fish at close proximity (Figure 3).

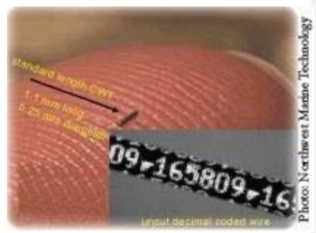


Figure 3. CWT tag for reference

In future, the expansion to coho survival exploration has high potential and could augment the work already being done at Big Qualicum and Cowichan Rivers including predator monitoring (seal haul out spots, otter dens, heron rookeries, etc.). PIT tags could be used to evaluate the possibility of a fall smolt migrant class leaving Black Creek but would require juvenile tagging in the head waters prior to smolts leaving. This report outlines the 2019 smolt tagging and the monitoring of the 2019 adult return from the 2018 tag group.

## 2019 Smolt Tagging:

Each spring at Black Creek,  the juvenile panels and trap box are installed in the fence.  The panels block the entire stream, forcing smolts down the intake pipe and in to the trap box (

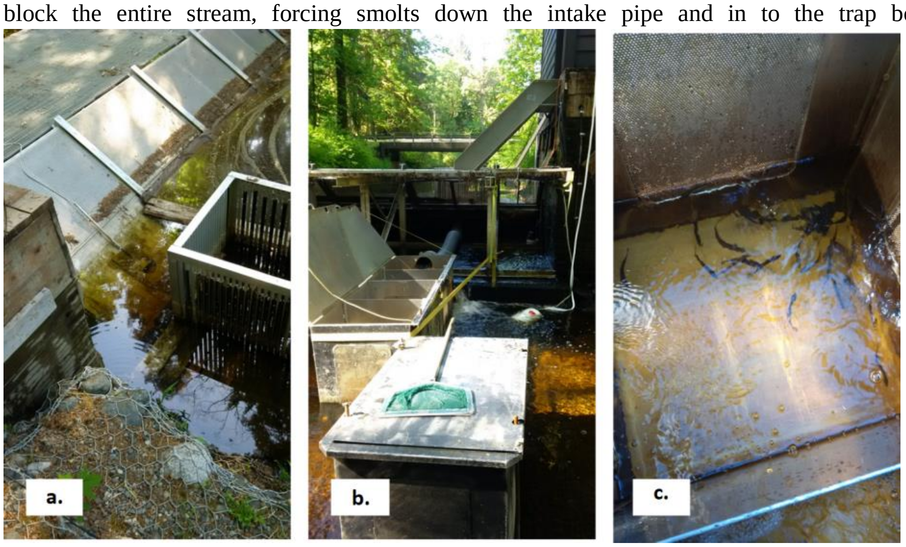


Figure 4).  The fence captures all smolts leaving Black Creek from April through to June. Technicians transfer the fish to the tally shack where biologicals are collected, tags are implanted and smolts counted and released.

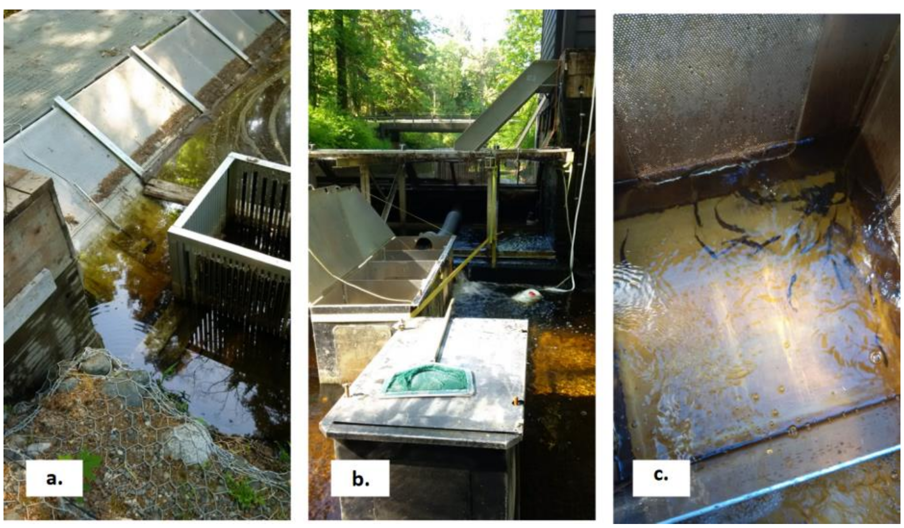


*Figure 4, a. Trap box intake.  b. Downstream view of intake pipe and holding box.  c. Coho smolts in trap box.*

For ease of handling, juveniles that were to be tagged and biosampled were anesthetized using MS 222. A random portion of the catch was selected to be tagged using Biomark pre-loaded 12 mm PIT tags injected into the ceolomic cavity of the Coho smolt (


Figure 5). The rest of the catch was tagged using CWT's or released untagged. A small portion of captured Coho smolts were measured and weighed for condition factor evaluation. Scales were also taken from various sizes of fish to evaluate smolt age structure.


*Figure 5, a. Anesthetized smolts being PIT Tagged. b. PIT tag incision.*

After the smolts were sampled and tagged, they were placed in a recovery bucket before being released back into Black Creek. Upon release, technicians typically allowed for volitional release method versus a "dumping" release method. The volitional release style allows fish to swim out of the holding buckets. Technicians monitored the recovery bucket for mortalities and shed tags. Short term retention tests were also conducted to evaluate initial mortality and tag loss (2018 and 2019). 2019 PIT tag retention checks were conducted twice, on April 30$^{th}$ and May 14$^{th}$. 50 PIT tagged Coho on each date were placed in the retention box and checked after 72 and 48 hours respectively. Fish were re-scanned for PIT tag presence and counted before being released. Fish were in good health visually, and no fish were found to have lost a PIT tag, but 2 fish were missing from the second tag group. It is unknown if those fish escaped or died, no carcasses were found in the retention tank. Initial tagging mortalities are low, but longer term is not known. Year one of the project (2018) had 25 reported tagging mortalities, but year two (2019) had zero reported tagging mortalities. Tagging mortality is strongly related to applicators experience, and mortality rates post tagging are directly related to the tagger, and their relative experience (Pellett, K. 2017). It was found that initial tag loss and mortality was low, but longer term trials elsewhere suggest tag loss and mortality are in the 1-5% range (Pellett, K. 2017, plus personal communications). More work is needed to assess long term mortality and tag loss. As a recommendation from 2018, Vidalife water conditioner was used in 2019 to help protect fish mucus layer and reduce fungus on smolts being handled.

The juvenile fence operated from April 10th to May 31st , 2019. CWT and PIT tagging commenced April 11th and 15th respectively, and the last tags were applied May 27th (PIT and CWT). A total of 46,469 smolts were counted at Black Creek, of which 4,300 were PIT tagged (9%), 41,306 were CWT'd (89%), and 863 smolts were counted and released untagged (2%). Figure 6 illustrates that the 2019 smolt count was below the 1996-2018 averages smolt outmigration of 51,310 smolts

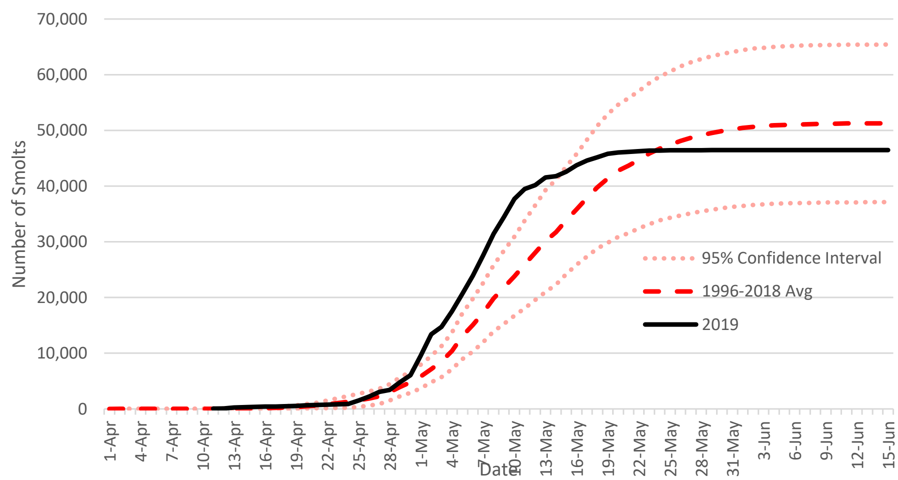


*Figure 6. 2019 Black Creek smolt count and 1996 – 2018 average with 95% confidence interval.*

PIT and CWT tag application was based on abundance of fish present for the day, with consideration for migration timing (i.e. early, middle or end of migration). Table 1 &

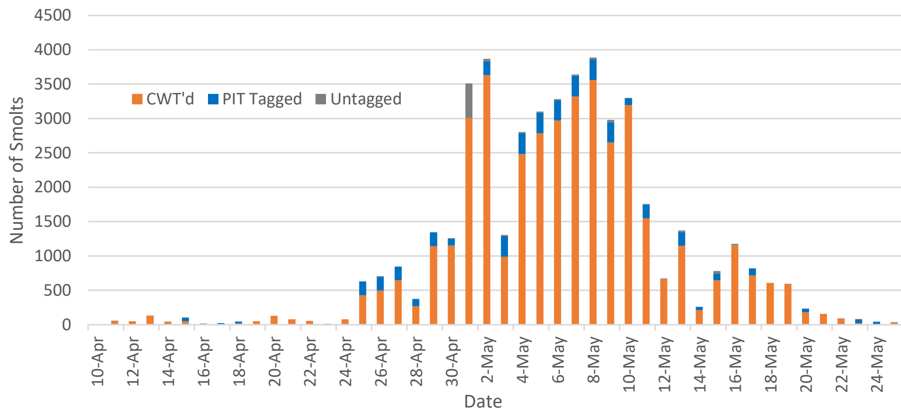


Figure 7 (below) provide the daily and cumulative smolt count of tagged (PIT & CWT), and untagged smolts.

*Table 1. Daily fence counts and daily tag applications at Black Creek in spring of 2019.*

| Date | Untagged | CWT'd | PIT Tagged | Daily Total | Running Total |
|---|---|---|---|---|---|
| 10-Apr | | | | | |
| 11-Apr | 1 | 55 | 0 | 56 | **56** |
| 12-Apr | 0 | 52 | 0 | 52 | **108** |
| 13-Apr | 4 | 129 | 0 | 133 | **241** |
| 14-Apr | 3 | 41 | 0 | 44 | **285** |
| 15-Apr | 4 | 53 | 50 | 107 | **392** |
| 16-Apr | 0 | 20 | 0 | 20 | **412** |
| 17-Apr | 0 | 1 | 23 | 24 | **436** |
| 18-Apr | 0 | 20 | 27 | 47 | **483** |
| 19-Apr | 0 | 51 | 0 | 51 | **534** |
| 20-Apr | 0 | 128 | 0 | 128 | **662** |
| 21-Apr | 0 | 78 | 0 | 78 | **740** |
| 22-Apr | 0 | 54 | 0 | 54 | **794** |
| 23-Apr | 0 | 13 | 0 | 13 | **807** |
| 24-Apr | 0 | 79 | 0 | 79 | **886** |
| 25-Apr | 4 | 428 | 200 | 632 | **1,518** |
| 26-Apr | 10 | 497 | 200 | 707 | **2,225** |
| 27-Apr | 0 | 644 | 200 | 844 | **3,069** |
| 28-Apr | 1 | 270 | 100 | 371 | **3,440** |
| 29-Apr | 2 | 1,146 | 200 | 1,348 | **4,788** |
| 30-Apr | 6 | 1,152 | 100 | 1,258 | **6,046** |
| 1-May | 500 | 3,010 | 0 | 3,510 | **9,556** |
| 2-May | 38 | 3,631 | 200 | 3,869 | **13,425** |
| 3-May | 15 | 990 | 300 | 1,305 | **14,730** |
| 4-May | 18 | 2,485 | 300 | 2,803 | **17,533** |
| 5-May | 13 | 2,787 | 300 | 3,100 | **20,633** |
| 6-May | 15 | 2,970 | 300 | 3,285 | **23,918** |
| 7-May | 20 | 3,321 | 300 | 3,641 | **27,559** |
| 8-May | 27 | 3,562 | 300 | 3,889 | **31,448** |
| 9-May | 32 | 2,649 | 300 | 2,981 | **34,429** |
| 10-May | 9 | 3,195 | 100 | 3,304 | **37,733** |
| 11-May | 9 | 1,550 | 200 | 1,759 | **39,492** |
| 12-May | 6 | 667 | 0 | 673 | **40,165** |
| 13-May | 27 | 1,147 | 200 | 1,374 | **41,539** |
| 14-May | 0 | 212 | 50 | 262 | **41,801** |
| 15-May | 34 | 645 | 100 | 779 | **42,580** |
| 16-May | 27 | 1,151 | 0 | 1,178 | **43,758** |
| 17-May | 5 | 718 | 100 | 823 | **44,581** |
| 18-May | 0 | 610 | 0 | 610 | **45,191** |
| 19-May | 3 | 592 | 0 | 595 | **45,786** |
| 20-May | 2 | 181 | 50 | 233 | **46,019** |
| 21-May | 0 | 156 | 0 | 156 | **46,175** |
| 22-May | 5 | 88 | 0 | 93 | **46,268** |
| 23-May | 9 | 25 | 50 | 84 | **46,352** |
| 24-May | 4 | 0 | 42 | 46 | **46,398** |
| 25-May | 5 | 30 | 0 | 35 | **46,433** |
| 26-May | 0 | 17 | 0 | 17 | **46,450** |
| 27-May | 0 | 6 | 8 | 14 | **46,464** |
| 28-May | | | | 0 | **46,464** |
| 29-May | 5 | 0 | 0 | 5 | **46,469** |
| 30-May | 0 | 0 | 0 | 0 | **46,469** |
| 31-May | 0 | 0 | 0 | 0 | **46,469** |
| Totals | 863 | 41,306 | 4,300 | 46,469 | |
| Tagging Percentages | 2% | 89% | 9% | | |
| Total Tagged % | | | 89% | | |

¶

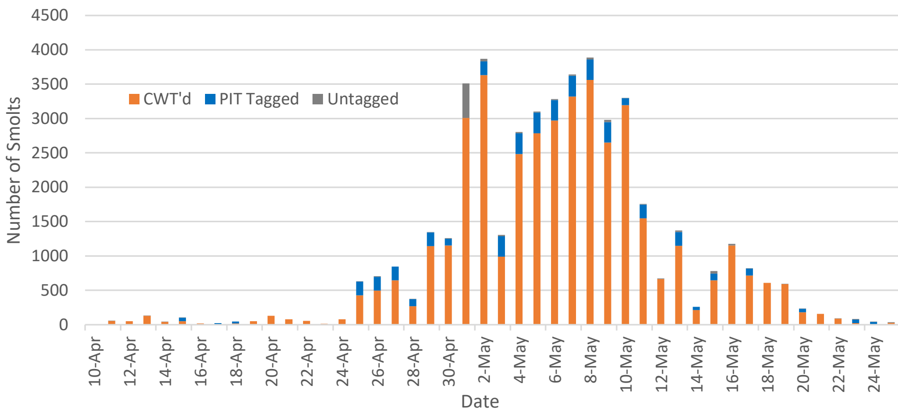


*Figure 7. Daily smolt abundance and applied treatment (2019)*

Nearly all PIT tag fished were measured for fork length. Lengths are paired to the unique 16 digit tag number. The distribution of tags were applied randomly across the population both years (Figure 8). The average length of PIT tagged Coho in 2019 was 112.87 mm, which is slightly less than the average in 2018 of 114.3 mm. Maximum length was 191 mm compared to 176 mm in 2018, and the minimum was 77 mm compared to 86 mm in 2018 (

). Very few smolts are encountered +170mm, but these large sizes are assumed proportionate as fish to be tagged are randomly selected.

| Year | 2018 | 2019 |
|---|---|---|
| Mean | 114.3 | 112.9 |
| Minimum | 86 | 77 |
| Maximum | 176 | 191 |
| Standard Error | 0.224 | 0.213 |
| Standard Deviation | 14.14 | 13.99 |
| Count | 3990 | 4297 |

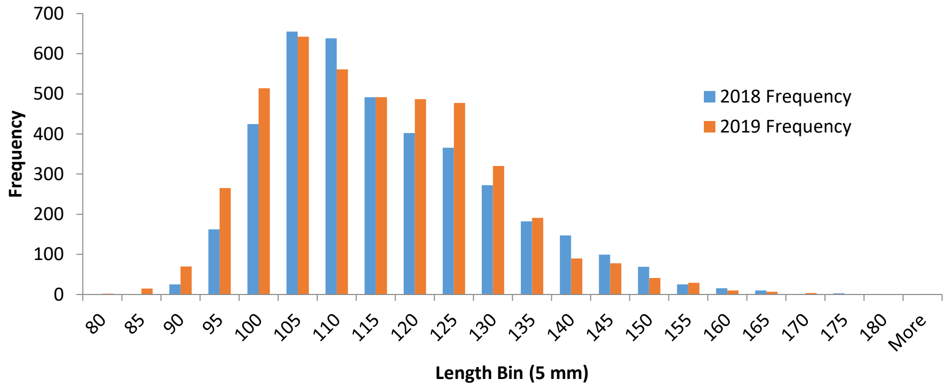


*Figure 8. Coho PIT tag length distribution between years*

*Table 2 PIT tagged Smolt length comparison*

| Year | 2018 | 2019 |
|---|---|---|
| Mean | 114.3 | 112.9 |
| Minimum | 86 | 77 |
| Maximum | 176 | 191 |
| Standard Error | 0.224 | 0.213 |
| Standard Deviation | 14.14 | 13.99 |
| Count | 3990 | 4297 |

## PIT Antenna Installs and Modifications:

One fixed site, and one temporary detection antenna were utilized as part of the adult program. The fixed antenna is located approximately 50 meters upstream of the fence and spans the creek, while the temporary antenna is placed in the adult trap box (Figure 9). Both of these antennas underwent modifications and repairs from the 2018 project.

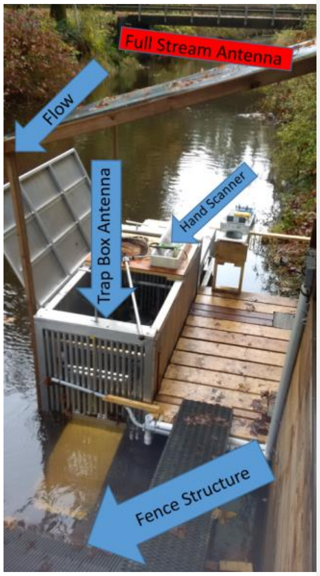


*Figure 9. PIT antenna set up at the Black Creek fence.*

Over the summer of 2019, a new concrete slab and adult trap box were installed at the fence to aid fish movement and to allow for improved video monitoring to occur. As a result, a new antenna was custom built and affixed near the entrance of the trap box(Figure 9). Its purpose and design is to detect and record all PIT tagged fish that enter or pass through the trap box. The 37 x 48 inch home built antenna is powered by a Biomark IS 1001 reader board on a 24 volt power supply. The Antenna was built out of PVC pipe with 5 wraps of 10 gage wire. The antenna was made water tight to ensure high efficiency. Wood 2x4's were used to mount the antenna to the trap box

The full stream loop antenna was also replaced and loop spacing narrowed. The new antenna is shorter (15 m) and provides better tag detection range. The intention of this antenna is to detect and record all PIT tagged fish migrating up Black Creek, regardless of water level. Trexx deck boards are anchored every 4 feet to the stream substrate using duckbill anchors and ready rod. The Trexx boards provided a solid substrate to secure the antenna cord to. The antenna loop is spaced at 28 inches as specified by Biomark (antenna supplier) for optimal efficiency (

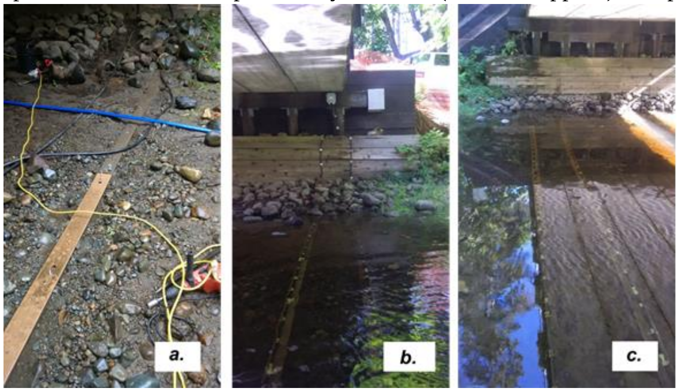


Figure 10). The antenna is powered by 2 -24 volt battery banks and a Biomark IS 1001 reader board.

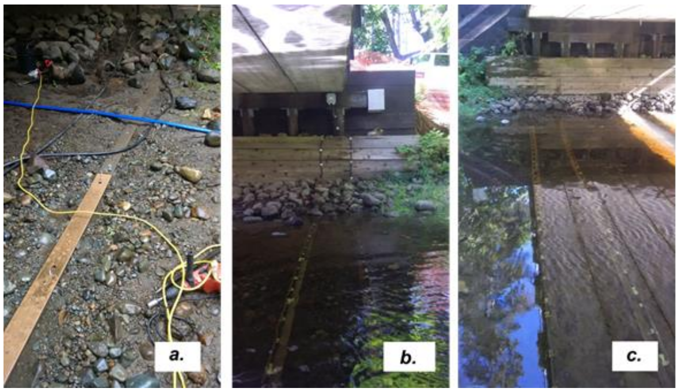


*Figure 10. a. Trexx deck boards anchored to stream stubstrate. b. Antenna attached to Trexx Board, 28 inch loop spacing. c. Biomark full stream loop antenna in place anchored to Trexx board.*

A Biomark HPR Lite hand held PIT tag reader was used decode PIT tags as they were injected into juveniles(Figure 11). This same reader was also used to scan for tags in adults and jacks returning in the fall of 2019.


*Figure 11. Biomark PIT hand scanner*

Electrical interference (noise) caused issues with antenna detections and efficiency in the fall of 2018. The noise was deemed to be caused by florescent lights and noisy electrical power supplies in the general vicinity. The lights were replaced with LED and isolated/shielded power supplies were installed. These modifications reduced noise levels enough to operate without drastic effects on the antennas.

## 2019 Adult Monitoring

Each fall, the adult enumeration equipment is installed at the fence (fence panels, trap box and video monitoring equipment). The fence panels block off the entire creek and forces fish to swim through the upstream trap box that is equipped with entry and exit gates. Video monitoring equipment is in place to augment fence operations and provide video counts if crews are not present. Sampling occurs at the fence, where fish are tagged and scanned for presence of tags, then released upstream of the fence to continue their migration(Figure 12). Due to the life history of Coho, jacks are encountered in the same year the tags are applied. Jacks are precocious male coho (2 year olds) that return the same year they out-migrated, visually differentiated from adults by size, with 45 cm fork length being the differentiation point. Adult Coho return the following year as 3 year olds, so 2019 was the first year PIT tagged adults were expected, and second year for jacks.

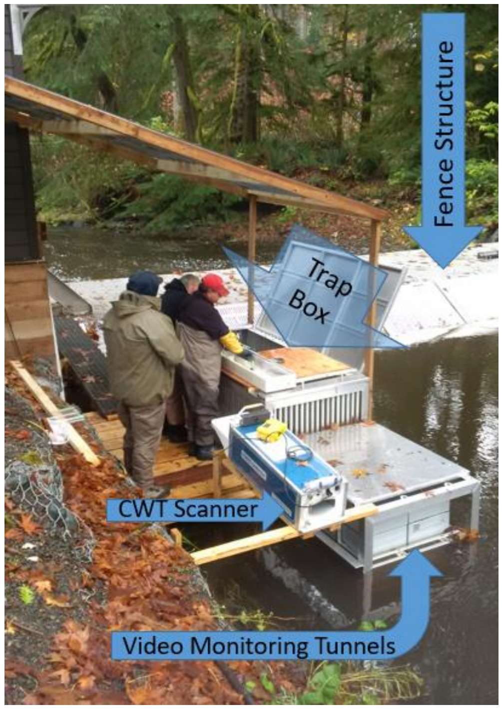

*Figure 12. Fall enumeration set up, with A-Tlegay crew sampling fish*

Fish didn't arrive to Black Creek until there were significant rains, which in turn elevated creek levels. The first event was Oct 16$^{th}$ and a second such event on Nov 11$^{th}$. More than 95% of the adults and jacks entered the creek after those two discharge spikes, and very little fish movement in between (

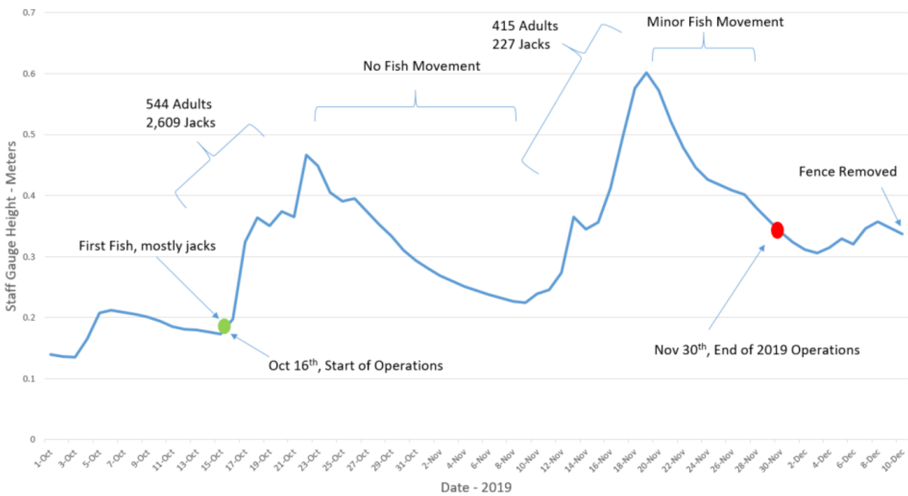


Figure 13).

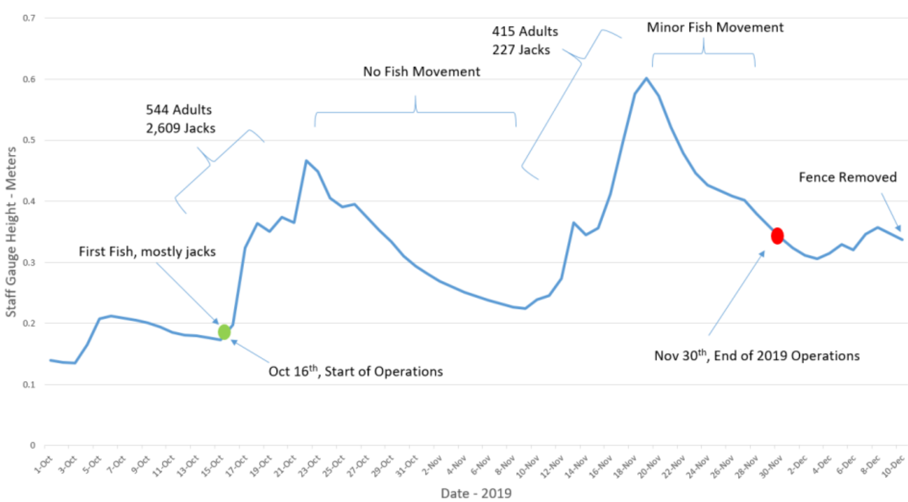


*Figure 13. Daily staff gauge readings in correlation to fish abundance.*

The adult fence equipment and PIT detection arrays were installed and operational by September 20th, with first fish arriving on October 16th. Fall crews monitored the fence from October 16th until November 18th, and relied on video monitoring until Nov 30th ( Figure 14) During video monitoring periods, fish were not sampled or visually marked, but were scanned for PIT tags with the trap box and full stream antennas. It is not possible to asses CWT status of video monitored fish. When the fence was in operation, each adult Coho was sampled for length, visually marked and scanned for presence of a CWT and PIT tag. 135 adults were scale sampled for age. Jacks were measured and then scanned for the presence of either a CWT or PIT tag, no scales taken.

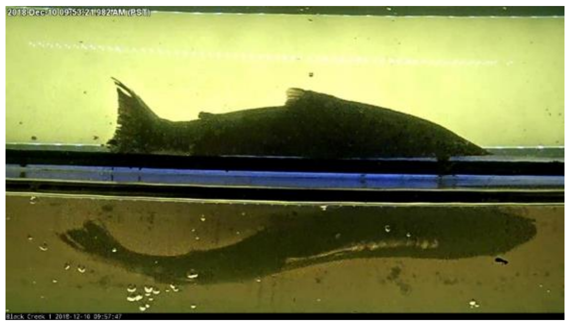

*Figure 14. Image of adult coho passing through video monitoring system*

PIT tag monitoring ran into a few un-anticipated issues. The new trap box antenna was installed and tested and functioned as intended. The trap box had a solid aluminum lid and it was discovered early in the field season that closing this aluminum lid “de-tuned” the antenna rendering it ineffective. Keeping the aluminum lid propped open alleviated this problem. On the night of November 14th the lid was accidentally shut completely and no data was collected. This was also the first night that fish were allowed to pass through video tunnels and not handled by the fence crew.. The full stream antenna was in place and functioning properly, acting as a backup. During this period, one adult PIT tag was detected on the full stream array, but no jacks. It is not believed that any detections were missed.

There were also a few issues with the hand scanner. On October 16th, the first day with fish, the hand scanner was not in use for the morning. We are unable to quantify how many detections were missed due to such high volume of tags that were encountered during this period, but any tagged fish that passed were likely detected on the full stream antenna. The hand scanner also experienced some technical issues. On October 18th, the hand reader stopped working. A replacement hand reader was brought in immediately, allowing crews to continue processing fish through the fence with no fish being missed during this time.

On October 18th, after 2 days of heavy fish migration the trap box data was downloaded. It was at this point that it was realized that the memory on the PIT reader was full and overwriting existing data. Based on full stream antenna detections, 126 jacks and 9 adult detections were over written. The trap box PIT reader was reconfigured after this to allow for more memory storage and prevent this from occurring again. This situation highlights why multiple antennas are necessary to operate a PIT tag monitoring program such as this.

A total of 745 adults and 2,643 jacks were physically counted through the fence, while an additional 231 adults and 203 jacks were counted under video review. A total of 26 adult and 183 jacks were detected with PIT tags in 2019.

Dead pitch, or carcass recovery efforts began November 18th, and was completed on November 30th. Low adult escapement and low creek flows made it difficult for crews to recover many carcasses.

Fence panels, trap box and video monitoring equipment was removed December 11th, and video monitoring to review was conducted for the periods when fish were allowed passage.

## 2019 Escapement Estimates:

A preliminary total of 976 adult and 2,909 jack Coho were counted through the fence at Black Creek in the fall of 2019. This is the lowest adult return for Black Creek since 2006, and well below the long term average adult escapement of 2,287 (

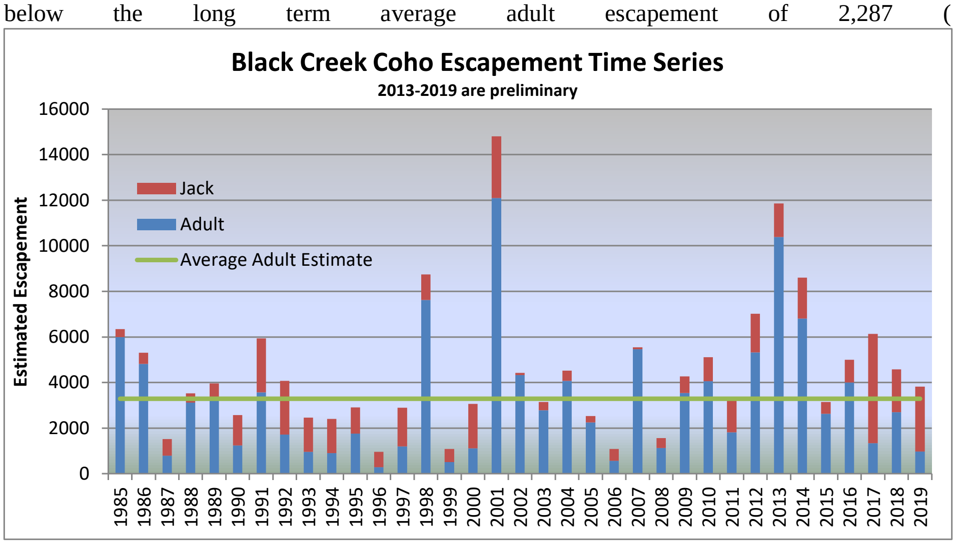


Figure 15). Typically a standard single-census Peterson mark recapture is used to estimate Coho abundance, but was not required as the fence was not topped and every fish that passed the fence at Black Creek in the fall of 2019 was counted.

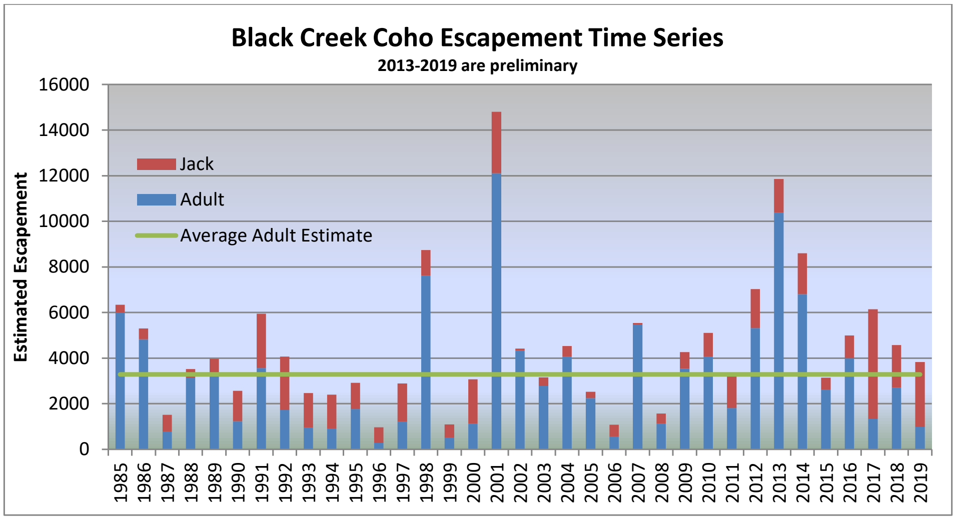


*Figure 15. Historical escapements to Black Creek, adults and jacks (1985 – 2019)*

## 2019 Adult PIT Tag Estimate:

An adult Coho estimate was also created based on PIT results. The full stream antenna was estimated to be 100% efficient for adult detections as all the PIT detections that were recorded in the trap box and hand scanner were also detected on the full stream antenna. 746 adults were scanned for the presence of a PIT tag, of which 20 were electronically recorded on the hand reader, yielding 2.68% tag rate (20/764). 26 adult tags were detected in total, producing an expansion of 970 fish .

Commented [VWP1]: Should have equations labeled and refer to the equation number similar to tables and figures

$$\frac{20 \text{ (PIT tag detections at fence)}}{746\ (adults\ sampled\ at\ fence)} \text{ x } 100 = 2.68\ \% \text{ of adults PIT tagged}$$

$$PIT\ Expansion\ Estimate = \frac{total\ PIT\ tag\ tecoveries}{tag\ rate}$$

$$= 26/0.0268$$
$$= 970\ Fish$$

The two escapement estimates are similar, a difference of 6 adult coho. This suggests that PIT tags may be an effective alternative tool to estimate Coho abundance, but will require additional years of study. It is assumed that the hand scanning at the fence did not miss any adult PIT detections, which is unlikely. With such low adult PIT mark rates, missing even 1 tag can drastically effect the output of this PIT tag estimate.

### 2019 Jack PIT Tag Estimate:

The first PIT tag jack recovery was October 2nd, before fence operations commenced. 4 PIT tag detections were recorded on the full stream antenna above the fence before October 16th when fence operations commenced, suggesting the fence was not perfectly sealed, or a predator carried a PIT tag past the antenna. It is believed to be the prior, as fish squeaked likely through in very low water conditions. The last jack PIT tag detection was November 16th. A total of 183 jack PIT tags were detected, 181 of which entered Black Creek, and 177 which entered during fence operations.

The full steam antenna detected 175 of the 177 total jack tags during fence operations, resulting in an estimated 98.9% efficiency rating on the full stream antenna for jacks. Based on that efficiency it is estimated that 179 PIT tagged jacks actually entered Black Creek during fence operations.

2,846 jacks were counted past the fence, 179 of which were PIT tagged, providing a 6.29% PIT tag mark rate. There were 4 tags that entered the creek before any type of monitoring, bringing the total tag recoveries to 183. Based on a 6.29% mark rate, it is estimated that 2,909 (183/.0629) jacks returned in 2019.

Until this recent PIT tag work, DFO has not been able to create a jack estimates for coho at Black Creek as too few carcasses are ever recovered in the dead pitch program (5 in 2018, none in 2019). Prior to 2018, DFO had no way of expanding or estimating jack returns, and the physical fence count was used. By using PIT tags there is sufficient data to support the creation of a jack estimate, rather than relying only on the fence count which is often a underestimation. The ability to estimate total jack escapement will also help with coho marine survival work in terms of giving a better idea of what percentage of the smolt population jacked, and are therefore removed from the adult marine survival estimate calculation for the same outmigration year

## 2019 Adult Exploitation and Marine Survival:

### Exploitation and Catch

Coho marine survivals (MS) and aggregate abundances of indicator stocks in Southern British Columbia have been forecasted annually since 1996 (DFO 2020). The exploitation rate (ER) for Black Creek Coho is assumed to be equivalent to the aggregated estimated derived for Georgia Basin Wild stocks. Aggregate exploitation for Georgia Basin Wild stocks is estimated at be 3.62% in 2019 (DFO, 2020). With this estimated ER, both CWT and PIT tagged catch of adult Black Creek Coho can be estimated by the following catch calculation.

$$\mathrm{C} = \frac{\mathrm{ER} * \mathrm{E}}{(1 - \mathrm{ER})}$$

Where C is estimated fishing mortality, E is the adult escapement. A total of 241 CWT, and 26 PIT tagged adults were estimated at Black Creek.

$$C_{CWT} = \frac{0.0362 * 241}{(1 - 0.0362)} = \mathbf{9.05} \qquad C_{PIT} = \frac{0.0362 * 26}{(1 - 0.0362)} = \mathbf{0.98}$$

CWT and PIT tagged fishing mortality is estimated to be 9.05 and 0.98fish respectively. In 2019, it was estimated through CWT monitoring programs that 52 Black Creek fish were intercepted in Northern fisheries. The DFO MS forecast used these 52 fish as it was the most appropriate data available, but the generic estimated ER of 3.62% was used as it is unknown what the PIT tag ER actually was. The Georgia Basin Wild stock ER was applied to both tag types for comparison purposes.

Marine survival (*MS*) is calculated as follows:

$$MS = \frac{100\ (C + M + E)}{R}$$

Where C is estimated fishing mortality, M is known pre-spawn natural adult mortality (assumed to be negligible), E is the adult escapement and R is tagged smolts (Meldrum et. al., 2016).

### MS based on CWT

28,546 CWT's were applied in the spring of 2018 after retention calculations. Of that release group, 1,071 CWT positive jacks were estimated to have returned in 2018, resulting in 27,475 effective tags for adult MS estimation in 2019. 241 adults were determined to be CWT'd after expanding the examined proportion of the escapement to the estimated total escapement.

$$MS_{CWT} = \frac{100\ (9.05 + 241)}{27{,}475} = 0.91\ \%$$

### MS based on PIT Tags

4,000 PIT tags were applied in the spring of 2018, with no tag loss during retention tests. 92 were determined to have returned as jacks in 2018, resulting in 3, 908 effective tags for adult marine survival estimation. In 2019, 26 adults were determined to be PIT tagged.

$$MS_{PIT} = \frac{100\ (.976 + 26)}{3{,}908} = 0.69\ \%$$

There is a 0.22% difference in MS estimations between the two tagging methods. The CWT calculation included a much larger sample size than that of PIT tags, but there was no expansion of PIT tag returns like there was with CWT's. Also, there is the possibility of "false positive" CWT detections, where a fish tests positive for a CWT but in fact is not CWT'd. False positive detections is believed to be very low, but could artificially increase MS estimation. There are no false positives with PIT tag detections. Tagging proportions likely play a role in MS evaluations between the two tag groups. In 2018, 72% of smolts were CWT'd, while only 10% were PIT tagged(Table 3). The difference in sample size and detection probabilities may explain the differences in MS rates. Further investigations in future years may provide insight, or patterns between the two evaluation methodologies. Analysis over a longer period of time needs to be conducted to compare the MS rates between the two tagging methodologies to assess if there is a statistical difference, but there is no rational to suggest a difference. Work conducted at Big Qualicum in 2016 also looked at comparing CWT and PIT tag marine survival rates on hatchery marked Coho, and it was found to be similar (Pellett, K. 2017)

## Tag Application Rates and Rates of Return:

It has been observed that the tagging proportions (tagged to untagged) of fish leaving Black Creek each spring does not correlate to the return tag rate proportions. 71% (2018) and 89% (2019) of the smolts leaving were CWT'd (10% and 9% PIT), yet jacks and adult tag rates were observed to be much less. Table 3 outlines the tagging percentages of smolts leaving and that of returning fish (jacks and adults). For both CWT and PIT tags, the rates of return are less in adults than that of jacks.

*Table 3. Observed tag rates on returning jacks and adults to Black Creek*

| | | | | Observed Tag Return Rates | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Tag Year | Tag Application Rates | | | Jacks | | | Adults | | |
| | Total Smolts | # CWT'd | # PIT | Estimated Return | CWT + | PIT + | Estimated Return | CWT + | PIT + |
| 2018 | 40309 | 28546 | 4000 | 1873 | 1071 | 92 | 976 | 239 | 26 |
| | | **71%** | **10%** | | **57%** | **5%** | | **24%** | **3%** |
| 2019 | 46469 | 41306 | 4300 | 2909 | 1495 | 179 | Results not available until after fall of 2020 | | |
| | | **89%** | **9%** | | **51%** | **6%** | | | |

Based on these observations, there are a few possible reasons:

1. Tagged fish are not surviving the same as untagged fish (differential mortality);
2. Stray rates of Coho are higher than expected;
3. We are missing a significant portion of early or late timed smolt out-migrants;

It is unlikely that tagging and handling would affect tagging proportion as drastically as observed, but more work is needed to evaluate these effects, and should be considered factors. Straying is when fish from outside sources return to a non-natal stream. Further work on possible straying events is required as there is some evidence from other local populations that this does occur but at this time is unquantifiable. There are also some documented cases of fall and winter smolts populations (Roni et al, 2012), but it is unclear if this is the case at Black Creek. Again further work is needed to evaluate this potential. There is evidence of juvenile sized Coho leaving Black Creek in the fall, recorded on the adult video monitoring system (Figure 16).


*Figure 16. Image of juvenile sized fish leaving Black Creek in the fall, image captured in adult monitoring program.*

## Additional Information PIT Tags Have Provided:

The main objective of this work is to evaluate MS, and compare differences between CWT and PIT tag methodologies. The use of PIT tags allows the evaluation of individual fish with associated biosamples, and is starting to provide information on which fish survive best. This type of evaluation is not possible with CWT's. Through this PIT tagging work, there is an increased ability to evaluate MS and population behavioral patterns.

It is noticed over the past 2 years of jack returns that they tend to come from the earlier, and larger smolts in the outmigration, but it's not known if it is size, the period of time, environmental factors or a combination of factors that drives jacking.

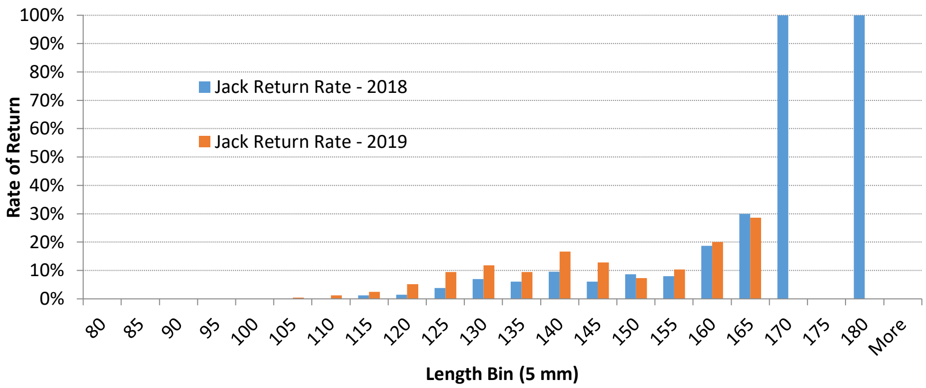


Figure 17 shows the survival rate by size bin range. The 170 + bin ranges only had 1 fish each, but both of those fish returned as jacks (100% survival). Based on jack data over the last two years, it is evident that larger the fish, the higher the jack rate. In the 125+ sizes, marine survival ranges from 4-100%, with an average of 20% survival. Fish less than 120 mm appear to have much lower jack survivals, and contributions to the jack escapement component.

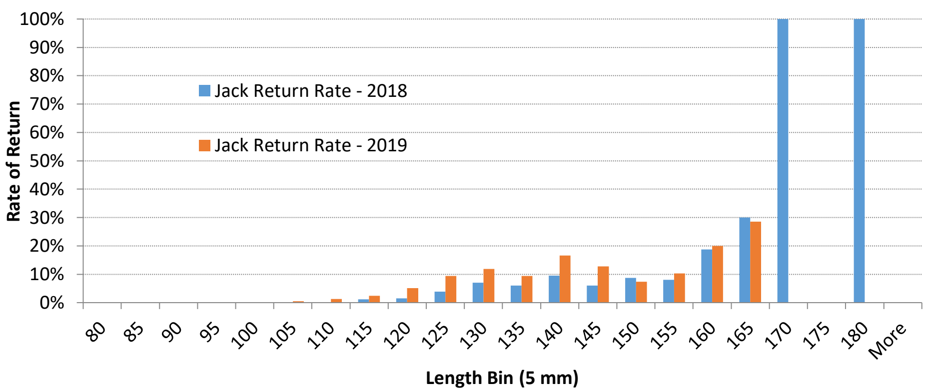


*Figure 17. 2018 and 2019 jack survival based on length.*

Only 1 year of adult PIT tag data is available to analyze. The survival rates based on size bin ranges vary, but is as high as 1.4% from some sizes (

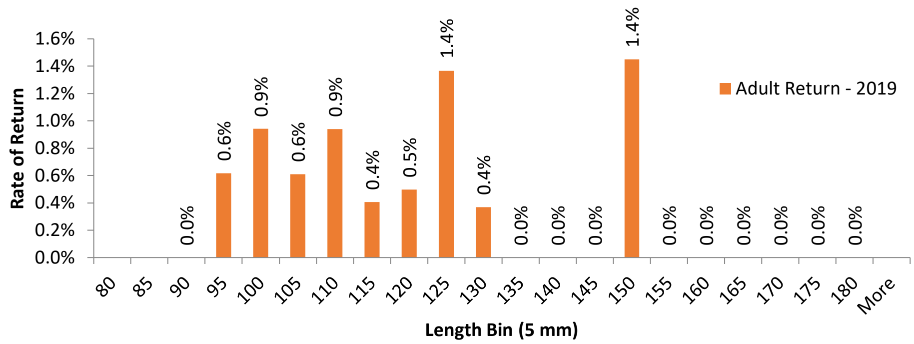


Figure 18 fish tagged in those groups.

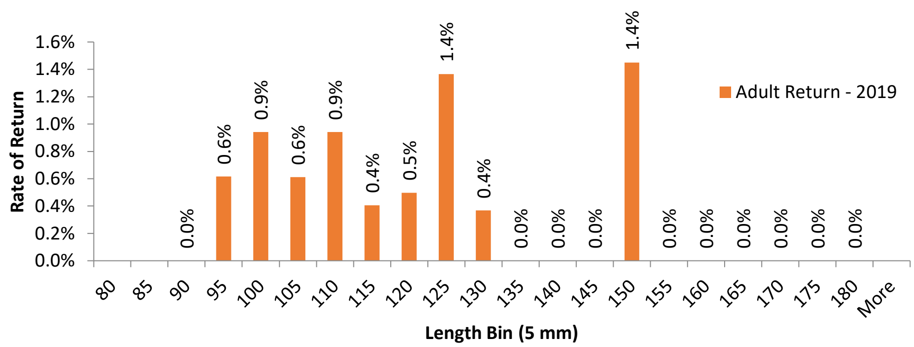


Figure 18. 2019 adult survival based on length). The sample size (n=26) is relatively small to draw conclusions from, but it does give some insight into what size of smolt contributes to the adult survivals. It appears that most of the adult survival came from smolts in the 95-130 mm ranges. The 150mm bin range is represented by 1 PIT tag from a small number of applications in that size range. Figure 8 above displays the annual size distribution of PIT tagged fish. No PIT returns came from fish under 95 mm or over 155 mm, but there were also very small numbers of fish tagged in those groups.

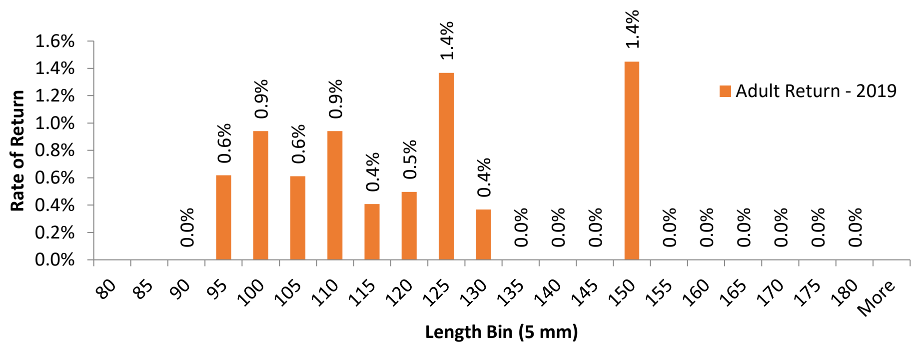

*Figure 18. 2019 adult survival based on length*

There is an obvious divide between the size of a smolt that jacks, or returns as an adult (

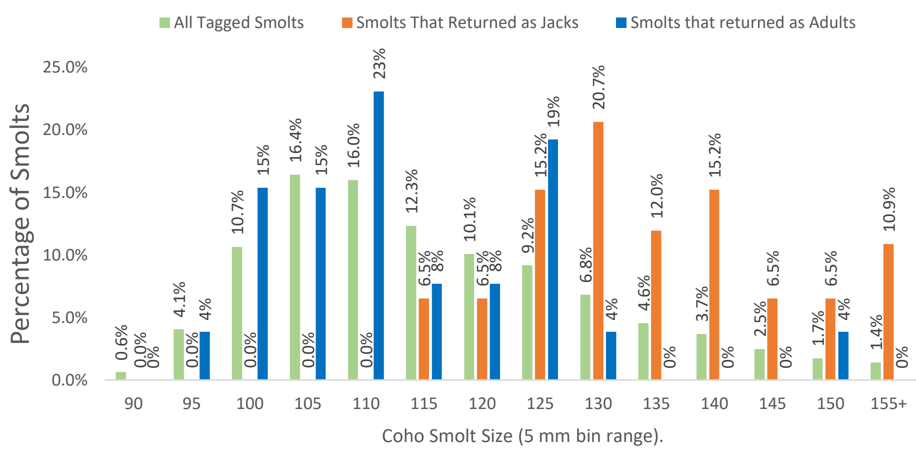


Figure 19) based on the bimodal distribution separating the two return groups (jack and adult). It appears that adult contributions are derived much more from an averaged size smolt, with 73% of adults coming from <120 mm bin ranges. Larger smolts tends to contribute more to the jack component, with 87% of jack returns coming from the >120mm bin ranges.

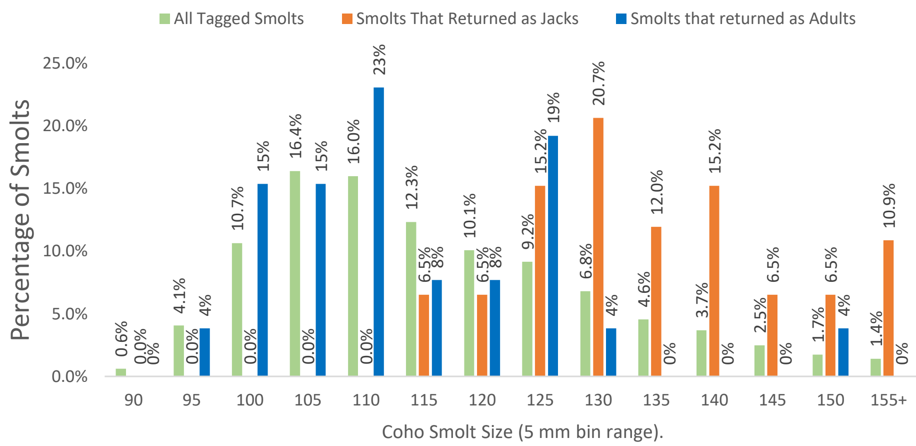


*Figure 19. 2018 smolt year size distribution for all smolts, and smolts that returned as a jack or adult.*

Based on the findings above, and many other well documented sources, smolt size appears to be the factor of whether a smolt will jack or return as an adult. In both years of this study, the daily average smolt size drops to ~120mm between May 1st and 5th, and the corresponding jack rate also drops(

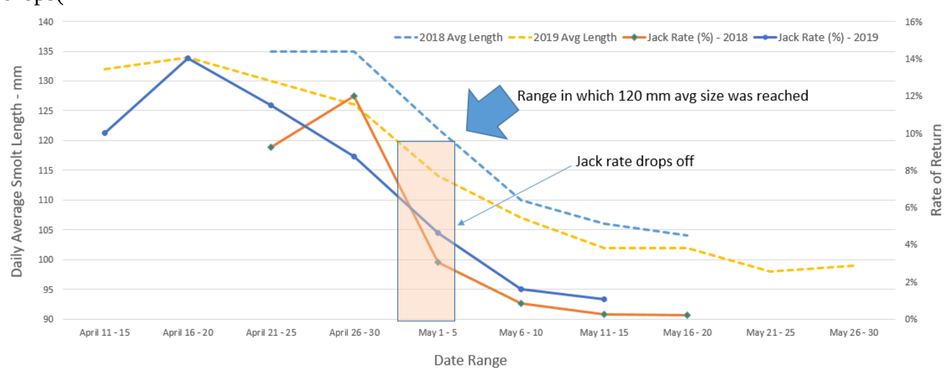


Figure 20). It is evident that the jack rate earlier on in the outmigration is higher because there is a more large smolts.

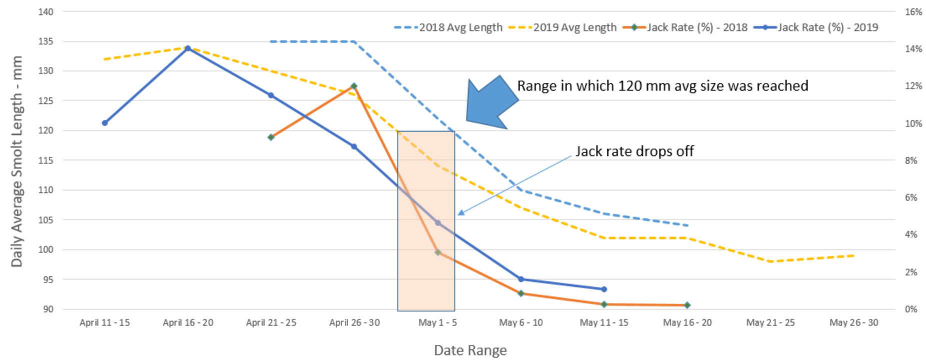


*Figure 20. Average daily PIT tag length and corresponding jack return rate.*

When plotting return rates (jacks and adults) against the daily average size of smolts (**Error! Reference source not found.**), the correlation is good for the jack relationship, but poor for the adult one, suggesting there isn't a strong relationship between smolt size and rate of return for adults, but is for jacks..

For jacks, the linear correlation coefficient values were 0.84 and 0.85 for 2018 and 2019 respectively. This again strongly supports that larger fish have a significantly higher jacking rate.

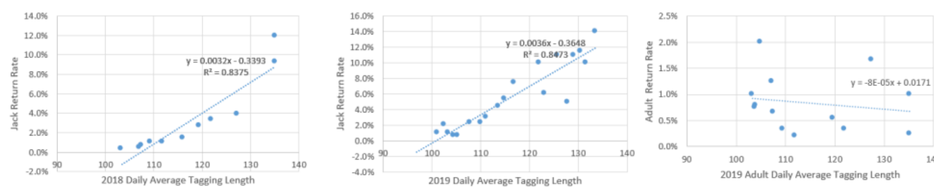


*Figure 21. Correlations curves plotting rates of return with average smolt length. 2018 jacks, 2019 jacks, 2018 BY adults*

In future, based on this work it may be possible to predict which smolts based on size and migration timing will become jacks and which smolts will effectively contribute to the adult return cohort. This is only year two of data and it will be interesting to see if there is any further inter-annual variability to that jacking event.

## Recommendations from 2019 and Moving Forward (2020):

There are a couple of recommendations from 2019 tagging and monitoring.

1. Adults
   a. Be more diligent in scanning for CWT and PIT tags during fence operations. It is imperative that accuracy in tag detection be high to achieve the most accurate MS evaluations. Missing tags will result in an under estimate of MS. Having multiple PIT antennas will help reduce missed tags by the ability to create efficiency test on each antenna and therefore are able to account for any missed tags.
   b. Collect all heads from adults and jacks during dead pitch operations and scan for CWT presence. This will provide a secondary CWT mark rate for comparative purposes.
   c. Leave trap box open at nights to allow night time adult migration and rely on video monitoring. Based on PIT tag detections, it was observed that some tagged fish entered the trap box multiple times over multiple days before being counted and allowed entry upstream. The downfall to this is that it will increase the error associated with the CWT component of the program.
   d. Implement stricter antenna download procedures. The large amount of data that was over written on the trap box antenna would have helped to better understand antenna efficiencies, fish behavior and may have affected the PIT tagged based MS evaluation.
2. Juvenile
   a. Improve biological data collection parameters. It would be ideal to collect both length and weight to gather fish condition factor information.
   b. Conduct some longer term CWT and PIT tag retention evaluations. It is not likely that short term retentions are providing adequate accountability for mortality or tag loss
   c. Apply PIT tags in Black Creek upper watershed on pre-smolts and monitor for downstream movement throughout the year, monitoring for possible fall out-migrants. Tagging in upper watershed will also limit tagging related mortality impacts on MS evaluations as those fish will likely drop out of the population before leaving Black Creek, and only tags leaving the fence location will be assed in MS evaluations.
3. General
   a. Further review of each of the possible factors affecting the proportion of tagged fish returning

2020 will again see more PIT tags applied to juvenile coho leaving Black Creek in April and May as a continuation of this multi-year project. The data and information being collected as part of this project is providing more information to support DFO salmon stock assessment. This preliminary report and evaluation of the PIT tag work will again be compiled in the spring of 2021, but once more years of data is compiled a more detailed report should be compiled to quantify the findings of this work.

**Acknowledgments:**

We would like the thank the Pacific Salmon Commission for providing multiyear project funding through the South Fund. A-Tlegay Fisheries Society staff for work in both the juvenile and adult programs. Without their expertise this project would not be possible, or successful. Kevin Pellett (DFO) for assisting in both project design and set up, as well as data review and summary. Pieter Van Will (DFO) for logistics and program overview assistance.

**References:**

**Pellett, K. 2017**. Experimental Marking of Juvenile Big Qualicum River Hatchery Coho with PIT Tags. Technical Report prepared for Fisheries & Oceans Canada and the Pacific Salmon Foundation – Salish Sea Marine Survival Project – Strait of Georgia Program.

**DFO, 2020**. 2020 Marine Survival Forecast of Southern British Columbia coho. DFO unpublished document. (Steve Baillie, DFO)

**Meldrum**, J., Campbell, K., Van Will, P., Stiff, H.W., Nagtegaal, D., Miyagi, E., and Duncan, K. **2017**. Enumeration of juvenile and adult Coho salmon at Black Creek, Vancouver Island, 2013. Can. Manuscr. Rep. Fish. Aquat. Sci. 3116: viii + 273 p.

**K. Pellett, personal comm**. Fisheries & Oceans Canada, Salmon Stock Assessment Biologist.

Philip **Roni**, Todd Bennett , Ranae Holland , George Pess , Karrie Hanson , Raymond Moses , Mike McHenry , William Ehinger & Jason Walter (**2012**). Factors Affecting Migration Timing, Growth, and Survival of Juvenile Coho Salmon in Two Coastal Washington Watersheds, Transactions of the American Fisheries Society, 141:4, 890-906, DOI: 10.1080/00028487.2012.675895

**Commented [VWP2]:** Make these all look the same