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A Fishwheel-ARIS Study to Compare Fish Size and Species Identification using an ARIS Data with those Confirmed from Fishwheel Catches

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EXECUTIVE SUMMARY

We operated an ARIS sonar system adjacent to the fishwheels deployed at the Crescent Island (Silverhope) site during August and September 2019 to compare to compare fish size and species identification using an ARIS length-based approach with those confirmed from the fishwheel catches. Our initial study design included three main components: (1) the comparison of the estimated proportions and behaviors of Sockeye and Pink salmon relative to fishwheel operations; (2) quantification of differences in the estimated proportions and behavior of fish approaching the fishwheels during daylight and night-time hours; and (3) direct comparisons of the length measurements determined from ARIS images just prior to when fish are individually sampled from fishwheel catches.

The delayed start to sampling in 2019 impeded our ability to compare estimated species composition based on ARIS data and the observed catch in the fishwheels (Component 1). Within four days of beginning sampling catches were dominated by Pink Salmon. Even without the delay in sampling operations it would have been difficult to compare night and daytime species composition due to the large catches of Pink Salmon and the concern for the health of Sockeye salmon (Component 2). In previous years, the fishwheels operated around the clock but during 2019 the fishwheels were only rarely run for more than 8 hours as fish catches during longer samples, such as overnight, would have filled the holding tanks beyond a safe capacity. For example, during 9.8 hours of sampling on 27 August 2019 the large fishwheel caught 454 Pink Salmon including 311 in 1.5 hours during the morning site visit. This catch eclipsed the total catch of 402 Pink Salmon caught in the large fishwheel during all sampling in 2017 and far outpaced the peak catch in 2017 of 90 Pink Salmon over a 30.2-hour sample on 30 Aug. The high abundance of Pink Salmon also added difficulty to fishwheel lengths of fish to individuals observed in the sonar data (Component 3). The best results came during periods of low fish abundance when fish were traveling individually or in small groups rather than when they were entering the fishwheel baskets en masse. Comparing lengths measured using the ARIS data with those collected on the large fishwheel gave valuable insight into the variability of sonar measurements. While in aggregate ARIS measurements were similar to measurements taken on the fishwheel, on an individual fish basis measurements were consistently off from fishwheel lengths. The average of the two ARIS measurements was more than 10% different than the fishwheel length for 20 of 62 fish.

Environmental conditions can play an important role in the accuracy of ARIS based measurements and both reviewers noted difficult conditions when reviewing this data. Subsequent to this study the same two technicians measured 72 fish from data collected at close range (5-15m). While there was still variability among these length measurements, the average difference was insignificant at less than 1cm, suggesting the length measurements from the two technicians are consistent when measuring less noisy data.

The small separation in the mean fork length between Pink and Coho salmon (1.2 cm) used for ARIS analysis was too small to use a mixture model for estimating proportions of the two species. Adjustments to fishwheel operations could yield a larger sample size of fish usable for ARIS analysis.

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INTRODUCTION

The management of the Fraser River salmon fisheries is complex. Five species of salmon migrate through marine areas to the Fraser River then upstream toward hundreds of terminal spawning areas (Roos 1991). Decisions to open and close fisheries are based on a combination of pre-season and in-season estimates of run timing, stock composition, and abundance (Woodey 1987).

The Mission abundance estimates are an important source of data used by decision makers to manage marine and freshwater fisheries in-season. The Mission hydroacoustic program estimates the daily passage of all salmon species migrating upstream. The total salmon estimated from acoustics is then partitioned into species and estimates of species proportions have historically been derived from daily catches in a gillnet test fishery that operates near Whonnock, BC. In 2005 and 2006, the Mission hydroacoustic program generated substantial over and underestimates of Sockeye Salmon (*Oncorhynchus nerka*) passage during the in-season period. In 2005, the errors were attributed primarily to incorrect species composition estimates, which resulted in incorrect partitioning of the estimated abundances of total salmon among species (PSC 2009). Determining the correct species composition is difficult since it varies across the river channel, and since the available test-fishing gear types have catchabilities that also vary across the river channel (Smith et al. 2009). For example, the Whonnock test-fishery samples less efficiently near shore than it does in the central part of the channel, thus it is likely to underestimate the relative abundance of groups that swim closer to shore (such as Pink Salmon (*O. gorbuscha*) or jack Chinook Salmon (*O. tshawytscha*); Robichaud et al. 2008). The species-partitioning problem is paramount in odd-numbered years, when substantial numbers of Pink Salmon migrate upstream past the Mission hydroacoustic site. In past years, this issue mainly affected Sockeye estimates in September (thus mostly affecting the estimates of Late-run Sockeye passage), but in more recent years Pink Salmon have initiated earlier upstream migration, potentially also affecting abundance estimation in August (thus affecting both Summer-run and Late-run Sockeye estimates). Moreover, in recent years the abundance of Chinook migrating past Mission in August has increased substantially, and this combined with low abundance years for Summer-run Sockeye (e.g., 2008 and 2009) may be creating further species-composition challenges for estimates of salmon passage at the Mission hydroacoustic site (Smith et al. 2009; Robichaud et al. 2010).

Studies and analyses conducted from 2009 to 2017 have demonstrated that spatially-stratified hydroacoustic counts can be combined with species composition data from the fishwheels and Whonnock test fisheries to produce scientifically defensible estimates of the number of Sockeye and Pink salmon that pass the Mission hydroacoustic site in odd-number years (Robichaud et al. 2010; English et al. 2016). Fish length data derived from DIDSON (2013) and ARIS (2015 and 2017) images was used in a mixture-model discrimination analysis to derive species composition estimates for the near-shore strata monitored by the DIDSON/ARIS systems at the Mission hydroacoustic site (Grant et al. 2014, Table 7 p. 45; Xie et al. 2014, Table 3). Substantial differences have been observed between the DIDSON/ARIS length-based species composition estimates for near-shore strata at the Mission site and those derived from fishwheel samples at Crescent Island (English et al. 2016). Both methods have their strengths and weaknesses. For the fishwheel, species should be identified accurately, but Sockeye and Pink salmon may not be equally vulnerable to the gear. For the DIDSON/ARIS, both species should be equally vulnerable to being observed in the image, but the measurement of lengths from DIDSON/ARIS images is imprecise and the length distributions of Sockeye and Pink salmon are highly overlapped. To date, the PSC estimates of Sockeye proportions derived from DIDSON/ARIS length-based approach have tended to be higher than those derived from the fishwheel samples (English et al. 2018). The need for improved comparisons and to better understand the potential causes of the discrepancies between DIDSON/ARIS and fishwheel based species proportions led to the development of this project.

While previous work was conducted using DIDSON, the newer technology ARIS system is preferred for this work because of its higher resolution capabilities and the fact that DIDSON technology is being phased out. Based on parallel testing of DIDSON and ARIS by the PSC (Lagasse et al. 2017) and others, we do not anticipate any impact on the applicability of our results by using ARIS instead of DIDSON.

For this project, we operated an ARIS sonar system adjacent to the fishwheels deployed at the Crescent Island (Silverhope) site during 2019. Efforts were severely hampered by extensive damages sustained by the large fishwheel, as well as the deflector log boom, and the subsequent time needed to repair them to operating condition. Due to a number of factors (limited sample time in August, low Sockeye Salmon abundance, and high Pink Salmon catches) work in 2019 focused on direct comparisons of the length measurements determined from ARIS images just prior to when fish are individually sampled from fishwheel catches. To this point additional ARIS data was collected in mid-late September (after the peak in the Pink Salmon migration) while the Matsqui fishwheel operations were part of a selective fishing initiative funded by the Habitat Conservation Trust Foundation. This selective fishing initiative also included the repair and operation of another fishwheel by the Yale First Nation (Crawford et al. 2020).

MATERIALS AND METHODS

Study Area

The study area locations included the Whonnock gillnet test fishery (located at approximately river kilometer (rkm) 56), the fishwheel site upstream from Crescent Island (rkm 71) and the Mission hydroacoustic site (rkm 81). The time required for Sockeye and Pink salmon to traverse the distance from the Whonnock test fishery to the hydroacoustic site is less than one day (24 hours).

Study Design

We operated an ARIS sonar system adjacent to the fishwheels deployed at the Crescent Island (Silverhope) site during August and September 2019 to compare to compare fish size and species identification using an ARIS length-based approach with those confirmed from the fishwheel catches. Our initial study design included three main components: (1) the comparison of the estimated proportions and behaviors of Sockeye and Pink salmon relative to fishwheel operations; (2) quantification of differences in the estimated proportions and behavior of fish approaching the fishwheels during daylight and night-time hours (Smith et al. 2009); and (3) direct comparisons of the length measurements determined from ARIS images just prior to when fish are individually sampled from fishwheel catches. Our intended experimental approach was to gather data and focus analyses on three main time periods of the migration: (1) predominant Sockeye migration (early in August), (2) predominant Pink migration (in late August), and (3) the “transition” period in mid-August when Sockeye proportions change from predominant to relatively rare. Data from each of these periods were to be further stratified for daytime and nighttime migrations.

Repairing the large fishwheel (see Appendix A) and the associated delay in sampling prevented us from making comparisons between the proportion of Sockeye and Pink salmon caught in the fishwheels and modeled with ARIS data (Component 1). No sampling was conducted during the Sockeye dominant migration period and only a small amount of sampling occurred during the transition period from Sockeye to Pink dominance. Additionally, the comparison of day and night catches (Component 2) was not possible because of the very poor return of Fraser Sockeye, concerns related to the effect of the Big Bar slide on the ability for summer-run Sockeye to reach their spawning areas, and the higher than expected abundance of Pink Salmon. If we operated the fishwheels overnight, the catch numbers would have exceeded the holding capacity of the live tanks and could have resulted in mortality of any Sockeye caught and likely mortalities of other species as well. Indeed, the abundance of Pink Salmon at times precluded our ability to operate the fishwheels during daylight hours unmanned. Therefore, the 2019 study was entirely focused on species identification and the direct comparisons of the length measurements determined from ARIS images just prior to when fish are individually sampled from fishwheel catches (Component 3).

As in previous years, two fishwheels were deployed and operated along the south bank of the Fraser River at the Crescent Island site 9 km downstream from the Mission Railway Bridge and 10 km downstream of the Mission acoustics site (English et al. 2018). The fishwheel operations period in 2019 was from 23 August to 25 September. The deployment was similar to the configuration used in 2009-2017 including: the 2009-2017 deflector logs and fishwheel attachment points, the floating shoreline abutment and fish weir, one 20 ft. diameter fishwheel and one 40 ft. diameter fishwheel. The ARIS sonar was focused on gathering image data for the common area sampled by the larger fishwheel. Despite the substantial repairs required to the large fishwheel (see Appendix A) and the deflector log-boom, the availability of most of the necessary equipment represented a substantially in-kind contribution to this project. The retained value of these components is approximately $150,000. An experienced field supervisor was responsible for ensuring the safe and correct deployment of the fishwheels, ARIS sonar, and related study equipment. The field crew was comprised of the supervisor and two Matsqui First Nation technicians who typically visited the fishwheels twice each day to process catches and maintain the equipment. Their first visit was generally around 09:00 to count and sample the overnight catches and restart the generator needed to power the ARIS sonar. The second daily visit provided the species counts and samples for the daytime catches. During periods of high fish abundance, the fishwheels were not fished overnight and were occasionally visited only once per day.

Fishwheel Deployment and Operation

Details related to the deployment and operation of the fishwheels and shoreline abutment can be found in previous reports (e.g., English et al. 2016; 2018). The dimensions for the small and large fishwheels are repeated here for easy reference. The small fishwheel had two welded-aluminum pontoons (11.6 m long × 0.9 m wide × 0.5 m deep) that were comprised of seven independent, pressure-tested compartments. It had three baskets (3.4 m long × 3.0 m wide × 2.1 m deep) that were framed with aluminum tubing (3.8 cm square) and lined with white, knotless, nylon mesh (6.4 cm stretch). The baskets were attached to a 3.7 m axle and designed to fish up to 3 m below the water surface. Pontoons for the large fishwheel were similar in width and depth to those of the regular fishwheel but were 17.7 m long. The large fishwheel baskets (6.1 m long × 4.3 m wide × 3 m deep) were framed with same aluminum tubing and lined with the same nylon mesh as the small fishwheel. The baskets were attached to an axle (5.2 m long) and designed to fish 5.8 m below the water surface.

The configuration of the fishwheel setup along with the deflector log boom and shoreline abutment is shown in Figure 1. Figure 2 provides a picture of the fishwheel site with the location of the ARIS sonar on a ladder mount near the shoreline just downstream from the fishwheels.

Fishwheel Biosampling

Every fish caught in each fishwheel was counted and identified to species. Fork lengths of fish lengths were recorded for a portion of captured fish. All individuals of a species were measured until 20 were measured for the day. Thereafter, only individuals which could also have a timestamp attached to them were measured. Initially capture times were recorded to the nearest minute but after an in season review later samples were recorded to the nearest second. Coho Salmon was the dominant species caught from 18-25 September 2019, after the peak in the Pink Salmon migration past the fishwheel site. To minimize possible stress on wild interior Fraser River Coho Salmon (*O. Kisutch*) in most cases only hatchery Coho Salmon were measured, and wild Coho were quickly returned to the river with minimal handling.

Fishwheel and ARIS Fish Length Comparisons

An ARIS 1800 sonar was deployed from the south shore of the Fraser River adjacent to the fishwheel. The ARIS was aimed towards the underwater region of the river where the large fishwheel basket ascended out of the water. From 24 August to 6 September and from 22 to 25 September. The ARIS collected data, while the crew was manning the fishwheels, over a range of 8 to 20 metres from the transducer. The operating frequency was 1,100 kHz using 96 acoustic beams and approximately 1,000 samples per beam. Figure 3 provides an ARIS screen image showing the location of the fishwheel basket.

The fishwheel crew provided the PSC ARIS review technicians with the capture times for measured salmon. The ARIS crew then attempted to locate the captured fish in the ARIS data and measure it if a clear image was obtained. Length measurements were taken by an experienced technician using the sizing tool of the ARISfish program developed by Sound Metrics Corporation. This is the same methodology used by the PSC Mission hydroacoustics program. To measure possible variability between technicians a subsample of fish was measured independently by a second technician who was unaware of the lengths obtained by the fishwheel crew and the other reviewer. Once the two sets of ARIS measurements were complete the data was combined with the measured lengths from the fishwheels.

ARIS Length-Based Species Proportions

Length measurements were input into a mixture model to predict the proportions of salmon species. The mixture model assumes that the frequency distribution of the fish lengths is a combination of multiple normal distributions derived from the standards and predicts the relative proportion within each distribution (Fleischman and Burwen 2003). In this application of the model, we use fish-length as a discriminatory variable to separate species.

RESULTS

Catches

The fishwheels were operated from 23 August to 6 September and from 18 to 25 September with the exception of 5 and 6 September when the small wheel was shut down to improve sonar imagery quality. The large fishwheel was operated for 160 hours and caught 117 adult Sockeye, 59 adult Chinook, 190 jack Chinook, 2,887 Pink, 338 Coho, 26 jack Coho, 2 Chum salmon (*O. keta*), 2 steelhead (*O. mykiss*) and 9 White sturgeon (*Acipenser transmontanus*; Table 1). The small fishwheel was operated for 153 hours and caught 18 Sockeye, 3 adult Chinook, 34 jack Chinook, 411 Pink, 166 adult Coho, 7 jack Coho, 1 steelhead, and 2 White Sturgeon. Figure 4 provides a graph showing the composition of the daily fishwheel catches of salmon. The length ranges of Sockeye and Pink salmon were once again heavily overlapped (Table 2).

Comparison of Length Measurements

The initial review identified 84 individual fish where the fishwheel capture time could be matched with imagery of the captured fish. A second review identified seven more fish for a total sample of 91 fish for analysis. Of those 91 fish, a subsample of 62 were reviewed by a second reviewer to investigate the consistency between reviewers.

For the full sample, Reviewer 1 had a mean length from the ARIS data that was 0.30 cm larger than the mean length recorded on the fishwheel although there was considerable variation on an individual fish basis (s=5.88 cm; Table 3). For the subsample of 62 fish reviewed twice, the mean difference in fish length between the ARIS and fishwheel was 0.03 cm (s=6.07 cm) for Reviewer 1 and -3.90 cm (s=4.46 cm) for Reviewer 2 (Figure 5).

ARIS Length-Based Species Proportions

The mixture model was effective in separating out the Coho jack group by the model fit but was unable to separate out the Pink and Coho adult groups due to so the small difference in each groups' mean length (Table 2).

DISCUSSION

Ability to Implement Study Components

The delayed start to sampling in 2019 impeded our ability to compare estimated species composition based on ARIS data and the observed catch in the fishwheels (Component 1). Within four days of beginning sampling catches were dominated by Pink Salmon. Even without the delay in sampling operations it would have been difficult to compare night and daytime species composition due to the large catches of Pink Salmon and the concern for the health of Sockeye salmon (Component 2). In previous years, the fishwheels operated around the clock but during 2019 the fishwheels were only rarely run for more than 8 hours as fish catches during longer samples, such as overnight, would have filled the holding tanks beyond a safe capacity. As an example, during 9.8 hours of sampling on 27 August, 2019 the large fishwheel caught 454

Pink Salmon including 311 in 1.5 hours during the morning site visit. This catch eclipsed the total catch of 402 Pink Salmon caught in the large fishwheel during all sampling in 2017 (11 to 31 August) and far outpaced the peak catch in 2017 of 90 Pink Salmon over a 30.2-hour sample on 30 Aug. The high abundance of Pink Salmon also added difficulty to fishwheel lengths of fish to individuals observed in the sonar data. The best results came during periods of low fish abundance when fish were traveling individually or in small groups rather than when they were entering the fishwheel baskets en masse.

ARIS and Fishwheel Length Comparison

Comparing lengths measured using the ARIS data with those collected on the large fishwheel gave valuable insight into the variability of sonar measurements. While in aggregate ARIS measurements were similar to measurements taken on the fishwheel, on an individual fish basis measurements were consistently off from fishwheel lengths. The average of the two ARIS measurements was more than 10% different than the fishwheel length for 20 of 62 fish.

Environmental conditions can play an important role in the accuracy of ARIS based measurements and both reviewers noted difficult conditions when reviewing this data. Subsequent to this study the same two technicians measured 72 fish from data collected at close range (5-15m). While there was still variability among these length measurements, the average difference was insignificant at less than 1cm, suggesting the length measurements from the two technicians are consistent when measuring less noisy data.

Species Identification

The small separation in the mean fork length between Pink and Coho salmon (1.2 cm) used for ARIS analysis was too small to use a mixture model for estimating proportions of the two species. Other species were not caught in large enough numbers for inclusion in the mixture model.

Previous Fishwheel Operations and Cost Estimates

As indicated above and in previous reports, one of the major sources of uncertainty in the Mission hydroacoustic estimates for Sockeye is the across-channel species composition at the Mission hydroacoustic site. In odd-numbered years, substantial numbers of Pink salmon migrate upstream past the Mission hydroacoustic site in August and September along with summer and late-summer Sockeye stocks. In recent years, the abundance of Chinook migrating past Mission in August has increased substantially, and this combined with low abundance years for Summer-run Sockeye (e.g., 2008) highlights the importance of species composition estimates for the Mission hydroacoustic site (Smith et al. 2009; Robichaud et al. 2010). Historically, data from the Whonnock gillnet test fishery has been used to determine the species composition at the Mission site for periods when Pink salmon abundance is not a factor (i.e., even-numbered years and July in odd-numbered years). Pacific Salmon Commission biologists have recognized that the abundance ratio of Fraser Sockeye to Pink salmon in August-September marine test fisheries (in odd-numbered years) is substantially different from those derived from the Whonnock gillnet test fishery. This recognition was emphasized by the large bias in Sockeye estimates generated during the 2005 season (PSC 2009). Fishwheel data from the Mission Railway Bridge sites sampled in 2007 confirmed previous observations that Pink salmon tend to be more abundant close to shore than in the center of the channel and the ratio of Pink to Sockeye is substantially different between near-shore and off-shore sampling locations (Robichaud et al. 2008). The estimates of species proportions derived from the DIDSON length-based method in 2013 and 2015 provided additional evidence of the predominance of Pink salmon in near-shore waters (Fleischman and Burwen 2003; Xie et al. 2013; Grant et al. 2014).

In 2009, 2011, 2013, 2015 and 2017, the deployment of DIDSON technology in near-shore areas improved the accuracy of estimates of near-shore salmon migration and PSC partitioned the Mission hydroacoustic counts into near-shore and off-shore strata, so the species composition estimates from the fishwheels could be applied to the near-shore counts, and species composition from Whonnock gillnet test fishery catches could be applied to the off-shore counts. The resulting daily estimates of the number of Sockeye passing Mission were consistent with the PSC's 'best judgement' estimates of the daily Sockeye abundance at Mission except for periods late in the year, when the stratified estimates were larger than the PSC estimates.

In each year examined, the transition from mostly Sockeye to mostly Pink salmon in near-shore waters occurred in August. In two years (2009 and 2015), the proportion of Sockeye in fishwheel catches began to diverge from those in the Whonnock test fishery in early August. In 2011, fishwheel operations didn't start until mid-August when Sockeye percentages were already lower in the fishwheel catches. In 2013, the percent Sockeye in the fishwheel and Whonnock catches were similar until 20 August, when they diverged rapidly from those in the Whonnock test fishery and Sockeye were less than 2% of the fishwheel catch at the end of August, as observed in other odd years. In 2017, the transition from sockeye to pink salmon dominance in the fishwheel catches occurred rapidly between Aug. 22 and Aug. 25 (English et al. 2018). In the two years (2009 and 2011) when the fishwheels were operated until 20 September, Pink salmon comprised over 99% of the salmon caught in September. Therefore, the key period for application of a stratified method estimating species proportions is clearly August.

In most years, the total costs for operating the fishwheels at the Crescent Island site for most of August in recent years has been $55,000. The daily costs for fishwheel operations with a local three person crew, crew boat and routine maintenance has been $900/d. The remainder of the costs are associated with annual fishwheel repairs, deployment, demobilization, and data analysis and reporting. These costs are kept reasonable because PSF and DFO have provided the large and small fishwheels, respectively, at no cost to the project. However, despite regular maintenance and a reliable off channel storage site, the large fishwheel sustained significant damage during the winter of 2018-19. This damage is probably due to snow and ice load on the baskets and one fishwheel pontoon getting hung up on a broken off piling at the storage site. The damage to the pontoons, tower structure and baskets required substantial repairs costing in excess of $44,000 in 2019.

By comparison, the costs of processing DIDSON or ARIS length measurements during the August period is approximately $7,000. This cost corresponds to the hiring of one person dedicated to measuring a sample of approximately 120 fish per day from each range strata, of which there are three to four on each bank. Costs are minimal because the PSC already operates a DIDSON or ARIS on each shore to produce estimates of total salmon abundance and requires staff at its hydroacoustics site 24/7 throughout the summer.

The ARIS length-based method is less expensive than the fishwheel method for providing the daily near-shore species composition estimates in August, but the fishwheel operation offers a number of additional benefits including:

1. The method is more direct and required less technical interpretation;

2. The gear provides a platform for biological sampling (e.g., lengths, DNA) and tagging;
3. Information is gathered from other species (e.g., sturgeon, Coho); and
4. It engages First Nations and provides harvest opportunities.

Further experiments using a fishwheel and ARIS simultaneously may be helpful in identifying the most scientifically defensible method for estimating near-shore species composition. Though the ARIS length-based method produced comparable estimates of species compositions to the fishwheel method for most time periods in the 2017 study, the comparisons only cover a period of 15 days during a single year. Changes in river conditions, as well as differences in the size, behaviour, and relative abundance of salmon species, as observed in 2019, could affect the estimates of either method in other years.

CONCLUSIONS

- The delayed start to sampling didn't allow for examining the target species and timeframes. In future years operating the wheel prior to the Pink Salmon run is necessary.
- The mixture model was not effective for predicting Coho and Pink salmon proportions due to the large overlap in the sizes of the two species.
- Although a large number of fish were examined for possible inclusion in the analysis, high fish density and suboptimal sonar imagery limited the number that were usable for length and mixture model analysis.
- In the future, adjustments to fish wheel operations could increase the sample size of fish available for analysis without needing to boost catches. Reducing air bubbles from the fishwheels should help improve image quality and thus the quality and availability of lengths from ARIS data. Additionally, improving the time stamping of caught fish to the nearest second can minimize uncertainty when linking fish with ARIS data and lower the processing effort. In-season efforts were put forth on both of these fronts including shutting down the smaller fishwheel as a means to not introduce bubbles into the river and changing how capture times were recorded.

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Table 1. Daily catch in the large and small fishwheels operated on the lower Fraser River near Crescent Island from 23 August to 25 September 2019.

Capture Method	Date	Rotation Speed (RPM)	Hours Operating	SockeyeAdultCaught	SockeyeJackCaught	ChinookAdultCaught	ChinookJackCaught	PinkAdultCaught	CohoAdultCaught	CohoJackCaught	SteelheadAdultCaught	ChumAdultCaught	SturgeonCaught	SturgeonPITTagApplied
Large Fishwheel	23-Aug	0.8	30.5	34	0	18	24	111	0	0	0	0	0	0
	24-Aug	1.1	23.5	35	0	18	33	102	0	0	0	0	1	0
	25-Aug	1.1	14.6	37	0	4	12	58	0	0	0	0	0	0
	26-Aug	0.7	6.5	0	0	1	17	92	0	0	1	0	0	0
	27-Aug	0.9	8.3	5	0	1	12	454	0	0	0	0	0	0
	28-Aug	0.9	7.6	2	0	0	6	151	0	0	0	0	0	0
	29-Aug	0.7	7.8	2	0	0	27	239	0	0	0	0	0	0
	30-Aug	0.5	2.5	0	0	0	3	39	0	0	0	0	0	0
	31-Aug	0.9	4.9	1	0	0	6	347	0	0	0	0	0	0
	1-Sep	0.3	2.7	0	0	0	2	137	1	0	0	0	0	0
	2-Sep	0.5	5.6	0	0	0	0	394	0	0	0	0	1	0
	3-Sep	0.3	1.2	0	0	0	0	327	1	0	0	0	1	0
	4-Sep	0.8	1.9	0	0	0	0	282	0	0	0	0	1	0
	5-Sep	0.8	2.4	0	0	0	0	31	0	0	0	0	1	0
	6-Sep		2.6	0	0	0	0	40	0	0	0	0	0	0
	18-Sep	0.3	5.8	0	0	2	18	16	37	0	0	0	0	0
	19-Sep	0.4	7.3	1	0	3	9	16	46	1	0	1	1	0
	20-Sep	0.5	5.8	0	0	6	11	12	51	0	0	0	1	0
	21-Sep	0.4	7.8	0	0	3	7	19	84	11	0	0	1	0
	22-Sep	0.8	2.3	0	0	1	2	2	25	1	0	0	1	0
	23-Sep		3.3	0	0	0	1	7	29	2	0	1	0	0
	24-Sep	0.9	2.5	0	0	1	0	8	25	4	1	0	0	0
	25-Sep		3.1	0	0	1	0	3	39	7	0	0	0	0
Large FW Total			**160**	**117**	**0**	**59**	**190**	**2,887**	**338**	**26**	**2**	**2**	**9**	**0**
Small Fishwheel	23-Aug	1.1	30.7	2	0	0	3	18	0	0	0	0	1	0
	24-Aug	0.6	22.0	10	0	0	4	19	0	0	0	0	0	0
	25-Aug	1.3	16.9	3	0	0	1	16	0	0	0	0	1	0
	26-Aug	1.2	6.0	2	0	0	2	21	0	0	1	0	0	0
	27-Aug	1.1	7.8	0	0	0	0	77	0	0	0	0	0	0
	28-Aug	1.1	7.5	1	0	0	6	30	0	0	0	0	0	0
	29-Aug	0.6	7.7	0	0	0	1	24	0	0	0	0	0	0
	30-Aug	0.7	2.3	0	0	0	1	20	0	0	0	0	0	0
	31-Aug	1.1	4.0	0	0	0	0	23	0	0	0	0	0	0
	1-Sep		2.3	0	0	0	0	6	0	0	0	0	0	0
	2-Sep		4.6	0	0	0	0	36	0	0	0	0	0	0
	3-Sep	0.7	1.2	0	0	0	0	59	1	0	0	0	0	0
	4-Sep	0.8	1.7	0	0	0	0	42	0	0	0	0	0	0
	18-Sep		5.9	0	0	0	2	5	7	1	0	0	0	0
	19-Sep		7.6	0	0	1	3	2	20	2	0	0	0	0
	20-Sep	0.6	6.0	0	0	1	2	7	28	1	0	0	0	0
	21-Sep	0.5	7.6	0	0	1	3	4	48	2	0	0	0	0
	22-Sep		2.3	0	0	0	3	2	11	0	0	0	0	0
	23-Sep	1.2	3.3	0	0	0	2	0	18	0	0	0	0	0
	24-Sep	1.1	2.5	0	0	0	0	0	11	1	0	0	0	0
	25-Sep		3.1	0	0	0	1	0	22	0	0	0	0	0
Small FW Total			**153**	**18**	**0**	**3**	**34**	**411**	**166**	**7**	**1**	**0**	**2**	**0**
FW Large+Small Total			**313**	**135**	**0**	**62**	**224**	**3,298**	**504**	**33**	**3**	**2**	**11**	**0**

Table 2. Length of fish in the large and small fishwheels operated on the lower Fraser River near Crescent Island from 23 August to 25 September 2019.

Species	Number Measured	Maximum Length (cm)	Minimum Length (cm)	Average Length (cm)
Sockeye	89	67	38	56.6
Chinook Adult	59	95	51	73.1
Chinook Jack	168	47	23	36.7
Pink	945	74	34	53.4
Coho Adult	203	66	41	53.3
Coho Jack	18	38	28	32.1
Steelhead	1	70	70	70.0
Chum	2	84	74	79.0
White Sturgeon	2	262	133	197.5

Table 3. Comparison of fish lengths measured from ARIS data relative to the biological length measured on the fishwheel.

	Full Sample	Duplicated Sample	
	Reviewer 1	Reviewer 1	Reviewer 2
Sample Size	91 fish	62 fish	62 fish
Mean Difference (ARIS - fishwheel)	.30 cm (s=5.88 cm)	.03 cm (s=6.07 cm)	-3.90 cm (s=4.96 cm)
Range of Difference (ARIS - fishwheel)	-17.4 to 14.4 cm	-17.4 to 14.4 cm	-14.5 to 7.3 cm

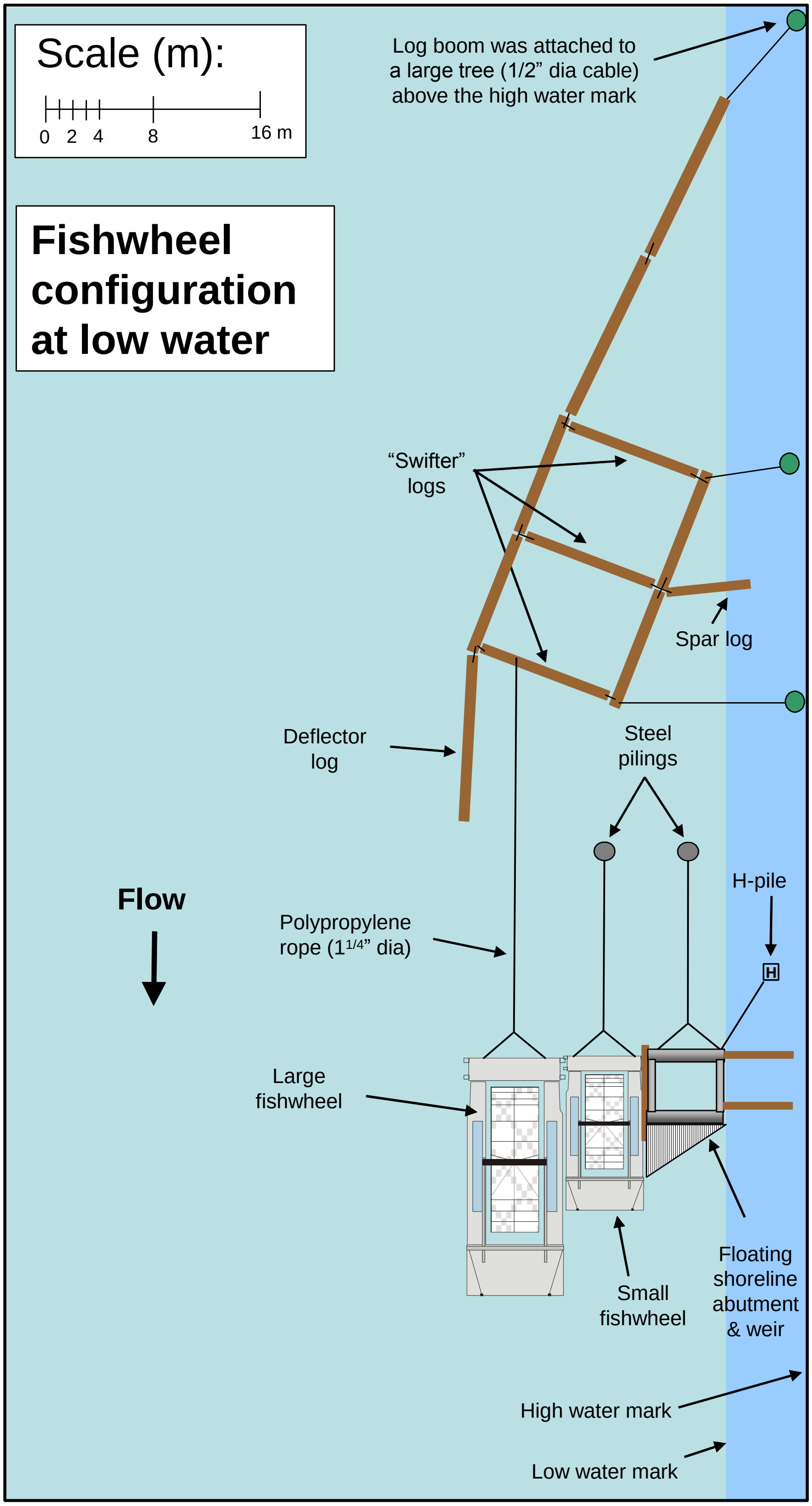

Figure 1. Schematic of the Crescent site showing the location of the log boom assembly, steel pilings, fishwheels, and floating shoreline abutment, 2009.

Figure 2. Fishwheel and sonar setup in 2019. Sonar on ladder mount near shore, small fishwheel on inside and large fishwheel on outside.

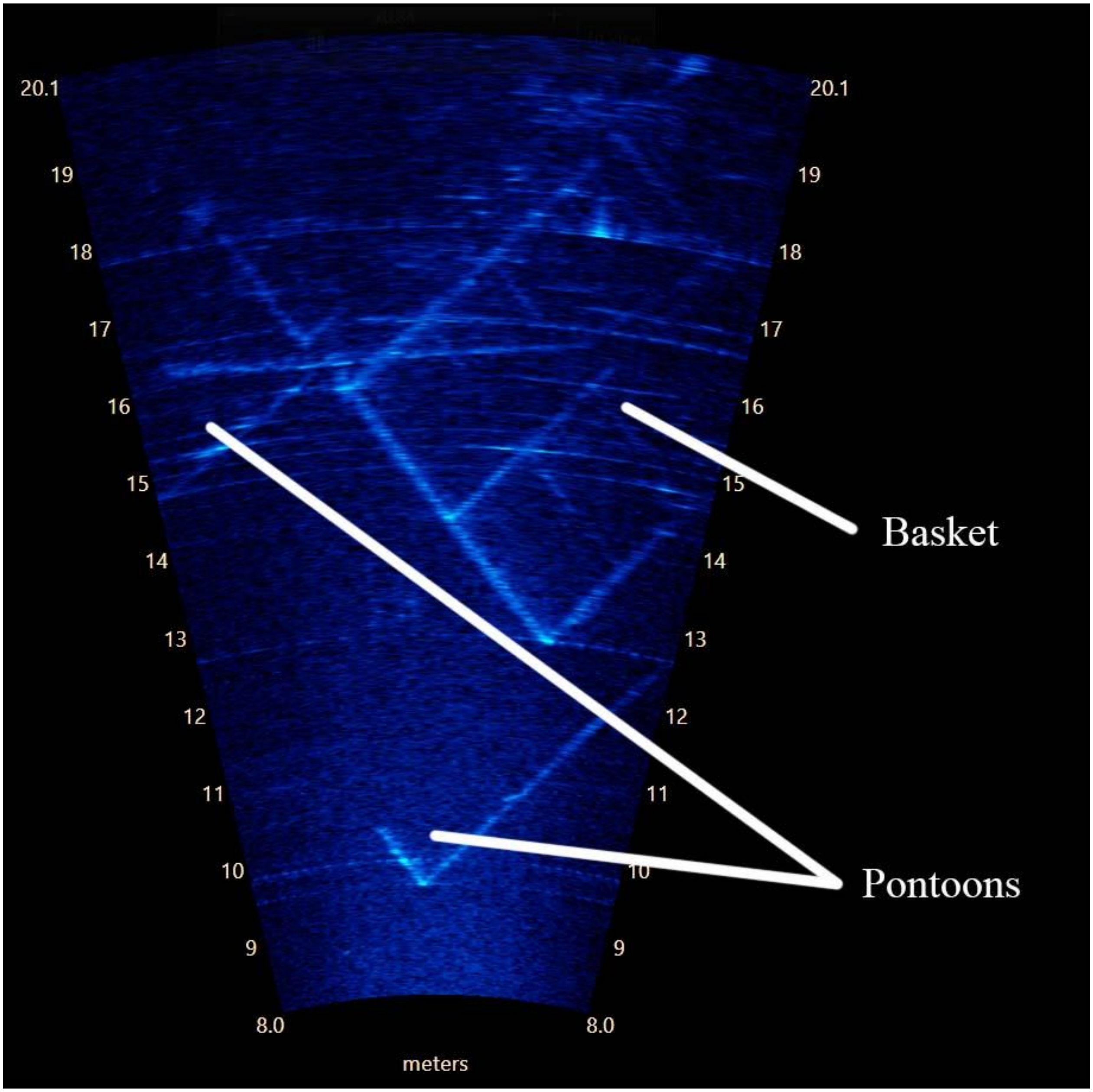

Figure 3. **ARIS screen image showing the location of the fishwheel basket between the 13 and 19 meter marks.**

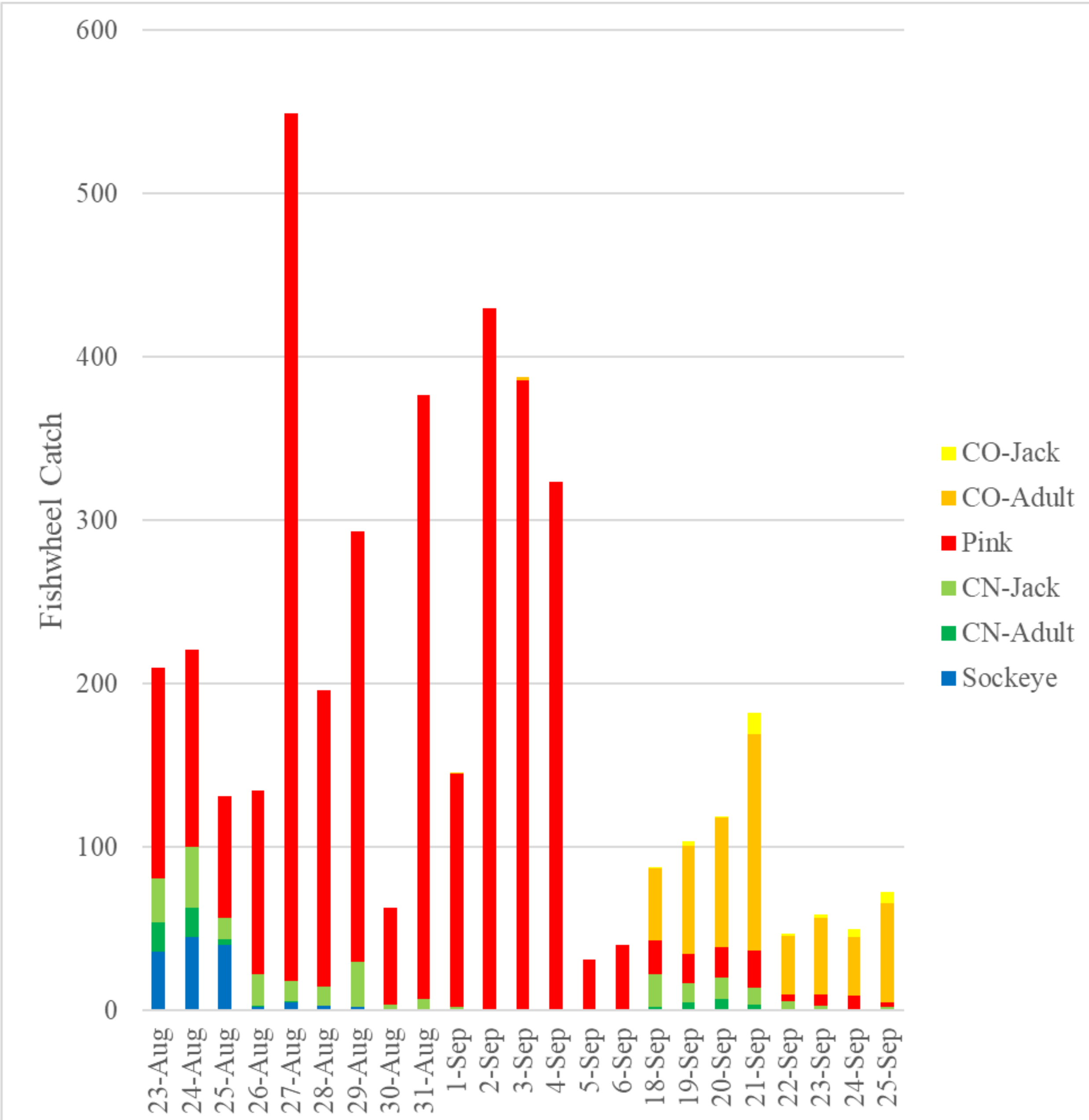

Figure 4. Combined fishwheel catch by species from 23 August to 25 September 2019.

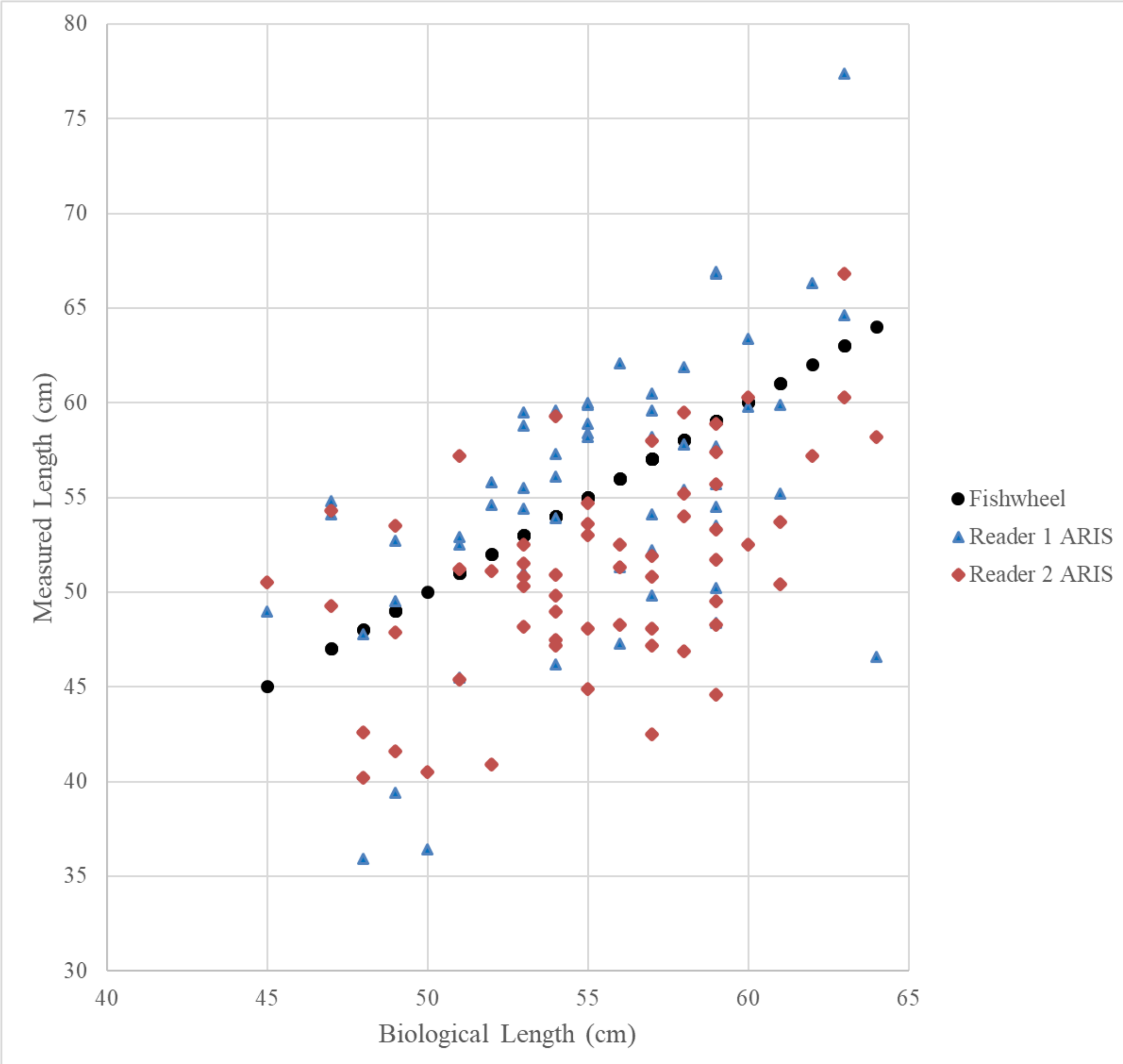

Figure 5. Comparison of fish lengths (n=62) measured from ARIS imagery and the corresponding biological length of those fish as measured from the large fishwheel.

APPENDIX A

Fishwheel Repairs and Deployment

A significant component of the work in 2019 was associated with the repair of the PSF large fishwheel used at the Matsqui fishing site.

Large Fishwheel Repairs 2019

This section provides a summary of the events and work conducted between late July and the 21 August 2019 related to the repair of the PSF large fishwheel. This summary was prepared and distributed to the PSF and other members of the project team on 28 August 2019.

On 29 July 2019, the project manager (Karl English) receive the following message from the lead project biologist (Jason Smith) after arriving in Whitehorse:

"Update from Mission:

- More photos attached showing damage to large fishwheel
- As of now, issues at the fishwheel include:
    - Partially folded starboard pontoon (near bow)
    - Starboard tower base has broken welds and is now sunken into pontoon
    - Welds broken on base plates of both port and starboard tower uprights
    - Starboard tower brace has peeled away and actually torn 6x6 aluminum upright
    - Brace on the top of the starboard tower has literally peeled away at the welds
    - The tower and basket assembly are tweaked to the starboard side and wedged on the pontoon deck
    - Most of the aluminum railing mounts are bent/ripped; and all the railings need replaced
    - At least 15 pieces of aluminum tubing need replaced
    - At least 50% of the plywood/lumber needs to be replaced on the baskets (could be more if they crumble when lifted off the axle)
    - Most if not all of the basket mesh is original (2008). There a bunch of small tears and few larger ones. I suspect we'd probably just patch it up this year
    - 4 new live tank "jumperboard" boxes must be built (3 are missing, and the one that is left is rotten)
    - The sample trough needs replaced
- Down at the fishwheel site, the swifter-log boom has been torn apart, probably half the logs are missing or need replaced, and those that are there need yanked off the bank with a tug boat

- We had Chris from High Voltage Welding come out to look at the damage this evening. He is going to get back to us tomorrow with a quote and timeline estimate. My sense is that he can't get it done within a 2-week period, but possibly 3 weeks. He asked all the right questions, and came recommended from LWS Welding. LWS is fully booked.
- We identified a good spot to do the repair work should it proceed, located only a few hundred metres upstream of their current position (land owned by Kelly Catherwood and family).
- I wasn't able to reach the PSF today, they were out of the office all day, but I'll try again tomorrow once I get an estimate from Chris.

Due to the current condition of the fishwheel (wedged baskets, unstable tower), the hoist mechanism is not useable. There is a high likelihood the entire structure could collapse under additional strain. The only way to remove the baskets to conduct repair work would be to remove the 3-baskets and axle as one piece with a crane. This would not be easy since someone will have to get in a bucket-lift to go up and unbolt the axle from the tower frame. Then the baskets would have to be taken off the axle on shore. The repair work is going to be costly no doubt, difficult, and time-consuming, and I suspect we'll discover more issues along the way. As the welder pointed out tonight, the tower and pontoons may have tweaks that can't be repaired, so there's no guarantee it'll all line up properly when re-assembled."

On 30 August 2019, just prior to leaving cell phone coverage for 10 days on the Tatshenshini/Alsek rivers, Mr. English spoke with Jason Smith and requested that he talk with PSF (Jason Hwang) to confirm support for repairing the fishwheel and a PSC representative to confirm that we could proceed with the proposed Fishwheel/ARIS study if we had to start the study two weeks later than initially planned.

Mr. English also spoke with Jason Hwang for just a few minutes before leaving cell coverage about the importance of repairing the PSF fishwheel for the 2019 PSC study, the 2019 HCTF selective fishing study and need to move toward more selective fishing methods for future in-river fisheries.

On 1 August 2019, Jason Smith sent the following message to PSF (Jason Hwang, Brian Riddell and Tim Sucic):

> *"Thank you for providing the PSF's perspective and for your offer to help contribute to the fishwheel repairs. In Karl's absence, I have discussed the status of the Fraser River fishwheel project with our President, Bob Bocking (cc'ed). We concluded that due to various uncertainties, it would be best for us to hold off making any decisions regarding the fishwheel project until Karl returns next week (Aug 8/9). In the meantime, we will ensure arrangements are made to be able to conduct the repair work on short notice. If you have any questions, please feel free to contact me."*

On Aug. 9th, Karl contacted Jason Smith as soon as he arrived back in Whitehorse and found out that no work had been done yet to repair the PSF fishwheel. On Aug. 10th, Karl received an estimate of the repair costs (at least $32K) from Jason Smith and he called Brian Riddell to confirm PSF support for the necessary fishwheel repairs. On Aug. 12, LGL personnel were mobilized to prepare a site for the fishwheel repairs. The fishwheel was towed onto the shore on August 13 and disassembled on Aug. 14 and 15. Welding repairs started on Aug. 16th. Karl joined the repair team on Aug. 17. The LGL-Matsqui crew members worked on repairing the fishwheel baskets while the High Voltage Welding team repaired the damaged pontoons, tower joints and tower pivot supports. On Aug. 18, the log boom setup was repaired and the smaller fishwheel and shoreline abutment were moved out of the Hatzic Slough site during the late night high tide. On Aug. 19, the smaller fishwheel and shoreline abutment were towed to the fishing site and secured in place and ready for the addition of the large fishwheel. On Aug. 20, the repairs were completed on the pontoons, towers, fishwheel baskets, the baskets were reattached to the axle and the tower assemble was re-attached to the pontoons. On Aug. 21, a high lift crane arrived around 10:30 am to lift the basket assembly into place high on the tower assembly. The re-assembly was completed by noon and the fishwheel was towed/pushed back into the water by 1 pm. The large fishwheel was then towed downstream to the fishing site. On Aug. 22, each of the fishwheel site components was secured in place and made ready to start fishing on Aug. 23rd.

Pictures of tower pivot and pontoon repairs and re-enforcements.

Protective log boom, shoreline abutment/floating weir and smaller fishwheel deployed on Aug. 19.

Raising the baskets and attaching the axle to the tower assembly.

Large fishwheel fully repaired and launched at 1 pm on Aug. 21.