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A Fishwheel-ARIS Study to Compare Species Proportions Derived from an ARIS Length-based Approach with those Derived from Fishwheel Catches

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EXECUTIVE SUMMARY

We operate an ARIS sonar system adjacent to the fishwheels deployed at the Crescent Island (Silverhope) site during August 2017 to compare estimates of species proportions derived from the ARIS length-based approach and those derived from the fishwheel catches. The study had two main components: (1) the comparison of the estimated proportions of Sockeye salmon (*Oncorhynchus nerka*) and Pink salmon (*O. gorbuscha*) by the ARIS length-based approach versus fishwheel operations (2) quantification of differences in the estimated proportions of fish approaching the fishwheels during daylight and night-time hours. Our experimental approach gathered data and focused 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 was further stratified for daytime and nighttime migrations. Fork lengths of all (or a representative subset) Sockeye and Pink salmon captured by the fishwheel were combined with lengths of a subset of fish measured from ARIS images recorded separately over each of the above periods. Species proportions of Sockeye and Pink salmon (and other species) were calculated from the total catches in the fishwheels during each period. These estimates were compared to mixture model estimate of proportions derived from the fishwheel and ARIS length measurements. Differences in the species proportions among methods could suggest bias or imprecision in fish length measurements from the ARIS images. The length distributions of Sockeye, Pink, Chinook (*O. tshawytscha*) salmon and resident fish caught in either the fishwheel or in the Whonnock variable mesh gillnet were used as standards for comparison with length distributions from in-season samples to derive estimates of species proportions from the mixture model. The follow points summarize our findings:

- During night time periods from 19 to 26 August when species composition transitions from Sockeye-dominant to Pink-dominant, the predictions of the mixture model were consistent with fishwheel catch proportions.
- Once Pink salmon dominate the species composition later in August, the mixture model is subject to more variation and predicts lower Pink proportions than observed in the fishwheel catches.
- The above findings are consistent with comparisons in previous Pink years (2013, 2015) between a mixture model based on DIDSON length measurements at the Mission site and fishwheel catch proportions (English et al. 2016).
- There were significant differences in the mixture model predictions of Pink proportions during day time sampling periods compared to night time, with generally higher predicted Pink proportions during day time periods.
- The diurnal differences shown in this experiment suggest that dividing the species composition estimates into a finer temporal resolution could improve the accuracy of estimates of species proportions.

TABLE OF CONTENTS

EXECUTIVE SUMMARY i
LIST OF TABLES iii
LIST OF FIGURES iv
INTRODUCTION 1
MATERIALS AND METHODS 2
Study Area 2
Study Design 2
Fishwheel Deployment and Operation 3
Fishwheel Species Composition 4
ARIS Length-Based Species Proportions 4
RESULTS 5
Comparison of Species Composition Estimates 5
DISCUSSION 6
Day-Night Differences in Species Composition 6
CONCLUSIONS 8
ACKNOWLEDGMENTS 10
LITERATURE CITED 11

LIST OF TABLES

Table 1. Daily catch in the large and small fishwheels operated on the lower Fraser River near Crescent Island from 11 to 31 August 2017..13

LIST OF FIGURES

Figure 1. Schematic of the Crescent site showing the location of the log boom assembly, steel pilings, fishwheels, and floating shoreline abutment, 2009................14
Figure 2. Fishwheel and sonar setup in 2017. 15
Figure 3. ARIS screen image showing the location of the fishwheel basket between the 15 and 19 meter marks on the right side of the image. 16
Figure 4. Fishwheel catch by species from 11 to 30 August 2017..17
Figure 5. Proportions of Pink salmon in fishwheel catch (blue line) and estimated by a mixture model based on ARIS fish length measurements (orange line) during primarily night time (top panel) and day time sampling periods (bottom panel)..18

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 2015 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). In 2013 and 2015, fish length data derived from DIDSON images was used in a mixture-model discrimination analysis to derive species composition estimates for the near-shore strata monitored by the DIDSON 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 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, both species should be equally vulnerable to being observed in the image, but the measurement of lengths from DIDSON 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 length-based approach have tended to be higher than those derived from the fishwheel samples. The need for improved comparisons and to better understand the potential causes of the discrepancies between DIDSON and fishwheel based species proportions led to the development of this project.

We use the term DIDSON above, but 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 August 2017 to compare the species proportion estimates derived from the two methods. During the first year of fishwheel operations at the Crescent Island site, a DIDSON sonar unit was used to assess the behavior of fish approaching the fishwheels during daylight and night-time hours (Smith et al. 2009). These assessments showed clear fishwheel avoidance behavior during daylight hours but no sign of avoidance during night-time hours. However, the data reported in the 2009 report was conducted in 2008 when there was no migration of Fraser River Pink salmon. Based on the 2008 study, we would expect to see larger differences in these species composition estimates during daylight hours, but the differences should be negligible or small during night-time hours. Therefore, one of the goals of this study was to test for difference in the species composition estimate derived from the ARIS length-based approach and those derived from the fishwheel catches during daylight hours and during night-time hours. The coincident operation of fishwheels and the ARIS sonar also provided information on behavioral differences between species (differences observed during periods of predominantly Sockeye and Pink migration). The study has quantified discrepancies between estimates of species proportions obtained from the two methods and helped elucidate potential causal mechanisms.

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 operate an ARIS sonar system adjacent to the fishwheels deployed at the Crescent Island (Silverhope) site during August 2017 to compare estimates of species proportions derived from the ARIS length-based approach and those derived from the fishwheel catches. As noted above, the study had two 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). Our experimental approach gathered 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 further stratified for daytime and nighttime migrations. Fork lengths of all (or a representative subset) Sockeye and Pink salmon captured by the fishwheel were combined with lengths of subset of fish taken from ARIS images recorded separately over each of the above periods. Species proportions of Sockeye and Pink salmon (and other species) were calculated from the total catches in the fishwheels during each period. These estimates were compared to mixture model estimate of proportions derived from the fishwheel and ARIS length measurements. Length based estimates of species proportions are derived from two types of samples: (1) "standards" or length distributions of fish for each species that could be present in an in-season sample (i.e., Sockeye, Pink, and Chinook) and (2) "mixtures" or a distribution of lengths from an in-season sample where the species proportions are unknown. Standards were derived from a combination of catches in prior periods when typically only one species was present in the catch. The lengths of fish caught either in the fishwheels or in the Whonnock variable mesh gillnet were used as standards. 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. The fishwheel operations period in 2017 was from 11 to 30 August. The deployment was similar to the configuration used in 2009-2015 including: the 2009-2015 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. The availability of all of these components 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 will visit 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 and an opportunity to refuel the generator for overnight operation. The second visit typically ended around 17:00 but occasionally was as late as midnight during a period when we were attempting to actively sample fish as they were being caught.

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). 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 Species Composition

Every fish caught in each fishwheel was counted and identified to species. For salmon, species composition was calculated twice each day (for daytime and nighttime catches) and for each fishwheel. Species composition was expressed as the percentage of each salmon species comprising the total catch of adult salmon (based upon the number of individuals caught).

ARIS Length-Based Species Proportions

An ARIS 1200 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 16 to 30 August, the ARIS collected data continuously over a range of 10 to 20 metres from the transducer. The operating frequency was 1,200 kHz using 48 acoustic beams and approximately 1,000 samples per beam. Figure 3 provides an ARIS screen image showing the location of the fishwheel basket on the right side of the image.

A sub-sample of fish lengths were measured from every hour of ARIS data for estimating salmon species composition. 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. Measurements were taken for the first twenty good quality fish images observed during the ten-minute period at the beginning of each hour. If fewer than twenty fish were observed then only those fish seen were measured, leading to fewer length samples during time periods of lower fish passage.

Length measurements for each hour were combined over the same twice-daily sampling periods as fishwheel catch and 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). We assumed 5 species groups for fitting normal distributions of the mixture model: a small fish group representing non-salmonid species, a Chinook jack salmon group, a Pink group, a Sockeye group, and a Chinook adult group. For model fitting, the mean length and standard deviation of the four salmonid distributions were held fixed and input as model parameters based on length measurements in the standards derived from the catches in the Whonnock gillnet test fishery and the fishwheel. The mean lengths for model fitting were updated on 22 August to reflect changes in the mean length measurements of Whonnock catch. Small resident fish are also routinely observed and counted in DIDSON images, including those recorded at the Mission site. Because there is minimal overlap between the sizes of the small resident fish and the sizes of Sockeye, Pink, or other salmon species (e.g., jack Chinook), their proportions were estimated by fitting a distribution to the observed length data in the mixture. The estimation of the proportion of these small-sized fish is not considered a source of bias in the mixture model estimates of salmon proportions.

Mixture model predictions of species proportions were estimated for each twice-daily sampling period for comparison to the fishwheel species catch proportions. The day and night time sampling periods were separated for comparison in response to potential differences in catchability and fish abundance between night and day time. The day time period generally spanned from 10:00 to 17:00, while the night time period went from 17:00 to 10:00 the next day. Thus, the night time period included some daylight hours including twilight periods. The ARIS sampling coverage during night time periods did not generally include 05:00 to 10:00 from the next morning due to the need to refuel and restart the generator used to power the unit.

RESULTS

The fishwheels were operated continuously from 11 to 30 August 2017 except for short intervals when they were stopped for routine maintenance and repairs. The large fishwheel was operated for 490 hours and caught 394 adult Sockeye, 2 jack Sockeye, 24 adult Chinook, 285 jack Chinook, 402 Pink salmon, 4 Coho (*O. kisutch*) and 2 sturgeon (Table 1). The small fishwheel was operated for 442 hours but caught very few fish relative to the large fishwheel (36 Sockeye, 22 jack Chinook and 26 Pink salmon). Figure 4 provides a graph showing the composition of the daily fishwheel catches of salmon.

Comparison of Species Composition Estimates

Predictions of Pink salmon proportions from the mixture model using ARIS length measurements followed similar trends to fishwheel Pink salmon catch proportions during night time periods from 19 to 25 August, but not from 26 to 30 August or during any of the day time periods (Figure 5). During the night time sampling periods, proportions of Pink salmon in fishwheel catch were very low (less than 10 percent) for the first week, but proportions increased rapidly starting on 23 August, reaching a maximum proportion of 100 percent on 26 August. Mixture model Pink proportions followed a similar trend during this period, increasing from 0 percent on 19 and 20 August to a maximum of 97 percent on 25 August. From 26 to 29 August, the mixture model predictions of Pink proportions decreased and were lower than the fishwheel Pink catch proportions by up to 60 percent.

During most day time periods, the Pink proportions predicted by the mixture model did not correspond to proportions caught by the fishwheel, however, fishwheel catches during these time periods were generally very low (mean = 5.1), and on several days fewer than 2 salmon were caught. Mixture model predictions of Pink proportions were generally higher during the day time periods than during the night time periods, especially from 19 to 25 August when day time proportions averaged 74 percent while night time proportions averaged 33 percent (Figure 5).

DISCUSSION

Day-Night Differences in Species Composition

During night time periods from 19 to 26 August when species composition transitions from Sockeye-dominant to Pink-dominant, the predictions of the mixture model were consistent with fishwheel catch proportions. Over the course of this week, both methods predict Pink proportions increasing from less than 10% to over 80%. The correspondence between the two methods suggests that they are both accurately predicting the transition from a Sockeye-dominated salmon migration to a Pink-dominated migration.

Once Pink salmon dominate the species composition later in August, the mixture model is subject to more variation and predicts lower Pink proportions than fishwheel catch. These findings are consistent with comparisons in previous Pink years (2013, 2015) between a mixture model based on DIDSON length measurements at the Mission site and fishwheel catch proportions (English et al. 2016). Once Pink salmon dominate the species composition, the PSC no longer uses the mixture model for estimating species composition of Mission passage; instead, Sockeye abundance is estimated based on CPUE at the Whonnock test fishery, and virtually all the remaining salmon passage is assumed to be Pink salmon except for small amounts of Chinook salmon (less than 1%). In 2017, the CPUE-based method was applied for species composition estimates instead of the mixture model starting on 25 August, around the same time that the mixture model and fishwheel estimates from this experiment start to diverge.

There were significant differences in the mixture model predictions of Pink proportions during day time sampling periods compared to night time, with generally higher predicted Pink proportions during day time periods. Fishwheel catches were generally very low during the day time fishing periods in 2017. Though the number of fish observed in ARIS images was larger than caught in the fishwheels during the day, the pattern of diel migration observed in the ARIS images in 2017 varies with the tidal cycle, with peaks in each days migration associated with the rising phase of the tide.

The mixture model predictions of species composition applied to Mission passage are typically generated over a 24-hour period, however, the diurnal differences shown in this experiment suggest that dividing the species composition estimates into a finer temporal resolution could improve the accuracy of estimates of species proportions. The distribution of lengths of Sockeye and Pink salmon were very similar in 2017 with Sockeye being smaller and Pink salmon larger than historical averages (2017 mean lengths from fishwheel catch – Sockeye 55.6 cm, Pink salmon 54.2 cm). We expected this overlap in length distribution to increase uncertainty in the mixture model estimates of species proportions. The favorable comparisons of fishwheel catch and mixture model species portions during the period of transition from Sockeye dominant to Pink dominant migration, provide some validation that the mixture model is capable of generating defensible estimates of species proportions even when length distributions are highly overlapped.

Previous Fishwheel Operations and Cost Estimates

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, and 2015, 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 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.

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. Regular maintenance and a reliable off channel storage site have ensured that both fishwheels and the shoreline abutment are in working order and readily available for deployment at the Crescent Island site.

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 would 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 this 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 could affect the estimates of either method in other years.

CONCLUSIONS

- During night time periods from 19 to 26 August when species composition transitions from Sockeye-dominant to Pink-dominant, the predictions of the mixture model were consistent with fishwheel catch proportions.
- Once Pink salmon dominate the species composition later in August, the mixture model is subject to more variation and predicts lower Pink proportions than fishwheel catch.
- These findings are consistent with comparisons in previous Pink years (2013, 2015) between a mixture model based on DIDSON length measurements at the Mission site and fishwheel catch proportions (English et al. 2016).
- There were significant differences in the mixture model predictions of Pink proportions during day time sampling periods compared to night time, with generally higher predicted Pink proportions during day time periods.
- Differences between the daytime and nighttime species composition provide an important potential explanation for the discrepancies between ARIS length-base species composition and those derived from fishwheel data. Sources of discrepancies between estimates derived from the two methods are likely related their relative weaknesses. Estimates of species proportions derived from the fishwheel catches are subject to potential differences in the relative catchability of Sockeye and Pink salmon between

periods whereas estimate of species proportions derived from the mixture model are subject to variation associated with overlapping length distributions.

- The diurnal differences shown in this experiment suggest that dividing the species composition estimates into a finer temporal resolution than every 24 hours could improve the accuracy of estimates of species proportions using the ARIS length-based method.
- 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 costs of processing the DIDSON 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 of several range strata on both banks.

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Table 1. Daily catch in the large and small fishwheels operated on the lower Fraser River near Crescent Island from 11 to 31 August 2017.

Capture Method	Date	Rotation Speed (RPM)	Hours Operating	SockeyeAdultCaught	SockeyeJackCaught	ChinookAdultCaught	ChinookJackCaught	PinkAdultCaught	CohoAdultCaught	CohoJackCaught	SteelheadAdultCaught	ChumAdultCaught	SturgeonCaught	SturgeonPITTagApplied	Pikeminnow
Large Fishwheel	2017-08-11	1.0	26.6	36	0	0	2	11	0	0	0	0	0	0	0
	2017-08-12	0.8	17.3	9	0	0	6	1	0	0	0	0	0	0	1
	2017-08-13	0.9	31.3	23	0	1	24	2	0	0	0	0	0	0	2
	2017-08-14	0.6	18.5	20	0	0	29	3	0	0	0	0	0	0	3
	2017-08-15	0.8	27.1	26	0	2	28	2	0	0	1	0	0	0	0
	2017-08-16	0.9	21.5	30	2	2	24	4	0	0	0	0	0	0	3
	2017-08-17	0.6	18.4	21	0	0	16	2	0	0	0	0	0	0	9
	2017-08-18	0.7	23.4	38	0	1	30	2	0	0	0	0	0	0	3
	2017-08-19	0.9	27.6	14	0	0	15	1	0	0	0	0	0	0	3
	2017-08-20	0.8	24.9	4	0	1	8	0	0	0	0	0	0	0	4
	2017-08-21	0.6	20.8	32	0	0	9	0	0	0	0	0	1	0	3
	2017-08-22	0.6	25.1	60	0	1	13	4	0	0	0	0	0	0	9
	2017-08-23	0.5	22.4	26	0	5	12	3	0	0	0	0	0	0	4
	2017-08-24	0.8	24.5	27	0	6	25	11	2	0	0	0	0	0	7
	2017-08-25	0.7	23.2	15	0	1	12	7	0	0	0	0	0	0	2
	2017-08-26	0.2	25.0	5	0	1	7	31	1	0	1	0	0	0	1
	2017-08-27	0.7	23.8	0	0	0	7	45	1	0	0	0	0	0	2
	2017-08-28	0.6	26.4	2	0	0	5	88	0	0	0	0	1	1	4
	2017-08-29	0.8	22.9	1	0	0	3	87	0	0	0	0	0	0	3
	2017-08-30	0.7	30.2	2	0	0	2	90	0	0	0	0	0	0	4
	2017-08-31	0.6	9.6	3	0	3	8	8	0	0	0	0	0	0	2
Large FW Total			**490**	**394**	**2**	**24**	**285**	**402**	**4**	**0**	**2**	**0**	**2**	**1**	**69**
Small Fishwheel	2017-08-13	0.7	25.3	1	0	0	1	0	0	0	0	0	0	0	0
	2017-08-14	0.7	19.2	2	0	0	4	0	0	0	0	0	0	0	1
	2017-08-15	0.8	27.1	2	0	0	2	0	0	0	0	0	0	0	0
	2017-08-16	1.0	21.2	2	0	0	1	1	0	0	0	0	0	0	1
	2017-08-17	0.9	18.4	1	0	0	0	0	0	0	0	0	0	0	4
	2017-08-18	0.9	23.5	9	0	0	2	0	0	0	0	0	0	0	1
	2017-08-19	1.1	27.6	1	0	0	1	0	0	0	0	0	0	0	2
	2017-08-20	1.1	25.3	1	0	0	2	0	0	0	0	0	0	0	1
	2017-08-21	0.9	20.8	1	0	0	1	0	0	0	0	0	0	0	0
	2017-08-22	0.4	25.2	4	0	0	2	1	0	0	0	0	0	0	2
	2017-08-23	0.8	22.4	1	0	0	0	0	0	0	0	0	0	0	0
	2017-08-24	0.9	24.5	5	0	0	1	0	0	0	0	0	0	0	3
	2017-08-25	0.9	23.2	2	0	0	4	1	0	0	0	0	0	0	1
	2017-08-26	0.6	25.0	0	0	0	0	2	0	0	0	0	0	0	2
	2017-08-27	0.6	23.4	0	0	0	0	6	0	0	0	0	0	0	3
	2017-08-28	0.4	26.6	1	0	0	0	6	0	0	0	0	0	0	2
	2017-08-29	1.0	22.7	1	0	0	0	4	0	0	0	0	0	0	0
	2017-08-30	0.9	15.0	1	0	0	0	3	0	0	0	0	0	0	0
	2017-08-31	0.9	25.5	1	0	0	1	2	0	0	0	0	0	0	2
Small FW Total			**442**	**36**	**0**	**0**	**22**	**26**	**0**	**0**	**0**	**0**	**0**	**0**	**25**
FW Large+Small Total			**932**	**430**	**2**	**24**	**307**	**428**	**4**	**0**	**2**	**0**	**2**	**1**	**94**

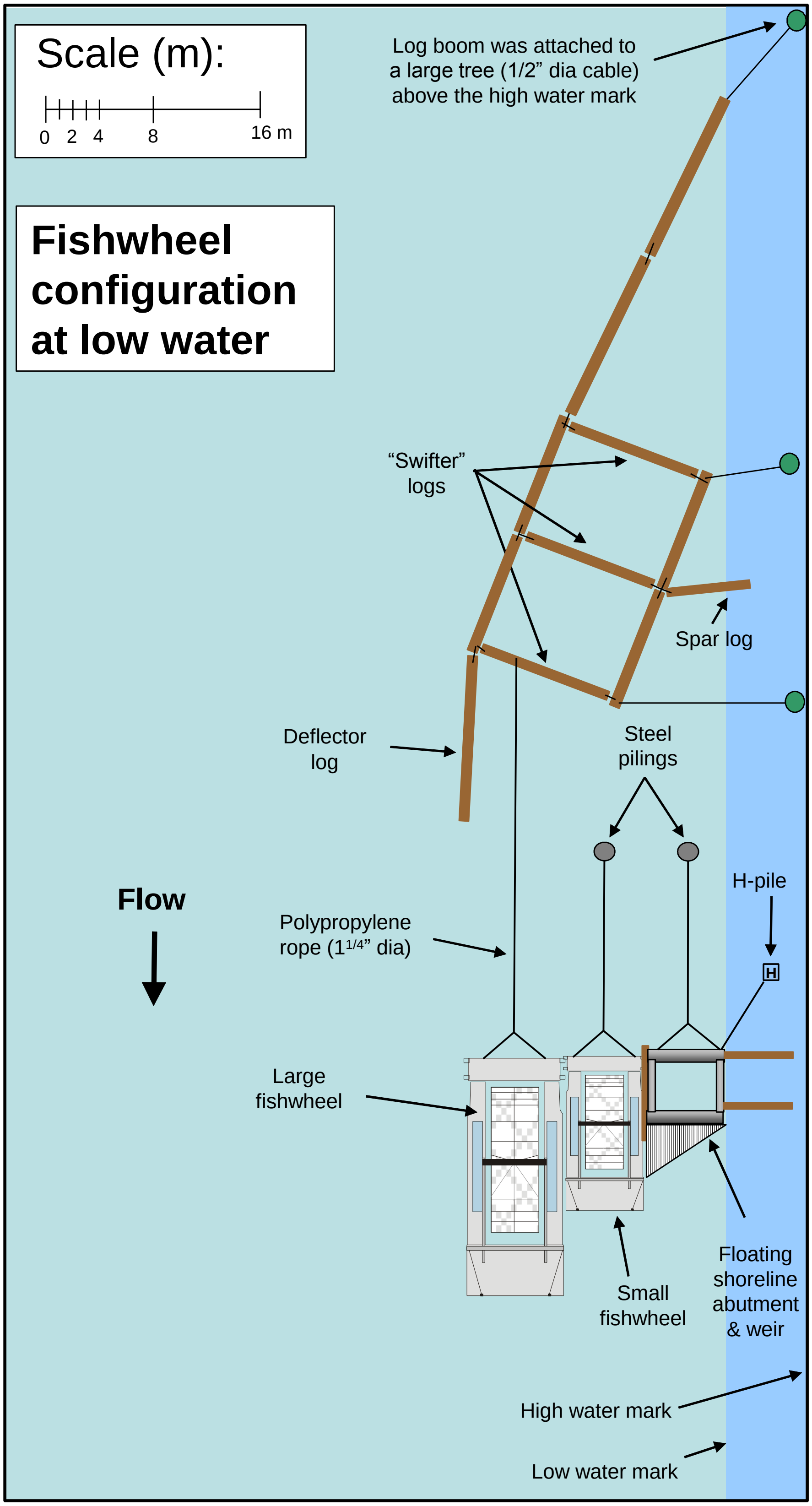

Figure 1. Schematic of the Crescent site showing the location of the log boom assembly, steel pilings, fishwheels, and floating shoreline abutment, 2009.

Figure 2. Fishwheel and sonar setup in 2017. Sonar on ladder mount near shore, small fishwheel on inside and large fishwheel on outside.

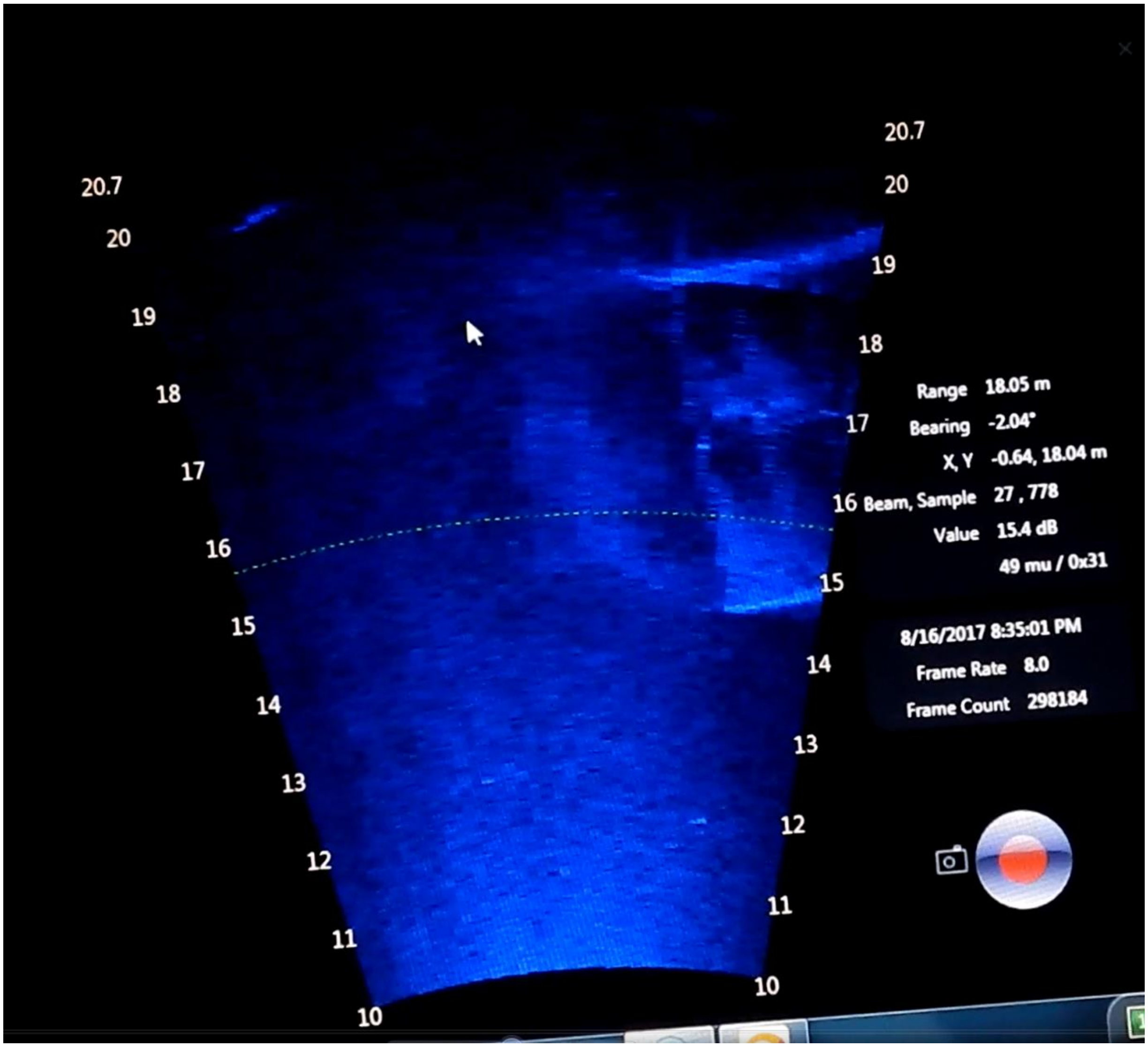

Figure 3. ARIS screen image showing the location of the fishwheel basket between the 15 and 19 meter marks on the right side of the image. A salmon is visible on the left side of the image near the 20 meter mark.

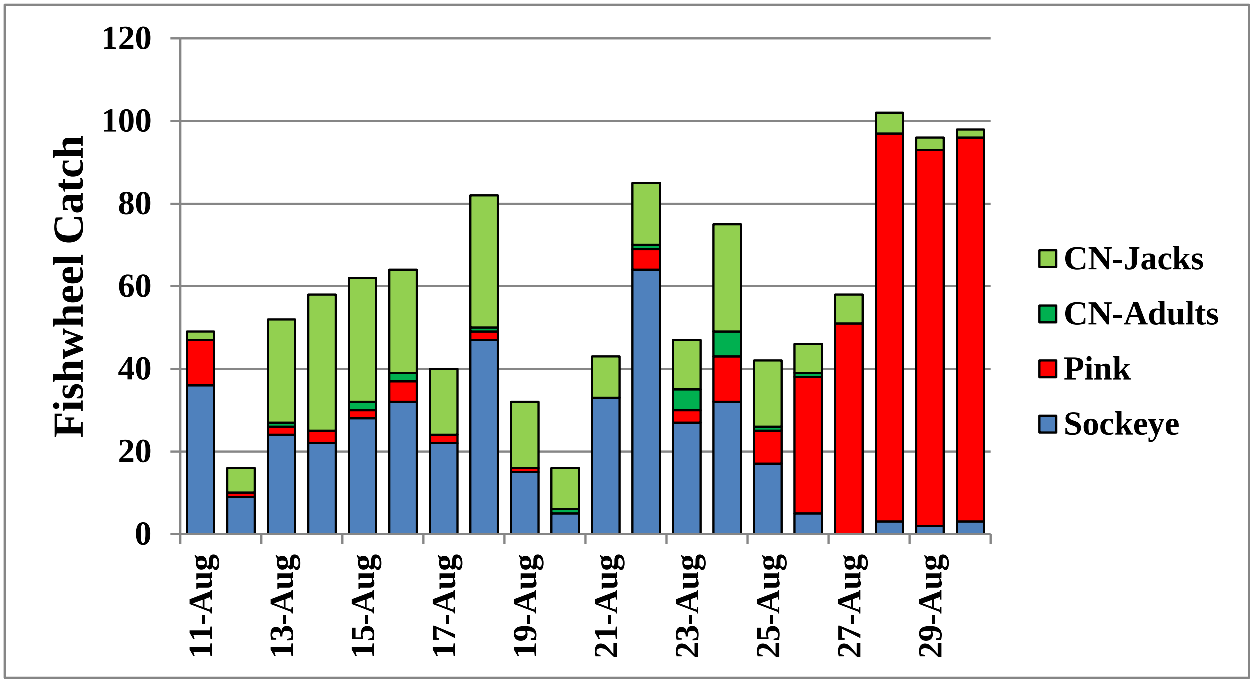

Figure 4. Fishwheel catch by species from 11 to 30 August 2017.

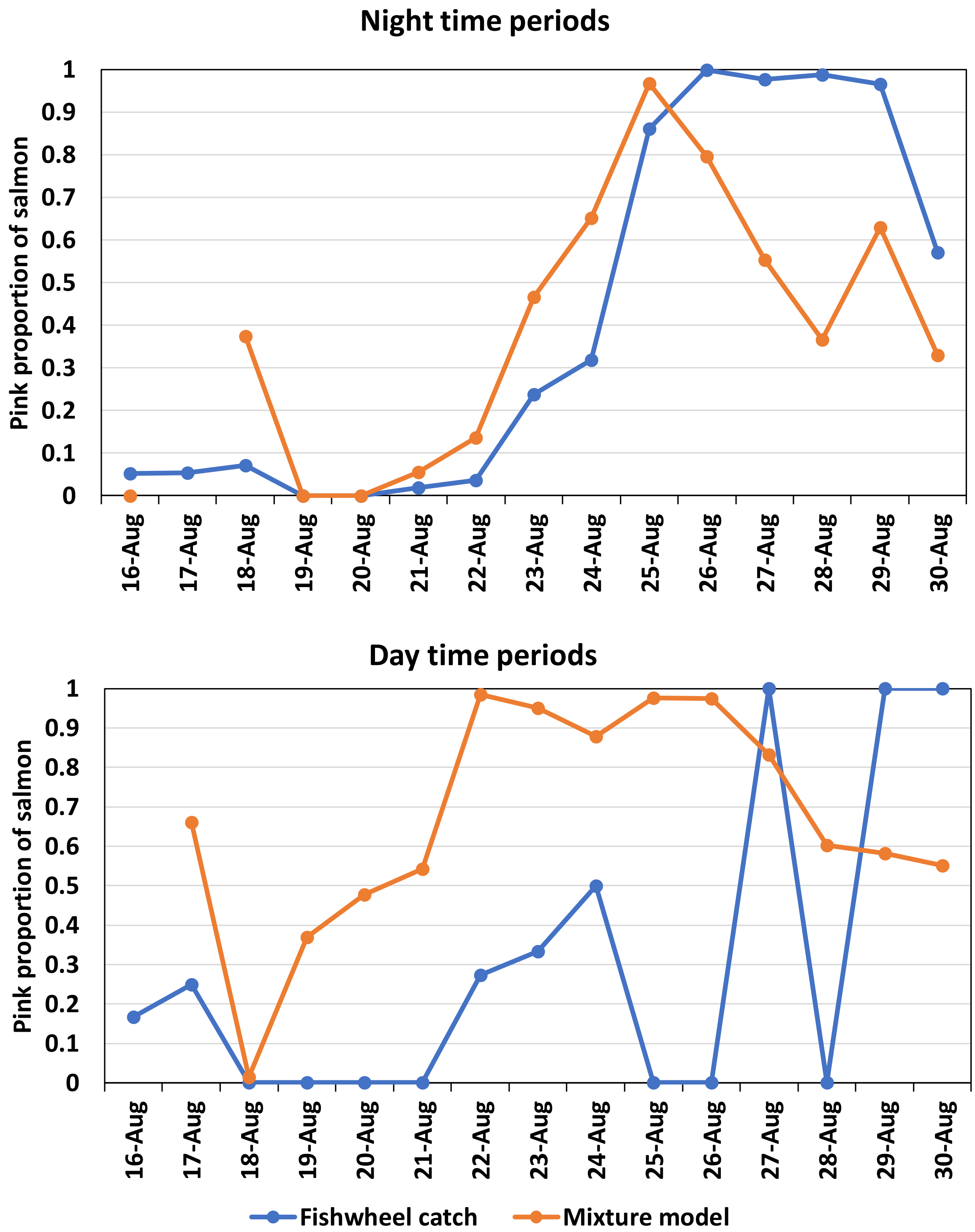

Figure 5. Proportions of Pink salmon in fishwheel catch (blue line) and estimated by a mixture model based on ARIS fish length measurements (orange line) during primarily night time (top panel) and day time sampling periods (bottom panel). The proportion of Pink salmon in fishwheel catch is calculated from total catches of Pink, Sockeye, and adult Chinook salmon for each sampling period.