Bridge River Project Water Use Plan

Seton Sockeye Salmon Smolts Monitoring Program

Implementation Year 7

Reference: BRGMON-13

Study Period: April to June 2019

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Bridge-Seton Water Use Plan

Implementation Year 7 (2019):

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EXECUTIVE SUMMARY

The objective of BRGMON-13 is to assess whether operational changes at the Seton Generating Station (the 'powerhouse') are affective at minimizing entrainment mortality of Sockeye salmon smolts out-migrating from Seton Lake. BC Hydro implements nightly shutdowns of the powerhouse (20:00 h to 02:00 h) between April 20 and May 20 to mitigate smolt entrainment. In 2019, a rotary screw trap (RST) was operated downstream of Seton Dam and marked fish were released in two locations: above the RST downstream of Seton Dam to estimate the Seton River smolt population size, and in the Seton Dam forebay to estimate the proportion of fish entrained through the powerhouse. Seasonal and daily run-timing were also estimated to refine shutdown timing. In 2019, over 10,000 Sockeye smolts were marked and released, representing the largest sample size to date.

BRGMON-13 addresses three management questions:

MQ1: What proportion of total Sockeye outmigrants from Seton Lake will pass through Seton Dam when the powerhouse is shut down each night between April 20th and May 20th?

MQ1 has three hypotheses. H_{1A} suggests 80% of the population will be diverted through Seton Dam during the nightly shutdown (02:00 h to 02:00 h) between April 20 and May 20. Raw capture data were used to estimate seasonal, daily, and hourly migration timings as a percentage of daily catch, and routing proportion was used to determine entrainment and diversion proportions. The percentage of fish diverted into the Seton River during nightly shutdowns between April 20 and May 20 met the target of 80% in all but four years (2008, 2013, 2015, 2018), and H_{1A} cannot be rejected.

H_{2A} and H_{3A} examine nightly and seasonal migration timings. H_{2A} suggests 90% of fish migrate between April 20 and May 20. In eight years, over 90% of smolts have been captured between April 20 and May 20, providing support for this hypothesis and suggesting the seasonal window adequately reflects migration timing. H_{3A} suggests 90% of fish migrate between 20:00 and 02:00, which has not been observed in any monitoring years, suggesting the nightly shutdown may need to be extended past 02:00 to increase fish protection.

MQ2: How is this proportion affected by the total release [of water from Seton Dam and the configuration of dam discharge facility used to release water?

The current marking program precludes the ability to answer MQ2. It cannot be determined if dam discharge or release configuration affects the proportion of fish passing through Seton Dam because only a single average capture efficiency can be calculated for each year. To answer this question, we recommend a stratified marking program and a telemetry study to associate recaptures and migration behaviours with different operational conditions. Radio telemetry would allow for high-resolution tracking of fish movements in the Seton Dam forebay, over the dam, or through the powerhouse under different operational and physical conditions.

MQ3: Are there refinements to the seasonal timing of powerhouse shutdowns to improve fish protection efficiency or reduce lost power generation opportunities?

Mean hourly catch data indicated that extending the nightly shutdown by two extra hours (i.e., to 04:00 h) during the April 20 to May 20 window would increase protective benefits to Sockeye

Salmon smolts. Catch data did not show strong support for increasing the seasonal extent of shutdowns; however, migration timing conclusions use raw catch data, which may not be accurate due to the assumption of equal capture efficiency. Capture efficiency varies with discharge and it is unlikely capture efficiency is consistent throughout the capture period due to changes in discharge. Considering these limitations, estimates of smolt migration timing have substantial uncertainty. A stratified population estimate using passive integrated responder (PIT) tags is recommended to improve run-timing estimates and accurately evaluate the percent of smolts migrating during the seasonal shutdown window.

Smolt Entrainment and Mortality

The proportion of smolts migrating through Seton Dam and the powerhouse was used to estimate entrainment rate and annual smolt mortality to determine whether BC Hydro is meeting its Sockeye smolt mortality target of 5%. Fish migrating through the powerhouse have an assumed mortality of 17% (Groves and Higgins 1995), while fish migrating though the various conveyance structures in the dam have an assumed mortality of 2%. According to these assumptions, to meet the 5% mortality target, 80% of fish must be routed though Seton Dam.

Among years when the powerhouse was operational during the smolt migration period, smolt mortality ranged from 3% in 2012 to 14% in 2008. Mortality in 2019 was estimated to be 2% and mostly attributed to dam-related mortality because the powerhouse was shut down for most of the migration period (April 20 to May 17). Mortality exceeded the management target of 5% in four out of eight years (2008, 2013, 2015, 2018); however, the methods used to estimate mortality do not account for variations in capture efficiency, variability in routing proportion, or mortality and residualization of marked fish above the dam. A more robust tagging method and mark-recapture modelling are required to resolve these uncertainties.

Next Steps

In addition to telemetry and improved run-timing estimates, further assessment of the relative timing of smolt migration between the Gates Creek and Portage Creek sockeye populations is warranted. Previous research suggests the Portage Creek population may migrate later than the Gates Creek population and there may be disproportionate dam-related effects to the Gates Creek population if the seasonal timing of the shutdowns is not matched to their peak in migration.

Overall, the current study design of BRGMON-13 has not been sufficient to answer the management questions. A positive step forward for this monitoring program would include a power analysis to determine appropriate stratification of the mark-recapture program to achieve the required level of certainty in abundance and run-timing estimates to answer the management questions. The addition of a telemetry component to assess mortality and behavioral responses to operations would also help to assess the effects of operations of the Seton Powerhouse on Sockeye smolt entrainment.

Status of Objectives, Management Questions and Hypotheses after Year 13 (2019)

Study Objectives	Management Questions	Management Hypotheses	Management Question Status 2006 - 2019
1.0 to assess the effectiveness of powerhouse shutdown to reduce total mortality of Sockeye salmon smolts leaving Seton Lake. 2.1 to collect data on the relative abundance, timing and biological characteristics of Sockeye salmon smolts leaving Seton Lake, 2.2 to assess the effect of powerhouse shutdown and dam release on fish attraction flows and fish bypass conditions at Seton Dam,	1. What proportion of total Sockeye outmigrants from Seton Lake will pass through Seton Dam when the powerhouse is shutdown each night (2000 – 0200) between April 20 and May 20?	H_{1A}: Nightly powerhouse shutdowns (accompanied by >25 m^3s^{-1} dam release) conducted 2000 to 0200 between April 20 and May 20 will result in >80% of Sockeye smolts being diverted to Seton River from Seton Lake. $H_{2A:}$ More than 90% of the smolts leave Seton Lake between April 20 and May 20. H_{3A}: More than 90% of the smolts leave Seton Lake between the hours of 2000 h and 0200 h.	In 2019, an estimated 2% of out-migrating Sockeye smolts were entrained through the powerhouse. The total Sockeye population estimate from April 1 to June 29, 2019 was 798,300 and 80% of migration from Seton Lake occurred between April 20 and May 20, 2019. Due to the batch marking methods selected for this monitor, only catch data can be used to estimate the proportion of smolts during the nightly and seasonal shutdown. The estimated percentage of fish migrating between April 20 and May 20 is greater than 90% eight out of 13 years (range 62%-98%). In 2019, 80% of fish were estimated to have migrated during the shutdown window between April 20 and May 20. Over the entire season less than 90% of fish have been captured between 20:00 and 02:00 in all study years, suggesting the shutdown nightly hours are not adequately timed to cover 90% of the migration. While catch data indicate the seasonal timing of the shutdown is adequate to protect 90% or more of smolts there are issues with using catch data as trap catch is affected by discharge. Therefore, seasonal migration timing may not be adequately represented by trap catch.

2.3 to assess the relationship between dam release and the proportion of fish entering the Dam approach channel and passing the dam into Seton River.	2. How is the proportion of Sockeye outmigrants leaving during shutdowns affected by total release from the Seton Dam and the configuration of dam discharge facilities used to release water?	--	It is not possible to answer this question or even provide anecdotal inferences using the current study design. Telemetry and stratified marking regimes are needed to answer this question.
2.4 to better understand the migration of other salmon species, all species captured during sampling will be enumerated.	3. Are there refinements to the seasonal timing or daily timing of powerhouse shutdowns to improve fish protection efficiency or reducing lost power generation opportunities?	--	Hourly average catch across all years indicates that the hours of 03:00 and 04:00 have similar catch rates to 20:00 and 21:00 (~10% per hour). Therefore, if additional protective measures are required for Sockeye smolts, extending the nightly shutdown by two more hours will likely offer greater benefits than extending the shutdown over a greater number of days. For example, catch data suggests that extending the shutdown to 04:00 each night between April 20 and May 20 could potentially protect 20% more fish each year. In all but 2 years (2008 and 2012) this likely would have resulted in the target of 80% of fish being routed through Seton Dam.

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1.0 INTRODUCTION

The Seton-Anderson watershed is part of the traditional territory of the St'át'imc Nation. Sockeye Salmon (*Oncorhynchus nerka*) are the largest population of Pacific salmon in the watershed, but the watershed also supports Pink Salmon (*O. gorbuscha*), Coho Salmon (*O. kisutch*), Chinook Salmon (*O. tshawytscha*), Rainbow and Steelhead Trout (*O. mykiss*), Gwenish (lake spawning Black Kokanee, *O. nerka*) and Bull Trout (*Salvelinus confluentus*). Sockeye Salmon and other salmonids are important as food, social and ceremonial resources for the St'át'imc people.

Sockeye Salmon in the Seton-Anderson watershed originate from two spawning areas: Gates Creek and Portage Creek. Gates Creek Sockeye are part of the early summer Sockeye run-timing group, which enter the Fraser River in early July and arrive at spawning grounds in mid-August. The Portage Creek population is a late migrating stock, entering the Fraser River in late September and spawning in Portage Creek in mid-November (Patterson et al., 2007).

The Seton hydroelectric facility, consisting of the Seton Dam, power canal and the Seton Generating Station (the 'powerhouse') was constructed in 1956 as part of the Bridge-Seton hydroelectric facility (Figure 1). Sockeye Salmon migrate through the dam when returning to spawn (Roscoe et al. 2011; Burnett et al. 2014) and during smolt out-migration from Seton and Anderson Lakes. Mitigating the effects of the hydro facility on salmon migration is a consideration of BC Hydro operations.

Smolt mortality resulting from the Seton Dam hydroelectric facility operations has been estimated for both the powerhouse and dam conveyance structures. The greatest source of mortality for out-migrating Sockeye smolts is entrainment through the powerhouse, most likely as a result of rapid changes in pressure (Ruggles and Murray 1983). A mortality rate of 17% was estimated during a previous study conducted at the powerhouse (Andrew and Green 1958). This estimate includes direct mortality and latent mortality from injuries, cumulative stress, disease and predation. For passage through the Seton Dam fish ladder, fish water release gate (FWRG) or siphons, mortality was estimated to range from 2-7%, depending on the configuration of the FWRG (Andrew and Green 1958). During the smolt migration period, the FWRG is in the "down" position, reducing estimated dam mortality to approximately 2%. Predation can be another substantial source of mortality for smolts, but accounting for predation or other natural mortality is beyond the scope of BRGMON-13.

The St’át’imc Settlement Agreement of 2011 stipulates a 5% entrainment mortality target for Sockeye smolts migrating from Seton Lake to the Fraser River. Louver lines, bubble curtains, screens, and a diversion canal have been proposed or attempted as methods to divert out-migrating smolts from the power canal, and powerhouse (Groves and Higgins 1995; BC Hydro 2011). However, technological methods of diverting smolts from the power canal have not been successful, and shutdowns of the powerhouse during peak smolt migration hours has been selected as the optimal operational measure (BC Hydro 2011).

Monitoring smolt entrainment through the powerhouse has been conducted since 2006. Until 2010 the program was operated to assess the migratory behaviour of Sockeye Salmon smolts for BC Hydro to develop operational strategies for reducing mortality. From 2011 to present, the program has been operated through the Bridge River Water Use Plan (WUP; BRGMON-13) to estimate the timing of smolt migrations, the proportion of fish entrained, and mortality rates during their seaward migration. As outlined in the Terms of Reference (TOR) for BRGMON-13 (BC Hydro 2011), the monitoring program is intended to refine the period and timing of powerhouse shutdowns used to route smolts down the Seton River based on estimated run-timing. An ancillary benefit of the monitoring program is annual population estimate of out-migrating smolts.

The BRGMON-13 Management Questions are:

1. What proportion of total Sockeye outmigrants from Seton Lake will pass through Seton Dam when the powerhouse is shutdown each night (20:00 h – 02:00 h) between April 20 and May 20?
2. How is this proportion affected by the total release from Seton Dam and the configuration of dam discharge facility used to release water?
3. Are there refinements to the seasonal timing or daily timing of powerhouse shutdowns to improve fish protection efficiency or reduce lost power generation opportunities?

The BRGMON-13 management hypotheses are:

H_{1A}) Nightly powerhouse shutdowns (accompanied by an >25 m^3s^{-1} dam release) conducted 20:00 h to 02:00 h between April 20 and May 20 will result in >80% of the Sockeye smolts being diverted to Seton River from Seton Lake.

H_{2A}) More than 90% of the smolts leave Seton Lake between April 20 and May 20.

H_{3A}) More than 90% of the smolts leave Seton Lake between 20:00 h and 02:00 h.

BRGMON-13 also estimates annual smolt mortality from both powerhouse entrainment and passage through Seton Dam. Combined annual smolt mortality estimates are compared to the 5% target outlined in the 2011 Settlement Agreement.

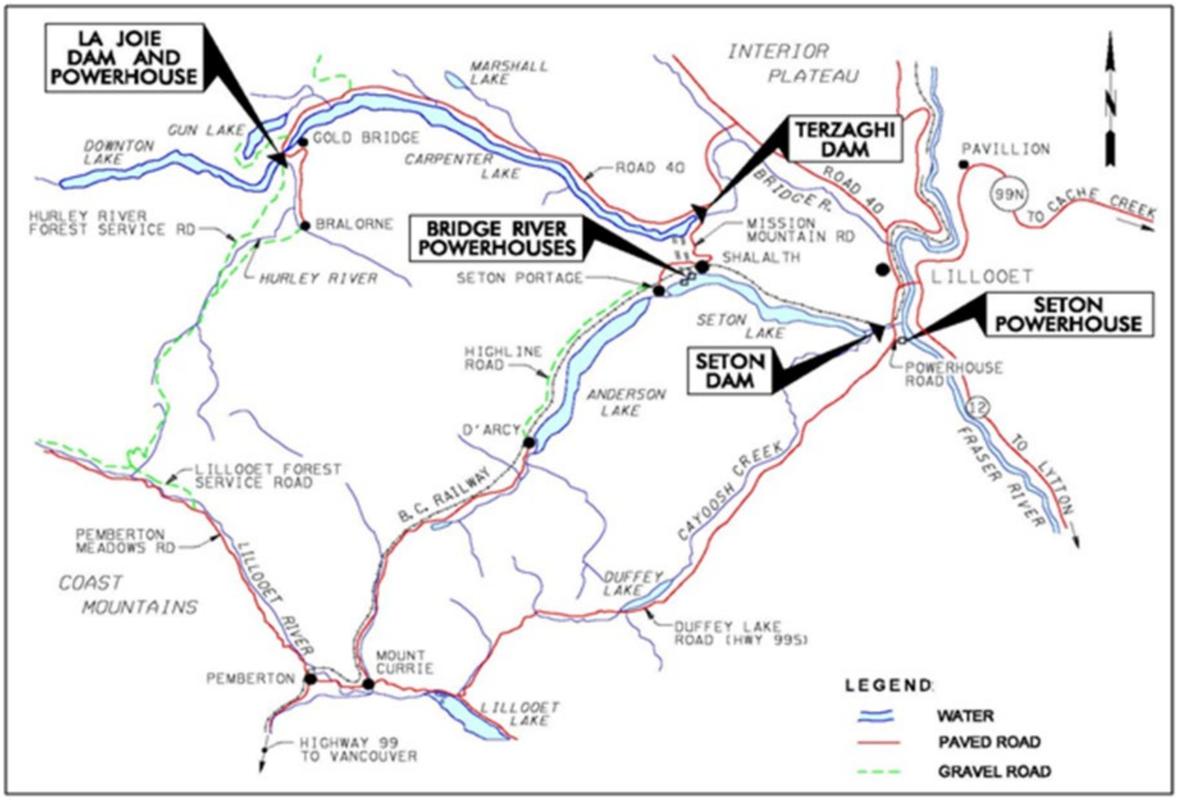

Figure 1. Location of BC Hydro facilities in the Bridge-Seton watersheds.

1.1 MONITORING PROGRAM

The monitoring program consists of a mark-recapture estimation program using releases of marked fish above and below Seton Dam. Below-dam releases estimate population size and above-dam releases determine the proportion of smolts traveling past Seton Dam during the shutdown period (MQ1). The monitoring program is also used to determine yearly run-timing and the daily migration timing of smolts to refine shutdown timing (MQ3). To answer MQ2, it was intended that Seton Dam discharge would be related to capture efficiency and routing proportions of smolts to determine if dam discharge could mitigate smolt mortality; however, the study design has not been structured adequately to answer this question.

As the most downstream facility within the larger Bridge-Seton system, the Seton hydroelectric facility is a hydraulic bottleneck, meaning that meeting the target hydrograph for Seton Dam is a lower priority than upstream water management. Beginning in 2016, discharges from Seton Dam have exceeded the WUP target hydrograph to manage reduced storage capacity in Downton Reservoir as a result of safety concerns with the upstream La Joie Dam. As a result of these modified operations, BC Hydro has increased releases into the Seton River since 2015 from the WUP target of 60 m^3s^{-1} to between 60 and 140 m^3s^{-1} during the Sockeye smolt migration. To account for higher discharges, a rotary screw trap (RST) replaced the previously used Incline Plane Trap (IPT) that was only safe for operation below discharges of 50 m^3s^{-1}. These modified operations are expected to occur for the foreseeable future.

The BRGMON-13 monitor has been overseen by several different entities (Table 1), and field methods and analytical approaches have varied. In 2018, Harrower et al. (2019) collated all previous data, highlighting inconsistencies and uncertainties in the dataset and study design. This report builds on Harrower et al. (2019) and has further modified the analytical approach to summarize information and identify limitations in the study design.

Table 1. Table of previous yearly monitoring reports prepared for the Sockeye smolt monitoring program and BRGMON-13.

Year	Authors	Report Title
2006	D.A. Levy, J. Sneep	Effectiveness of Seton Powerhouse shutdowns for reducing entrainment mortality of Sockeye Salmon smolts during 2006
2007	D.A. Levy, J. Sneep	Effectiveness of Seton Powerhouse shutdowns for reducing entrainment mortality of Sockeye Salmon smolts during 2007
2008	D.A. Levy, J. Sneep, S. Hall	Effectiveness of Seton Powerhouse shutdowns for reducing entrainment mortality of Sockeye Salmon smolts during 2008
2009	D.A. Levy, J. Sneep	Effectiveness of Seton Powerhouse shutdowns for reducing entrainment mortality of Sockeye Salmon smolts during 2009
2010	J. Sneep	Seton River Sockeye Smolt Monitoring Program: 2010 results
2011	J. Sneep, S. Hall, Lillooet Tribal Council	Seton River Sockeye Smolt Monitoring Program: 2011 results
2012	J. Sneep, B. Adolph, D.A. Levy	Seton Sockeye Smolt Monitoring in 2012 with a summary of historical data
2013	B. Adolph, D.A. Levy	Seton River Sockeye Smolt Monitoring: Implementation Year 8
2014	J. Hopkins, B. Adolph, D.A. Levy	Seton River Sockeye Smolt Monitoring: Implementation Year 9
2015	J. Hopkins, B. Adolph, D.A. Levy	Seton River Sockeye Smolt Monitoring: Implementation Year 10
2016	No report	
2017	R. Ledoux, S. Lingard	Seton River Sockeye Smolt Monitoring: Implementation Year 12
2018	W.L. Harrower, L. Kleynhans, B. Adolph, R. Ledoux	Reducing entrainment mortality of Seton River Sockeye smolts during high discharge: 2006 to 2018 review

2.0 METHODS

2.1 STUDY SITE

The Seton River is at the outflow of Seton Lake and flows east 4 km into the Fraser River at the town of Lillooet, BC. Seton Dam is located ~0.5 km downstream of Seton Lake and diverts Seton Lake outflow into a 4 km long power canal while also regulating flows into the Seton River (Figure 2). The power canal flows to the Seton Generating Station (the 'powerhouse') which then discharges the diverted water into the Fraser River. The fish trap site is located approximately 500 m downstream of Seton Dam in the Seton River (Figure 2).

Daily Seton Dam discharge was calculated as the sum of discharge from the fish ladder, FWRG, radial gate and all five siphons. Daily mean dam discharge from 2006 to 2019 are presented, but no analyses were completed. Daily turbine discharge for the powerhouse is also presented, and an annual percent of hours the powerhouse was operational between 02:01 h and 19:59 h was calculated for each year.

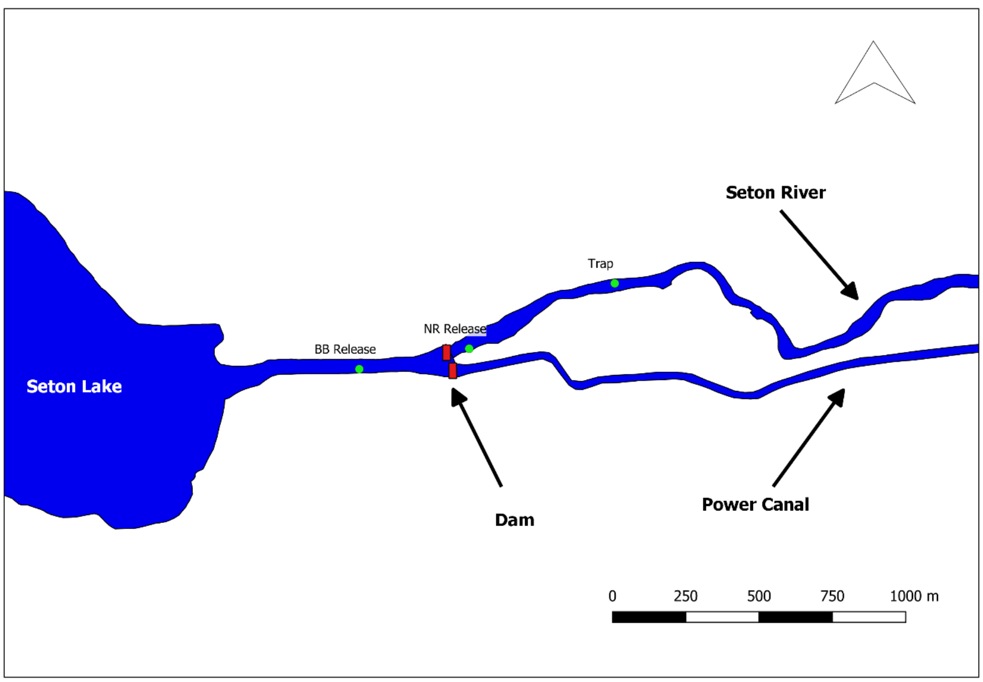

Figure 2. Study Site configuration for BRGMON-13 in 2019. Fish were released either in the approach channel upstream of Seton Dam, or downstream of Seton Dam, and were marked with a coloured dye specific to the location: Bismark Brown (BB) or Natural Red (NR).

2.2 SMOLT CAPTURE

A fish trap was deployed in the Seton River downstream of Seton Dam to capture out-migrating smolts (Figure 2). An IPT was used from 2006 to 2015 and an RST has been used since 2017. The eight-foot diameter RST was installed between April 15 and June 28 and monitored by a crew of three technicians. Traps were checked and cleaned every one to two hours between 10:00 h and 06:00 h. Salmon smolts were identified to species, enumerated, and released downstream of the trap unless they were retained for mark-recapture trials.

Two colours of immersion dye were used to mark fish to inform mark-recapture abundance, capture efficiency, and routing proportions (the relative proportion of smolts migrating down the Seton River vs. entrained through the powerhouse). Neutral Red (NR) dye was used to assess trap capture efficiency and estimate population abundance, and Bismark Brown (BB) dye was used to determine routing proportion. Mark-recapture estimates were generated for each year, while routing proportions were assessed in 2008, 2011, 2012, and 2019.

Smolts were batch marked using NR or BB diluted to 0.035 g/l and 0.045 g/l, respectively. Fish were immersed in aerated immersion tanks for 45 minutes, after which they were immediately transported to their release location in an aerated holding tank. NR-marked fish were released below the dam ~200 m downstream of the fishway entrance (n= 5,331 in 2019), while BB fish were released above the Seton Dam in the approach channel (n = 5,332 in 2019; Figure 2). All fish were released at or near civil twilight. The number of fish released each night varied, but in 2019, daily releases ranged from 50 to 200 fish.

Handling methods were consistent with those detailed in previous reports (Sneep et al. 2011, 2012; Harrower et al. 2019). Fork length and weight were recorded from a sub-sample of Sockeye smolts from each shift to the nearest millimeter (mm) and tenth of a gram (g).

2.3 CAPTURE EFFICIENCY

Since 2006, smolt recaptures have been used to assess capture efficiency, or the proportion of marked smolts re-captured relative to the total number released. Capture efficiency is used to expand trap catch to migration abundance. In most years, a single capture efficiency was calculated for the entire season (Table 2). In 2007, 2008, and 2010, Sneep et al. (2011, 2012) estimated capture efficiency for different discharge regimes (we used these efficiencies when calculating historic abundance). Of note is that capture efficiency is expected to vary between RSTs and IPTs, limiting comparisons pre- and post-2016.

Table 2. Number of fish released for mark-recapture experiments and resulting capture efficiency for the Seton River trap from 2006 to 2019. No fish were released in 2016.

Study Year	Release Location	Seton River ($m^3 s^{-1}$)	# Trials	# Marks Released	# Recaptures	Capture Efficiency (%)
2006	Below Dam	25 to 30	1	311	22	7.07
2007	Below Dam	25 to 30	1	416	26	6.25
	Below Dam	50+	3	1,049	60	5.72
2008	Below Dam	25 to 30	3	1,034	82	7.93
	Below Dam	31 to 35	1	660	38	5.76
2009	Below Dam	25 to 30	4	2,310	212	9.18
2010	Below Dam	25 to 30	3	1,012	105	10.38
2011	Below Dam	31 to 35	7	1,517	90	5.93
	Above Dam	31 to 35	8	3,756	162	4.31
2012	Below Dam	25 to 30	5	602	68	11.31
	Above Dam	25 to 30	9	2,795	167	5.97
2013	Below Dam	25 to 30	2	248	18	7.87
2014	Below Dam	25 to 50	4	904	52	5.75
2015	Below Dam	25 to 50	3	630	55	8.73
2016	-	-	-	-	-	-
2017	Below Dam	64 to 115	5	1,001	28	2.80
2018	Below Dam	11 to 85	4	700	22	3.14
2019	Below Dam	58 to 79	29	5,331	328	6.15
	Above Dam (shutdown)	58 to 79	19	4,518	199	4.40
	Above Dam (operational)	38 to 58	10	814	42	5.20

2.4 Routing Proportions

Routing proportion was estimated in four years from recaptures of fish released above the dam. The first estimates of routing proportions occurred in 2008 when an IPT was operated in the power canal. The 2008 experiment estimated that when the powerhouse was operating and dam discharges were approximately 20 m^3s^{-1}, 84% of smolts migrated via the powerhouse and 16% via the dam into the Seton River (Levy et al. 2008). Subsequent to 2008, trapping in the power canal was not permitted due to safety concerns.

In 2011, 2012, and 2019, marked fish were released above the dam and recaptured in the Seton River trap (IPT in 2011 and 2012, RST in 2019). To estimate routing proportion, the number of fish recaptured from releases above the dam was expanded by the capture efficiency for fish released below the dam, then divided by total number of fish released above the dam:

$$Proportion\ down\ Seton\ River = \frac{1}{\#\ fish\ released\ above\ dam} * \frac{(\#\ above\ dam\ captured\ in\ RST)}{(RST\ Efficiency)}$$

We assumed that 100% of fish migrated down the river when the powerhouse was not operating, which is different than in past years were some fish were assumed to migrate through the power canal when it was not operating (Sneep et al. 2012; Harrower et al. 2019). In years where no above-dam marks were released, a standard routing proportion from the Levy et al (2008) study of 84% Seton River and 16% powerhouse was used during powerhouse operation periods (Table 3).

Table 3. Summary of routing percentages used to estimate smolt population size in each year when the powerhouse was operational. No sampling was done in 2016.

Year	Smolts migrating down Seton River (%)	Smolts migrating down Power Canal (%)
2006	16	84
2007	16	84
2008	16	84
2009	16	84
2010	16	84
2011	34	66
2012	31	69
2013	16	84
2014	Powerhouse Shutdown	
2015	16	84
2016	-	-
2017	Powerhouse Shutdown	
2018	16	84
2019	73	27

2.5 SEASONAL AND DAILY RUN TIMING

To address MQ1, raw capture data were used to estimate seasonal migration timing and the magnitude of daily and hourly run-timing as a percentage of daily catch. Raw capture data were used for this component because the marking program was not structured to estimate percent of total population by day or hour, largely due to the assumption of a fixed capture efficiency throughout the season. Hourly catch was transformed to percentage of total annual catch to assess both the percentage of smolts leaving Seton Lake during the April 20 to May 20 window, and during the nightly shutdown period.

In 2019, catch data were divided into “operational” or “shutdown” categories. Operational catch represents all hours outside the powerhouse shutdown (02:01 h to 19:59 h daily between April 20 and May 20 and all hours outside of the April 20 and May 20 period). Shutdown catch is from the hours of the nightly shutdown (20:00 h to 02:00 h) from April 20 to May 20. This approach differs from previous analyses and reports where catch was assigned as “night” or “day” and did not reflect shutdown window hours. Data from previous monitor years were re-assigned to “shutdown” and “operational” periods.

2.6 ABUNDANCE AND MORTALITY

Estimates of abundance and mortality were calculated for each monitoring year using similar methods to those described in Sneep et al. (2011, 2012). Hourly capture data were compiled to estimate smolt abundance for shutdown and operational phases according to proportions travelling via Seton Dam and the powerhouse. First, the number of fish passing the trap per hour was calculated by dividing hourly trap catch by the capture efficiency. Hourly abundances were summed and multiplied by the dam mortality rate (2%), to estimate the number of mortalities due to dam passage. Combining the total number of fish captured (corrected by capture efficiency) with the number of mortalities due to dam passage provided an estimate of the total number of fish travelling via the Seton River. The number of fish entrained through the powerhouse was calculated by applying routing proportions to hourly abundance. Hourly estimates were then summed for both operational and shutdown periods to estimate total abundance.

An estimate of annual powerhouse smolt mortality was generated by applying the 17% mortality rate (Andrew and Green 1958; Groves and Higgins 1995) to the estimated number of smolts migrating down the power canal. Summing entrainment and dam mortalities provided an estimate of total mortality. Methods to calculate abundance and mortality are summarized in Table 4, and the data needed to calculate each metric is presented in Table 5. Mortality was not estimated for 2006 and 2007 because the trap was not run consistently.

Table 4. Approach to estimate the number of smolts passing through Seton Dam and power canal.

Step	Estimate	Description
1	Fish passing the trap per hour.	Divide hourly total catch by capture efficiency to obtain corrected smolt population estimates corrected for recapture rate. In past reports, population estimates have accounted for smolts missed while the trap was not fishing during trap cleaning. However, capture efficiency considers that marked fish were passing the trap while not fishing. Therefore, expanding only the unmarked catch is a source of bias that has been eliminated. Previous data has been re-analysed.
2	Mortalities due to dam passage.	Mortality through the dam is assumed to be 2%; multiply the estimated total number of fish passing the trap (Step 1) by 0.02.
3	Fish passing down the Seton River	Add the population size estimates in step 1 to the estimate of mortality due to passing through the dam (Step 2).
4	Population passing the powerhouse on an hourly basis.	For each hour the powerhouse was operating, the number of smolts passing the Seton River (Step 3) was divided by the percent estimated to pass Seton Dam and multiplied by the percent estimated to pass the power canal (routing proportions in Table 3). In past reports, assumptions regarding the proportion of fish entering the power canal when the powerhouse is not operating have been inconsistent. As no data has been collected to indicate fish enter the power canal when the powerhouse isn't operating, here it is assumed to be zero.
5	Shutdown and operational population estimates	Sum the hourly values to obtain numbers of smolts passing during operational and shutdown periods.
6	Entrainment mortality	Mortality through the powerhouse is assumed to be 17%; multiply the annual power canal population (Step 5) by 0.17.
7	Total annual mortality	Sum of entrainment (Step 6) and dam (Step 3) mortality.

Table 5. Summary of basic calculations used to answer Bridge-River Water Use Plan BRGMON-13 Management Questions.

Metric	Calculation	Data used to derive metric	Management Question addressed
Raw capture data	Percent catch during powerhouse operation and shutdown relative to total number of captures.	Raw capture data	Refine dates and timing of shutdowns (MQ#1)
Capture efficiency	Number of recaptures ÷ number marked smolts for the entire year	Marked fish recaptured from releases below the dam	Estimate capture efficiency to estimate total river population (MQ #3)
Number of smolts in the Seton River	Total catch of smolts during operational and shutdown periods ÷ capture efficiency.	Raw capture data and capture efficiency	Refine dates and timing of shutdowns (MQ#1)
Number of smolts entrained in power canal	Total Seton River estimate x proportion estimated to go down the river ÷ proportion estimated to go down power canal.	Raw capture data and routing proportions from previous reports.	Refine seasonal and daily timing of shutdowns (MQ#3)
Yearly mortality rate	(Number entrained in power canal x 0.17 + number in Seton River x 0.02) ÷ Total number of smolts	Population estimates and mortality estimates (from Groves and Higgins, 1995; Andrew and Green 1958).	Assessing management targets (Settlement Agreement 2011); estimating mortality and routing proportions (MQ #3)
Yearly population estimate	Sum of daily population estimates in Seton River and Power Canal	Sum of number in Seton River and in power canal	Estimating outmigration run size (MQ#3)

3.0 RESULTS

3.1 SETON DAM AND POWERHOUSE DISCHARGE

Discharge from Seton Dam between April 1 and June 28, 2019 varied between 38 m^3s^{-1} and 79 m^3s^{-1} (Figure 3). Prior to 2016, discharge generally fell between 25 m^3s^{-1} and 40 m^3s^{-1} during the Sockeye smolt migration period, but has exceeded 60 m^3s^{-1} from 2017-2019 (Figure 3). In 2019, the WUP target maximum was exceeded for 4 days (April 20 to April 23). After May 20th discharge decreased on May 23 from 53 m^3s^{-1} to 47 m^3s^{-1} and decreased from 47 m^3s^{-1} to 40 m^3s^{-1} on May 27.

Powerhouse operations varied among study years. In 2014 and 2017, the powerhouse was completely shut down between April 20 and May 20 for maintenance, and in 2019, the powerhouse was not operated until May 17 (Figure 3). The proportion of time the powerhouse has been operated during non-shutdown hours between April 20 and May 20 ranged from 4% in 2012 to 95% in 2008 (Table 6).

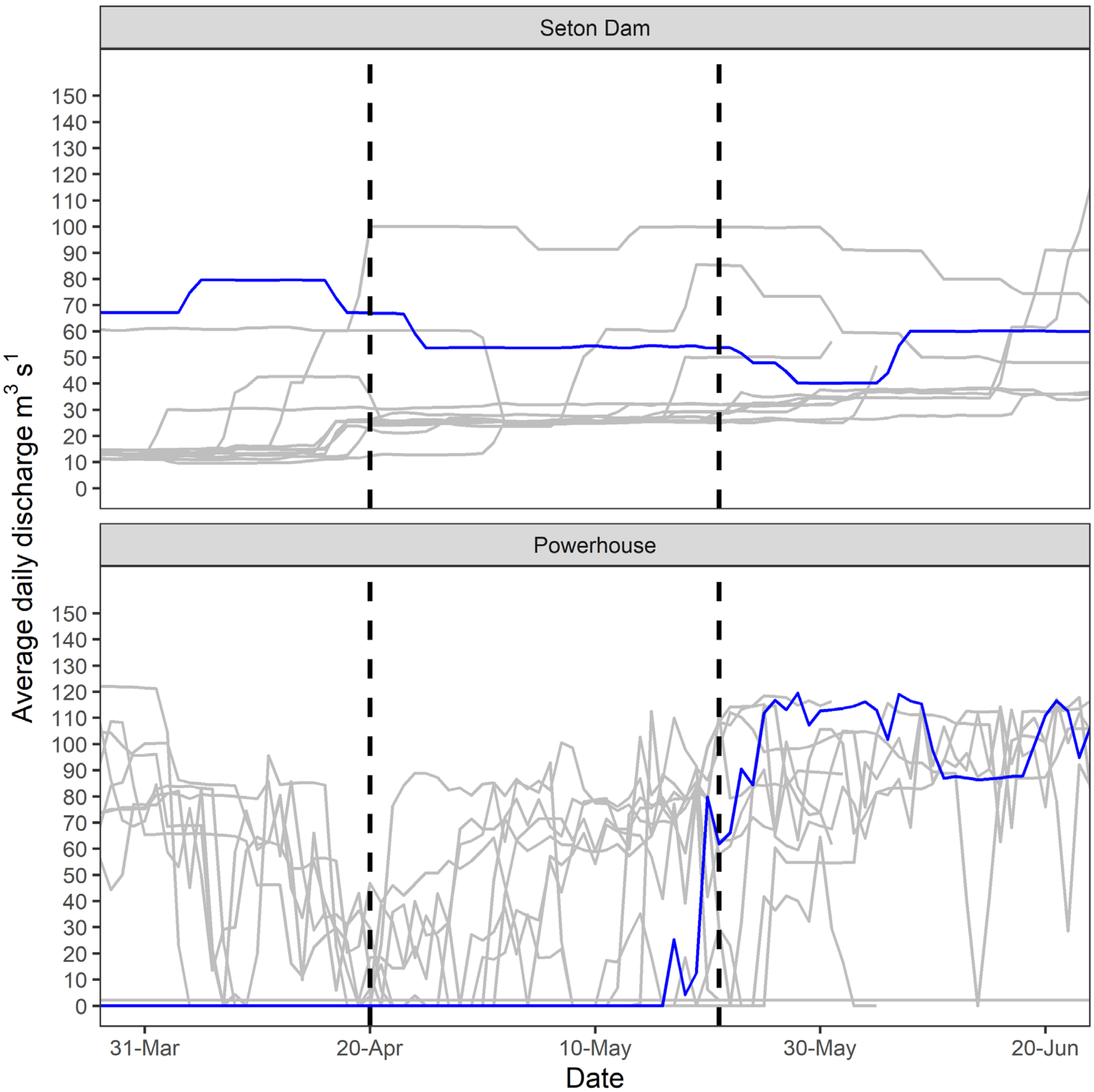

Figure 3. Mean daily discharge at Seton Dam and the powerhouse during the Sockeye smolt migration period from 2006 to 2019. The period when the powerhouse is shut down for 6-hours each night is shown between dotted lines (April 20 to May 20). Discharge in 2019 is shown in blue.

Table 6. Percent of non-shutdown hours (02:01 h to 19:59 h) from April 20 to May 20 the Seton Powerhouse was operated each year. The powerhouse was completely shut down in 2014 and 2017 for maintenance. There was no monitoring in 2016.

Year	% of Hours
2006	60
2007	62
2008	94
2009	45
2010	27
2011	80
2012	4
2013	48
2014	0
2015	70
2016	-
2017	0
2018	54
2019	6

3.2 SMOLT CAPTURE

In 2019, the RST was operated for 74 days between April 15 and June 28, the longest trap operation period in the history of the program (Table 7). As in 2018, the monitoring period was extended to capture Coho and Chinook Salmon smolts (reported in a separate document in prep.). Between June 1 and June 28, <5% of the total Sockeye catch was obtained. The total Sockeye smolt catch in 2019 was 48,366, which falls in the mid-range of all other years (Table 7).

Table 7. Duration of smolt trapping on the Seton River from 2006 to 2019, including the first and last dates of trapping and number of days fished. An incline plane trap was used until 2015, and a rotary screw trap between 2017 and 2019. There was no monitoring in 2016.

Year	Earliest Date	Latest Date	Total Days	Total Catch
2006	21 April	03 June	43	28,021
2007	18 April	31 May	43	37,686
2008	19 April	31 May	42	8,964
2009	16 April	04 June	49	18,018
2010	15 April	16 June	62	27,335
2011	15 April	30 May	45	144,128
2012	15 April	30 May	45	249,940
2013	19 April	02 June	44	16,015
2014	14 April	30 May	46	39,731
2015	15 April	15 June	61	77,098
2016	-	-	-	-
2017	10 April	01 June	52	43,181
2018	15 April	21 June	67	6,962
2019	15 April	28 June	74	48,542

3.3 SOCKEYE SMOLT LENGTH

Mean fork length varied between years (Figure 4). The largest smolts were captured in 2018 and smallest in 2012. Mean fork length in 2019 was 109.1 mm (SE = 0.23, N = 2,920), which falls within the range of all other years.

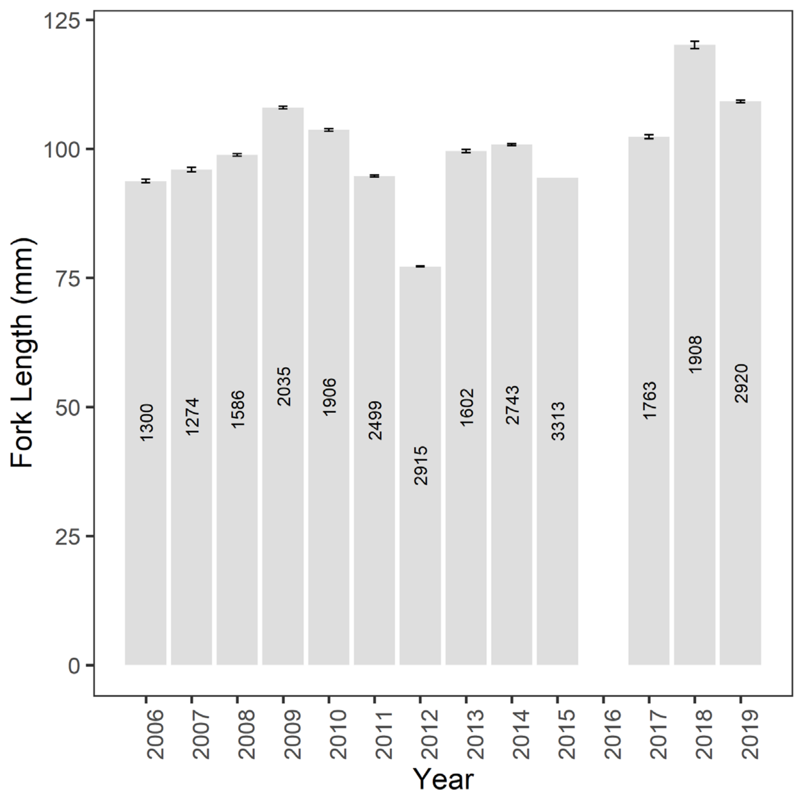

Figure 4. Mean fork length of Sockeye smolts in the Seton River between 2006 – 2019, with standard errors. Sample size for each year is displayed in the middle of each bar. There was no monitoring in 2016.

3.4 CAPTURE EFFICIENCY

The 2019 estimate of capture efficiency from below dam releases was 6.15% (328 recaptures of 5,331 released; Table 2). Of the 5,332 marked fish released above the dam, 4.5% (n = 241) were recaptured (Table 2). The number of fish marked and released in 2019 surpassed all other years. In 2019, 29 trials were conducted at each location, compared to between one and nine trials in previous years (Table 2).

3.5 ROUTING PROPORTIONS AND SMOLT ABUNDANCE

Recaptures of marked fish released above Seton Dam in 2019 allowed estimation of a year-specific routing proportion for fish leaving Seton Lake. We assumed that no fish migrated through the powerhouse during shutdowns and therefore 100% of fish would be expected to pass through Seton Dam. In 2019, most marked fish released above Seton Dam (85%; 4,518 of 5,332) were released when the powerhouse was shut down between April 20 and May 17, with the remainder released after May 17 during normal powerhouse operations.

An estimated 73% of fish migrated through Seton Dam when the powerhouse was shut down (prior to May 17), while 83% migrated through Seton Dam when the powerhouse was operational (after May 17). According to established methods of this monitor, 27% of the population was entrained into the power canal when the powerhouse was shut down, contrary to the 100% diversion proportion expected. Current mark-recapture methods were unable to account for the difference in expected versus estimated diversion proportion, and the 27% of smolts that did not migrate over Seton Dam during this time are unaccounted for. To estimate entrainment mortality for 2019, the more conservative overall routing proportion (using the entire sample of above dam recaptures; 73% river and 27% powerhouse) was applied to trap catches because so few fish were released after May 17 (n = 814) and discharge was more variable during this period.

Given routing proportions and associated mortality estimates, estimated Sockeye smolt abundance in 2019 was 798,300, which falls within the range of historic estimates (395,700 - to 3,220,900; Table 8). The powerhouse was operational beginning on May 17, after which an estimated 2% (17,300) of the smolt population migrated through the powerhouse, the lowest on record (Table 8). In previous years, percentages ranged from 8% (2011 and 2012) to 76% (2008). The low entrainment rate is a direct reflection of the amount of time the powerhouse was shut down in 2019.

Table 8. Total population estimates using standardized method across years for Seton-Anderson Sockeye smolts. Population sizes are rounded to the nearest 100 fish. In 2016, no sampling occurred due to high discharges. There was no monitoring in 2016.

Study Year	Seton River Abundance	Power Canal Abundance	Total Annual Abundance Estimate	Percent Total Population through Power Canal
2006	606,900	505,500 [a]	1,112,400	45%
2007	874,000	646,700 [a]	1,520,700	43%
2008	115,500	367,700	483,200	76%
2009	271,700	39,600	311,300	13%
2010	360,900	57,400	418,300	14%
2011	2,958,800	262,100	3,220,900	8%
2012	2,453,800	209,500	2,753,300	8%
2013	239,200	256,400	495,600	52%
2014	838,900	0	838,900	0%
2015	1,506,600	681,700	1,738,300	39%
2016	-	-	-	-
2017	1,556,300	0	1,566,300	0%
2018	223,000	172,700	395,700	44%
2019	781,100	17,300	798,300	2%

[a] estimate based on “shutdown” sampling numbers only because operational catches were not consistent in these years.

3.6 Seasonal and Daily Run-timing

3.6.1 Seasonal Run-timing

In 2019, the Sockeye smolt outmigration spanned the entire trap operation period between April 15 and June 28, but a negligible percentage of the catch was obtained after June 1st (<5%). Run timing peaks have varied among study years were not always uni-modal. In seven of 13 years, the migration has been multimodal and peak catches have been observed between mid-April and the end of May (Figure 5). The 2019 migration peaked in the first week of May (Figure 5).

In eight of 11 years (including 2019), at least 90% of fish have been captured between the seasonal shutdown dates (Table 9). The percent of fish captured between April 20 and May 20 ranged from 62% in 2008 to 98% in 2010 and 2011 (as estimated from daily proportion of total catch; Table 9). The lower percentage observed in 2008 is likely a result of an atypically flat run-timing (Figure 5). These results provide support to H_{2A}, that >90% of smolts leave Seton Lake between April 20 and May 20.

Table 9. Percentage of Sockeye smolt caught in the Seton River during specific periods of interest from 2008 to 2019. There was no monitoring in 2016.

Year	% of Total catch			
	During shutdown hours of 20:00-02:00		All hours April 20 to May 20	During Hours 02:01 to 19:59
	April 20 to May 20	Entire season		April 20 to May 20
2008	45	45	62	17
2009	68	68	85	17
2010	70	40	98	28
2011	77	77	98	21
2012	36	37	82	46
2013	71	71	95	24
2014	70	70	90	20
2015	71	71	92	21
2016	-	-	-	-
2017	83	87	94	11
2018	69	70	90	21
2019	80	80	93	13

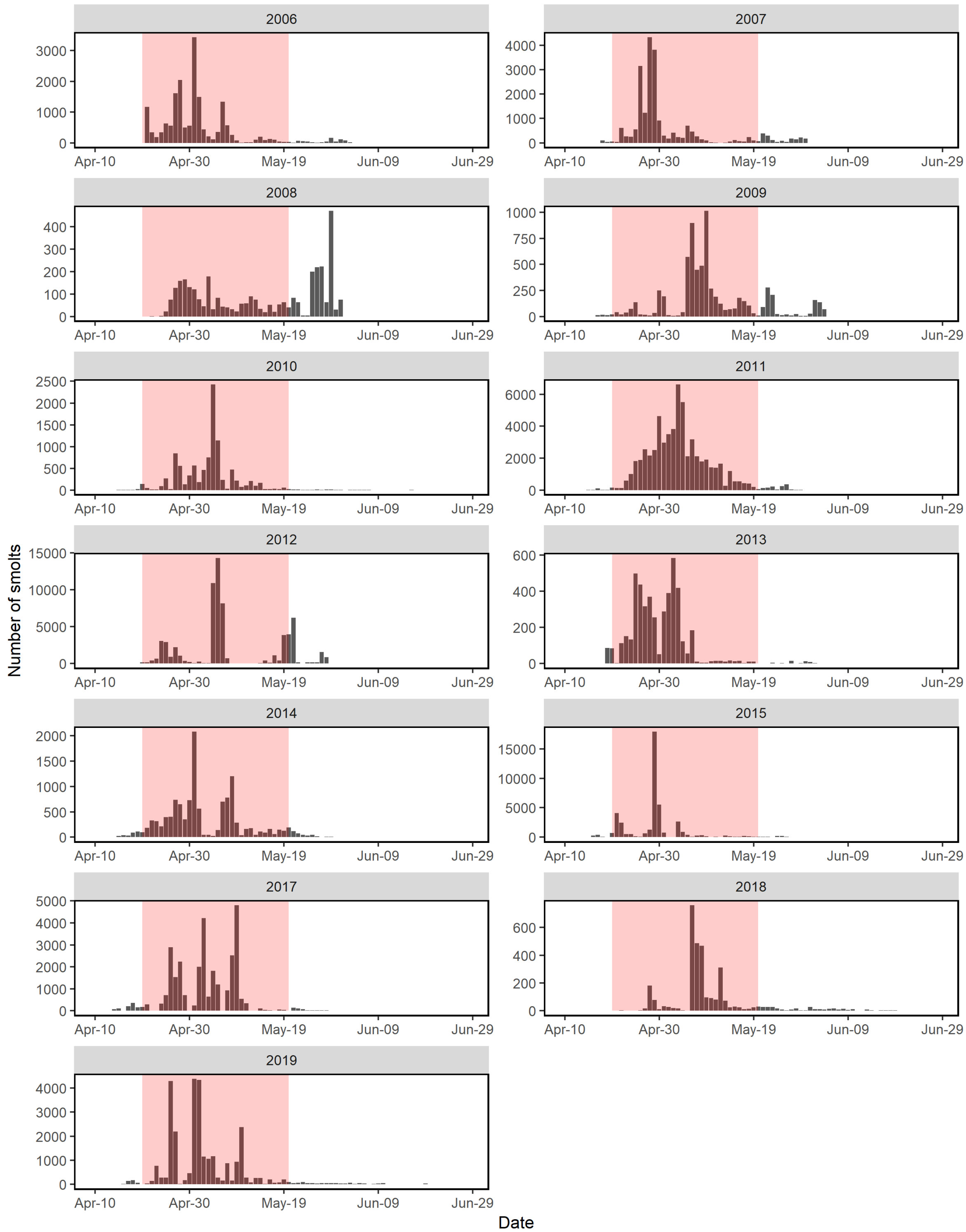

Figure 5. Daily trap catch of Sockeye Salmon smolts below Seton Dam from 2006 to 2019. An inclined plane trap was used from 2006 to 2016, and a rotary screw trap used between 2017 and 2019. Red shading indicates the current seasonal shutdown window. There was no monitoring in 2016.

3.6.2 Daily Run-timing

Hourly catch data grouped into years the powerhouse was shutdown (2014, 2017, and most of 2019) or operated (all other years) was used to evaluate how the powerhouse influenced the percent of fish captured during non-shutdown hours. In years when the powerhouse was not operated during the smolt migration, there was <1% difference in the proportion of fish captured during non-shutdown hours relative to years where the powerhouse was operated (Figure 6). The negligible difference in hourly proportion captured between shutdown and non-shutdown years indicates data from all years can be used to refine nightly shutdown timing.

The percent captured during the shutdown hours of 20:00 and 02:00 between April 20 and May 20 varied from 36% in 2012 to 83% in 2017 (Table 9). The percent of fish captured during non-shutdown hours between April 20 and May 20 ranged from 11% in 2017 to 46% in 2012 (Table 9). H_{3A}, that >90% of smolts leave Seton Lake between 20:00 h and 02:00 h, is therefore rejected.

Capture proportions were consistent between April 20 to May 20 and when considering the entire season (April 15 to June 1), suggesting that extending nightly shutdowns later in the season would not improve fish protection. Mean hourly catches (Figure 6) indicate that ~20% of fish are caught between 02:00 and 04:00, and extending the end of the shutdown window to 04:00 may positively affect fish protection.

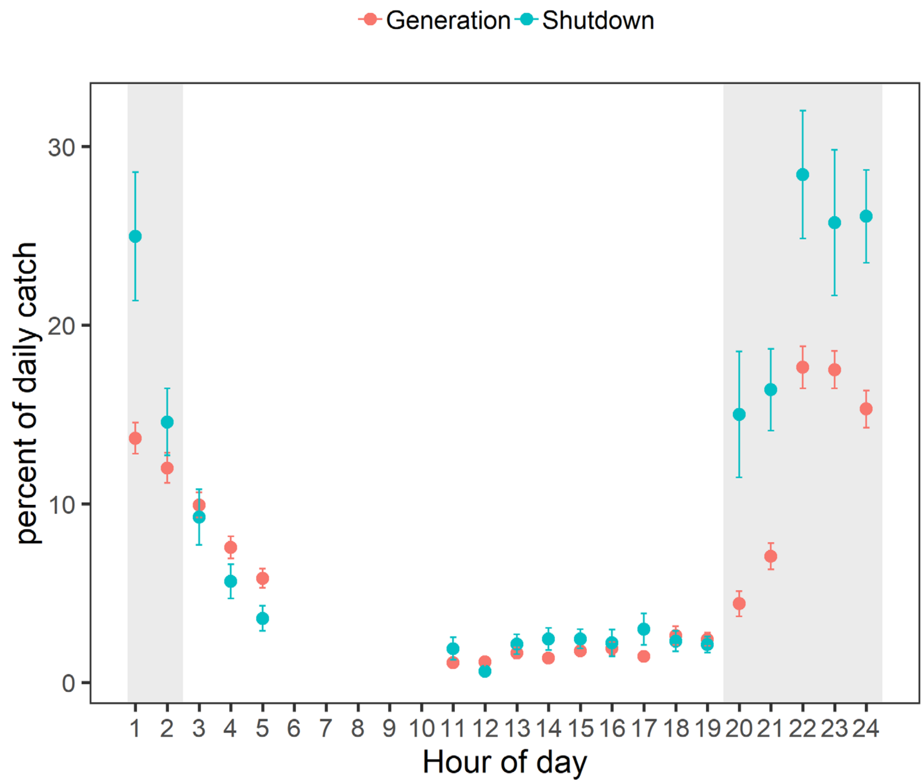

Figure 6. Mean percent daily catch by hour from 2008 to 2019 with standard error for Sockeye smolts captured at a fish trap below Seton Dam. Blue symbols represent years the powerhouse was shut down for all or most of the seasonal shutdown period, April 20 to May 20 (2014, 2017, 2019). Red symbols represent all other years where generation occurred during that same period. Data from 06:00 h to 10:00 h were sparse and are not shown.

3.7 Entrainment Rate and Smolt Mortality

Estimates of dam and entrainment mortality have varied amongst years, depending on routing proportions and powerhouse operations. A powerhouse entrainment rate of 20% or less must be met to meet the 5% mortality target and target diversion rate of 80% stipulated in hypothesis H_{1A}. Between 2006 and 2019, annual entrainment rate has varied from 0% in 2014 and 2017, when the powerhouse did not operate, to 76% in 2008 (Figure 7). In seven out of 11 years with mortality data, the 20% entrainment target has been achieved or exceeded, including in 2019 (the estimated entrainment was 2%; Figure 7).

Total smolt mortality (sum of powerhouse and dam mortality) was 2% in 2019, the lowest ever recorded. Since 2008, estimated total smolt mortality has exceeded the 5% target in four of the nine years the powerhouse was operational during the shutdown period. The highest estimated mortality rate was 14% in 2008 (Figure 8).

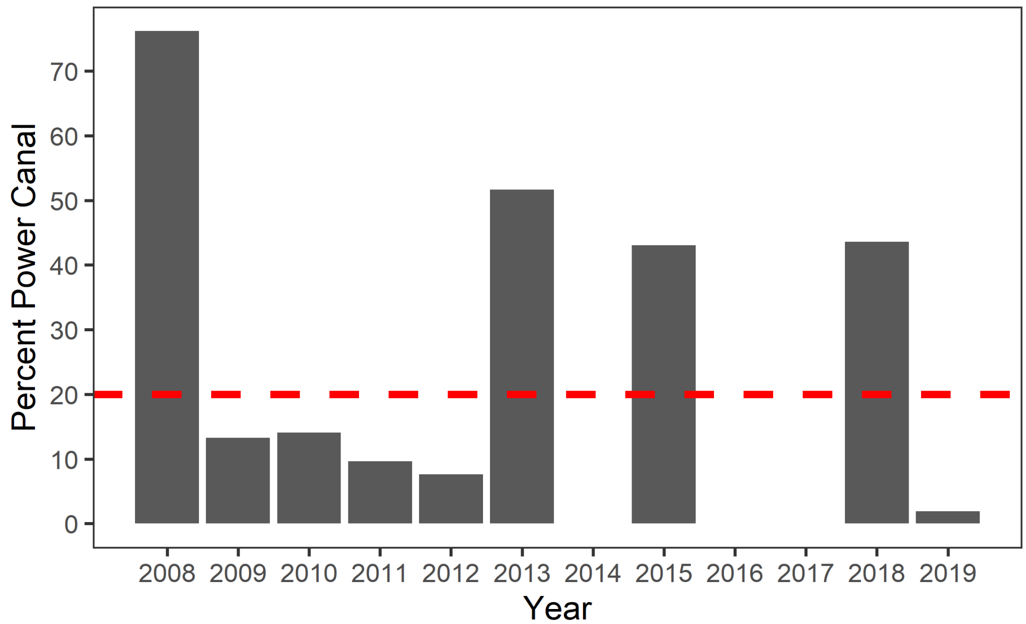

Figure 7. Percent of total estimated Sockeye Salmon smolt population entrained through the Seton powerhouse annually since 2008. In 2014 and 2017 the powerhouse was not operational, and entrainment was 0%. The red dashed line represents a 20% entrainment rate, required to meet the 5% mortality target. There was no monitoring in 2016.

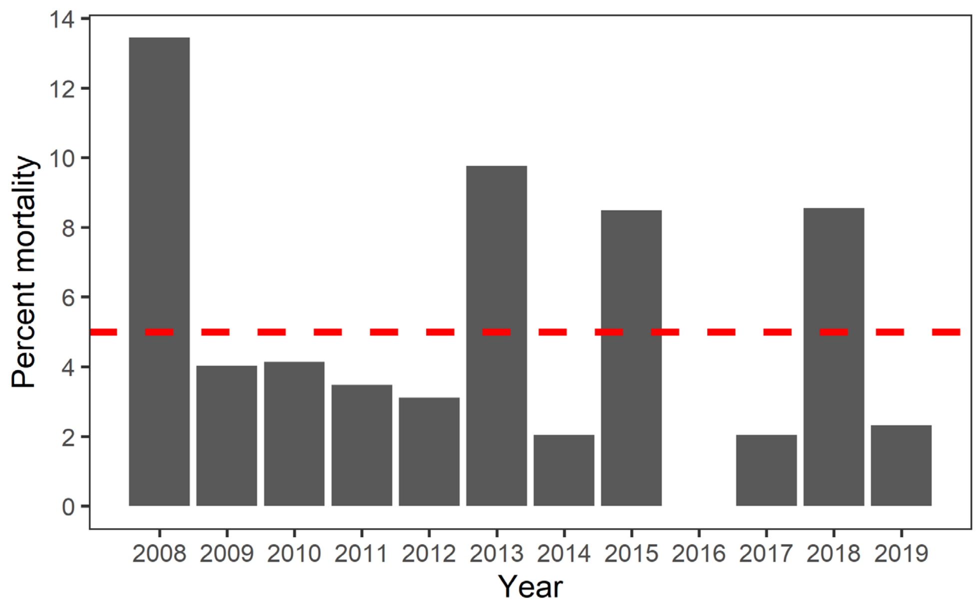

Figure 8. Annual Sockeye smolt mortality estimates for all conveyance structures (powerhouse and dam) presented as a percentage of the total smolt population. The horizontal dashed line indicates the 5% smolt mortality target outlined in the Settlement Agreement (2011). There was no monitoring in 2016.

4.0 DISCUSSION

In 2019 the number of fish marked was the greatest to date in this monitor. Nonetheless, due to the almost complete shutdown of the powerhouse during the smolt migration period, data for this year is limited. Additionally, with < 5% of the annual catch obtained while the powerhouse was operational, the smolt mortality estimate (~2%) was among the lowest on record.

Although the powerhouse was shut down for most of the migration, mark-recapture methods estimated that 27% of fish released above the dam did not pass Seton Dam. This result highlights shortcomings of the current methods to account for alternate outcomes for fish other than entrainment, which is only assumed to be possible when the powerhouse is operating. Fish released above the dam could have died from other causes (e.g., predation, stress), residualized, or delayed migration. Previous tagging studies of juvenile Sockeye Salmon in the Fraser River watershed suggest residualization of tagged fish ranges from 4.5 to 6% (Welch et al. 2005; Melnychuk and Hausch 2011). A similar study of Chinook smolts in the Snake River found that as the migration period increased mortality of tagged fish decreased, but delays in migration became more common (up to 10% of fish; Buchanan et al. 2009). Additionally, using a single mean annual capture efficiency throughout the migration period likely contributes to error in estimates.

All results and estimates of smolt mortality presented here and in past reports have significant limitations. Quantifying and reducing uncertainty and error in estimates is instrumental to effectively address management questions for BRGMON-13 and would require several methodological changes.

A detailed discussion of each management is presented below, with recommendations for improvements to study design.

4.1 MANAGEMENT QUESTION #1: WHAT PROPORTION OF TOTAL SOCKEYE OUTMIGRANTS FROM SETON LAKE WILL PASS THROUGH SETON DAM WHEN THE POWERHOUSE IS SHUTDOWN EACH NIGHT (20:00:02:00) BETWEEN APRIL 20 AND MAY 20?

The three alternative hypotheses for BRGMON-13 relate to the timing of shutdowns and proportion of fish moving, and support Management Question 1:

> H_{1A}) Nightly powerhouse shutdowns (accompanied by an >25 m^3s^{-1} dam release) conducted 20:00 h to 02:00 h between April 20 and May 20 will result in >80% of the Sockeye smolts being diverted to Seton River from Seton Lake.

H_{2A}) More than 90% of the smolts leave Seton Lake between April 20 and May 20.

H_{3A}) More than 90% of the smolts leave Seton Lake between 20:00 h and 02:00 h.

The percentage of fish diverted into Seton River during the nightly shutdowns between April 20 and May 20 has met the target of 80% in seven of the 11 years with data, indicating hypothesis H_{1A} cannot be rejected. Hypothesis H_{2A} is also not rejected; 90% or more of the catch has been obtained between April 20 and May 20 in eight of eleven years with data. Exceptions occurred in years when there were modest spikes in abundance after May 20, which may reflect a pulse of Portage Creek Sockeye smolts, which migrate later than Gates Creek smolts (BRGMON-6; Limnotek 2016). The Portage population may have had a larger influence on timing distributions in 2008 because catches and overall abundance were low and the relative proportion of the Portage Creek smolts may have been high relative to other years. In 2012, smolt abundance was high and there was again a later pulse of fish, which could be attributed to a longer migration period due to the greater number of fish leaving the lake. Continued monitoring of run-timing after May 20 as well as stock identification are needed to determine if an adjustment to the seasonal timing of shutdowns is warranted to increase protections for Portage Creek sockeye.

The percent of catch obtained between 20:00 h and 02:00 h between April 20 and May 20 (36-83%) as well as across the entire season (37-87%) failed to meet the hypothesis that >90% of smolts out-migrate between 20:00 h and 02:00 h; however, in 8 of 11 years, the proportion of smolts captured from 20:00-02:00 was approximately 70% or greater (68-87%). Mean percentages of daily hourly catch among years show that approximately 20% of fish are caught between 02:00 and 04:00, suggesting that >90% of smolt migration occurs between 20:00 to 4:00. The implications of this daily smolt migration timing for powerhouse operating refinements are discussed under MQ3.

Although these data have provided insight into the effectiveness of the daily and seasonal timing of powerhouse shutdowns, conclusions are based on raw catch data. To address these uncertainties, a stratified marking program is required such that capture efficiency can be calculated throughout the season and be used to correct catch data and reflect variability.

4.2 Management question #2: How is the proportion of fish passing through Seton Dam during the shutdown window affected by total release from the Seton dam and the configuration of dam discharge facilities used to release water?

The current methods used to determine the proportion of fish migrating through Seton Dam assume routing proportions are fixed throughout the season and, in the absence of year-specific data, fixed among years. Routing proportions determined in this and previous reports are likely inaccurate due to the inability to meet several assumptions including: 1) capture efficiency is homogenous through the entire season, 2) mortality of marked fish is negligible (e.g., predation, handling, and transport stress), and 3) fish do not enter the power canal when the powerhouse is not operational. Results from 2019 highlight the consequences of such limiting assumptions: 27% of marked fish released above the dam could not be accounted for using established methods. Due to these uncertainties this management question cannot be addressed.

To address MQ2, we recommend implementing a radio telemetry study. Telemetry that allows for passive detection would provide the level of detail necessary to assess seasonal and daily movement behavior and understand effects of operational conditions.

4.3 Management question #3: Are there any refinements to seasonal timing of powerhouse shutdowns to improve fish protection efficiency or reducing lost power generations opportunities?

There are two options for improving fish protection: extending the hours of the nightly shutdown duration or increasing the number of days for the seasonal shutdown window. Options to improve efficiency of shutdown timing include increasing diversion rates through operations at Seton Dam (both total discharge and configuration of conveyance structures) or shifting the timing of the shutdowns nightly and/or seasonally.

Hourly catch data from all years suggests extending nightly shutdowns by one or two hours (i.e., to 03:00 h or 04:00 h) may provide the additional protective measures needed to meet the 90% assumption in hypothesis H_{3A}. Hourly catch data provide reliable insight into the effectiveness of the nightly shutdown because discharge, and therefore capture efficiency, is generally constant within a day.

Conversely, catch data do not support extending the seasonal shutdown window by more days, as 90% of the catch occurred between April 20 and May 20 in most years (see MQ1). However, seasonal catch data may not accurately represent seasonal abundance and migration timing because the assumption of equal capture probabilities is likely not valid.

Capture efficiency is affected by discharge, which varied throughout the migration period. Capture efficiency typically decreases as discharge increases, as documented in other juvenile salmonid monitoring programs (Lingard et al. 2018; Schick and Macnair 2018).

The proposed stratified mark-recapture program suggested for MQ1 would also reduce uncertainty in the seasonal run-timing of smolts and help to determine whether changing the length of the seasonal shutdown period would improve fish protection. In addition, delineating the migration timing of Gates Creek and Portage Creek populations is needed to ensure shutdowns are timed to maximize protection of both populations. The Portage population was recently assessed as being in poor condition with less than 1,000 individuals returning in two of the past four years (DFO 2018), and disproportionate effects to Portage Creek Sockeye may occur if the powerhouse shutdowns do not adequately protect this population. To resolve this uncertainty, DNA samples should be collected from a sub-sample of fish each day in the remaining two years of the monitor (scales may be used to retroactively evaluate population structure from previous years).

4.4 SMOLT ENTRAINMENT AND MORTALITY

Entrainment rate is directly influenced by powerhouse operations, as the annual routing proportion is applied to catch data for hours the powerhouse was operational. Entrainment rate has varied widely among years and reflects powerhouse operations. For example, in 2012, only 36% of fish were estimated to migrate during shutdown hours between April 20 and May 20, but only 8% of fish were estimated to be entrained because the powerhouse was only operated for 3.8% of potential non-shutdown hours. Comparatively, the highest entrainment rate was observed in 2008 when the powerhouse was operated 94% of potential non-shutdown hours, as well as during a portion of shutdown hours. In 2019, entrainment rate was estimated to be 2%, reflecting the powerhouse shutdown until May 17.

Mortality rates are proportional to entrainment rates because fixed mortality rates are applied. Smolt mortality has exceeded the 5% target in four years of the 13 for which analysis was possible. The 2% smolt mortality estimated for 2019 was among the lowest on record, again due to the almost complete shutdown of the powerhouse during the smolt migration period. Similarly, low mortality rates were estimated in 2014 and 2017 when the powerhouse was completely shut down.

To reduce uncertainty in entrainment and mortality rates, a better understanding of routing proportions is required. Sneep et al. (2011 and 2012) used above dam releases when the powerhouse was operational to estimate the proportion of smolts that remained above the dam, and assumed these fish entered the powerhouse. The same methods were used in 2019, but most fish were released when the powerhouse wasn't operational and an estimated 27% of fish did not pass through the dam. In theory, with the powerhouse off, 100% of fish should have passed through Seton Dam. It is likely that a portion of the 27% is attributable to the error associated with using average capture efficiency for the RST; however, other sources of above-dam mortality are likely. Handling and transport can influence predator avoidance abilities and induce physiological stress in juvenile salmon (Gadomski et al. 1994; Carey and McCormick 1998; Jepsen et al. 2001; Portz et al. 2005). To improve confidence in estimates of routing proportion and account for other factors, including mortality and residualization, a telemetry study that monitors individual fish movement is necessary.

Assessing the variation in mortality through Seton Dam and the powerhouse within and among years would further improve the accuracy of smolt mortality estimates. Currently, fixed mortality rates from a study conducted 60 years ago (Andrew and Green 1958) are applied to each conveyance structure. Mortality can depend on numerous factors (e.g., time of year, predation, discharge, water temperature, fish health) and smolts may have different sensitives to migration barriers in 2019 relative to 1958. More accurate mortality estimates could be obtained with the proposed telemetry study.

5.0 RECOMMENDATIONS

BRGMON-13 monitoring is an essential component of the continued management of Sockeye Salmon in the Seton-Anderson; however, methodological limitations hinder our ability to answer the specific management questions. In addition, advancements in fish monitoring technologies have occurred since the TOR was published in 2011. Recommendations for improving the BRGMON-13 monitoring program are presented below.

1) Change Marking Methodology

The current batch marking methods do not differentiate catches at different operational and/or discharge conditions. We recommend using PIT tags to mark fish, which would allow individual fish migrations to be associated with specific release dates and operational conditions (MQ2). Fish released below the dam would be tagged with 12 mm PIT tags to determine daily or weekly recapture rates. This would increase the accuracy of population estimates and provide uncertainty in annual abundance.

2) Maintain focus on consistent mark-recapture effort

The marking effort should be consistent and structured throughout the monitoring period to provide adequate statistical power when estimating abundance. The mark-recapture simulation completed in 2018 (Harrower et al. 2019) indicated that marking in previous years has been insufficient to confidently estimate population size, and increasing the marking effort will help to improve accuracy and reduce uncertainty.

3) Add an Autonomous Telemetry Component

A radio telemetry study would greatly improve the ability to determine routing proportions and assess mortality and residualization in Seton Lake. Radio telemetry has been utilized previously to assess Seton resident fish entrainment (Burnett & Parkinson 2018) and is likely the most affordable and effective technology to passively collect fish movement data. Radio telemetry would provide the resolution required to assess operational conditions when individual fish migrate through a given route.

1) DNA Analysis to Verify Stock Specific Run-Timing

More detailed knowledge of run-timing differences between populations is needed to adequately address the management questions. We recommend collecting DNA samples from a sub-sample of fish each day in the remaining two years of the monitor, and investigating the feasibility of using historic scale samples to determine historic run composition.

2) Implement Best Practices and SOP's for fish handling

Structured holding studies need to be implemented throughout the season to assess tagging and transport effects on a sub sample of fish. Best practices for holding and transport should be developed with attention to fish density and water quality during fish sampling, tagging and transport.

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