Bridge River Project Water Use Plan

Seton Sockeye Smolt Monitoring Program

Implementation Year 4

Reference: BRGMON-13

2015 Data Report

Study Period: 2015

St’at’imc Eco-Resources
Jessica Hopkins, Bonnie Adolph, and Dave Levy

December 2015

Executive Summary

Status of Objectives, Management Questions and Hypotheses after Year 10 (2015-2016)

Study Objectives	Management Questions	Management Hypotheses	Year 10 Status
1. Primary objective is to assess the effectiveness of powerhouse shutdowns for reducing the total mortality of sockeye salmon smolts migrating out of Seton Lake.	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_{o1}: 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.	During 2015, 68% of the smolt migration took place during the combined seasonal and diel closure window
2.1 Monitoring the timing, magnitude, and diel schedule of the sockeye smolt migration; 2.2 Assessing the relationship between dam release and the proportion of fish entering the dam approach channel and migrating into Seton River; and; 2.3 Assessing the effects of powerhouse shutdown and dam releases on fish attraction flows and bypass conditions at Seton Dam.	2. How is this proportion affected by total release from the Seton dam and the configuration of dam discharge facilities used to release water?	H_{o2}: Less than 90% of the smolts leave Seton Lake between April 20 and May 20	During 2015, 93% of the smolts were captured between April 20 and May 20
3. Estimate entrainment mortality in relation to the 5% mortality target as defined in the St'at'imc Hydro Agreements	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?	H_{o3}: Less than 90% of the smolts leave Seton Lake between the hours of 0800 h and 0200 h	During 2015, 73% of the total smolt captures occurred during the diel closure window

Executive Summary

Since 2006, St'át'imc and BC Hydro have collaborated to monitor sockeye smolt mortality associated with entrainment into the Seton powercanal. Turbine mortality is mitigated by shutting down the generator for 6-h duration outages that overlap peak nighttime smolt migrations. In those years when there is a maintenance outage that overlaps the smolt migration, impacts can be fully avoided for the period of overlap. As part of the St'át'imc - BC Hydro Settlement Agreement, monitoring is conducted annually to evaluate compliance with a 5% smolt mortality target.

Sampling was conducted in 2015 to monitor the seasonal timing, magnitude, and diel migrations of sockeye smolts out of Seton Lake. Sampling included:

- operating an inclined plane trap (IPT) in the Seton River below Seton Dam for 6 weeks during the sockeye smolt migration period;
- sampling during day- and night-time hours to monitor diel migration patterns;
- conducting mark-recapture trials, including the release of marks below the dam;
- collecting biological data (i.e., forklengths) from a subset of sampled smolts to enable analysis of trends in smolt size between years;

Seton Generator and Power Canal shutdowns in 2015 were highly compliant with the recommended shutdown schedule set for 20:00 - 02:00 between April 20 - May 20. Approximately 10% of the smolts migrated during the daytime and both daytime and nighttime migrations were pulsed and displayed several peaks over the migration period. It was estimated that 73% of the smolts migrated between the hours of 20:00 - 02:00. Observed seasonal patterns of migration indicated an earlier-timed migration in 2015 by about 1 week when compared to the long term average. In 2015, median migration dates were April 29 and May 3 during nighttime and daytime periods respectively. Long term (10 year duration) median migration dates were May 2 and May 10 for nighttime and daytime periods respectively.

During 2015, DNA samples of smolts were analysed to determine whether there were outmigration timing differences. The median migration date for Gates Creek smolts (May 4) was slightly earlier than the median migration date for Portage Creek smolts (May 7).

The report recommends that a modeling approach be initiated for predicting sockeye smolt mortality as a function of the respective flow discharges down the power canal and the bypass facilities.

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1.0 Introduction

The St'at'imc and BC Hydro have worked together since 2006 to devise practical methods for mitigating sockeye salmon smolt mortality of at the Seton Powerhouse (Figure 1). This mortality is a consequence of entrainment into the Power Canal and subsequent smolt passage through the turbine. Smolt mortality rates have been monitored since 2006.

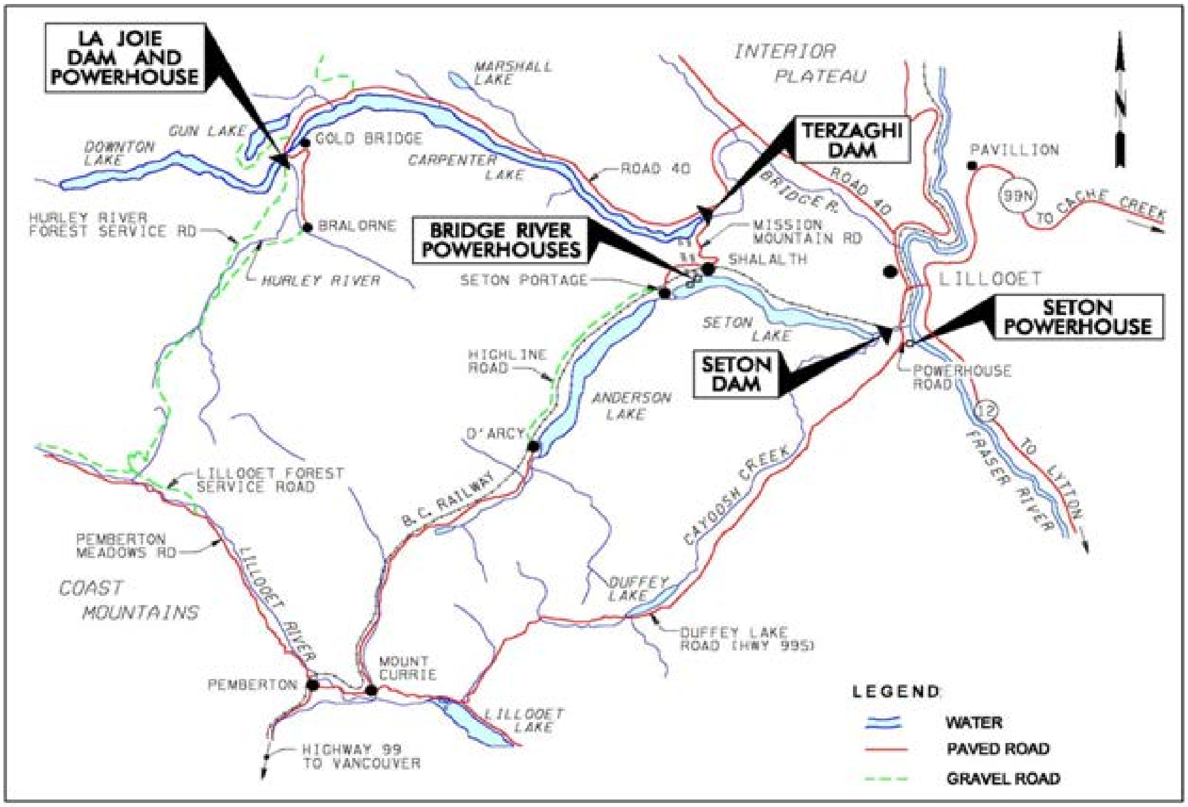

Figure 1. Location of BC Hydro facilities in the Bridge/Seton watersheds.

This data report presents the 2015 data set and compares results with previous findings. In view of budgetary considerations, a decision was taken in 2013 to streamline the annual reporting procedure to include full presentation of the data together with a focused and succinct report write-up. This approach has been carried over to 2015. Further descriptive information including methods are contained in the previous reports that cover the 10-year monitoring period, as listed in the Table below. These reports are available from BC Hydro via the authors upon request. The 2012 and previous reports contain a complete description of methods that have been consistently followed since 2006.

Date	Authors	Title
2015	J. Hopkins, B. Adolph and D.A. Levy	Seton River sockeye smolt monitoring: implementation year 10 (present report)
2014	J. Hopkins, B. Adolph and D.A. Levy	Seton River sockeye smolt monitoring: implementation year 9
2013	B.Adolph and D.A. Levy	Seton River sockeye smolt monitoring: implementation year 8.
2012	J. Sneep, B. Adolph and D.A. Levy	Seton sockeye smolt monitoring in 2012 with a summary of historical data.
2011	J. Sneep,S. Hall and Lillooet Tribal Council	Seton River sockeye smolt monitoring program: 2011 sampling results.
2010	J. Sneep	Seton River sockeye smolt monitoring program: 2010 sampling results.
2009	D.A. Levy and J. Sneep	Effectiveness of Seton Powerhouse shutdowns for reducing entrainment mortality of sockeye salmon smolts during 2009.
2008	D.A. Levy, J. Sneep and S. Hall	Effectiveness of Seton Powerhouse shutdowns for reducing entrainment mortality of sockeye salmon smolts during 2008.
2007	D.A. Levy and J. Sneep	Effectiveness of Seton Powerhouse shutdowns for reducing entrainment mortality of sockeye salmon smolts during 2007.
2006	D.A. Levy and J. Sneep	Effectiveness of Seton Powerhouse shutdowns for reducing entrainment mortality of sockeye salmon smolts during 2006.

Methods;

2.0 Results

2.1 Seton River Discharge

Discharge records into the Seton River and powercanal are maintained by BC Hydro. Discharge through the mid-April to late May smolt migration was relatively stable until May 21 when the river was ramped from 27 cms to 31 cms. (Figure 2). Thus the flow discharge into the Seton River was relatively constant over the period of the 2015 smolt migration.

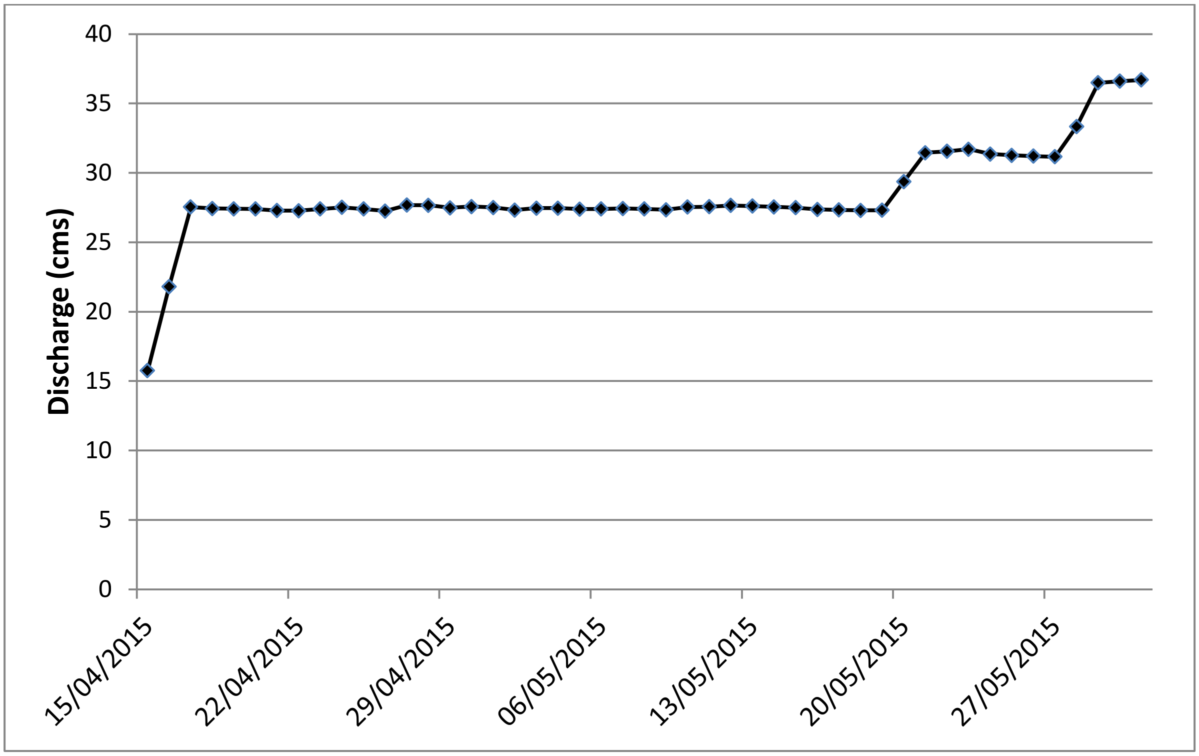

Figure 2. Seton River discharges during the 2015 smolt migration period.

Following the termination of the smolt sampling at the end of May, flows remained at approximately 36 cms, eventually rising to 93 cms on June 19 in order to manage high water levels in Carpenter and Downton Reservoirs, coupled with high inflows from Seton and Anderson Lake tributary inputs. A comparison of the powercanal and Seton River discharges is shown in Figure 3.

During 2015, hourly discharges were documented to reflect shutdown hours in relation to diel smolt migrations. The analysis for 2015 (Table 1) indicates good compliance of the shutdown schedule in relation to the operating practice of a 6-hr nightly shutdown period between 20:00 - 02:00.

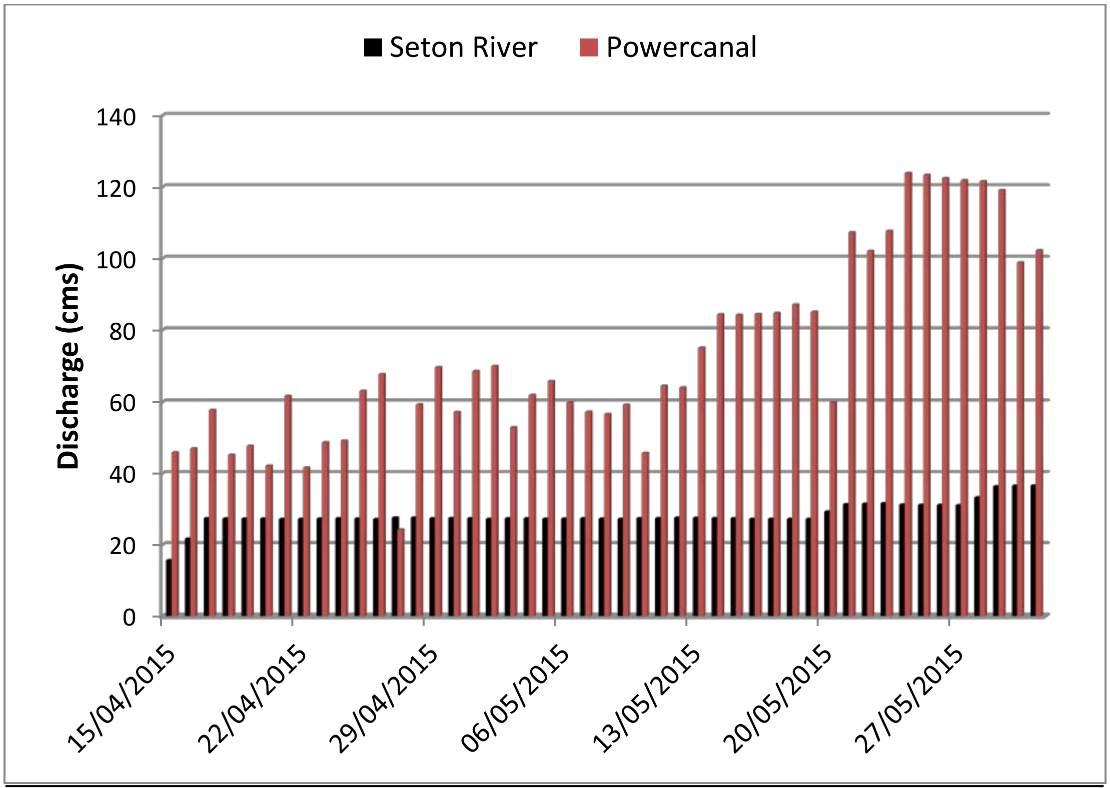

Figure 3. Daily averaged water flows into the Seton River and the Seton Powercanal during the smolt migration period in 2015.

2.2 Sockeye Smolt Monitoring Data

2.2.1 Inclined Plane Trap Catches

There were intermediate smolt catches in 2015 compared with 2006-2015 IPT results. Table 2 provides the total annual catches, broken out by daytime and nighttime sampling periods, as well as the maximum daily or nightly catch results. Nighttime and daytime periods yielded catches of 69,980 and 7,075 smolts, respectively, during 45 days of trapping. In contrast, during 2012, the year with the highest migration recorded over the past 10 years, a single daytime catch yielded 45,817 smolts, equivalent to 59% of the total seasonal smolt catch of 77,055 in 2015. The total catch numbers are shown graphically in Figure 4

Table 1. Hourly shutdowns in 2015 (black dots) and recommended shutdown schedule (20:00 - 02:00 hours) designed for optimal smolt protection (red-shaded cells). Numbers in the top row indicate time of day.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Apr. 20	•	•	•	•	•	•	•														•	•	•	•
Apr. 21	•	•	•	•																	•	•	•	•
Apr. 22	•	•								•	•	•	•	•								•	•	•
Apr. 23	•	•	•	•	•	•																•	•	•
Apr. 24	•	•	•	•	•	•																•	•	•
Apr. 25	•	•	•																			•	•	•
Apr. 26	•	•																				•	•	•
Apr. 27	•	•	•	•	•	•	•	•	•	•	•	•	•	•								•	•	•
Apr. 28	•	•	•																		•	•	•	•
Apr. 29	•	•																			•	•	•	•
Apr. 30	•	•	•																		•	•	•	•
May 1	•	•	•																		•	•	•	•
May 2	•	•																			•	•	•	•
May 3	•	•	•	•																	•	•	•	•
May 4	•	•	•																		•	•	•	•
May 5	•	•																			•	•	•	•
May 6	•	•																			•	•	•	•
May 7	•	•	•																		•	•	•	•
May 8	•	•	•	•																	•	•	•	•
May 9	•	•	•																			•	•	•
May 10	•	•	•	•	•	•	•															•	•	•
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May 17	•	•																			•	•	•	•
May 18	•	•																				•	•	•
May 19	•	•																			•	•	•	•
May 20	•	•							•	•	•	•	•	•	•	•								

Table 2. Total and maximum daily catches of sockeye smolts between 2006-2015.

	Total Catch	Total nighttime Catch	Total daytime Catch	Daytime - Nighttime ratio	Maximum 1-day catch (nighttime)	Maximum 1-day catch (daytime)
2006	34,143	34,143	---------	---------	6,705	---------
2007	43,450	43,450	---------	---------	7,059	---------
2008	8,694	7,026	1,668	0.19	632	731
2009	18,048	13,486	4,562	0.25	1,641	717
2010	27,335	20,532	6,803	0.25	3,096	2,167
2011	144,128	136,388	7,740	0.05	12,177	1,561
2012	249,979	129,153	120,826	0.48	40,574	45,817
2013	16,330	15,534	796	0.05	1,540	141
2014	39,492	34,447	5,045	0.15	5,706	592
2015	77,055	69,980	7,075	0.10	23,518	1,200

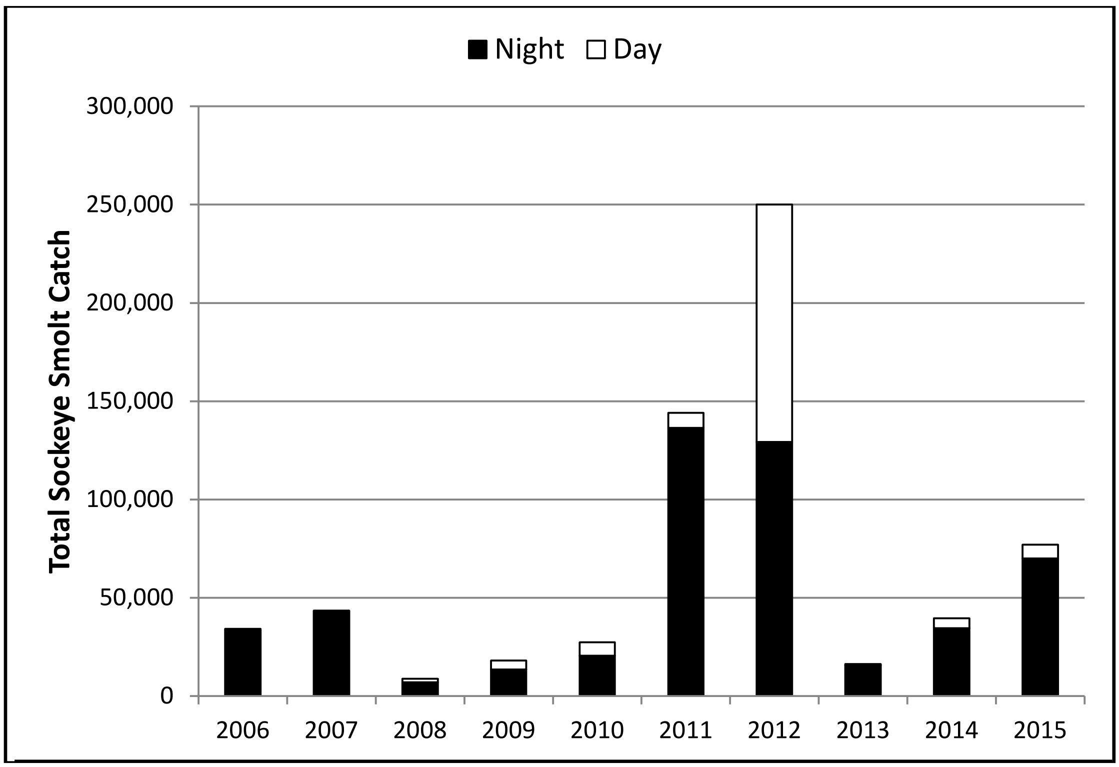

Figure 4. Smolt catches in daytime and nighttime periods between 2006-2015. There was no daytime sampling undertaken in 2006 and 2007.

2.2.2 Seasonal Migration Timing

As in previous years, the smolt outmigration spanned the period between mid-April through the termination of sampling at the end of May. Figure 5 shows the nighttime and daytime smolt catch results. Seasonal catches in 2015 were distributed over time in a similar fashion as in previous years and showed an intermediate level of abundance, consistent with the total catch and maximum 1-day catch data (Table 2).

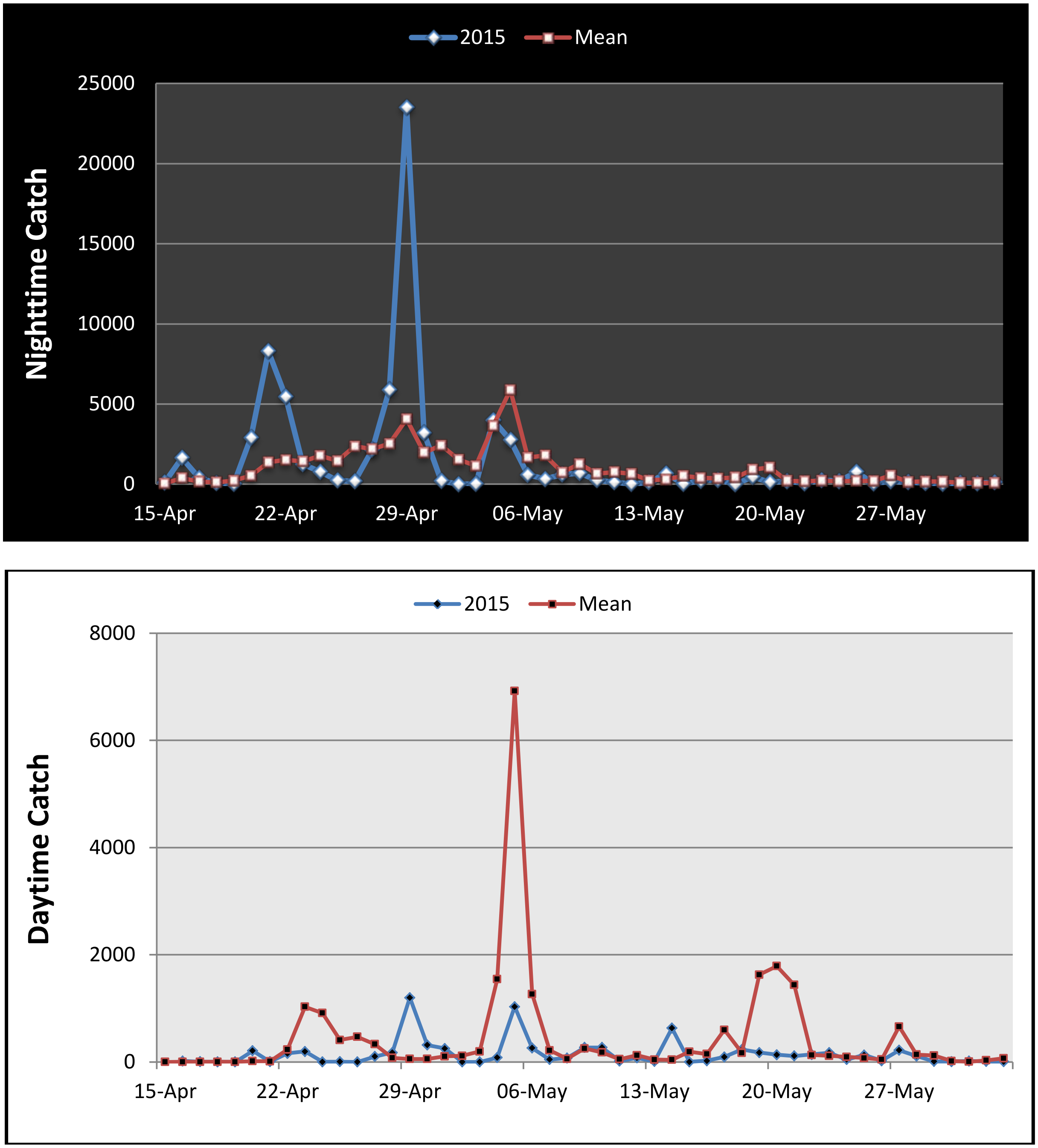

Figure 5. Night vs. daytime smolt catches in 2015 compared with 2006-2015 mean.

Comparison of the mean proportion of smolt catches over the migration period (Figure 6) indicated different patterns between nighttime and daytime. Whereas the nighttime proportions were relatively uniformly distributed (seasonally), there was a higher proportion of daytime migrators from May onwards at the tail end of the migration with only low proportions occurring during April[1].

[1] There was no daytime sampling during the month of April in 2009 and 2010.

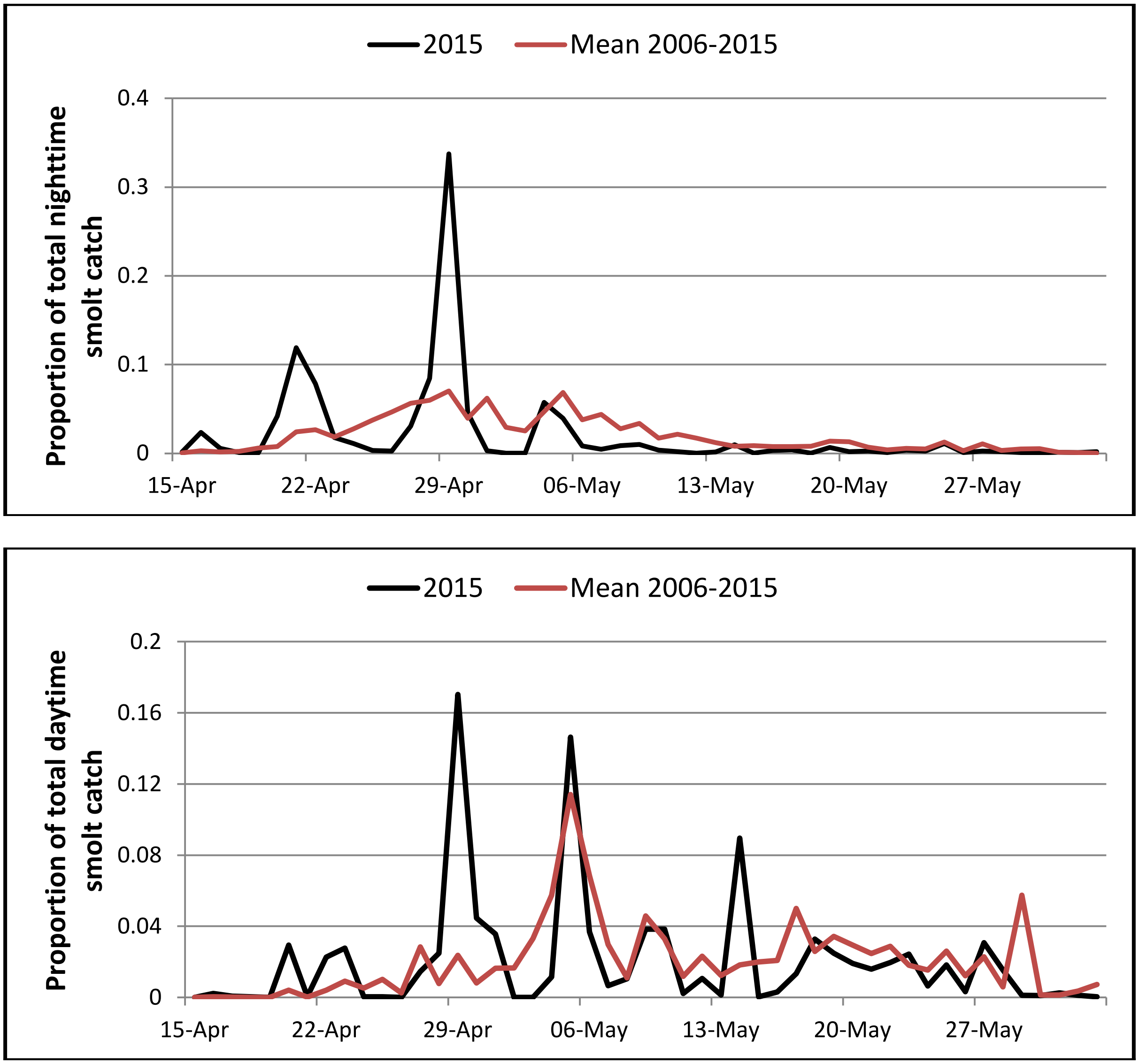

Figure 6. Seasonal proportions of nighttime (upper) and daytime (lower) smolt catches.

As in previous years, the catch data were transformed into time-density plots (Mundy 1982) to measure the median migration dates and to compare migration patterns between years (Figure 7). The median migration dates in 2015 were April 28 and May 3 for nighttime and daytime migrations respectively. Median migration dates are May 2 and May 9 for the consolidated data set (Figure 7; upper panel) indicating that both the 2015 nighttime smolt migration were 5 days earlier than in previous years while the daytime migration was about 7 days earlier than average. Median outmigration timing across all of the 9 years shows that daytime migrations on average occur about 1 week later in the outmigration period when compared to nighttime migrations.

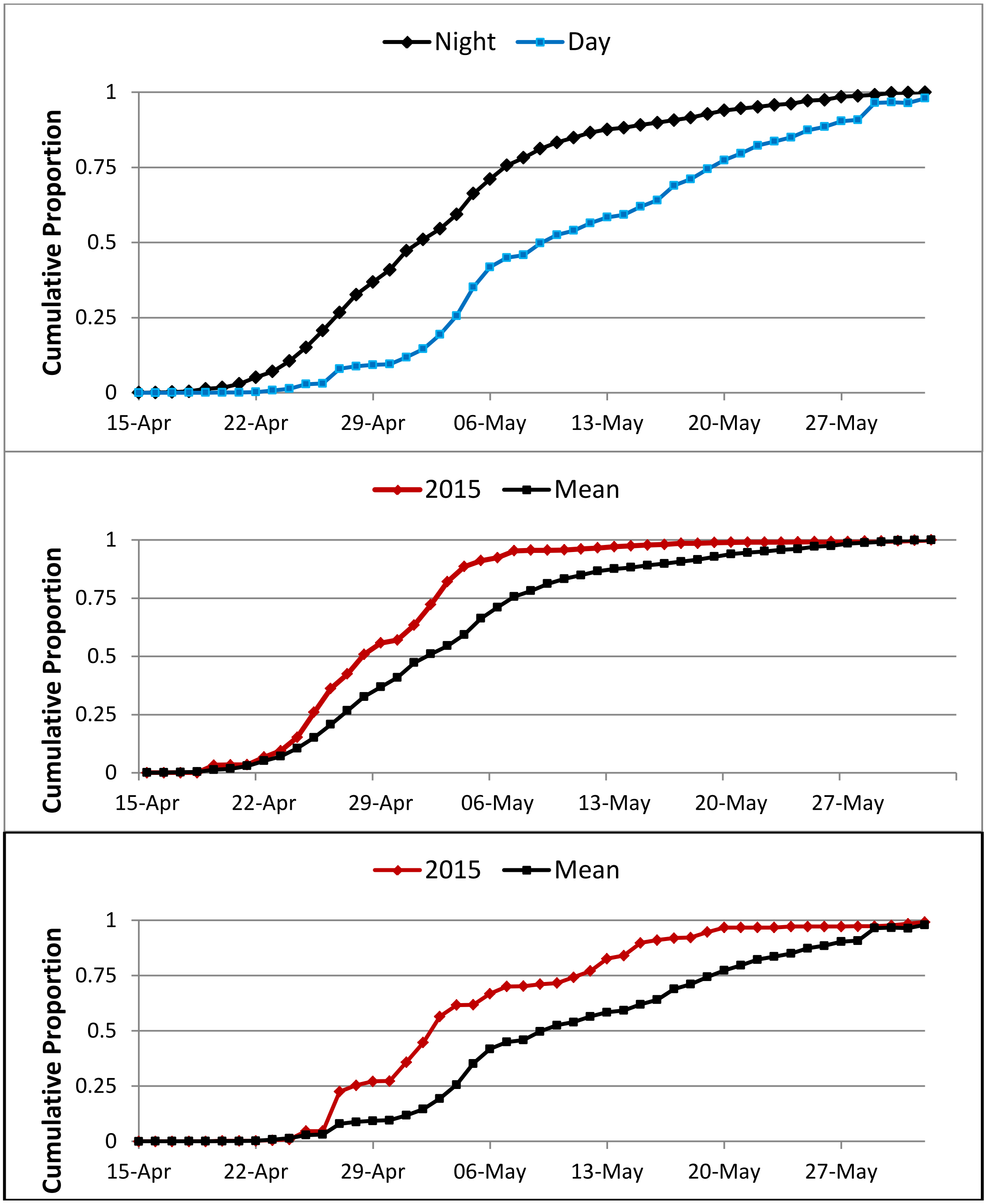

Figure 7. Time-density plots for (top to bottom) 1. 2015 nighttime and daytime proportional catches; 2. mean nighttime proportional catches; and 3) mean daytime proportional catches for the 10 years of observations.

Seasonal timing together with day-night catch comparisons were also evaluated by plotting day and night catch histograms (Figure 8). Patterns varied between years with some years (nightime - 2011) being unimodal, others being skewed (nighttime - 2008 and 2010) and others being multimodal (2012, 2014 and 2015 - both daytime and nighttime periods). The differences between night and day catches were most strongly reflected in the 2011, 2013, 2014 and 2015 data sets.

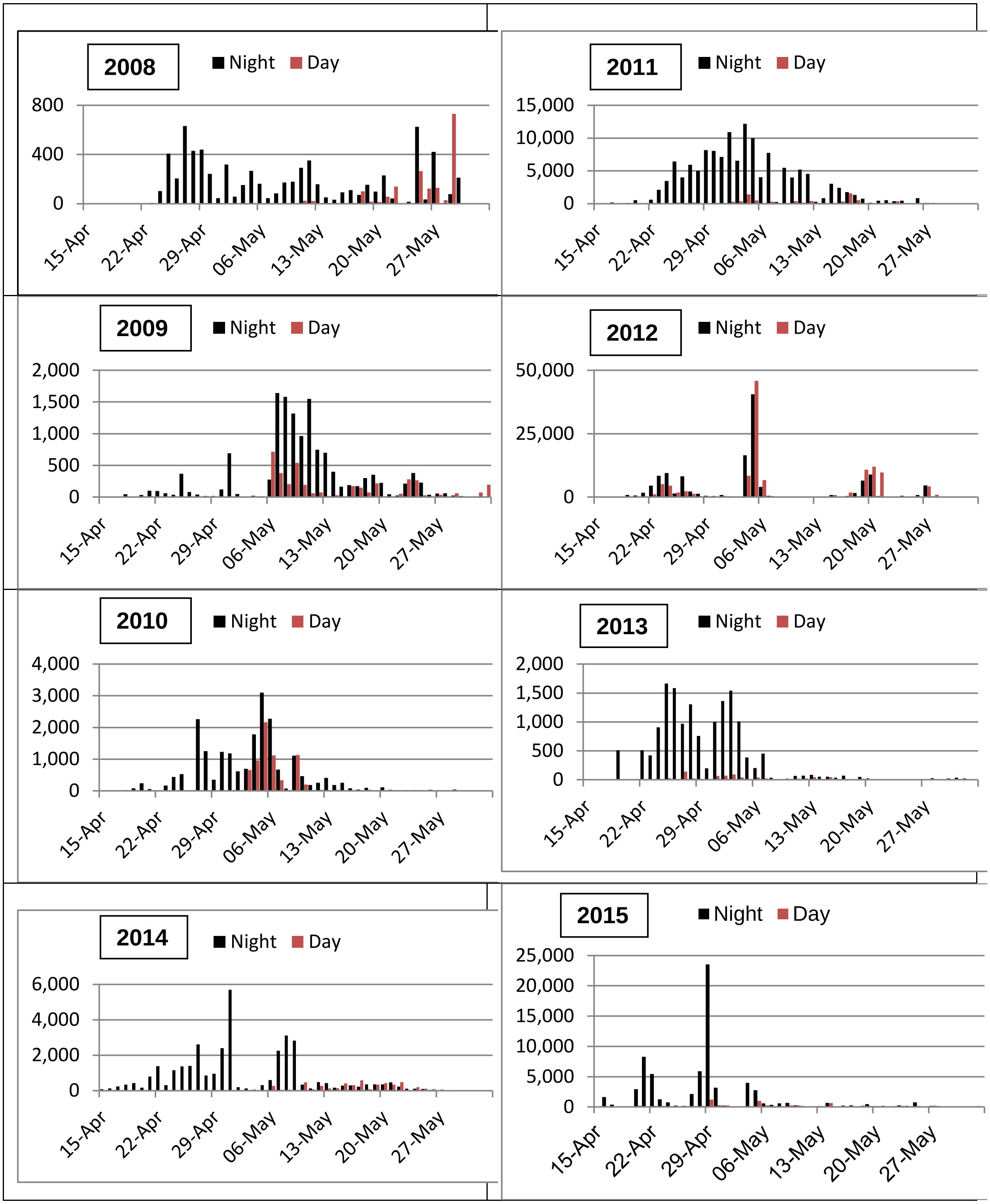

Figure 8. Day and night catch histograms for 2008 - 2015 when daytime and nighttime periods were consistently sampled.

Understanding of smolt diel timing patterns is essential for scheduling 6-h shutdowns so as to maximize the mortality mitigation benefits. In 2006 it was determined that a 6-h period between 20:00 and 02:00 would be optimal for 6-hr duration shutdowns and that has been followed annually. In every year, including 2015 this was the optimal protection window (Figure 9). During 2015, 73% of the nightly migration occurred between 20:00 - 02:00 justifying this diel shutdown scheduling to optimize the protective benefits of the 6-hr shutdowns. In previous years, daytime catches generally increased from early morning through to mid-day/early evening[2] (Figure 9 - lower panel). During 2015 numbers dropped between 15:50 and 20:30 and then increased during the nighttime sampling periods.

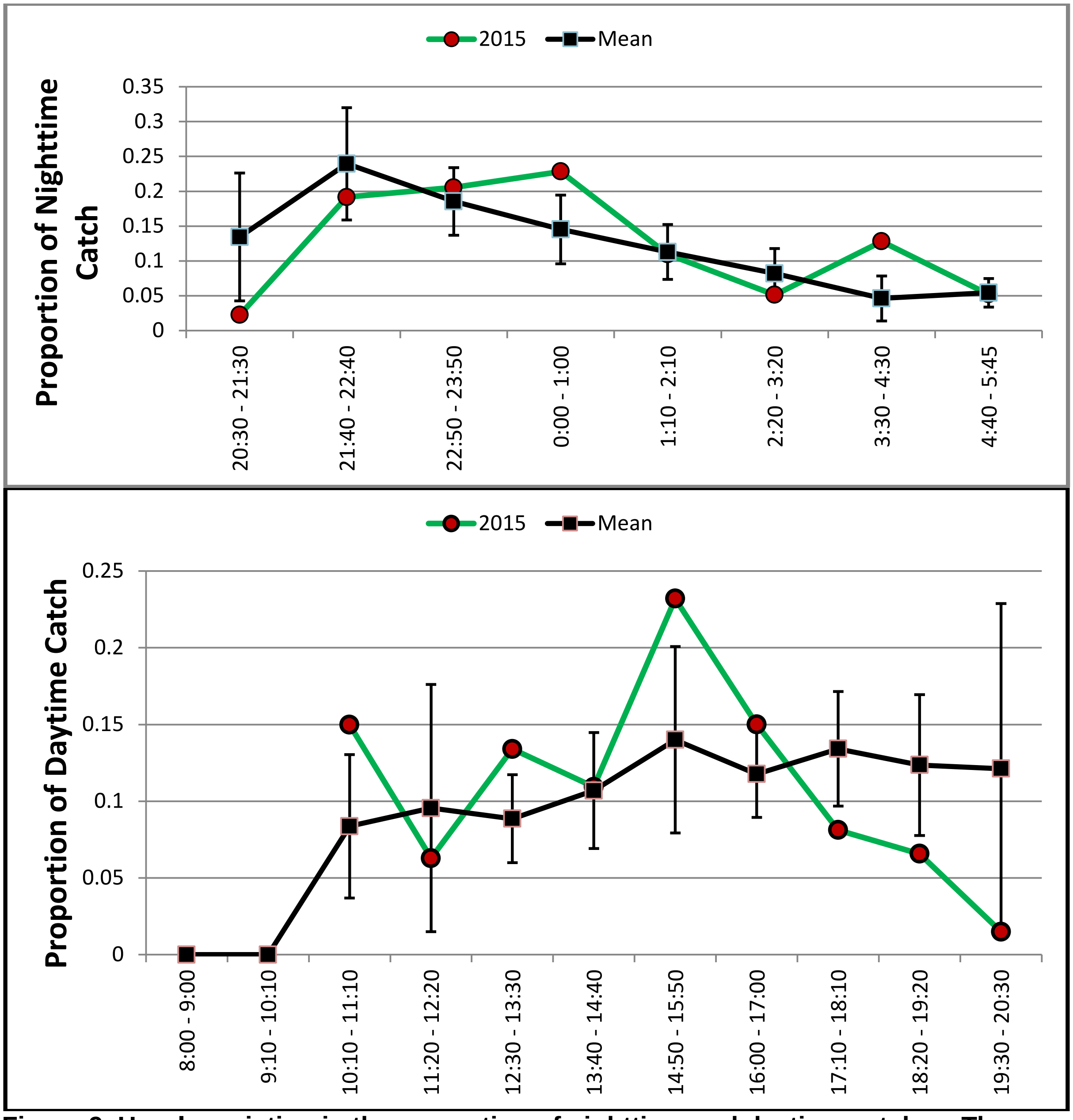

Figure 9. Hourly variation in the proportion of nighttime and daytime catches. The means are calculated from data collected between 2006 - 2015. Error bars show ± 1 standard deviation around the mean.

[2] Sampling did not occur between 06:00 - 10:00 in order to optimize the available personpower within the available budget envelope.

2.2.3 Smolt Size Characteristics

Sockeye smolts have showed large interannual differences in fork length distribution (Table 3, Figure 10). Largest smolts were captured in 2009 (mean = 109 mm) and smallest smolts occurred in 2012 (mean = 77 mm). During 2015, smolts were intermediate sized with a mean fork length of 94 mm. The large variation in body size between years suggests annual variability in Seton and Anderson Lake rearing conditions for sockeye juveniles, although the mechanism involved is presently unknown. Density-dependent relationships between smolt abundance and body size are discussed on p.18.

The size measurements reported below are all based on fork lengths. The fork length data can be converted to wet weights using the regression equation formula shown in Figure 11.

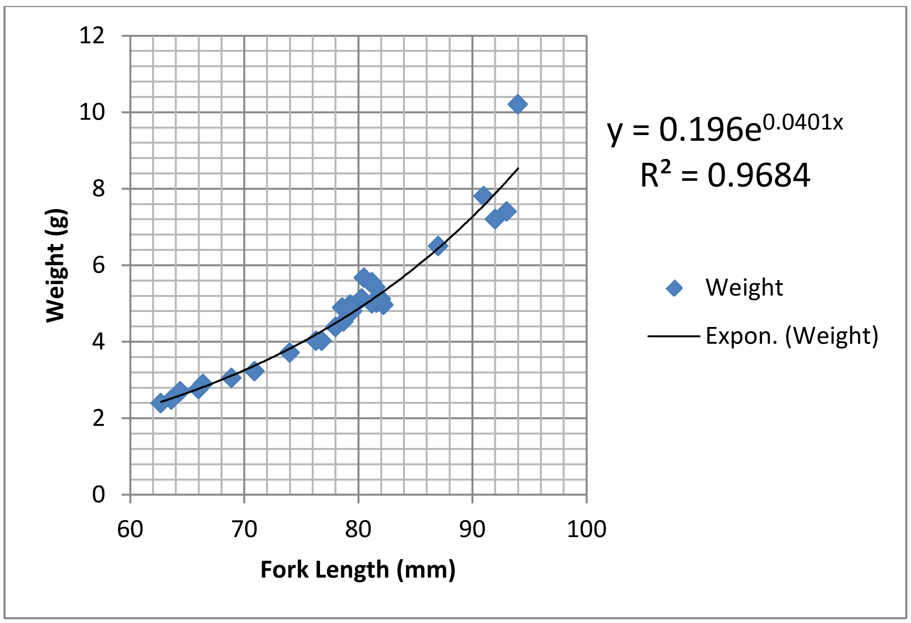

Figure 11. Length-weight regression for sockeye smolts sampled at Cultus Lake. Source: Foerster (1968; Table 73).

Table 3. Mean forklengths of age-1 sockeye smolts captured in the Seton River, by study year.

	Night Sampling			Day Sampling			All Periods		
	Mean	Std Dev	n	Mean	Std Dev	n	Mean	Std Dev	n
2006	93	9	1239	-	-	-	93	9	1239
2007	98	7	1183	-	-	-	98	7	1183
2008	99	6	1049	102	6	394	100	6	1443
2009	109	6	1003	110	6	873	109	6	1876
2010	105	6	1246	106	6	464	105	6	1710
2011	94	7	1555	95	8	921	94	7	2476
2012	77	6	1499	78	6	1414	77	6	2913
2013	100	13	1042	99	12	560	100	13	1600
2014	101	9	1727	100	10	1004	101	10	2732
2015	93	8	1779	95	8	1238	94	8	3017

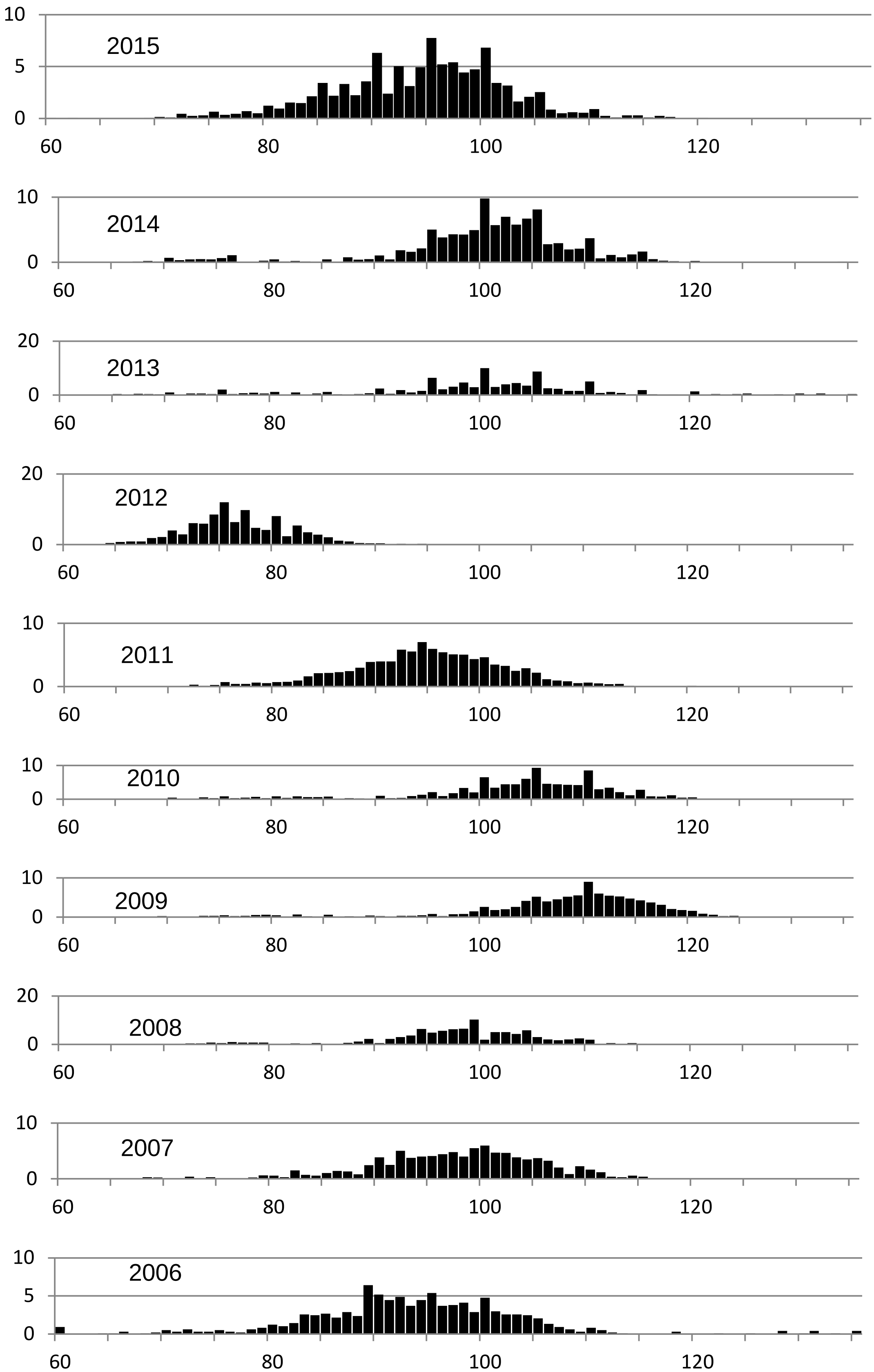

Figure 10. Smolt length frequency histograms for the 10 study years.

To test whether the observed differences in body size (Figure 12) were statistically significant, a 1-way analysis of variance (ANOVA) was undertaken and indicated highly significant fork length differences between years (p-value <<0.05) (Table 3)..

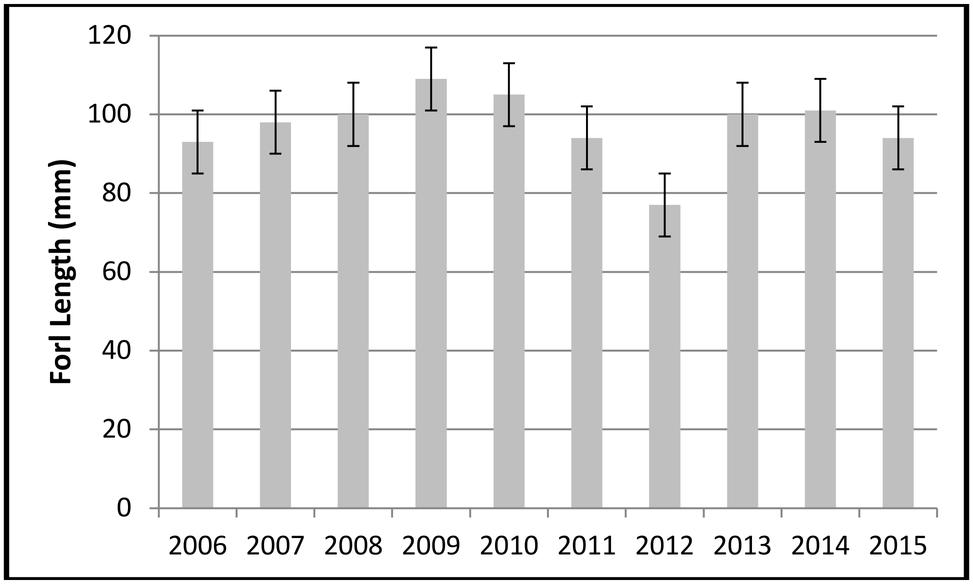

Figure 12. Sockeye smolt fork length time series: mean ± 1 standard deviation.

Table 3. 1-way ANOVA results for smolt size vs. year

Group Name	N (count)	Mean	Std. Dev.
Group 1	1239	93	9
Group 2	1183	98	7
Group 3	1443	100	6
Group 4	1876	109	6
Group 5	1710	105	6
Group 6	2476	94	7
Group 7	2913	77	6
Group 8	1600	100	13
Group 9	2732	101	10
Group 10	3017	94	8

Source of Variation	Sum of Squares	d.f.	Variance	F	p
Between Groups:	1661776	9	184641	2862.56	0.0000
Within Groups:	1301594	20179	64		
Total:	2963370	20188			

2.2.4 DNA Sampling Results

DNA analysis of sockeye specimens was undertaken by DFO's Pacific Biological Station using molecular genetic techniques. A total of 200 sockeye smolts was sampled over the 30-day period between April 20 - May 20 with a target of 7-10 night-time captured smolts sampled per 24-hour period. Samples were analyzed following the end of the field season to determine the stock origin of sockeye smolts migrating down the Seton River.

Results obtained during 2015 (Figure 13) suggested temporal separation of smolts originating from the two sockeye populations in the Seton system: Gates Creek and Portage Creek. Gates Creek smolts migrated earlier than Portage Creek smolts. Median migration dates in the 2 populations were May 4 and May 7, respectively (Figure 14).

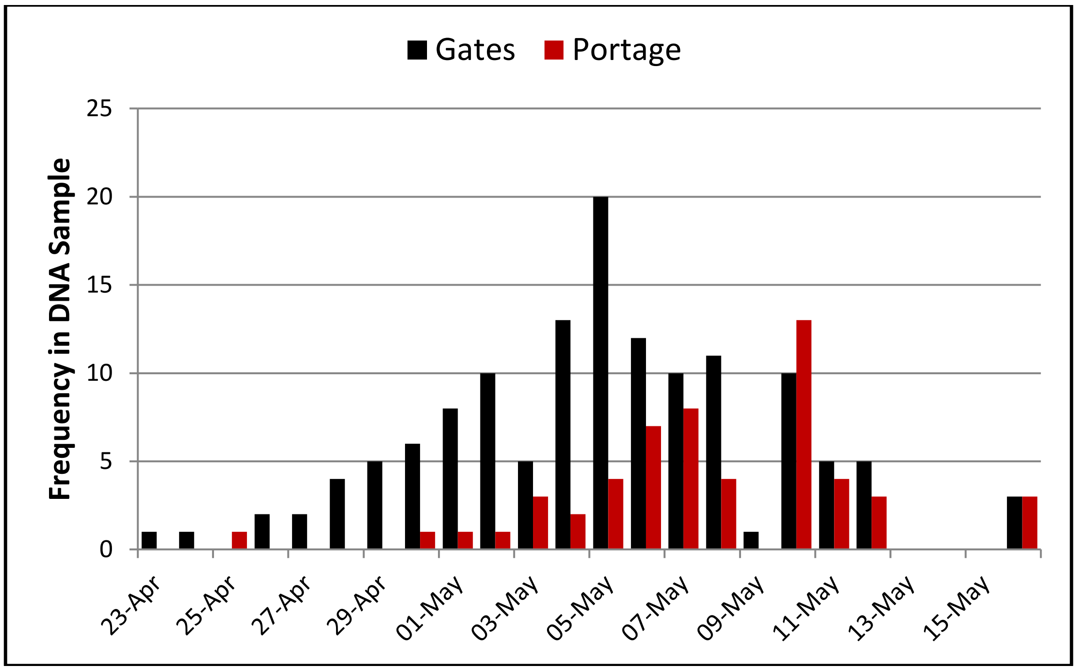

Figure 13. Results of DNA sampling.

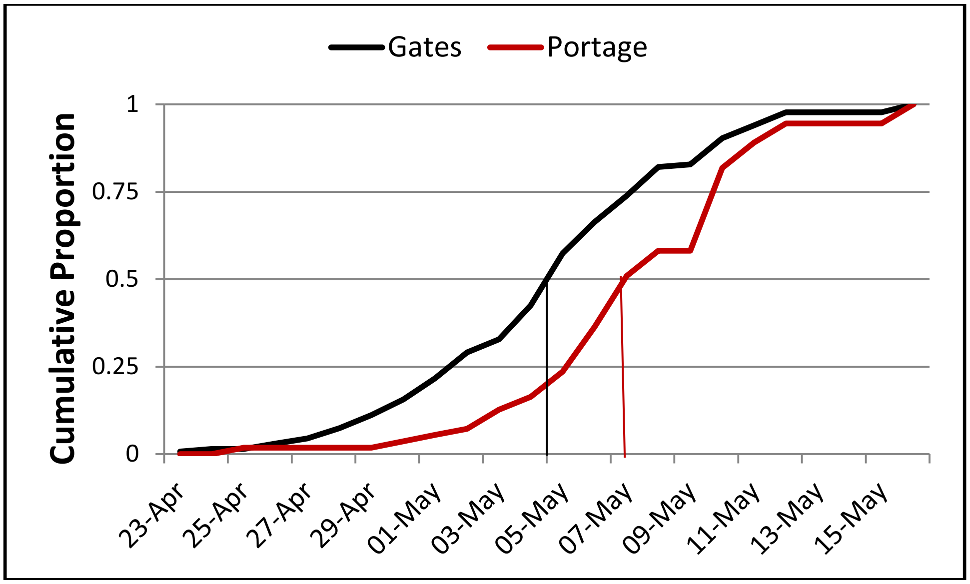

Figure 14. Time density plot for sockeye smolts migrating down the Seton River.

2.2.5 Smolt Abundance

Smolt abundance was determined by the Peterson mark-recapture method. The equation that calculates population size is:

$$N = MC/R$$

where N = population size
M = number smolts marked
C = number smolts captured in the sample
R = number of recaptures

Tables 4 and 5 show the mark recapture statistics for 2006 - 2015 during nighttime and daytime releases respectively. The dye experiments are run somewhat opportunistically depending on the availability of smolts from previous IPT catches. Experience has shown that dye-marked fish disperse out of the Seton River within several hours so each batch of dyed fish doesn't comingle with previous marked batches.

Table 4. Summary of nighttime mark-recapture experiment results (stratified by discharge) from the Seton River IPT, 2006 to 2015.

Study Year	Seton River Q ($m^3 \cdot s^{-1}$)	# of Trials	# of Marks Released	# of Marks Recaptured	% Recapture
2006	25 to 30	1	311	22	7.07
2007	25 to 30	1	416	26	6.25
	50+	3	1049	60	5.72
2008	25 to 30	3	1034	82	7.93
	31 to 35	1	660	38	5.76
2009	25 to 30	4	2310	212	9.18
2010	25 to 30	3	1012	105	10.38
2011	31 to 35	7	1517	90	5.93
2012	25 to 30	5	602	68	11.3
2013	25 to 30	2	248	18	7.26
2014	25 to 50	4	904	52	5.75
2015	25 to 50	3	630	55	8.73
All years	25 to 50	37	10,693	828	7.27

Table 5 Summary of daytime mark-recapture experiment results from the Seton River IPT, 2006 to 2015.

Study Year	Seton River Q ($m^3 \cdot s^{-1}$)	# of Trials	# of Marks Released	# of Marks Recaptured	% Recapture Rate
2008	31 to 35	2	590	58	9.83
2009	25 to 30	2	1048	54	5.15
2010	25 to 30	1	386	25	6.48
	31 to 35	1	383	23	6.01
2011	31 to 35	5	748	62	8.29
2012	25 to 30	5	492	47	9.55
2013	25 to 30	1	119	6	5.04
2014	25 to 50	4	1236	38	3.07
2015	25 to 50	1	200	17	8.50
All years	25 to 50	22	5202	330	6.88

In 2008 when an IPT was fished in the powercanal and mark-recapture experiments were conducted, 84% of the smolts were estimated to migrate via the powercanal when the power canal discharge was ca. 80 cms (Levy et al. 2008). This entrainment rate estimate has been utilized in all of the annual calculations of smolt abundance, including 2015.

There were 4 mark-recapture trials below the dam in 2015 (3 nighttime and 1 daytime) which yielded recapture rates of 8.73% during nighttime and 8.50 % during daytime. During previous years different approaches have been adopted to estimate smolt population size.[3]

[3] The different approaches have involved either the estimation of the hourly exposure of smolts under different operating conditions or mark-recapture experiments conducted above and below the dam.

and mortality rate. During 2015, the following procedure was applied for both daytime and nighttime calculations (Appendix 1):

1) summarize the hourly trap catches by date in a date x time matrix,
2) scale the matrix by the inverse of recapture rate to obtain Seton smolt population estimates by day and by night,
3) expand the matrix to estimate the power canal population on an hourly basis by taking the Seton River smolt count multiplied by 0.84 (power canal diversion rate) and divided by 0.16 (proportion that passed through the Seton Dam),
4) sum the hourly values to obtain daily values,
5) estimate turbine mortality by multiplying the hourly powercanal population by 0.17 (assumed mortality rate utilized since 2006; Groves and Higgins 1995),
6) sum the hourly mortalities to obtain total mortality rate

Table 6 provides the annual time series of population estimates; the 2015 estimate was 1,019,000 , an intermediate level of smolt abundance over the 10-year time series.

Table 6. Total population estimates for Seton-Anderson sockeye smolts.

Year	Seton River (Night)	Seton River (Day)	Power Canal (Day + Night)	Total Smolt Pop
2015	87,980	10,671	820,645	1,019,300
2014	583,800	163,900	1,588,900	2,336,600
2013	188,000	10,700	253,000	452,000
2012	1,550,000	1,662,000	2,851,000	6,100,000
2011	3,074,000	102,700	1,656,100	4,800,000
2010	237,300	117,500	54,800	174,600
2009	166,500	99,700	46,100	312,300
2008	106,500	19,000	417,700	543,200
2007	889,900	220,000	1.070,000	2,200,000
2006	618,500	160,000	990,000	1,800,000

Seton sockeye smolt populations displayed a density-dependent effect of population size on smolt growth (Figure 14). Similar density dependence has been demonstrated for sockeye smolts in other sockeye lakes including Quesnel and Shuswap (DFO unpublished), Babine (Johnson 1958), Owikeno (Ruggles 1966) and various Alaskan lakes (Kyle et al. 1997).

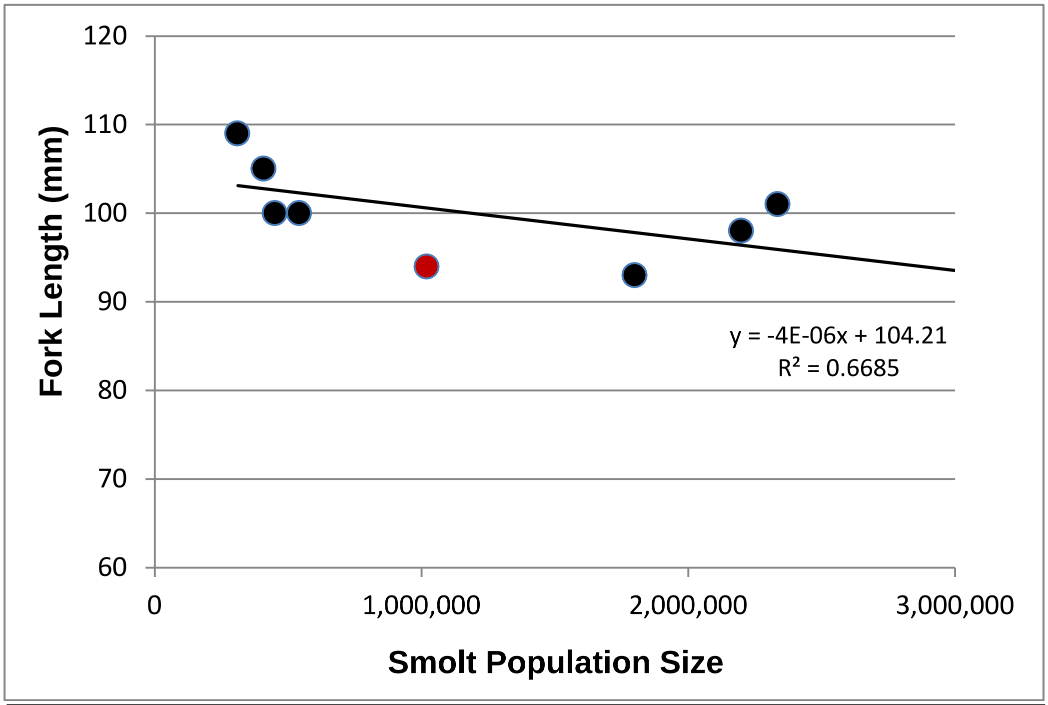

Figure 14. Smolt abundance vs. body size in the Seton River between 2006 - 2015. 2015 data point shown in red.

2.2.6 Smolt Mortality

Table 7 provides the estimated mortality rate across 8 years of monitoring. The results are shown graphically in Figure 15 relative to the 5% mortality rate target.

Table 7. Summary of estimated mortality rates for Seton-Anderson sockeye smolts, 2006 to 2014.

Study Year	Mortality Rate Estimate (%)
2015	7.5
2014	0
2013	9.5
2012	8.0
2011	7.1
2010	4.0
2009	4.2
2008	13.5[4]
2007	-
2006	-

[4] Power canal sampling in 2008 precluded some plant shutdowns, contributing to a higher mortality estimate for that year.

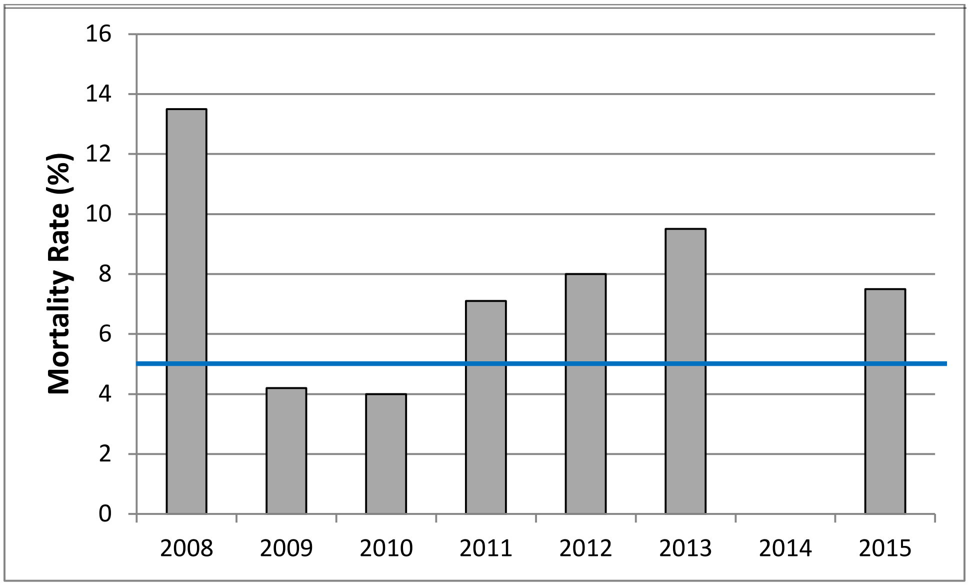

Figure 15. Time series of sockeye smolt mortality estimates relative to a 5% mortality rate target.

3.0 Discussion and Recommendations

The Seton smolt monitoring program was implemented in 2015 for the 10th consecutive year. The primary purpose of the program is to monitor the effectiveness of smolt mortality mitigation via nightly plant shutdowns. The mortality target, as specified in the St'at'imc Hydro Agreement, is 5%. As shown in Table 6 this mortality rate has been exceeded in some years due to non-optimal nightly shutdown timing (i.e. 20:00 - 02:00) in relation to peak smolt migrations. During 2015, entrainment mortality was estimated at 7.5%, above the 5% mortality target.

In order to optimize smolt protection benefits, It is recommended that attempt should be made to schedule 24 h maintenance shutdowns between April 20 - May 20 where practical as this timing would minimize turbine entrainment and would also protect daytime migrators when there are no scheduled daily shutdowns. Daytime migrations can be a significant component of seasonal migration in some years as occurred in 2012 when high numbers of smolts migrated during daytime (Table 6), exceeding the nocturnal smolt counts.

During the smolt migration in 2015 Seton River discharge was stable and varied between 27 - 31 cms making it unnecessary to adjust the counts due to seasonal discharge differences.

The smolt population size in 2015 was 1,019,000 which represents an intermediate level of abundance over the 10-year time series. The lowest population observed was 312,000 smolts in 2009 and the largest was 6,100,000 smolts in 2012. Smolts were average-sized in 2015 (mean fork length = 94 mm, standard deviation = 8). Seton River smolts originate in 1 of 2 spawning areas: Gates Creek and Portage Creek. Gates Creek sockeye comprise part of the Early Summer sockeye run to the Fraser, while Portage Creek sockeye are Late Run. In future, the BRGMON 13 and BRGMON 6 will collaborate to enumerate the relative numbers of Gates and Portage smolts by means of DNA analysis to determine whether there are downstream timing migration differences in the 2 populations.

During 2015, daytime migrators comprised 9% of the total trap catches (Table 2). During the 2012 migration, the year when highest numbers of daytime migrators were observed, 48% of the trap catches occurred during daytime. In both years there was a seasonal time lag in outmigration behavior, with peak daytime migrations occurring about 1 week later than peak nighttime migrations (Figure 6). This pattern is also reflected in Figure 7.These observations suggest that the propensity of smolts to migrate during the daytime increases over the season due to physiological factors related to overall life cycle migration timing.

As in previous years, the greatest percentage (73%) of the 2014 nighttime migration occurred between the hours of 20:00 - 02:00. This pattern has been highly consistent between years and verifies the effectiveness of the 20:00 - 02:00 plant closures.

The observation of density-dependent growth (Figure 14) for sockeye smolts in the Seton-Anderson system suggests the operation of a within-lake growth and survival mechanism. The 2015 data point falls slightly below the trend line generated by the 10-year data set. In view of the prevailing fry migration pattern involving the rapid dispersal of Gates Creek fry into Seton Lake, this would be the likely habitat where mortality and growth mechanisms would operate. Marine survival of sockeye is related to smolt size; larger smolts survive better (Henderson and Cass 1991). During 2015, there was a medium-high density of average-sized smolts (mean fork length of 94 mm) while in other years e.g. 2012 there was a relatively high number of relatively small smolts (Figure 14).

DNA sampling of sockeye smolts indicated potential differences in migration timing with Gates Creek smolts preceding Portage Creek smolts by 2 days. As 2015 was the first year of DNA sampling carried out by the BRGMON 13 project, it will be informative to repeat the sampling in 2016. The objective would be to verify the timing differences and to evaluate their biological significance.

In view of the extensive 10-year duration of monitoring observations collected by BRGMON 13, it would be timely to implement a modeling approach to estimate smolt entrainment rates. The goal of the program would be to model entrainment rate as a function of the proportional water flow rates in the power canal and the bypass facilities. Field monitoring and potentially experimental flow manipulations could be undertaken to verify the modeling predictions.

4.0 References

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Appendix 1. Data Matrices for Mortality Rate Calculations

Estimated smolts in powercanal by hour and date.

	20	21	22	23	24	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Apr. 20	•	•	•	•	•	•	•	•	•	•	•	•	0	0	0	62	0	0	62	0	124	0	247	0
Apr. 21	•	•	•	•	•	•	•	•	•	•	0	0	0	0	0	0	1112	7844	865	0	0	0	9821	0
Apr. 22	•	•	•	•	•	•	•	0	0	•	0	0	0	0	•	•	•	•	•	124	62	0	12044	0
Apr. 23	•	•	•	•	•	•	•	•	•	•	•	0	0	0	0	62	0	62	0	0	0	0	124	0
Apr. 24	1564	7878	•	•	•	•	•	•	•	•	•	0	0	0	0	0	0	0	0	124	62	0	185	0
Apr. 25	0	1022	•	•	•	•	•	•	120	•	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Apr. 26	0	541	•	•	•	•	•	541	601	•	0	0	0	0	0	62	124	741	4262	926	185	0	6300	0
Apr. 27	782	13952	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	865	3274	0	10809	0
Apr. 28	1924	•	•	•	•	•	•	•	0	•	0	0	0	4756	4571	6547	10191	23594	7535	13835	3088	0	74118	0
Apr. 29	3789	•	•	•	•	•	•	7337	0	•	0	0	0	1174	0	0	1668	14021	432	1606	62	432	19394	0
Apr. 30	6014	•	•	•	•	•	•	•	1143	•	0	0	0	124	432	2409	926	5497	2471	865	0	2779	15503	0
May-01	0	•	•	•	•	•	•	•	0	•	0	0	0	0	0	0	0	0	0	0	0	0	0	0
May-02	0	•	•	•	•	•	•	0	0	•	0	0	0	0	0	0	0	0	0	0	0	0	0	0
May-03	0	•	•	•	•	•	•	•	•	•	0	0	0	0	0	0	0	0	62	1359	3582	0	5003	0
May-04	11667	•	•	•	•	•	•	•	0	•	0	0	0	34032	679	4324	8276	5559	5991	2532	2285	0	63679	0
May-05	3789	•	•	•	•	•	•	16357	0	•	0	0	0	7103	1235	3706	124	0	3582	124	124	0	15997	0
May-06	120	•	•	•	•	•	•	1985	842	•	0	0	0	2162	0	0	0	62	124	494	0	0	2841	0
May-07	60	•	•	•	•	•	•	•	301	•	0	0	0	0	0	0	3088	185	803	494	0	0	4571	0
May-08	0	•	•	•	•	•	•	•	•	•	0	0	0	0	0	2038	2594	3953	3026	1976	3088	0	16676	0
May-09	301	0	•	•	•	•	•	•	301	•	0	0	0	5868	1297	8647	371	494	0	0	0	0	16676	0
May-10	0	1022	•	•	•	•	•	•	•	•	•	•	0	0	0	618	62	0	185	124	0	0	988	0
May-11	0	•	•	•	•	•	•	782	421	•	0	0	0	0	3768	309	62	0	432	0	62	0	4632	0
May-12	0	•	•	•	•	•	•	•	60	•	0	0	0	247	0	0	0	0	62	0	0	309	618	0
May-13	180	•	•	•	•	•	•	•	722	•	0	0	0	0	556	1915	8153	13650	11735	2038	926	0	38974	0
May-14	0	3969	•	•	•	•	•	3428	1624	•	0	0	0	62	0	62	0	0	0	0	0	0	124	0
May-15	0	0	•	•	•	•	120	120	0	•	0	0	0	62	0	0	185	0	494	371	185	0	1297	0
May-16	722	361	•	•	•	•	1263	1443	541	•	0	0	0	0	926	371	0	0	494	62	1050	2903	5806	0
May-17	361	•	•	•	•	•	•	1443	1143	•	0	0	0	185	0	11735	2224	0	62	62	0	0	14268	0
May-18	0	0	•	•	•	•	•	0	0	•	0	0	0	0	185	679	1421	5497	865	2162	0	0	10809	0
May-19	1383	•	•	•	•	•	•	1143	1323	•	0	0	0	371	679	741	0	5806	679	0	0	0	8276	0
May-20	962	902	1383	1082	541	•	•	902	421	•	0	0	0	•	•	•	•	•	•	•	•	0	6918	0
	33617	29648	1383	1082	541	0	1383	35481	9562	0	0	0	0	56144	14329	44285	40579	86965	44224	30141	18159	6424	366697	0

Estimated mortalities in Seton Generator by hour and date.

	20	21	22	23	24	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Apr. 20	0	0	0	0																				
Apr. 21																								
Apr. 22	0	0	0	0													0	0	0	21	11		2048	
Apr. 23	0	0	0	0														11					21	
Apr. 24	266	1339	0	0	0																			
Apr. 25		174	0	0	0																			
Apr. 26		92																126	725	158	32		1071	
Apr. 27																								
Apr. 28																								
Apr. 29																								
Apr. 30														21	74	410	158	935	420					
May-01																								
May-02		0	0																					
May-03																			11	231	609			
May-04															116	735	1407	945	1019	431	389		10826	
May-05														1208	210	630	21		609	21	21		2720	
May-06	20	0	0											368				11	21	84			483	
May-07																	525	32	137	84			777	
May-08		0	0	0	0											347	441	672	515	336	525		2835	
May-09	51		0	0	0									998	221	1470	63	84					2835	
May-10		174	0	0	0	0						0				105	11		32	21			168	
May-11		0	0	0	0										641	53	11		74		11		788	
May-12		0	0	0	0									42					11			53	105	
May-13	31	0	0	0	0	0									95	326	1386	2321	1995	347	158		6626	
May-14		675	0	0	0	0								11		11							21	
May-15			0	0	0	0	20	20		0				11										
May-16	123	0	0	0	0										158	63			84	11	179	494	987	
May-17	61	0	0	0	0									32		1995	378		11	11			2426	
May-18			0	0	0	0	0								32	116	242	935	147	368			1838	
May-19	235	0	0	0	0	0								63	116	126		987	116				1407	
May-20	164	153	235	184	92	0	0							0	0	0	0	0	0	0	0		1176	
	951	2607	235	184	92	0	20	20	0	0	0	0	0	2751	1659	6384	4641	7056	5922	2121	1932	546	39155	0