Bridge River Power Development Water Use Plan

Seton River Sockeye Smolt Monitoring

Implementation Year 2

Reference: BRGMON-13

2013 Data Report

Study Period: April 1, 2013 - March 31, 2014

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October 31, 2013

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 2013 to monitor the seasonal timing, magnitude, and diel migrations of sockeye smolts out of Seton Lake, along with physical conditions in the Seton River. 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 nighttime 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;
- monitoring water temperature and ambient light intensity at the sampling site.

Results from 2013 indicated a relatively low smolt run totaling an estimated 452,000 fish. In an apparent response to the low numbers, sockeye smolts in 2013 were relatively large, suggesting density dependence in growth patterns in Anderson and/or Seton Lakes.

The shutdown schedule in 2013 deviated from the optimum diel scheduling between 22:00 - 02:00 with only 83 out of 180 potential shutdown hours scheduled during the optimum window. In consequence, smolt mortality rate in 2013 was relatively high and was estimated as 9.5 % relative to the 5% mortality target.

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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 smolt entrainment into the Power Canal and subsequent fish passage through the turbine. Smolt mortality rates have been monitored since 2006.

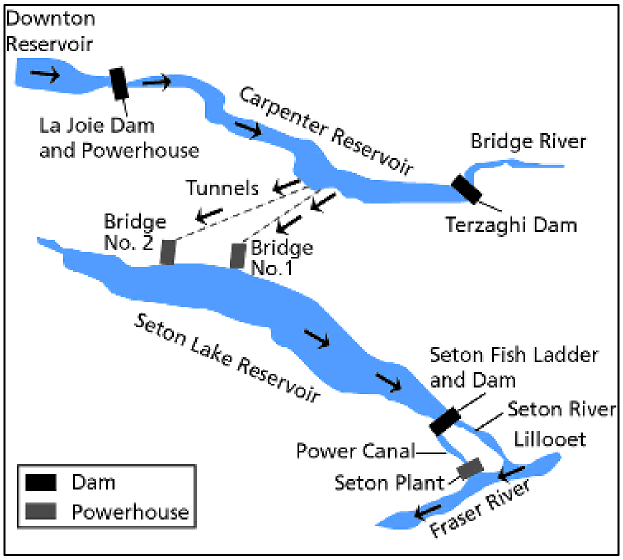

Figure 1. Location of BC Hydro facilities in the Bridge/Seton watersheds.

In view of budgetary considerations, a decision was taken in 2013 to streamline the annual reporting to include full presentation of the data together with a focused and succinct report write-up. Further descriptive information including methods are contained in the previous reports that cover the 7-year monitoring period, as listed below. The reports are available from BC Hydro via the authors upon request. The 2012 report, including a complete description of methods that have been consistently followed since 2006, is posted here Ahmed - can you provide a link?

Date	Authors	Title
2006	D.A. Levy and J. Sneep	Effectiveness of Seton Powerhouse shutdowns for reducing entrainment mortality of sockeye salmon smolts during 2006.
2007	D.A. Levy and J. Sneep	Effectiveness of Seton Powerhouse shutdowns for reducing entrainment mortality of sockeye salmon smolts during 2007.
2008	D.A. Levy, J. Sneep and S. Hall	Effectiveness of Seton Powerhouse shutdowns for reducing entrainment mortality of sockeye salmon smolts during 2008.
2009	D.A. Levy and 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 sampling results.
2011	J. Sneep,S. Hall and Lillooet Tribal Council	Seton River sockeye smolt monitoring program: 2011 sampling results.
2012	J. Sneep, B. Adolph and D.A. Levy	Seton sockeye smolt monitoring in 2012 with a summary of historical data.

2.0 Results

2.1 Physical Characteristics

2.1.1 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 and slightly below 30 cms over the sampling period (Figure 2). The uniformity of flow in 2013 precluding the need for making adjustments to trap catchability during the smolt migration, as was also the case in 2011 and 2012.

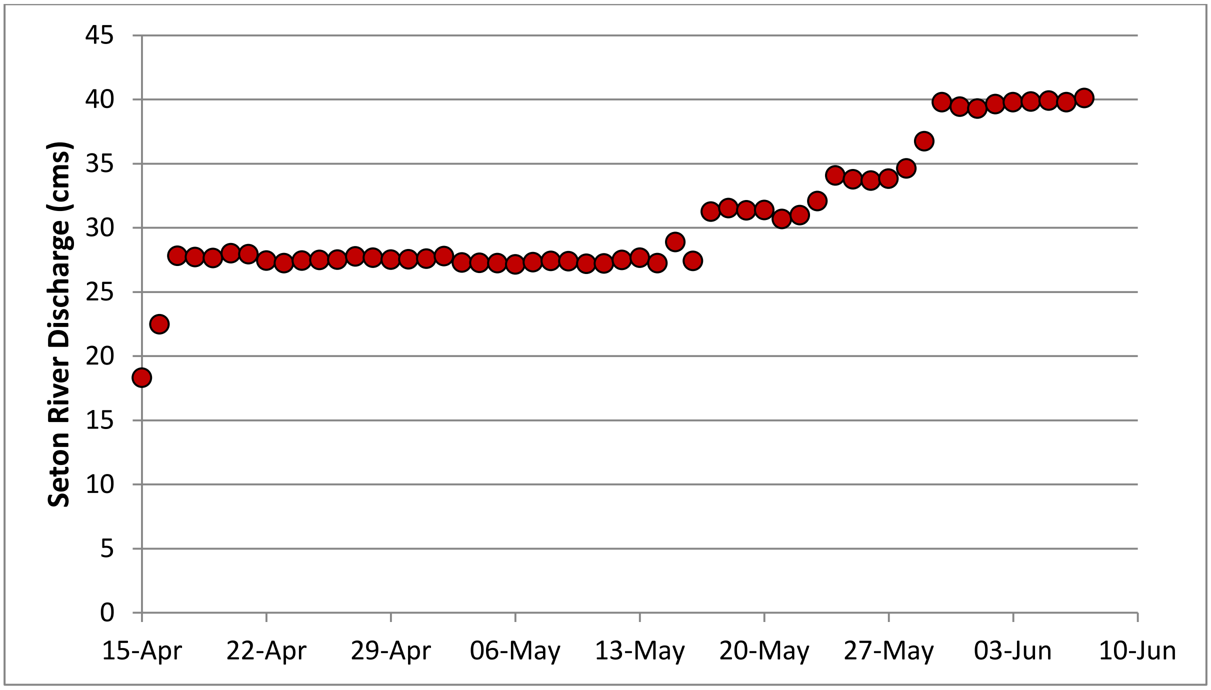

Figure 2. Seton River discharges during the 2013 smolt migration period.

Discharges into the generating station via the powercanal were relatively low during the first part of the smolt migration period between April 22 - May 6 (Figure 3). Thereafter flows increased to around 80 cms until early June. The variation in the powercanal discharge reflects the large number of plant shutdowns and variability in daily powercanal discharges during the smolt migration period.

Due to diel variation in smolt migrations the average daily discharge is less informative than the hourly discharges which reflect shutdown hours in relation to diel smolt migrations. Analysis was undertaken (Table 1) to document plant shutdown periods in relation to the preferred (optimal) operating practice of a 6-hr nightly shutdown period between 08:00 - 02:00. Out of 186 optimal shutdown hours over the period April 20 - May 20, a total of 84 shutdown hours were implemented.

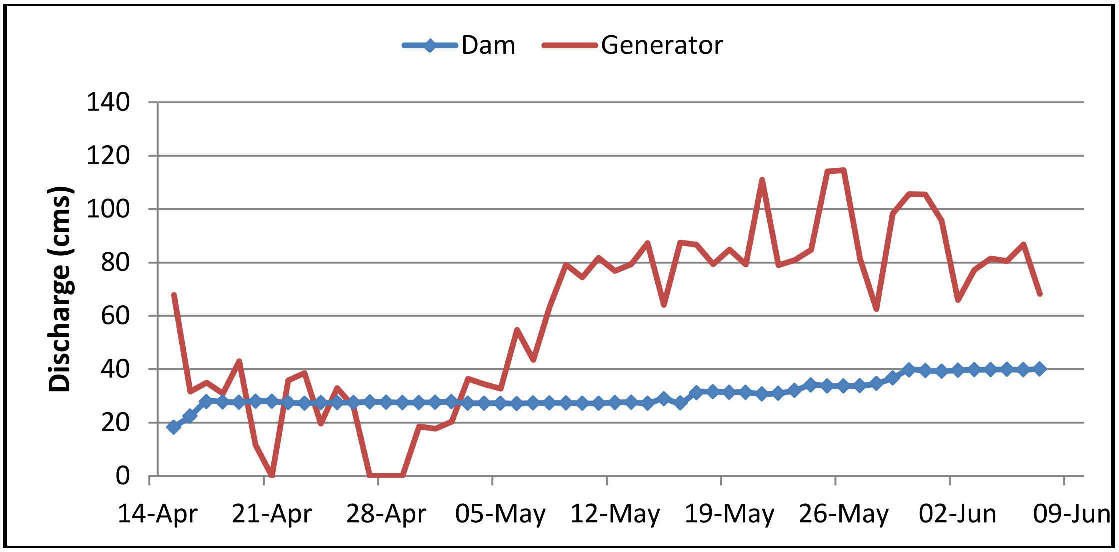

Figure 3. Daily averaged water flows though the generating station and the Seton Dam during the smolt migration period in 2013.

Table 1. Hourly shutdowns in 2013 (black dots) in comparison with 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		•	•	•	•	•																		
May 11	•	•	•	•	•																			
May 12	•	•	•	•	•	•	•																	
May 13		•	•	•	•	•	•																	
May 14		•	•	•	•	•																		
May 15										•	•	•	•	•	•	•	•	•						
May 16	•	•	•	•	•	•																		
May 17	•	•	•	•	•	•																		
May 18			•	•	•	•	•	•																
May 19		•	•	•	•	•	•																	
May 20			•	•	•	•	•																	

2.1.2 Temperature

River and air temperatures throughout the smolt migration are shown in Figure 4. Both hourly and daily temperatures followed a warming trend that was more extreme in 2013 compared to those observed in previous years (Figure 5). It is likely that a temperature of 5^{0}C serves as a migration cue for sockeye smolts (Sneep et al. 2012) and this temperature was surpassed at the start of the migration period. There was a rapid warming In early May and temperatures reached 12^{o}C at the end of the first week of May. None of the previous temperature records since 2006 (Figure 5) surpassed 11^{o}C even at the end of May.

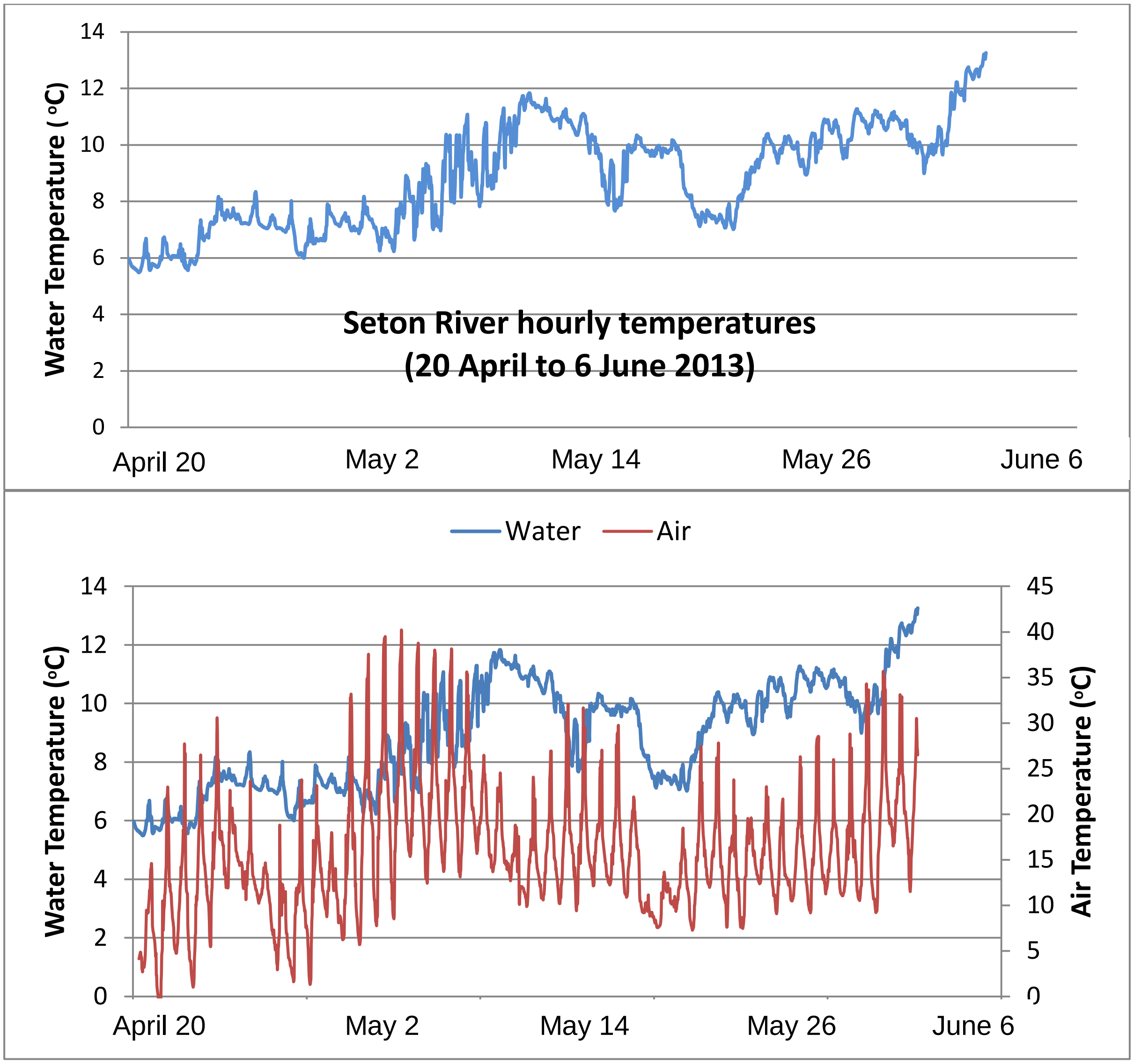

Figure 4. Top: Seton River temperatures; Bottom: Seton River air and water temperatures.

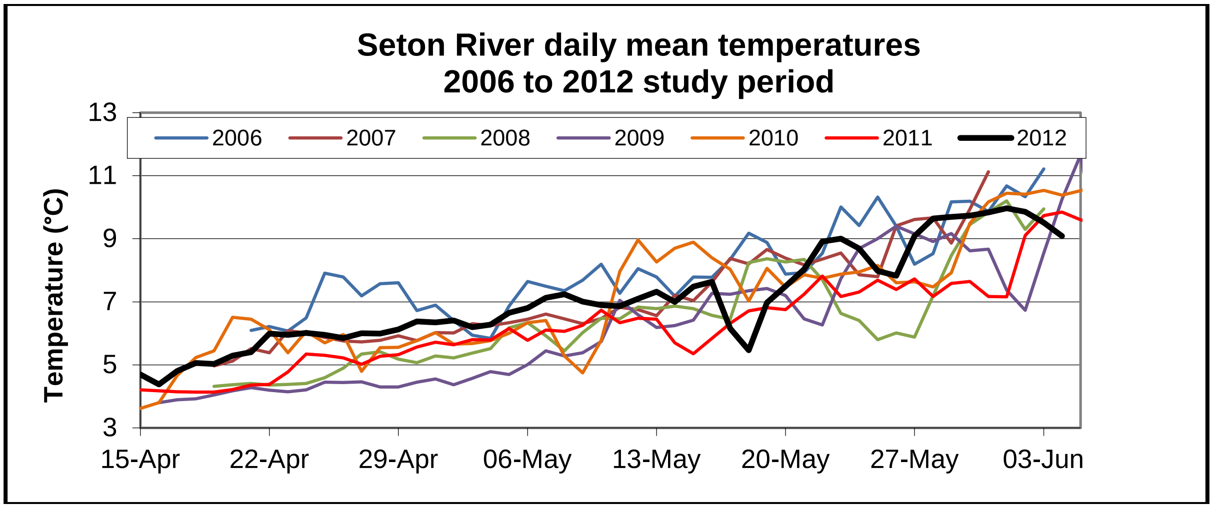

Figure 5. Historical water temperature observations at the smolt trapping site.

Following the rapid heating in early May temperatures moderated and decreased to 7°C by the third week of May, a more typical value for this period in the migration. It was evident (Figure 4 - bottom panel) that changes in air temperature were driving the water temperature fluctuations and co-varied with a time lag of several days. Although the temperature conditions were more extreme in 2013 they were within a "comfortable" range for sockeye smolts.

2.1.3 Light Intensity

Light conditions fluctuated as expected (Figure 6) with relatively low light levels on May 20 and 21. There were 2 full moons during the smolt migration period.

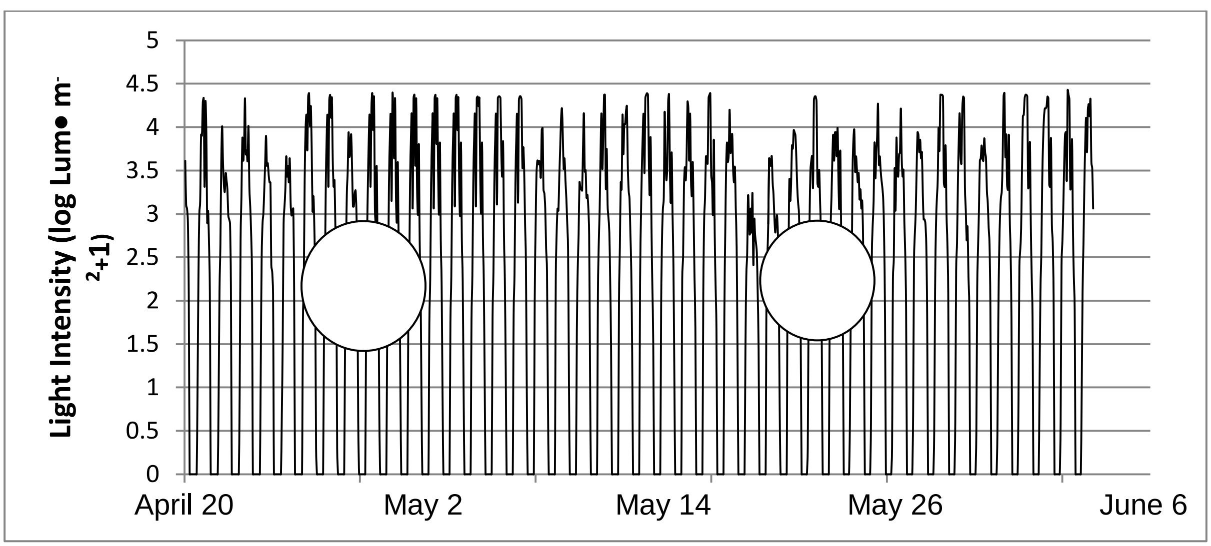

Figure 6. Light conditions at the Seton River sampling site. Circles indicate full moon conditions.

2.2 Sockeye Smolt Monitoring Data

2.2.1 Inclined Plane Trap Catch Data

Compared with 2006-2012 IPT results, catches in 2013 were the second lowest on record; catches in 2008 were the lowest in the time series. 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. Catches in 2013 had the lowest daytime to nighttime catch ratio (5%) in the time series and there were only 796 smolts captured in 30 days of trapping. In contrast, in 2012 a single daytime catch yielded 45,817 smolts, a 58-fold difference. The numbers captured in 2013 were similar to those in 2009 which was the same cycle year (Seton sockeye are 4-yr old animals). The catch numbers are shown graphically in Figure 7.

Table 2. Total and maximum daily catches of sockeye smolts between 2006-2013.

	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

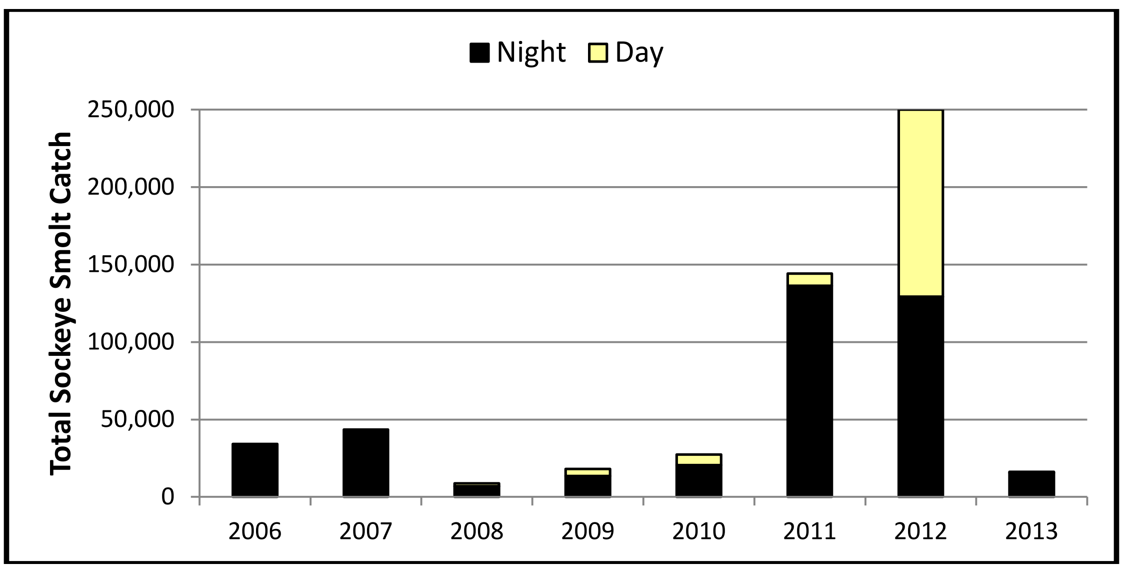

Figure 7. Smolt catches in daytime and nighttime periods between 2006-2013. There was no daytime sampling undertaken in 2006 and 2007.

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 8 shows the nighttime and daytime smolt catch results plotted on a logarithmic axis to effectively display the data which cover 4 orders of magnitude. Seasonal catches in 2013 were distributed over time in a similar fashion as in previous years and lower than all other years except 2008, consistent with the total catch and maximum 1-day catch data (Table 2).

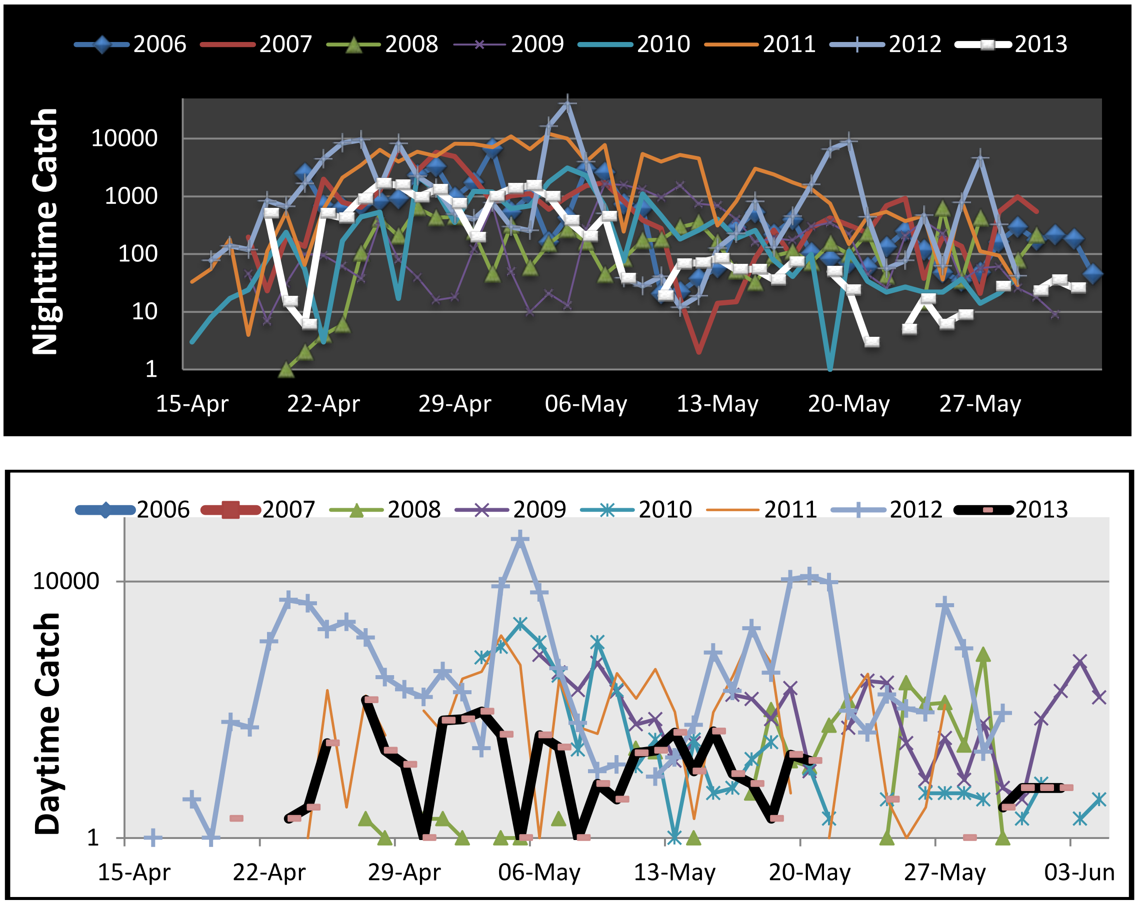

Figure 8. Nighttime vs. daytime catches plotted with a logarithmic axis.

Comparison of the mean proportion of smolt catches over the migration period (Figure 9) indicated different patterns between nighttime and daytime. Whereas the nighttime proportions were 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] The data have been plotted on a log scale due to the large variation (5 orders of magnitude) in the catch records when plotted as a proportion of the annual smolt run.

[1] There was no daytime sampling in April during 2009 and 2010. Daytime sampling during those years commenced in early May so sampling could be extended into June in an attempt to account for the later season daytime migrators (as observed in 2008).

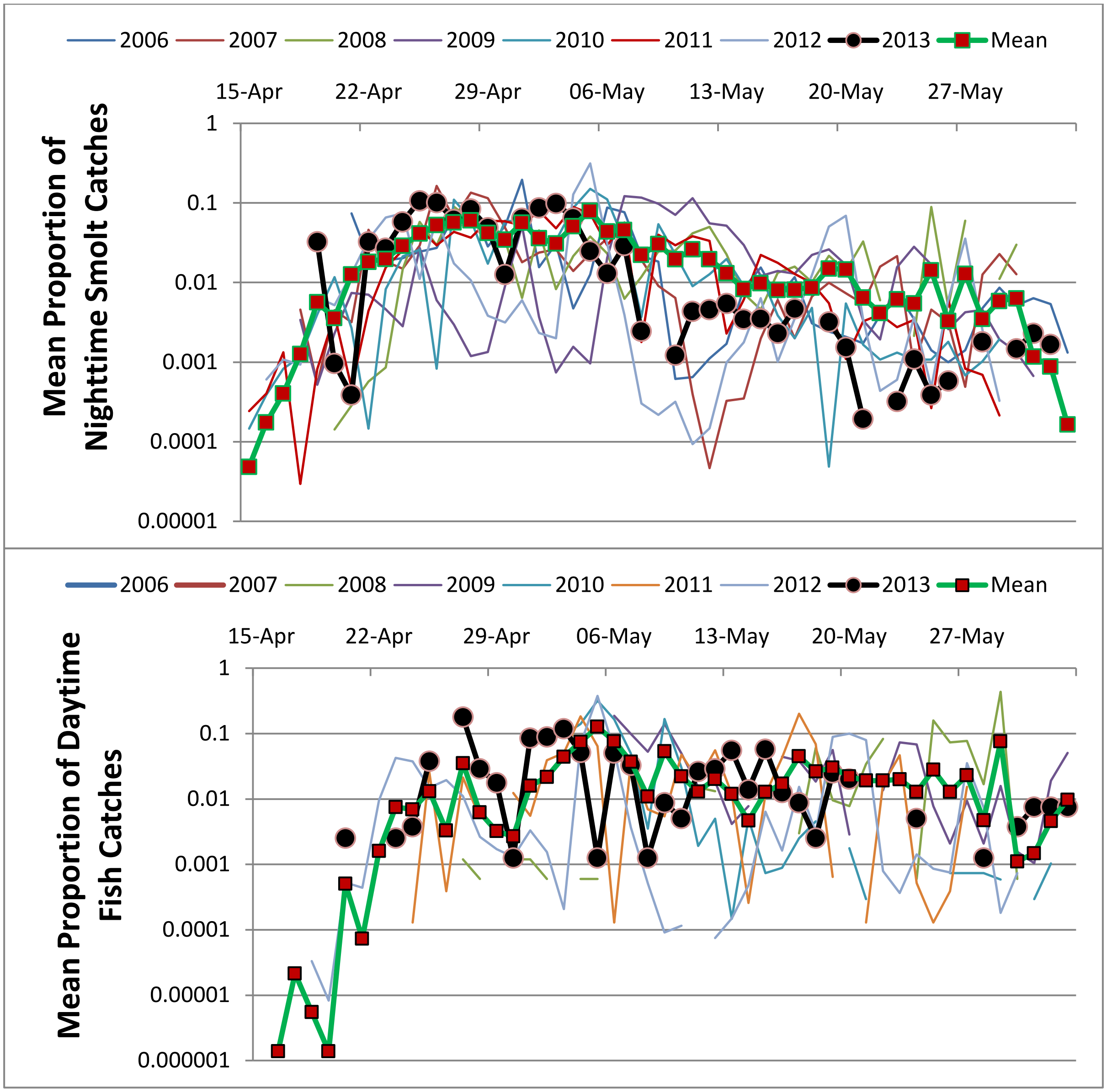

Figure 9. Seasonal proportions of daytime and nighttime smolt catches plotted with a logarithmic axis.

As in previous years, the catch data were transformed into time-density plots to measure the median migration dates and to compare migration patterns between years (Figure 10). The median migration dates in 2013 were April 28 and May 2 for nighttime and daytime migrations respectively. Median migration dates are May 2 and May 9 for the consolidated data set (Figure 10; lower panel) indicating that the 2013 smolt migration was 4-5 days earlier than observed in previous years. Median outmigration timing in 2013 across all of the 8 years shows that daytime migrations on average occur later in the outmigration period, by about 6 days very similar to previously observed values.

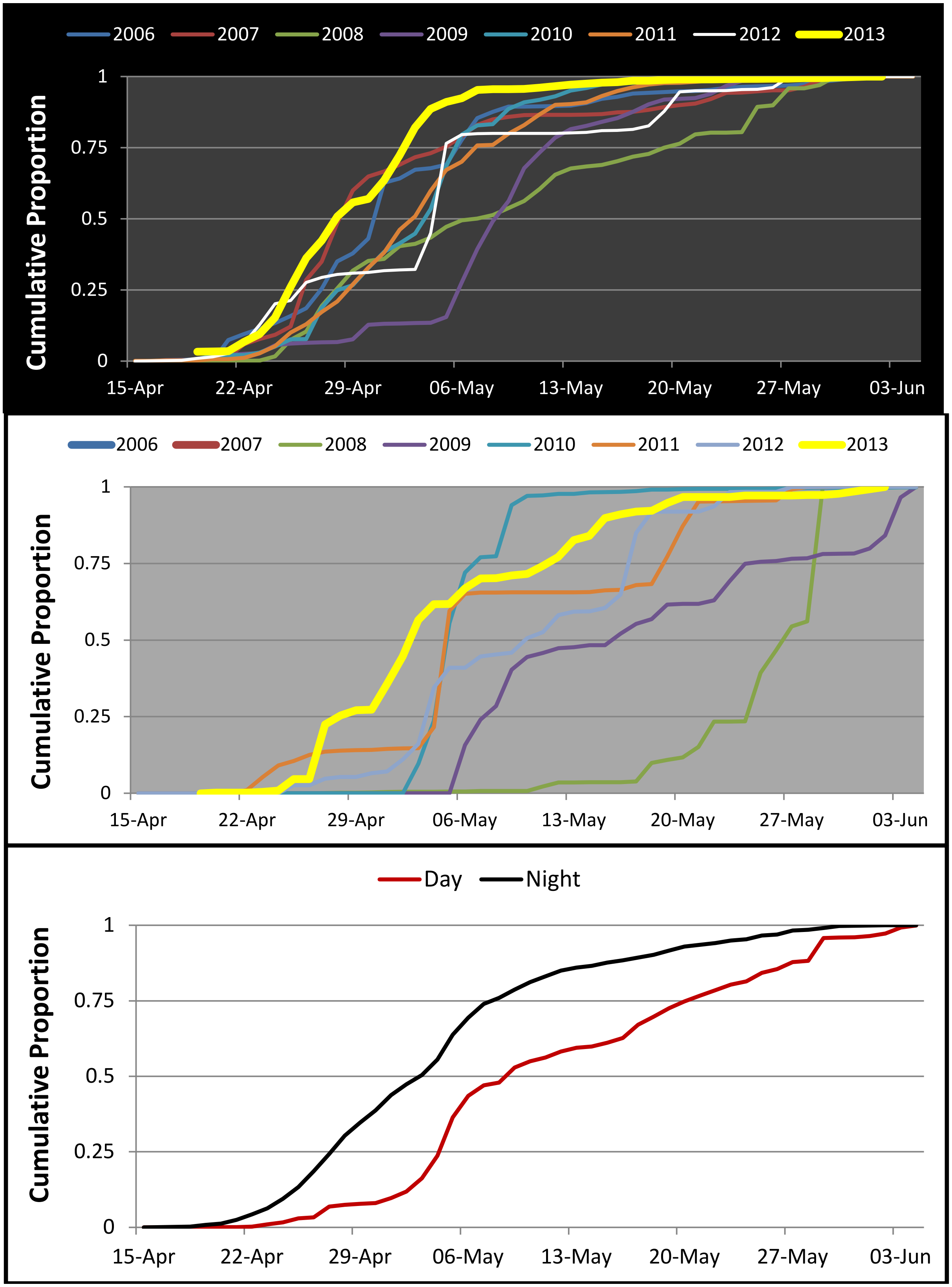

Figure 10. Time-density plots for (top to bottom) nighttime, daytime and average proportional catches for the 8 years of observations.

Seasonal timing together with day-night catch comparisons were also evaluated by plotting day and night catch histograms (Figure 11). Patterns varied between years with some years (nighttime - 2011) being unimodal, others being skewed (nighttime - 2008 and 2010) and others being pulsed (2012 both daytime and nighttime). The differences between night and day catches were most strongly reflected in the 2011 and 2013 data sets.

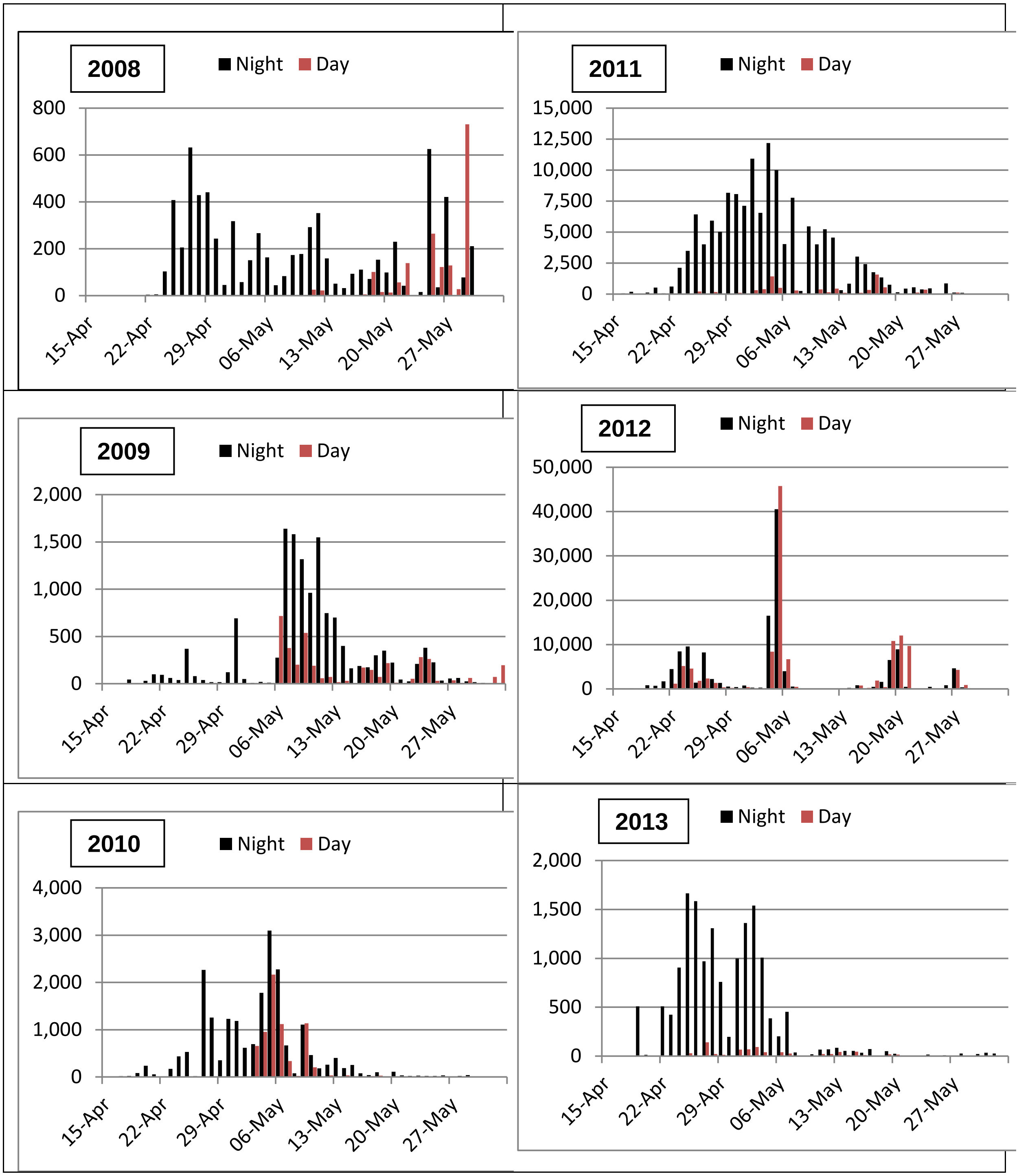

Figure 11. Day and night catch histograms for 2008 - 2013 when daytime and nighttime periods were consistently sampled.

2.2.3 Diel Timing

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, with the exception of 2013 (Table 1). In every year, including 2013 this was the optimal protection window (Figure 12). During 2013, 86% 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. As in previous years, daytime catches generally increased from early morning through to early evening[2] (Figure 12 - lower panel).

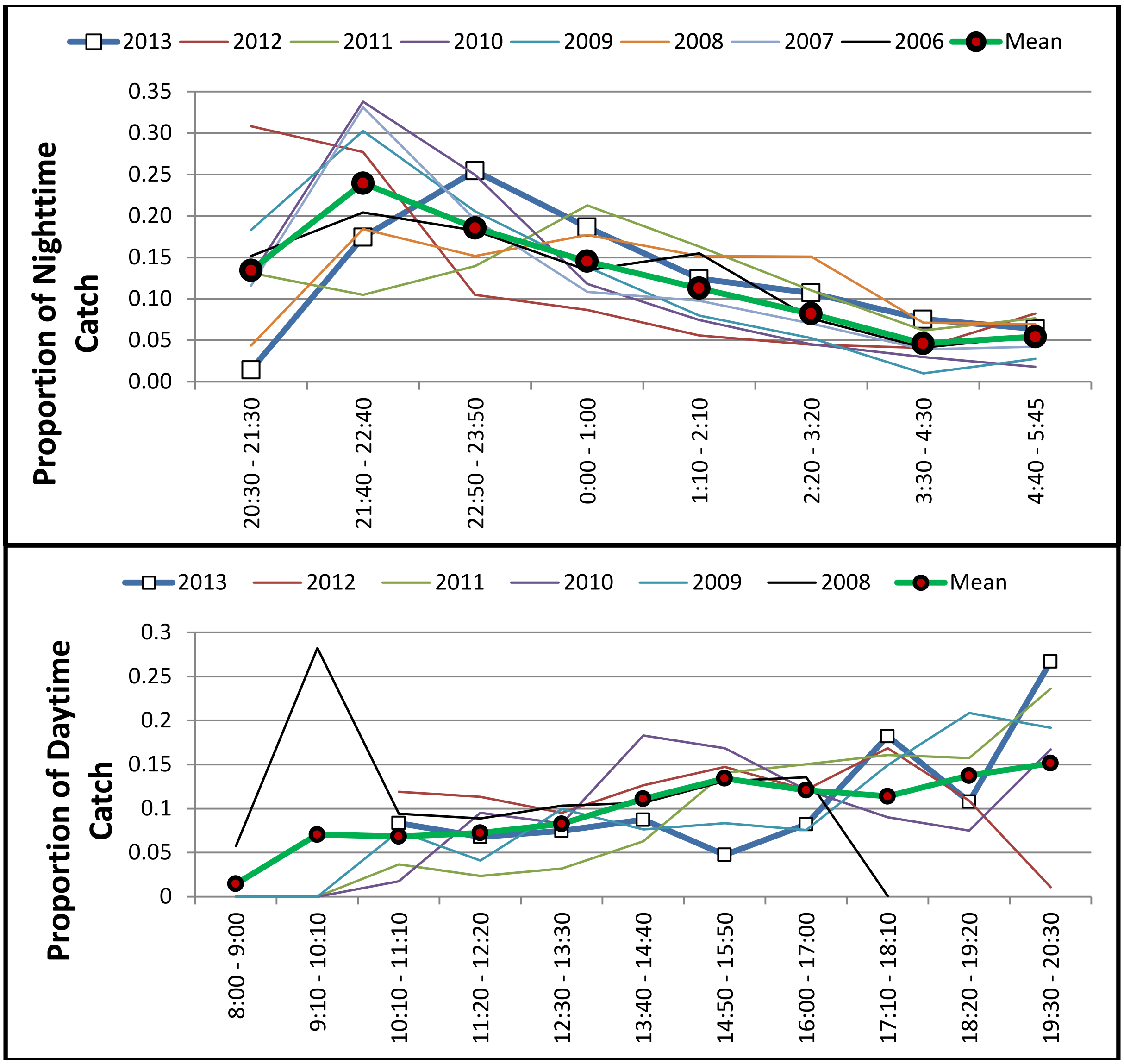

Figure 12. Hourly variation in the proportion of nighttime and daytime catches.

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

2.2.4 Smolt Size Characteristics

Sockeye smolts in the Seton River showed large interannual differences in fork length distribution (Table 3, Figure 13). Largest smolts were captured in 2009 (mean = 109 mm) and smallest smolts occurred in 2012 (mean = 77 mm). During 2013, smolts were relatively large with a mean fork length of 100 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. Section 4.2.5 evaluates density-dependent relationships between smolt abundance and body size.

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

	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

[a] *Daytime sampling was sporadic and opportunistic in 2006 and 2007*

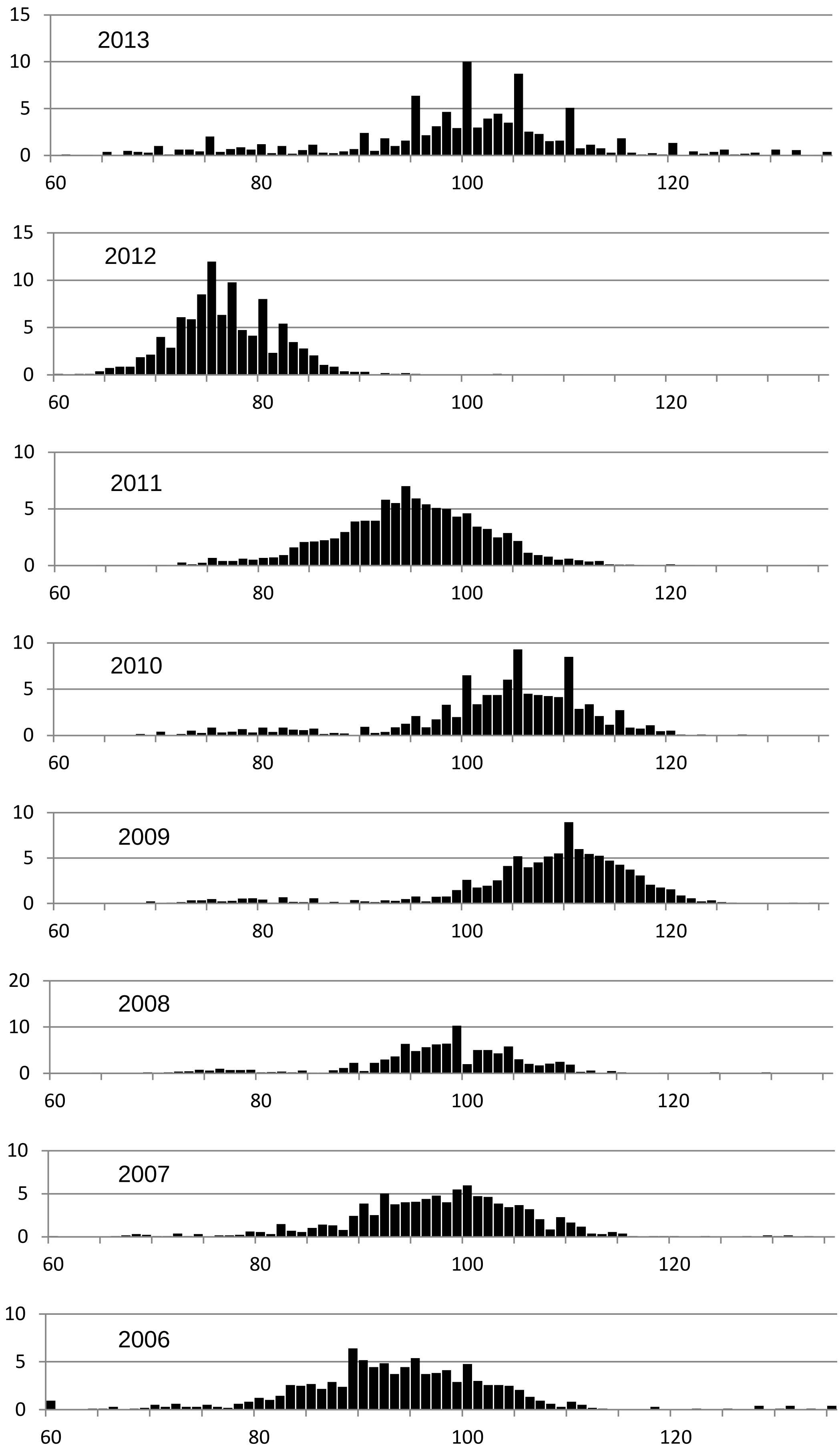

Figure 13. Smolt length frequency histograms for the 8 study years.

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 - 2013 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 don't comingle with previous marked batches.

Table 3. Summary of nighttime mark-recapture experiment results (stratified by discharge) from the Seton River IPT, 2006 to 2013. 2013 data reflect trials of marked smolts released below the dam.

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
All years		30	9159	721	7.87

Table 4 Summary of daytime mark-recapture experiment results from the Seton River IPT, 2006 to 2013. 2013 data reflect trials of marked smolts released below the dam.

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
All years		17	3766	275	7.30

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. This entrainment rate estimate was utilized in the 2013 calculations of smolt abundance.

There were 3 mark-recapture trials below the dam in 2013 (2 nighttime and 1 daytime) which yielded recapture rates of 7.26% during nighttime and 5.04 % during daytime. Mean values over 8 years of testing were 7.87% and 7.30% during nighttime and daytime periods respectively (Tables 3-4). Due to the low number of trials in 2013, the mean recapture rate values across the entire data series were utilized to provide the Peterson population estimates for the Seton River.

During previous years different approaches have been adopted to estimate smolt population size[3] and mortality rate. During 2013 a novel approach was adopted that was conceptually simpler and involved the following steps for both daytime and nighttime periods:

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 mortality by multiplying the hourly powercanal population by 0.17 (assumed mortality rate utilized since 2006),
6) sum the hourly mortalities to obtain total mortality rate

Data matrices showing the calculated values are provided in Appendix 1,

[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.

Table 5 provides the annual time series of population estimates; the 2013 estimate was 452,000 smolts.

Table 5. Total Population Estimates for Seton-Anderson Sockeye Smolts, including Seton River (day + night) and Power Canal estimates

Year	Seton River Night Pop. Est.	Seton River Day Pop. Est.	Power Canal Pop. Est. (Day + Night)	Total Smolt Pop
2006	618,500	ca.160,000	ca. 990,000	1.8 M
2007	889,900	ca. 220,000	ca.1.070,000	2.2 M
2008	106,500	19,000	417,700	543,000
2009	166,500	99,700	46,100	312,000
2010	237,300	117,500	54,800	410,000
2011	3,074,000	102,700	1,656,100	4.8 M
2012	1,550,000	1,662,000	2,851,000	6.1M
2013	**188,000**	**10,700**	**253,000**	**452,000**

[a] Daytime sampling was not systematic in 2006 and 2007. Therefore the daytime proportions in those years were based on the mean day:night catch ratio from 2008 to 2010.

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

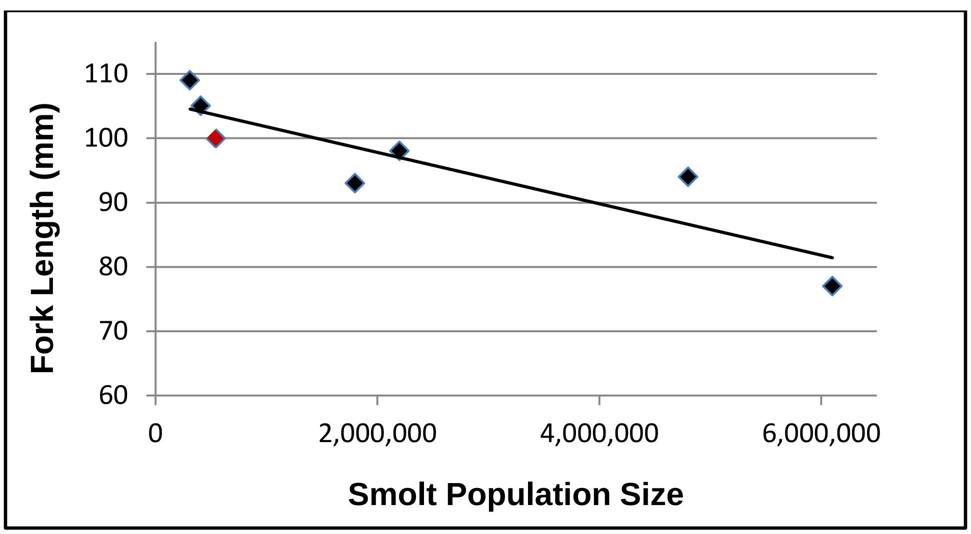

Figure 14. Smolt abundance vs. body size in the Seton River between 2006 - 2013. 2013 data point shaded red.

2.2.6 Smolt Mortality

Assumptions for the mortality rate calculations in 2013 include:

- 84% of the smolts migrated down the canal and 16% passed through the dam whenever the plant was running (based on the 2008 power canal sampling data); 100% of the smolts migrated through the dam when the plant was shutdown;
- mortality associated with passage through the turbine is 17%, with no incremental mortality associated with passage through the dam; and,
- the study period covered 100% of the smolt migration window.

In 2011 a correction factor of 2% mortality was added to the Seton River smolt migrants for mortality associated with passage through the dam (Groves and Higgins 1995). This assumption was relaxed in 2013 since there are only very few injured smolts captured in the Seton River IPT and few dead smolts. In 2013, the mortality rate estimate was 9.5% (Table 6).

Table 6. Summary of estimated mortality rates for Seton-Anderson sockeye smolts, 2006 to 2013.

Study Year	Mortality Rate Estimate (%)
2006	-
2007	-
2008	13.5[1]
2009	4.2
2010	4.0
2011	7.1
2012	8.0
2013	9.5

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

3.0 Discussion and Recommendations

In terms of scheduling shutdowns, in 2013 83% of the nocturnal catch occurred between 20:00 and 02:00 making this scheduling optimal from a smolt protection standpoint. This diel trend has been observed since 2006, and in previous years shutdowns targeted this time period to keep mortality rates below the 5% mortality rate target that is specified in the 2011 Settlement Agreement. The diel shutdowns in 2013 were sporadic (Table 1) and most occurred outside of the 20:00 - 02:00 optimal shutdown window. The consequence of the non-optimal shutdown schedule was a higher than 5% mortality (9.5%). This is inconsistent with the spirit and intent of minimizing smolt mortality and reflects competing operational priorities. Ahmed - can you provide the rationale for the non-optimal shutdown scheduling?

Daytime:nighttime catch ratios (Table 2) were 0.05 for 2013 compared to 0.03 - 0.56 in previous years:

	Daytime: Nighttime migration ratio
2006	--
2007	--
2008	0.20
2009	0.41
2010	0.34
2011	0.03
2012	0.56
2013	0.05

There is no immediate requirement to re-visit the nightly shutdown schedule as the 20:00 - 02:00 timing is optimal. The main recommendation from the 2013 results is to revert to the optimal shutdown timing in future years and to continue to monitor the mortality rate.

The demonstration of density-dependent growth (Figure 14) for sockeye smolts in the Seton-Anderson system strongly suggests a within-lake growth and survival mechanism. The 2013 data point falls close to the trend line generated by the 8-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 likely occur. This question will be further addressed by BRGMON 6 during 2014. Marine survival of sockeye is related to smolt size: larger smolts survive better. During 2013, there was a low number of relatively large smolts while in other years e.g. 2012 there was a relatively high number of very small smolts (Figure 13). The marine survival consequences of the density-dependent growth patterns are unknown at present.

No changes in monitoring procedures are recommended for 2014 or for future years. The IPT however will need to be replaced prior to April 2014 or substantially rebuilt to maintain sampling consistency between years and to avoid safety issues resulting from a lack of trap integrity.

4.0 References

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Appendix 1: Population size and mortality rate calculations

Trap Catches

Night	20:30 - 21:	21:40 - 22:	22:50 - 23:	0:00 - 1:00	1:10 - 2:10	2:20 - 3:20	3:30 - 4:30	4:40 - 5:45	5:55 -7:00	
	1	2	3	4	5	6	7	8	9	
Apr-19	45	46	55	71	67	87	51	85		
Apr-20		11	1			2				
Apr-21				1			3	2		
Apr-22	2	49	66	60	59	114	110	48		
Apr-23	8	150	72	97	21	6	14	24	27	
Apr-24		5	132	133	100	37	33	32	12	
Apr-25	1	318	498	420	179	134	48	37	26	
Apr-26		22	85	209	367	435	201	189	69	
Apr-27	11	130	316	230	118	63	43	42		
Apr-28	111	362	297	186	123	64	64	28	30	
Apr-29	2	54	255	248	85	52	41	13	5	
Apr-30		51	26	18	13	13	31	45		
May-01		233	277	104	84	103	81	93		
May-02		387	183	101	83	110	131	119	230	
May-03	9	318	574	331	146	67	32	7	31	
May-04	1	123	413	167	111	71	18	15	70	
May-05		29	34	121	77	42	46	22	7	
May-06		14	55	47	16	22	14	15	7	
May-07		115	181	53	42	21	20	9		
May-08		11	1	5	5	2	5	5	1	
May-09										
May-10		1	1	2	2	3	5	2		
May-11		1	8	12	7	10	14	11		
May-12	2	2	10	6	10	7	10	14	1	
May-13	1	15	6	4	12	10	13	10	3	
May-14		1	3	4	3	9	6	8	11	
May-15	2	8	8	4	12	2	1	3	4	
May-16		3	13		1	3	5	2	8	
May-17	2	9	14		9	13	7	6	2	
May-18										
May-19		4	2	3	5	9	9	11	3	
May-20		4	9		1	2	1	1		
May-21							2		1	
May-22										
May-23		1					1	1		
May-24				1	1	4	4			
May-25			1		1		2	2		
May-26			4	1	1			1		
May-27										
May-28			3	10	4		2		1	
May-29										
May-30	3		1			3			13	
May-31	3	2	7	1	1	1	2	1	9	
Jun-01		1	6	1	4	1	2	3	2	
	203	2480	3617	2651	1770	1522	1072	906	573	14794

Trap Catches

Day	10:10 - 11:	11:20 - 12:	12:30 - 13:	13:40 - 14:	14:50 - 15:	16:00 - 17:	17:10 - 18:1	18:20 - 19:	19:30 - 20:30	
	1	2	3	4	5	6	7	8	9	
Apr-20						1	1			
Apr-21										
Apr-22										
Apr-23	1								1	
Apr-24	2				1					
Apr-25	1	6		1	1		12	9		
Apr-26										
Apr-27							47	14	80	
Apr-28		2	5		1	2	8	2	1	
Apr-29	1				1	6	1		5	
Apr-30		1								
May-01							49	13	4	
May-02	12	1		23	16	3	12	1	1	
May-03		1			1	25	1	14	49	
May-04	2						1	9	27	
May-05	3	9				1				
May-06			7	7	1				24	
May-07			21	5						
May-08		1								
May-09					1			6		
May-10					4					
May-11	4		1	6	3	3			4	
May-12		9	4	1	1		4	5		
May-13	12			8	1	12			8	
May-14	2	2	5			1				
May-15	4	16	9	12						
May-16		3	2	3		1				
May-17						5			1	
May-18										
May-19	11						6	1	2	
May-20	5		1					10		
May-21										
May-22										
May-23	3									
May-24	1									
May-25										
May-26										
May-27										
May-28					1					
May-29										
May-30			1		2					
May-31		1		2		1			1	
Jun-01	1				2					
Jun-02		1	2			3				
	65	53	58	68	37	64	142	84	208	779

River Population

Night

	20:30 - 21:	21:40 - 22:	22:50 - 23:	0:00 - 1:00	1:10 - 2:10	2:20 - 3:20	3:30 - 4:30	4:40 - 5:45	5:55 -7:00	
	1	2	3	4	5	6	7	8	9	Sum
Apr-19	572	584	699	902	851	1105	648	1080	0	6442
Apr-20	0	140	13	0	0	25	0	0	0	178
Apr-21	0	0	0	13	0	0	38	25	0	76
Apr-22	25	623	839	762	750	1449	1398	610	0	6455
Apr-23	102	1906	915	1233	267	76	178	305	343	5324
Apr-24	0	64	1677	1690	1271	470	419	407	152	6150
Apr-25	13	4041	6328	5337	2274	1703	610	470	330	21105
Apr-26	0	280	1080	2656	4663	5527	2554	2402	877	20038
Apr-27	140	1652	4015	2922	1499	801	546	534	0	12109
Apr-28	1410	4600	3774	2363	1563	813	813	356	381	16074
Apr-29	25	686	3240	3151	1080	661	521	165	64	9593
Apr-30	0	648	330	229	165	165	394	572	0	2503
May-01	0	2961	3520	1321	1067	1309	1029	1182	0	12389
May-02	0	4917	2325	1283	1055	1398	1665	1512	2922	17078
May-03	114	4041	7294	4206	1855	851	407	89	394	19250
May-04	13	1563	5248	2122	1410	902	229	191	889	12567
May-05	0	368	432	1537	978	534	584	280	89	4803
May-06	0	178	699	597	203	280	178	191	89	2414
May-07	0	1461	2300	673	534	267	254	114	0	5604
May-08	0	140	13	64	64	25	64	64	13	445
May-09	0	0	0	0	0	0	0	0	0	0
May-10	0	13	13	25	25	38	64	25	0	203
May-11	0	13	102	152	89	127	178	140	0	801
May-12	25	25	127	76	127	89	127	178	13	788
May-13	13	191	76	51	152	127	165	127	38	940
May-14	0	13	38	51	38	114	76	102	140	572
May-15	25	102	102	51	152	25	13	38	51	559
May-16	0	38	165	0	13	38	64	25	102	445
May-17	25	114	178	0	114	165	89	76	25	788
May-18	0	0	0	0	0	0	0	0	0	0
May-19	0	51	25	38	64	114	114	140	38	584
May-20	0	51	114	0	13	25	13	13	0	229
May-21	0	0	0	0	0	0	25	0	13	38
May-22	0	0	0	0	0	0	0	0	0	0
May-23	0	13	0	0	0	0	13	13	0	38
May-24	0	0	0	13	13	51	51	0	0	127
May-25	0	0	13	0	13	0	25	25	0	76
May-26	0	0	51	13	13	0	0	13	0	89
May-27	0	0	0	0	0	0	0	0	0	0
May-28	0	0	38	127	51	0	25	0	13	254
May-29	0	0	0	0	0	0	0	0	0	0
May-30	38	0	13	0	0	38	0	0	165	254
May-31	38	25	89	13	13	13	25	13	114	343
Jun-01	0	13	76	13	51	13	25	38	25	254
										187980
nolts in powercanal										1879799

River Population

Day

	10:10 - 11:	11:20 - 12:	12:30 - 13:	13:40 - 14:	14:50 - 15:	16:00 - 17:	17:10 - 18:1	18:20 - 19:	19:30 - 20:30	
	1	2	3	4	5	6	7	8	9	
Apr-19	0	0	0	0	0	14	14	0	0	27
Apr-20	0	0	0	0	0	0	0	0	0	0
Apr-21	0	0	0	0	0	0	0	0	0	0
Apr-22	14	0	0	0	0	0	0	0	14	27
Apr-23	27	0	0	0	14	0	0	0	0	41
Apr-24	14	82	0	14	14	0	164	123	0	411
Apr-25	0	0	0	0	0	0	0	0	0	0
Apr-26	0	0	0	0	0	0	644	192	1096	1932
Apr-27	0	27	68	0	14	27	110	27	14	288
Apr-28	14	0	0	0	14	82	14	0	68	192
Apr-29	0	14	0	0	0	0	0	0	0	14
Apr-30	0	0	0	0	0	0	671	178	55	904
May-01	164	14	0	315	219	41	164	14	14	945
May-02	0	14	0	0	14	342	14	192	671	1247
May-03	27	0	0	0	0	0	14	123	370	534
May-04	41	123	0	0	0	14	0	0	0	178
May-05	0	0	96	96	14	0	0	0	329	534
May-06	0	0	288	68	0	0	0	0	0	356
May-07	0	14	0	0	0	0	0	0	0	14
May-08	0	0	0	0	14	0	0	82	0	96
May-09	0	0	0	0	55	0	0	0	0	55
May-10	55	0	14	82	41	41	0	0	55	288
May-11	0	123	55	14	14	0	55	68	0	329
May-12	164	0	0	110	14	164	0	0	110	562
May-13	27	27	68	0	0	14	0	0	0	137
May-14	55	219	123	164	0	0	0	0	0	562
May-15	0	41	27	41	0	14	0	0	0	123
May-16	0	0	0	0	0	68	0	0	14	82
May-17	0	0	0	0	0	0	0	0	0	0
May-18	151	0	0	0	0	0	82	14	27	274
May-19	68	0	14	0	0	0	0	137	0	219
May-20	0	0	0	0	0	0	0	0	0	0
May-21	0	0	0	0	0	0	0	0	0	0
May-22	41	0	0	0	0	0	0	0	0	41
May-23	14	0	0	0	0	0	0	0	0	14
May-24	0	0	0	0	0	0	0	0	0	0
May-25	0	0	0	0	0	0	0	0	0	0
May-26	0	0	0	0	0	0	0	0	0	0
May-27	0	0	0	0	14	0	0	0	0	14
May-28	0	0	0	0	0	0	0	0	0	0
May-29	0	0	14	0	27	0	0	0	0	41
May-30	0	14	0	27	0	14	0	0	14	68
May-31	14	0	0	0	27	0	0	0	0	41
Jun-01	0	14	27	0	0	41	0	0	0	82
										10671
										106712.3

Smolts in powercanal[4]:

	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	734	67	0	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	
Apr. 21	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	
Apr. 22	133	3269	4403	4003	•	•	•	•	•	•	•	•	•	•	•	•	•	0	0	0	0	0	0	72	
Apr. 23	534	10006	4803	6471	•	•	•	•	•	•	•	•	•	•	•	•	0	0	0	72	0	0	0	0	
Apr. 24	0	334	8806	8872	6671	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	0	
Apr. 25	67	21213	33221	28018	11941	•	•	•	•	•	•	•	•	•	•	•	•	•	0	0	0	0	0	0	
Apr. 26	0	1488	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	0	0	0	0	3380	1007	5763	
Apr. 27	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	
Apr. 28	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	
Apr. 29	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	
Apr. 30	•	•	•	•	•	•	•	•	•	•	•	•	0	0	0	0	0	0	0	•	•	•	•	•	
May-01	•	•	•	•	•	•	•	•	•	•	•	0	0	0	0	863	72	0	•	•	•	•	•	•	
May-02	0	26816	12208	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	72	1007	3624	
May-03	•	•	•	•	•	•	•	•	•	•	•	0	0	0	0	144	0	0	0	0	0	72	•	•	
May-04	•	•	•	•	•	•	•	•	•	•	•	•	•	•	0	216	647	0	0	0	72	0	0	0	
May-05	•	•	•	•	•	•	•	•	•	•	•	•	•	0	0	0	0	503	503	72	0	0	0	1728	
May-06	0	934	3869	•	•	•	•	•	•	•	•	0	0	0	0	0	0	1510	360	0	0	0	0	0	
May-07	•	•	•	•	•	•	•	•	•	•	•	0	0	0	0	0	72	0	0	0	0	0	0	0	
May-08	0	734	67	334	334	•	•	•	•	•	•	0	0	0	0	0	0	0	0	72	0	0	432	0	
May-09	0	0	0	0	0	•	•	•	•	•	0	0	0	0	0	0	0	0	0	288	0	0	0	0	
May-10	0	67	67	133	133	200	•	•	•	•	•	0	0	0	0	288	0	72	432	216	216	0	0	288	
May-11	0	67	534	801	467	•	•	•	•	•	0	0	0	0	0	0	647	288	72	72	0	288	360	0	
May-12	133	133	667	400	667	•	•	•	•	•	•	•	0	0	0	863	0	0	675	72	863	0	0	675	
May-13	67	1001	400	267	801	667	•	•	•	•	•	•	0	0	0	144	144	360	0	0	72	0	0	0	
May-14	0	67	200	267	200	600	•	•	•	•	•	0	0	0	0	288	1151	647	863	0	0	0	0	0	
May-15	133	534	534	267	801	133	67	200	267	0	0	0	0	0	•	•	•	•	•	•	•	•	•	0	
May-16	0	200	867	0	67	•	•	•	•	•	•	0	0	0	0	0	0	0	0	0	360	0	0	72	
May-17	133	600	934	0	600	•	•	•	•	•	•	0	0	0	0	0	0	0	0	0	0	0	0	0	
May-18	0	0	0	0	0	0	0	•	•	•	•	•	•	0	0	791	0	0	0	0	0	432	72	144	
May-19	0	267	133	200	334	600	•	•	•	•	•	•	0	0	0	360	0	72	0	0	0	0	719	0	
May-20	0	267	600	0	67	133	67	•	•	•	•	•	0	0	0	0	0	0	0	0	0	0	0	0	
	1201	67710	72179	50032	23081	2335	133	200	267	0	0	0	0	0	0	3955	2733	3452	2805	863	1582	4243	3596	12154	252521

[4] Top row is time of day, red shade is optimal scheduling of nightly shutdowns, charcoal shade = no sampling, orange shade is daytime period

Morts in generator

	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		126	11																						
Apr. 21																									
Apr. 22	23	668	748	680																				12	
Apr. 23	91	1701	817	1100																12					
Apr. 24		67	1487	1608	1134																				
Apr. 25	11	3806	6848	4783	2030																				
Apr. 26		248																				676	171	978	
Apr. 27																									
Apr. 28																									
Apr. 29																									
Apr. 30																									
May-01																147	12								
May-02		4389	2076																			12	171	599	
May-03																24						12			
May-04																37	110				12				
May-05																		88	88	12				293	
May-06		169	624															257	61						
May-07																	12								
May-08		126	11	67	67															12			73		
May-09																				49					
May-10		11	11	23	23	34										49		12	73	37	37			49	
May-11		11	91	136	79												110	49	12	12		49	61		
May-12	23	23	113	68	113											147			98	12	147			98	
May-13	11	170	68	45	138	113										24	24	61			12				
May-14		11	34	45	34	102										49	196	110	147						
May-15	23	91	91	45	138	23	11	34	45																
May-16		34	147		11																61			12	
May-17	23	102	159		102																				
May-18																134						73	12	24	
May-19		45	23	34	67	102										61		12					122		
May-20		45	102		11	23	11																		
	204	11511	12270	8505	3924	397	23	34	45	0	0	0	0	0	0	672	465	587	477	147	269	721	611	2066	42929