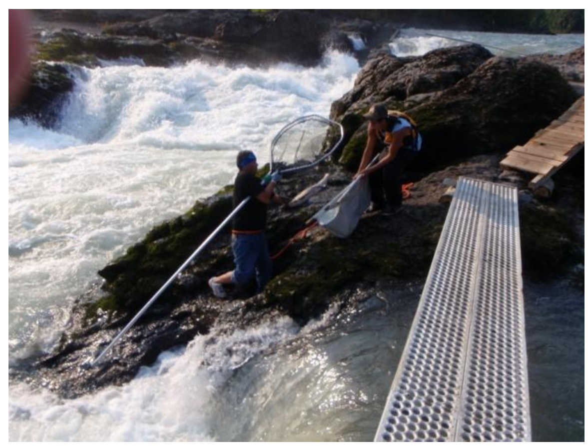



The Wet'suwet'en Fisheries

Bulkley/Morice River Steelhead Tagging Project
at
Moricetown Canyon

SUMMARY REPORT for 2012

Prepared by

SKR Consultants Ltd.
Smithers, B.C.

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Executive Summary

Since 1999, the Moricetown Salmon Tagging Project has been conducted on the Bulkley River by the Wet'suwet'en Fisheries and Fisheries and Oceans Canada, with the inclusion of data collection for steelhead (*Oncorhynchus mykiss*) under assistance from the Skeena Fish and Wildlife Branch of the British Columbia Ministry of Forests, Lands and Natural Resource Operations, the Pacific Salmon Foundation, and the British Columbia Living Rivers Trust Fund. This mark and recapture project has involved sampling by beach seine for tag application immediately downstream of Moricetown Canyon (i.e. referred to as "campground") and re-sampling by dip net at the base of Moricetown Falls and fishway (i.e. referred to as "canyon"). In 2012, steelhead catch at both the campground and at the canyon were respectable in comparison to the earlier years of this study, but somewhat lower than the highest year (i.e. 2010) as a result of fewer steelhead arriving and reduced sampling effort due to budget constraints. Of the 2890 steelhead that were examined at the canyon, 125 were recaptures of the 1196 steelhead tagged at the campground. The stratified abundance estimates for steelhead arriving at Moricetown from July 30th to October 18th, with a 2.5% correction for tag loss, were 21 926 (95% C.I. 16 456 – 27 395) using Maximum Likelihood Darroch and 22 931 using Schaefer methods. The stratified abundance estimates are provided to identify potential inaccuracies, bias and misleading precision of an estimate of 27 465 steelhead (95% C.I. 23 709 – 33 167) using the pooled Petersen estimate for inter-annual comparisons of steelhead abundance to previous years. In general, the pooled Petersen estimate for steelhead abundance in 2012 was significantly lower than the highest and most precise estimate of steelhead arriving at Moricetown in 2010 (i.e. 41 140 with 95% C.I.: 38 058 – 44 934) and significantly higher than estimates made for 2003, 2004, 2005, 2006, and 2011.

Some extrapolations of the pooled-Petersen estimates for 2012 have also been included to represent the number of steelhead that actually migrated upstream of Moricetown Canyon as of the final date of sampling at the canyon in comparison to the estimate of steelhead that arrived at the campground. Based on the 2009 acoustic telemetry study estimating 34% of steelhead that arrived at the campground but did not migrate upstream of Moricetown Canyon while the dip net fishery was operating (Welch et al. 2009 & 2010), a range of rates of fallback (i.e. 10%, 20% and 40%) have been used as examples of how the range of adjustments can modify the estimates of steelhead abundance upstream of Moricetown. The corrected pooled-Petersen estimates for steelhead migrating upstream of Moricetown are 24 178 with 10% fallback, 21 431 with 20% fallback, and 16 479 with 40% fallback of steelhead that arrived at the campground and are predicted not to have migrated past the canyon as of October 18th in 2012.

In conclusion, the Wet'suwet'en Fisheries office and field staff have had another very successful year conducting the 2012 Morictown Steelhead tagging project in cooperation with Fisheries and Oceans Canada and the Ministry of Forest, Land and Natural Resource Operations. Their interest and dedication toward protecting the Bulkley/Morice river steelhead, efforts to improve their fish handling methodologies, upgrades to the electronic data entry system, improvements to data quality, statistically useful results, and overall support for this program are commendable and clearly show many advantages for this project to continue for at least a few more cycles of steelhead generations.

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Acknowledgements

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1.0 INTRODUCTION

The Moricetown Steelhead Tagging Project on the Bulkley River, conducted by the Wet'suwet'en Fisheries in conjunction with various contributions from Fisheries and Oceans Canada (FOC), the Fisheries Section of the British Columbia Ministry of Forests, Lands and Natural Resource Operations (BC Fisheries), and the British Columbia Living Rivers Trust Fund (LRTF), was continued in 2012 for its 14th consecutive year. The Pacific Salmon Foundation and BC Fisheries have reviewed the project and administered funds from the LRTF for SKR Consultants Ltd. to provide a technical report summarizing the 2012 steelhead tagging results. The summary report of the 2012 results includes:

- summaries of field activities, quality assurance and corrections of the 2012 data that was entered by the Wet'suwet'en Fisheries office prior to analysis,
- intra and inter-annual comparisons of cumulative steelhead catch by beach seine and dip net sampling methods,
- a review of temporal stratification from tag application immediately downstream of the canyon (i.e. beach seine) to catch at the canyon falls and fishway (i.e. canyon),
- presentation of the 2012 steelhead abundance estimates, and
- an overview of potential correlations of Moricetown Steelhead abundance with the Skeena Tyee Steelhead Test Index.

2.0 METHODS

Sampling methods for the Moricetown Steelhead Tagging Project were consistent with previous years' methodologies, and included beach seine sampling at two sites (i.e. "campground" or sites 1 and 2, *see* Figure 1) located immediately downstream of the Moricetown Canyon, and dip net sampling approximately 450 metres upstream at the base of Moricetown Falls, almost exclusively on river left from the fish-way entrance to the falls (i.e. "canyon" or site 3, *see* Figure 1). A few minor modifications were made to fish handling methodologies including:

- use of a newly provided, knotless rubber mesh net for fish release from the canyon tagging tub,
- use of the newly designed cradles made with a smooth rubber material for fish transfer from dip net to the tagging tub (Figure 2),
- more constant use of the water pump and PVC release tube to reduce handling stress at the canyon tagging location,
- the addition of a second runner during the peak migration to reduce fish handling time and excessive time out of water,
- use of newly provided knee pads for the beach seine taggers to speed up processing time, and
- release of steelhead by beach seine crews without sampling whenever high catches increase processing time causing stress or potential suffocation.

Steelhead were marked using a combination of anchor tags and lower and upper caudal punches for the downstream and upstream locations, respectively. The caudal punches were applied to assess tag loss. The sampling in 2012 was conducted from Monday to Friday each week (i.e. weekdays), excluding statutory holidays, with no additional efforts on weekends, which has occurred in some previous years when applied tag numbers were lower. Sampling efforts at both the campground and the canyon were reduced to one crew during September and October in 2012. For steelhead abundance estimates of the mix of Bulkley and Morice river steelhead arriving at Moricetown, the canyon (i.e. site 3, Figure 1) near the base of the Moricetown Falls has been considered to be the re-sampling site for the steelhead tagged downstream of the Moricetown canyon at the campground (i.e. sites 1 and 2, Figure 1).

Photo from Google Earth 2009

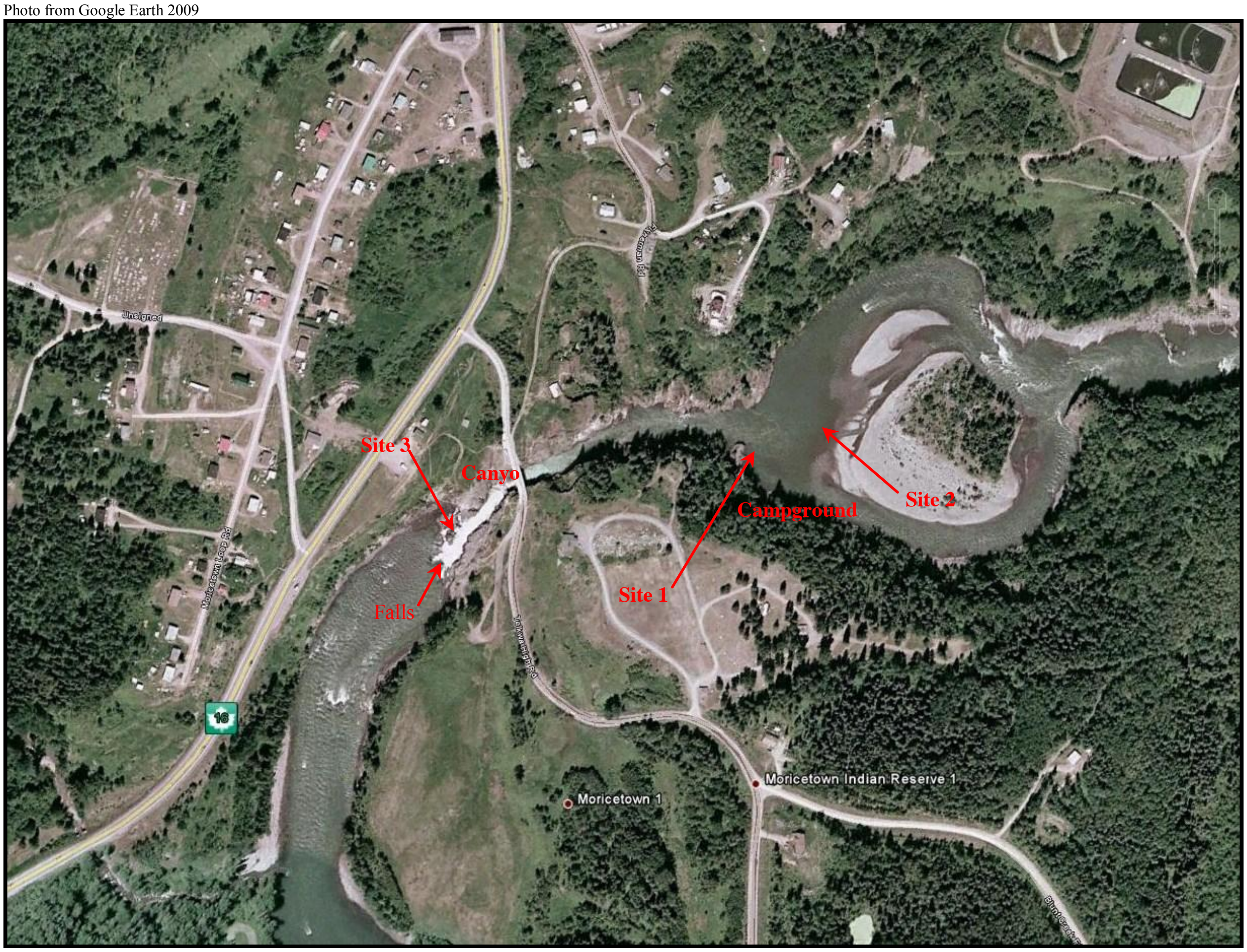


Figure 1. Aerial Photograph of Campground (Site 1) Campground/Island (Site 2) Beach Seine locations and the Canyon Dip Net location (Site 3) on the Bulkley River in Moricetown, B.C. .

Photo courtesy of Dean Peard

Figure 2. View of newly designed fish carrying cradle being used by runner to transfer fish from dip netter to canyon tagging station.

2.1 Data Collection

Field data forms for dip net and beach seining activities were submitted daily throughout the field season to the Wet'suwet'en Fisheries office in Moricetown, B.C. and copies of the submitted steelhead data were obtained weekly by Skeena Fish and Wildlife personnel for preliminary weekly updates of the status of steelhead abundance. Wet'suwet'en Fisheries staff entered the data collected into a Microsoft Access data entry tool designed by Walter Joseph (Wet'suwet'en Fisheries). Newly marked fish and recaptured fish were differentiated in the database. "Applied tag" was the tag status entered for all newly tagged fish; "recaptured" was the tag status entered for recaptured fish. Recaptured fish that had lost their tag, as identified by the presence of a caudal punch, were identified in the database with "lost tag" entered as the tag status. Individual records also requested date, time, harvested (yes/no), tag number and tag colour applied or recaptured, sex (male, female or unknown), fork length (cm), adipose clip present (yes/no), caudal punch (top/bottom), and comments. Since 2011, detailed check boxes for fish condition included scale loss, net marks, torn tail, torn fins, bleeding gills, bite marks, cysts, fungus, and sea lice.

2.2 Quality Assurance

Field support and quality assurance visits were conducted regularly by BC Fisheries personnel in August, September and the first half of October in 2012. Field visits were conducted to present new sampling modifications, to assess on site data record keeping, fish handling techniques, species identification, sampling effort, and to deliver necessary supplies for steelhead tagging. In conjunction with field visits, copies of all field data forms from the previous week were collected and assessed for common errors or missing information. Data entry checks based on detailed comparisons of every field data form to the entered steelhead data were conducted and all corrections were noted on hard copies and corrected in the database provided by the Wet'suwet'en Fisheries office prior to data analysis for this summary report.

2.3 Assessment of Ocean Age Composition

As requested, an assessment of the age composition of adult steelhead returning to Moricetown has been added to this report due to interests arising from the relatively low percentage (i.e.13%) of steelhead with fork lengths ≤ 60 cm speculated to represent the 2011 smolts that returned to spawn after only one winter at sea, and a useful number of 2012 recaptures of tagged repeat spawners from previous years (i.e. 34 recaptures of steelhead with tags applied in 2010 and one from 2008) allowing an estimation of the proportion of the 2012 return representing the 2010 smolts that returned to spawn after two ocean winters. This preliminary interpretation of the data was derived to present the ocean age distribution of steelhead in the 2012 return, with the intent to illustrate the complexity of factors associated with fluctuations in steelhead abundance. The following assumptions and equations were used to estimate the numbers and approximate ratios of the various age classes for 2012:

2011 smolts → One Ocean Winter (OW) → **1-OW Returns**

$$= \frac{\textit{Number of steelhead sampled with Fork Length} \leq 60\ cm}{\textit{Sample Size (campground and canyon combined)}} * \text{Abundance Estimate (2012)}$$

2011 smolts →Two Ocean Winters (OW) → **2-OW Returns**

$$= \frac{\textit{Number of steelhead sampled with Fork Length} > 60\ cm}{\textit{Sample Size (campground and canyon combined)}} * \text{Abundance Estimate (2012) - Repeat Spawners (2012)}$$

2010 smolts → Three Ocean Winters (OW) → 3-OW Returns

= not measurable without aging data, but not suspected, thus excluded from estimations

2011 Spawners → No Ocean Winters (no -OW) after tagged return → RS0-OW Returns

= Assumption is < 0.1% of return (no recaptures), thus excluded from estimations

2010 Spawners → One Ocean Winters (0-OW) after tagged return → **Repeat Spawners (RS)**

$$= \frac{\textit{Tags applied at campground (2012)}}{\textit{Recaptures at Canyon of Tags Applied (2012)}} * \frac{\textit{Recaptures of Repeat Spawners (2010)}}{\textit{total \# of tags applied (2010)}} * \textit{Abundance Estimate (2010)}$$

2009 Spawners → No Ocean Winters (0-OW) after tagged return → RS2-OW Returns

= Assumption is < 0.1% of return (no recaptures), thus excluded from estimations

2008 Spawners → Three Ocean Winters (0-OW) → 2+OW Returns

= Assumption is < 0.1% of return (one recapture in 2012), thus excluded from estimations

Ranges of these estimates could also be calculated based on upper and lower 95% confidence intervals of the Petersen estimates (*see* Section 2.2), but these ranges were not calculated due to the compounding risks of error with this extrapolation. It is also important to note that the number of smolts from each year is comprised of different age fry that originated from spawning that occurred one to three years prior to their migration to the ocean, which further increases the complexity of explaining the annual fluctuations in steelhead returns.

2.4 STEELHEAD ABUNDANCE ASSESSMENTS

The experimental design for the Moricetown salmon tagging project was originally intended to be used for mark-recapture estimates of Pacific salmon at their spawning locations, but little data for steelhead abundance upstream of Moricetown Canyon has been collected. In an attempt to acquire annual estimates of steelhead abundance at Moricetown Canyon, three methods for mark-recapture estimates have been attempted (i.e. *pooled Petersen*, *Schaefer*, and the *Maximum Likelihood Darroch*) based on tag application at the campground in conjunction with re-sampling at the canyon (i.e. the base of the Moricetown Falls and fishways). Since the initiation of annual data analysis for steelhead returns to Moricetown canyon, estimates of steelhead abundance have been most commonly derived using a pooled Petersen estimate (Ricker 1975, Krebs 1999) with 95% confidence intervals (CI) derived from poisson or normal approximations (i.e. <50 and >49 recaptures, respectively) for each year (Krebs 1999):

$$N = \frac{(M+1)(C+1)}{(R+1)}$$

$$CI_{lower} = \frac{M}{\frac{R}{C} + \left\{1.96\left[\sqrt{\frac{(1-R/M)(R/C)(1-R/C)}{(C-1)}}\right] + \frac{1}{2C}\right\}}$$

$$CI_{upper} = \frac{M}{\frac{R}{C} - \left\{1.96\left[\sqrt{\frac{(1-R/M)(R/C)(1-R/C)}{(C-1)}}\right] + \frac{1}{2C}\right\}}$$

Where: N = Petersen estimate at time of last marking
M = Number of individuals marked below canyon by beach seine
C = Total captured at canyon by dip net
R = Total recaptures at canyon by dip net

The Stratified Population Assessment System (SPAS, Arnason *et al*., 1996) has been applied using data collected since 2004 in an attempt to account for the open population and temporal stratification attributes of this sampling design. SPAS provides Schaefer estimates (Ricker1975) for comparison to Petersen estimates. Maximum Likelihood Darroch (ML Darroch) estimates have also been added in further attempts to account for heterogeneity of catch in different temporal strata and to provide confidence intervals for some interpretation of precision and comparison to Petersen estimates of the same year. Temporal Strata for Schaefer and ML Darroch estimates using the 2012 mark-recapture steelhead data were based on 7 day units starting with July 28th to August 23rd (week 1) to October 13th to 19th (week 12) and applied tags were corrected for 2.5% tag loss that was estimated based on the number of lost tag recaptures at the canyon that had lower caudal punches (i.e. secondary markings from the campground) since the start of this project.

3.0 RESULTS AND DISCUSSION

For the 2012 Moricetown salmon and steelhead mark-recapture program, tag application was conducted by beach seine capture from July 30th to October 11th at the campground, and re-sampling and additional tag application was conducted at the canyon from July 27th to October 18th. In 2012, a total of 1196 steelhead were tagged at the campground and 2890 were re-sampled at the canyon despite unusually high river level conditions in July and early August. Summaries with discussion regarding the results of the present sampling methods, the cumulative steelhead catch at the campground using beach seining and at canyon using dip nets, and abundance estimates for steelhead arriving at Moricetown are provided in the following sections:

- Sampling Methods,
- Cumulative Steelhead Catch,
- Ocean Age Composition and Forecasts for 2013, and
- Moricetown Steelhead Abundance Estimates.

3.1 Sampling Methods

The sampling methodologies for the Moricetown salmon and steelhead tagging program had some minor modifications in 2012 from the methods used in 2010 and 2011 (*see* SKR 2011). Useful efforts were made toward reducing handling stress on steelhead including a flow control mechanism on the dip nets and exclusive use of a PVC fish cradle for transporting fish from the canyon sampling to the tagging and release location. Overall, sampling conditions were suitable for sampling methods except for high river levels that flowed over the fishway and limited fish sampling during most of July. The following sections include:

- a summary of the data quality assurance,
- a comparisons of fork lengths to assess a potential bias in abundance estimates as a result of using different sampling methods at the tag application and re-sampling locations, and
- a summary of data related to the condition of steelhead when sampled using the two sampling methodologies.

3.1.1 Quality Assurance

Based on hard copies of the field data collected by BC Fisheries from the Wet'suwet'en Fisheries office, data were well recorded and documents were well preserved by all crews. A very thorough review was conducted for the data entry, with comparison of all data on every steelhead field form in conjunction with corrections to mistakenly entered data. Some minor but common errors include misplaced data (e.g. fork lengths in gender fields), fish conditions were typed in comment field instead of checked in appropriate column, and approximately 40 steelhead records were accidently missed. Overall, data entry validation was exceptionally manageable for 2012, and data fidelity was achieved following corrections to all the identified errors. The new data entry tool used in 2012 appeared to notably improve the data quality and was further modified for the 2013 field season with the creation of updated field data forms that incorporated the following additions:

- "Caudal Punch on Release" was differentiated from "caudal punch of recapture",
- "Condition on Release" was added based on **"E"** = Excellent (i.e. lively with no damage), **"G"** = Good (i.e. lively, but some scale loss), **"M"** = Moderate (i.e. slow to swim away), **"W"** = Weak condition (i.e. needed some resuscitation),
- "Gill Bleeding" changed to "Gill Damage" to group bleeding and damage,
- "Torn Tail" changed to "Tail Damage", and
- "Torn Fin" changed to "Fin Damage".

3.1.2 Steelhead Fork Lengths at Different Sampling Locations

The two different sampling methodologies used for tag application and re-sampling (i.e. beach seine versus dip net) and the occurrence of sampling at two different locations (i.e. campground versus canyon) with different habitat characteristics (i.e. slow versus high velocity river flow) has been hypothesized to bias the mark recapture abundance estimate due to potential size selectivity. However, no notable differences in fork length distributions between steelhead sampled at the campground and canyon locations were identified in 2011 (SKR 2012) or in 2012 (Table 1, Figure 2). Interestingly, the multi-modal size distribution indicative of ocean years suggests a notably lower proportion and conceivably low abundance of steelhead returning after one year than more than one year at sea in 2012 than in 2010 or 2011 (Figure 3). Further assessment of the fork lengths recorded for tag application and recaptures from both the canyon and campground locations are presented in Figure 4, and show no obvious differences and improved precision at the two locations in comparison to results in 2010. Overall, fork length distributions of steelhead handled at the two sampling locations in 2012 suggest that the Moricetown mark recapture program has incorporated all of the different size/age classes of steelhead at similar distributions and precision for this abundance estimate.

Interestingly, the relatively low abundance of steelhead returning to Moricetown Canyon after "one ocean winter" (i.e. the relatively low frequencies surrounding the lower mode of fork lengths ranging from 45 to 60 cm for 2012, *see* Figure 2) provides some intuition that the "two ocean winter" returns in 2013 may be low due to:

- low numbers of steelhead smolts in 2011 potentially related to poor freshwater survival in 2010/2011 since the numbers of steelhead spawners in 2009 and 2010 were not weak (note: freshwater survival did not appear to be a factor in 2009/2010 due to reasonable numbers of "two ocean winter" returns in 2012) and/or
- detrimental ocean conditions that impacted steelhead survival in 2010/2011 that were not specific to the different migratory pattern of "one ocean winter" returns.

Some potential exceptions to this hypothesis include:

- the unsuspected possibility that an extremely higher majority of the 2010 smolts chose two ocean winters than one ocean winter in 2012, and/or
- ocean survival of the 2012 "one ocean winter" returns was impacted (e.g. Skeena Commercial Fishery) independent of the 2011 steelhead smolts that chose two ocean winters.

Although this indicator will not be appropriate for predicting high return years due to the variability of ocean survival, it appears to be a potentially useful indicator of low to moderate steelhead returns. Overall, this indication of potentially low returns of steelhead in 2013 is merely speculated, but as more data are collected, there is potential for further refinements to this type of forecast to eventually provide some scientific support to the ongoing management and protection of the Bulkley/Morice and Skeena River steelhead. Despite the inaccuracies of this forecast, the estimate remains useful for pre-field planning for the 2013 sampling intensities and provision of preliminary target sample sizes for the 2013 field crews.

Table 1. Summary of fork lengths of steelhead sampled or recaptured at the canyon and campground sites in 2012.

Sample Location	*Canyon*	*Canyon*	*Canyon*	*Campground*	*Campground*	*Campground*
Tag Origin of Recapture	*Canyon*	*Campground*		*Canyon*	*Campground*	
Sample Size	85.0	134.0	2622.0	106.0	124.0	1233.0
Minimum	48.5	47.0	26.5	47.0	27.0	42.0
Maximum	79.0	91.0	94.0	89.0	89.0	92.5
Range	30.5	44.0	67.5	42.0	62.0	50.5
Median	69.00	68.00	69.00	69.25	70.00	69.00
Mean	**68.55**	**67.70**	**68.00**	**68.91**	**68.53**	**68.37**
Std Dev.	6.51	6.86	7.61	7.76	8.02	7.71

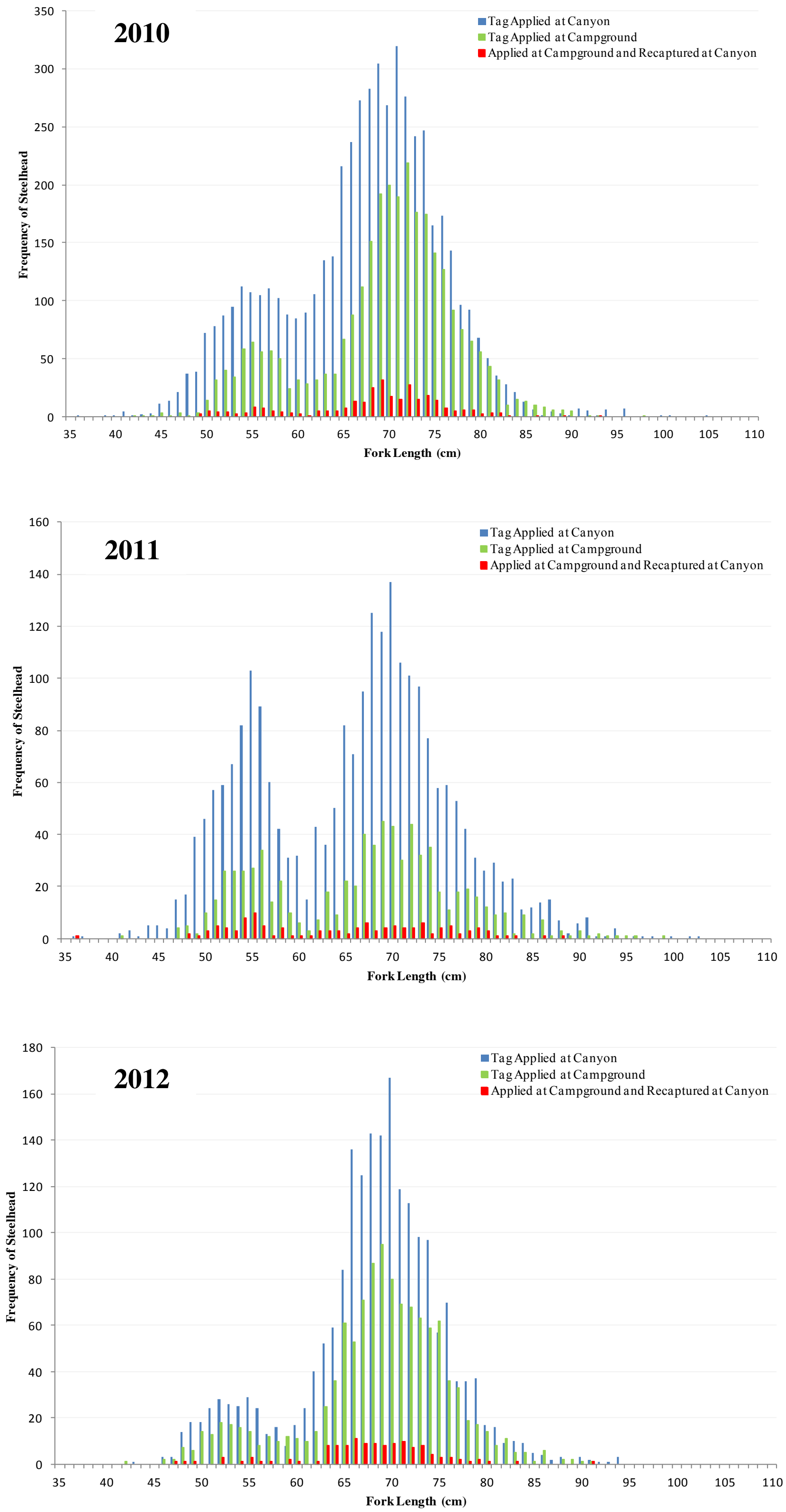


Figure 3. Histograms displaying distributions of fork lengths recorded for steelhead tagged at the campground, tagged at the canyon, and recaptures at the canyon of steelhead tagged at the campground from 2010 to 2012.

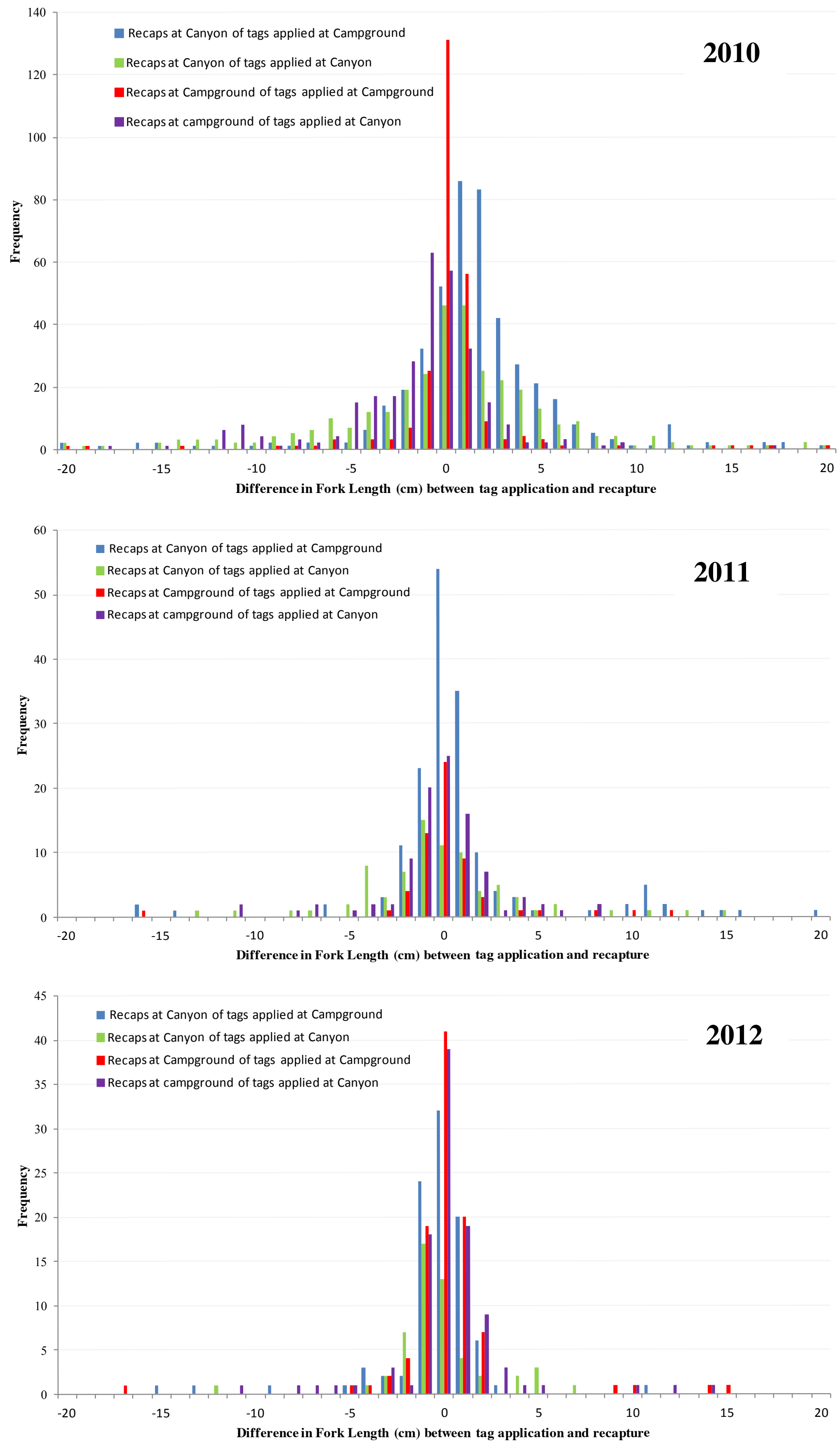


Figure 4. Histogram displaying differences between steelhead fork lengths recorded at tag application and recapture locations in 2010, 2011, and 2012.

3.1.3 Fish Condition

Fish condition criteria recorded are grouped into two broad categories: "natural condition criteria" (i.e. Table 2: bite marks, cysts, fungus, lice) and "condition criteria related to fish handling" (Table 3: scale loss, net marks, bleeding gills, torn tail, torn fin) though some criteria could fall into both categories (e.g. fungus, scale loss). No alarming rates of natural causes of degradation in steelhead health were observed in 2012, although the proportion of steelhead with cysts (i.e. 1.70 % inclusive of steelhead with tags applied at the campground and canyon combined) and bite marks (i.e. 2.13 %, also inclusive of steelhead that had tags applied at the campground and canyon combined) in 2012 were nearly double the results in 2011 (i.e. 0.09 % and 1.30%, respectively). Some useful results related to the impacts of beach seining and dip netting on steelhead health were diligently recorded in 2012 with a summary presented for comparison to 2011 in Table 3. Although there were no notable differences in health conditions on release of fish handled during beach seine operations in 2012 compared to 2011(Table 3), the release of approximately 100 fish without handling when too many steelhead were captured in a single set was undoubtedly a safe practice and should be continued. The use of the new rubber material cradle for transporting fish from the dip net to the canyon tagging station appeared to have the most notable reduction of stress and injuries to fish during handling with a notable reduction of torn fins, torn tails, and net marks in comparison to the 2011 results (Table 3). Overall, the data collected with regard to fish health is useful, should not be omitted from future sampling records and could be enhanced, for example by the addition of details for the degree of scale loss and the type of net marks which could be advantageous toward improving the design of the sampling methodologies for this program.

Table 2. "Natural" condition factors related to the health of steelhead at Moricetown Canyon in 2012 and 2011 for comparison.

2011

TagStatus	Recapture Location	Location Tag Applied	Sample Size	Bite Marks	Cyst	Fungus	Sea Lice
Applied		Campground	911	33 (3.62%)	11 (1.21%)	1 (0.11%)	4 (0.44%)
Recaptured	Campground	Canyon	145	1 (0.69%)	1 (0.69%)	0 (0%)	0 (0%)
Recaptured	Campground	Campground	78	0 (0%)	1 (1.28%)	1 (1.28%)	0 (0%)
Applied		Canyon	2559	12 (0.47%)	21 (0.82%)	2 (0.08%)	7 (0.27%)
Recaptured	Canyon	Canyon	106	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Recaptured	Canyon	Campground	115	3 (2.61%)	3 (2.61%)	0 (0%)	1 (0.87%)

2012

TagStatus	Recapture Location	Location Tag Applied	Sample Size	Bite Marks	Cyst	Fungus	Sea Lice
Applied		Campground	1174	40 (3.41%)	24 (2.04%)	0 (0%)	5 (0.43%)
Recaptured	Campground	Canyon	144	5 (3.47%)	1 (0.69%)	0 (0%)	0 (0%)
Recaptured	Campground	Campground	113	5 (4.42%)	4 (3.54%)	0 (0%)	0 (0%)
Applied		Canyon	2540	39 (1.54%)	39 (1.54%)	2 (0.08%)	5 (0.20%)
Recaptured	Canyon	Canyon	89	2 (2.25%)	1 (1.12%)	0 (0%)	0 (0%)
Recaptured	Canyon	Campground	125	2 (1.60%)	1 (0.80%)	0 (0%)	0 (0%)

Table 3. Steelhead condition factors related to fish handling during the tagging program conducted at Moricetown Canyon in 2012 and 2011 for comparison.

2011

TagStatus	Recapture Location	Location Tag Applied	Sample Size	Scale Loss	Net Marks	Bleeding Gills	Torn Tail	Torn Fin
Applied		Campground	911	554 (60.8%)	65 (7.14%)	6 (0.66%)	8 (0.88%)	3 (0.33%)
Recaptured	Campground	Canyon	145	44 (30.4%)	36 (24.8%)	3 (2.07%)	25 (17.2%)	12 (8.28%)
Recaptured	Campground	Campground	78	50 (64.1%)	4 (5.13%)	0 (0%)	0 (0%)	0 (0%)
Applied		Canyon	2559	924 (36.1%)	602 (23.5%)	45 (1.76%)	398 (15.6%)	372 (14.5%)
Recaptured	Canyon	Canyon	106	47 (44.3%)	31 (29.2%)	1 (0.94%)	23 (21.7%)	18 (17.0%)
Recaptured	Canyon	Campground	115	62 (53.9%)	11 (9.57%)	0 (0%)	6 (5.22%)	2 (1.74%)

2012

TagStatus	Recapture Location	Location Tag Applied	Sample Size	Scale Loss	Net Marks	Bleeding Gills	Torn Tail	Torn Fin
Applied		Campground	1174	592 (50.4%)	54 (4.5%)	2 (0.17%)	12 (1.02%)	6 (0.51%)
Recaptured	Campground	Canyon	144	73 (50.7%)	20 (13.9%)	1 (0.69%)	1 (0.69%)	1 (0.69%)
Recaptured	Campground	Campground	113	48 (42.5%)	4 (3.54%)	0 (0%)	0 (0%)	0 (0%)
Applied		Canyon	2540	1079 (42.5%)	406 (16.0%)	95 (3.74%)	229 (9.02%)	116 (4.57%)
Recaptured	Canyon	Canyon	89	30 (33.7%)	13 (14.6%)	3 (3.37%)	10 (11.2%)	8 (8.99%)
Recaptured	Canyon	Campground	125	28 (22.4%)	18 (14.4%)	1 (0.80%)	17 (13.6%)	4 (3.20%)

3.2 CUMULATIVE STEELHEAD CATCH

Indices of cumulative catch for estimating steelhead abundance have not been derived for the Moricetown sampling locations due to difficulties determining a suitable unit of effort (i.e. steelhead per net section, sets per day, dip netting efforts could not be derived) and incorporating appropriate corrections for setting locations (e.g. difficulties with a species selective fishery), influences of different densities of other species on efficiency, variable net lengths (e.g. variable net length tied on shore), and significant effects of flow conditions. Nevertheless, the total catch of steelhead at the campground was 1196 (i.e. 3rd highest), in comparison to totals ranging from 164 to 3510 steelhead in previous years (Table 4). The total catch of steelhead at the canyon of 2890 was also relatively good (i.e. 3rd highest) in comparison to totals at the canyon ranging from 1010 to 6323 steelhead in previous years (Table 4). As noted in previous years (SKR 2011), the number of steelhead sampled at either the campground or canyon location does not appear to be closely correlated with steelhead abundance estimates (i.e. pooled Petersen estimates). In addition, the lack of continuous sampling (i.e. 7 days per week), the occurrence of inconsistent sampling effort among years (e.g. sampling on occasional weekends or variable numbers of crews per day), and the different end dates of sampling for each year further complicate inter-annual comparisons of the cumulative catch. The summary of steelhead sampling results in table 4 does suggest that sampling appears to be adaptable to varying river flow conditions based on the success during high river levels in 2011 and reasonable success during low river levels in 2006.

Based on the catch results from 1999 to 2012, inter-annual variability of catch efficiency, the timing of steelhead migration, and the delay of steelhead migration at Moricetown are summarized in the following sections.

Table 4. Steelhead sampled at the beach seine sites and dip net site during the steelhead tagging program conducted at Moricetown Canyon from 1999 to 2012.

	Campground Sites Tag Application[1]			Canyon Site Resampling		
Year	**# of steelhead**	**Ranking**	**% of Highest (i.e. 2010)**	**# of steelhead**	**Ranking**	**% of Highest (i.e. 2010)**
1999	164	14th	5.6%	1555	11th	24.6%
2000	225	12th	7.6%	1010	14th	16.0%
2001	322	10th	10.9%	1183	12th	18.7%
2002	846	5th	28.7%	1933	6th	30.6%
2003	670	7h	22.7%	1864	7th	29.5%
2004	319	11th	10.8%	1615	10th	25.5%
2005	523	9th	17.7%	1697	9h	26.8%
2006	595	8th	20.2%	1777	8h	28.1%
2007	224	13th	7.6%	1101	13th	17.4%
2008	799	6th	25.7%	1988	5th	31.4%
2009	1316	2nd	47.1%	2263	4th	35.8%
2010	3510	1st	100 %	6323	1st	100%
2011	1131	4th	32.2%	2896	2nd	45.8%
2012	1196	3rd	34.1%	2890	3rd	45.7%

Note [1] Number of steelhead includes all recaptures

3.2.1 Inter-Annual Variability of Catch Efficiency

Catch efficiency by both the beach seine and dip net methods have shown inter-annual variability since the start of the Moricetown steelhead tagging program due to crew experience, the development of technical aspects of the sampling methods and the partially selective fishery for different species in previous years. In addition, abundance of other species in the system (e.g. some years with high abundance of coho or pink salmon), and targeted effort to various species at different times of the year, as well as environmental variables (e.g. water level) can affect catch efficiency for individual species. The number of steelhead tagged at the campground locations for the different years divided by the corresponding Petersen estimates was 5.3% in 2012 which indicates that the catch efficiency by beach seine was fourth highest within the range from 0.5 % (i.e. 2000) to 7.2% (i.e. 2010) of the total estimated return of steelhead to Moricetown Canyon since the initiation of this project (Table 5). Total catch at the canyon sites divided by the corresponding Petersen estimates was 10.5% in 2011 and indicates that the catch efficiency by dip net was only the sixth highest within the range from 1.8 % (i.e. 2000) to 15.4% (2010) of the total estimated return (Table 5). The total number of recaptures at the canyon divided by the total number of steelhead marked at the campground locations is also displayed in Table 5, since it may be useful for estimating abundance in-season if an adjustment for the delay of steelhead migration from the campground locations to the canyon can be derived (i.e. temporal stratification). As mentioned in previous reports (SKR 2011, 2012), no correlations between Petersen estimates and cumulative catch adjusted by catch efficiencies are obvious; thus cumulative catch of steelhead by beach seine or dip net still requires further investigation of other factors (e.g. river conditions, sampling effort units) that may influence the correlation of cumulative catch to abundance. It is worth noting that the estimated proportion of steelhead arriving at Moricetown and sampled by beach seine or dip net has continued to be a considerable proportion of the population in 2012 (i.e. [M]+[C]-[R]/[N] = 14.4%), although significantly less than recent years (i.e. estimates of 19.3% in 2011 and 21.4% in 2010). It is still important to reiterate the importance of minimizing the impacts of handling on steelhead health if sampling is to continue at this intensity.

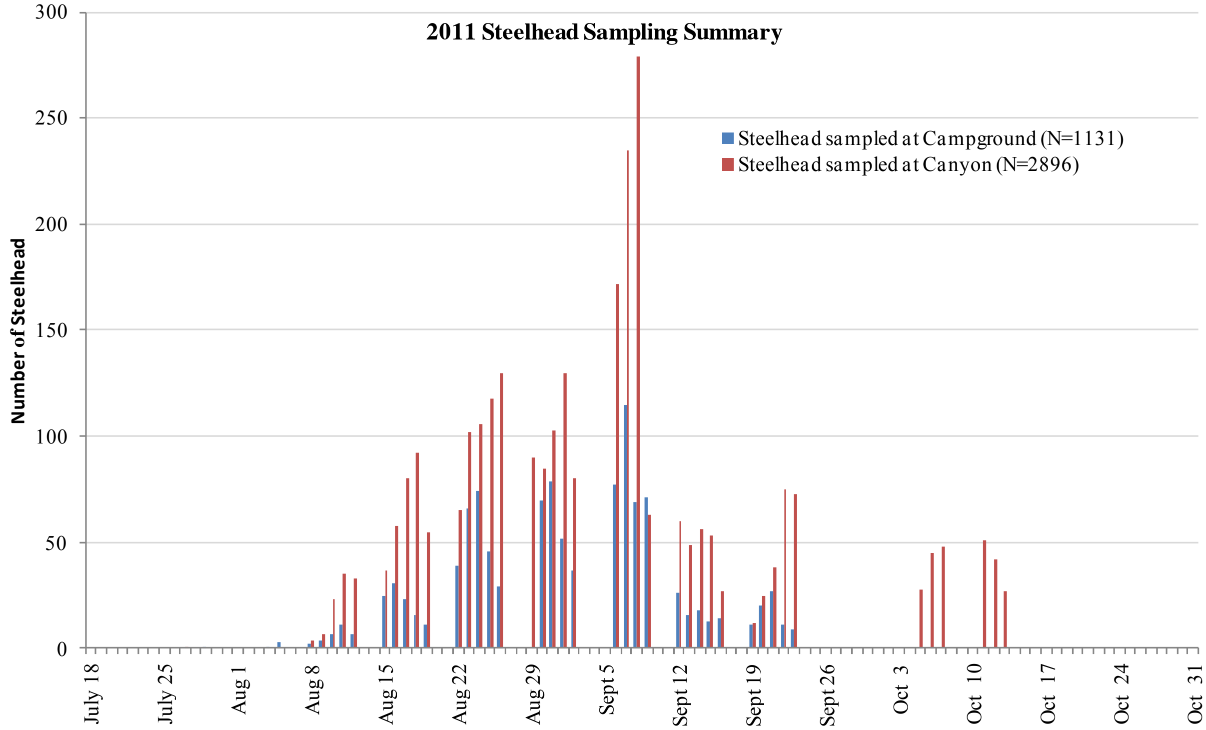
Table 5. Catch efficiencies related to Petersen steelhead abundance estimates at Moricetown Canyon.

Year of Study	Number of Steelhead (Ranking)			Petersen Estimate [N]	Catch Efficiency			Canyon Sampling End Date
	Marked at Beach Seine [M]	Examined at Canyon [C]	Recaptured at Canyon [R]		Beach Seine [M/N]	Canyon Dip Net [C/N]	Canyon Dip Net [R/M]	
1999	164	1555	8	**28,527**	0.6%	5.5%	4.9%	Oct. 25th
2000	225	734	3	**41,428**	0.5%	1.8%	1.3%	Oct. 18th
2001	322	1184	23	**15,948**	2.0%	7.4%	6.5%	Oct. 17th
2002	846	2068	68	**25,398**	3.3%	7.6%	7.7%	Sept. 30th
2003	670	1864	102	**12,150**	5.5%	15.3%	15.1%	Sept. 19th
2004	319	1615	32	**15,670**	2.0%	10.3%	10.0%	Sept. 13th
2005	523	1697	57	**15,341**	3.4%	11.1%	10.9%	Sept. 27th
2006	595	1777	69	**15,138**	3.9%	11.7%	11.6%	Sept. 26th
2007	224	1101	12	**19,073**	1.2%	5.8%	3.1%	Sept. 28th
2008	759	1988	54	**27,484**	2.8%	7.2%	7.1%	Oct. 9th
2009	1390	2297	127	**24,973**	5.6%	9.1%	7.7%	Oct.1st
2010	2946	6323	452	**41,140**	7.2%	15.4%	15.3%	Oct. 22nd
2011	931	2896	140	**19,149**	4.9%	15.1%	15.1%	Oct. 13th
2012	1196	2890	125	**27,465**	5.3%	10.5%	10.5%	Oct. 18th

Note: Some minor corrections from previous reports included: inclusion of recaptures at canyon re-sample site in [C], and exclusion of tags applied after the last day sampled at the Canyon for [M]. Green font indicates maximum values and red font minimum values for each column.

3.2.2 Timing of Steelhead Arrival at Moricetown

Sampling started on July 30th in 2012 and the beginning of steelhead arrival, indicated by the earliest dates that steelhead were captured, was August 8th at the campground and August 8th at the canyon. The more definitive measure of when steelhead began arriving at Moricetown may be better represented by when more than 5 steelhead were captured; August 13th at both locations in 2012 compared to earlier dates of July 27th (2008 and 2010) at the canyon and July 20th (2004) at the campground. It is important to note, that the high discharge flowing over the Moricetown fish way in 2012 likely reduced dip net efficiency, thus giving some bias to the estimated arrival time of steelhead in 2012. Daily steelhead catch results by beach seine immediately downstream of Moricetown Canyon (i.e. campground) and by dip net at the Moricetown Canyon falls and fishway (i.e. canyon) have been presented for comparisons of run timing at the two locations (Figure 5) and to present the annual variability in the timing of steelhead arrival based on the sampling methods used for the Moricetown Tagging Project (Figure 6). Due to the intra-annual variability in catch efficiency and apparent variability between the proportions of campground to canyon sampling (*see* Table 5), the catch at the sites have not been pooled. The main surge of steelhead arriving at the campground site started on August 20th in 2012 and did not appear to be as delayed as the late date of the initial capture indicated that it might be. The main surge of steelhead in 2012 from August 20th to August 31st was not extremely late in comparison to weeks beginning as early as August 9th in 2010, and as late as September 12th in 2006 (Figure 6). The main surge of steelhead arriving at the canyon was during the week following the initial surge at the campground which supports that the majority of steelhead (i.e. not just fish tagged at the campground) delay their attempt to pass the Moricetown falls by approximately one week (Figure 5). Overall, the extension of sampling and tag application at the campground to October 11th and sampling at the canyon to October 18th in 2012 appear to have provided a relatively complete estimate of steelhead arriving at Moricetown in the fall of 2012.



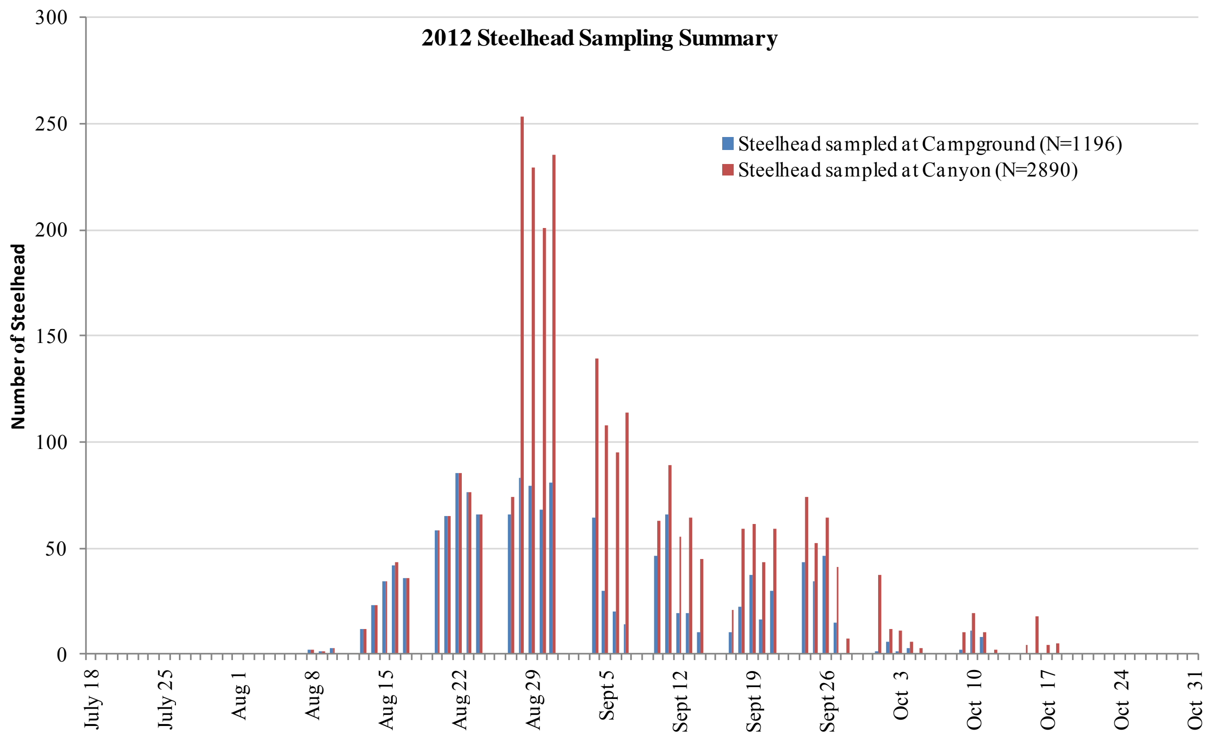
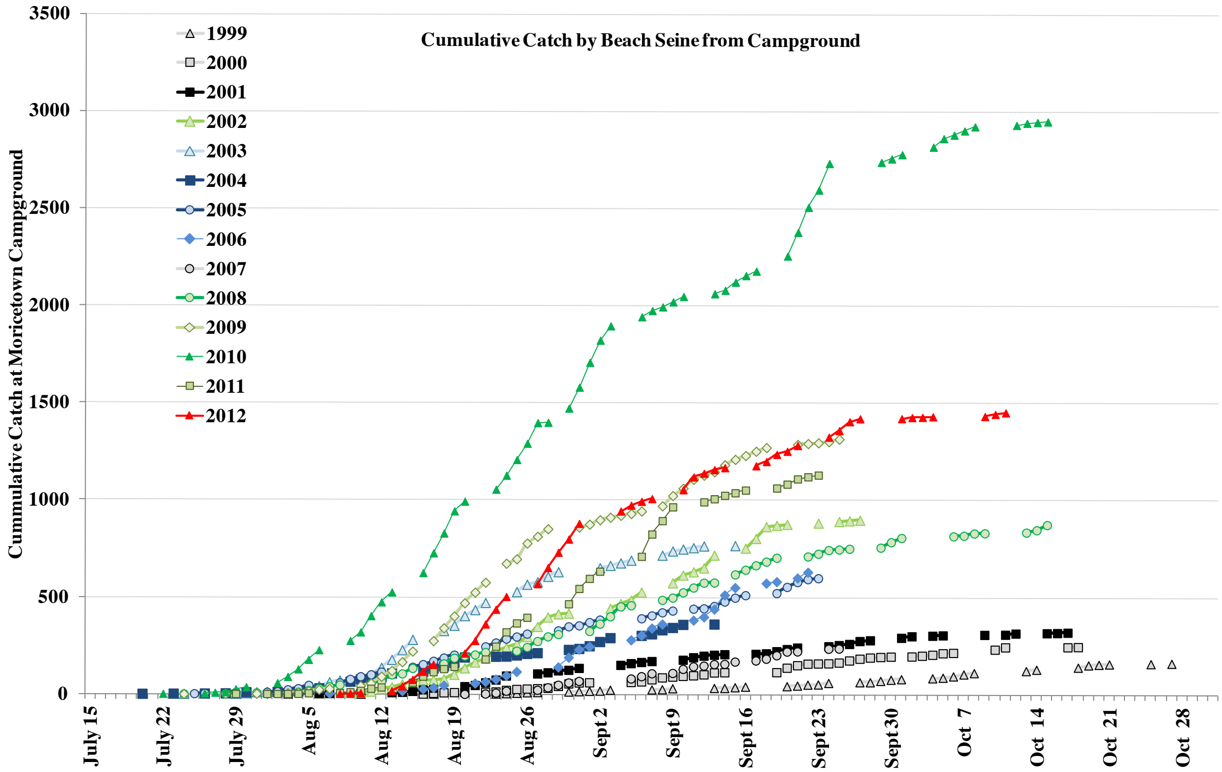


Figure 5. Distribution of steelhead catch at the campground and canyon location during the Moricetown steelhead mark and recapture study in 2012 and 2011 for comparison.



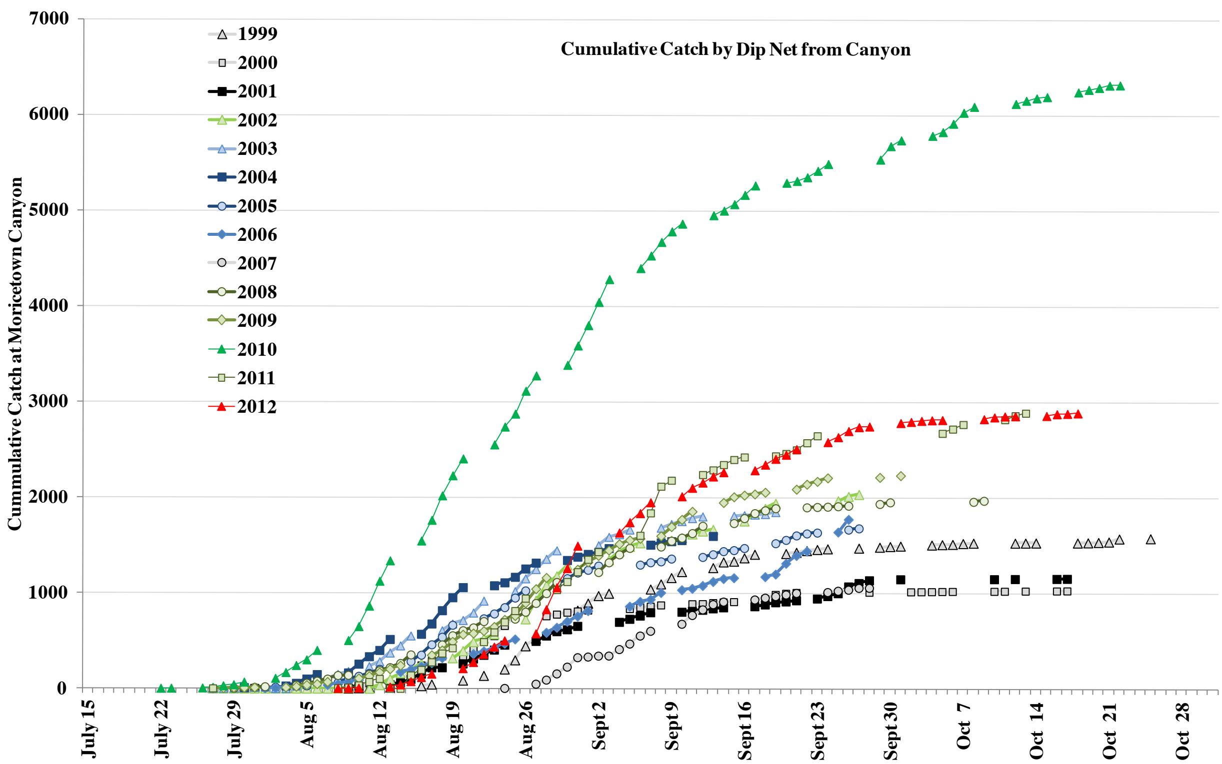


Figure 6. Cumulative catch of steelhead at Moricetown campground tag application sites 1 and 2 (top) and canyon resampling site 3 (bottom) from 1999 to 2012.

3.2.2.1 Associations of River Temperature and Water Levels with Steelhead Migration

Water temperature data loggers were placed in the Bulkley River downstream of the Moricetown Canyon by B.C. Fisheries from August 1st to November 12th in 2010, August 3rd to September 23rd in 2011, and August 23rd to August 18th in 2012. In 2012, the data logger was discovered out of the water on September 16th, thus data was omitted back to September 9th where fluctuations in temperature indicated that the data logger had been exposed to air. Minimum and maximum daily temperatures based on hourly recorded data for the 2010 to 2012 sampling periods have been presented in Figure 7. Fluctuations in water levels in the Bulkley River near Moricetown during the 2010 to 2012 sampling periods are also presented in Figure 8 and display the unusually high flows at the start of the 2012 sampling that may have influenced the sampling intensity as well as relatively low flows during the autumn of 2012 may later be associated with poor freshwater survival of juvenile steelhead despite high estimates of returns in 2011.

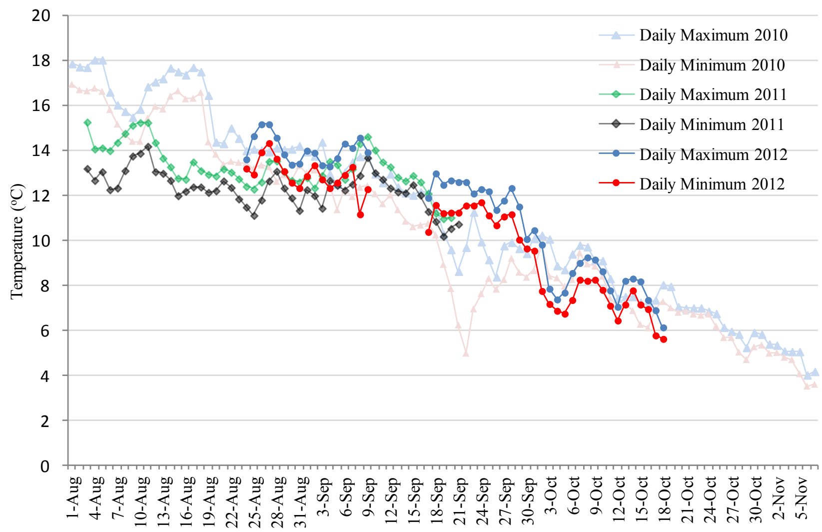


Figure 7. Summary of minimum and maximum water temperatures for the Bulkley River at Moricetown from the BC Fisheries Moricetown data logger in 2010 and 2011.

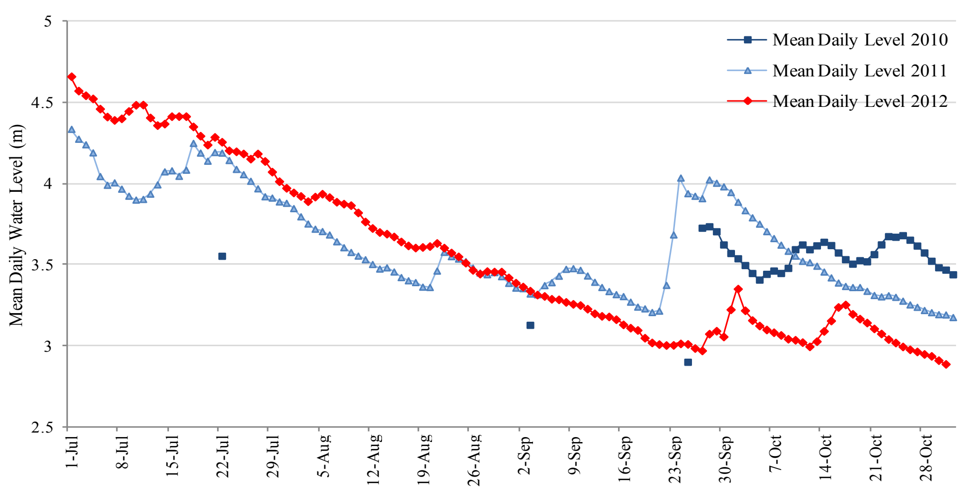
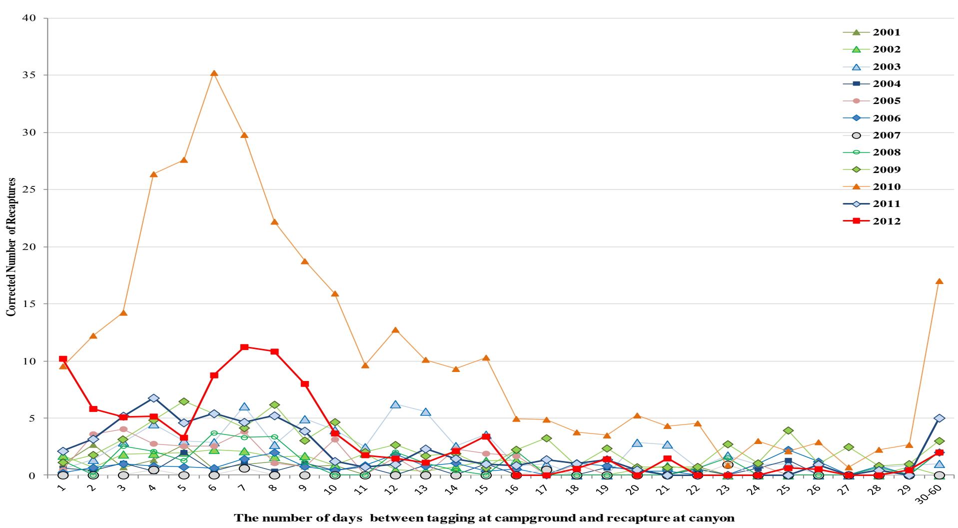


Figure 8. Real-time water levels of the Bulkley River from Environment Canada Hydrometric Station (08EE005) near Smithers, B.C.

3.2.3 Delay of Steelhead Migration at Moricetown Canyon

The tightly confined canyon, falls and fish way in Moricetown Canyon has locally been considered a bottleneck to all fish migration due to the observed congregation of migrating salmon and steelhead at the entrance to the canyon throughout the sport fishing season. A notable delay of steelhead migration from the Moricetown campground to the canyon has been supported by historical data for steelhead that were marked at the campground and recaptured at the canyon (Figure 9). In 2012, a total of 125 recaptures had a median delay of 6.6 days between tagging and recapture in comparison to the pooled median of 7.5 days for all of the years combined ranging from 4.4 days in 2001 (note: only 21 recaptures) to 12.8 days in 2006 which had very low river levels throughout the sampling period (Table 6). An unusual mode of recaptures less than two days after application was apparent in 2012 (Figure 9), but the correlation of the dates when tags were applied to the number of days to recapture shows no significant trend based on the regression analysis presented in Figure 10 that may support the credibility of using the pooled median for future in-season abundance estimates. In addition, no significant difference between the medians was identified when comparing the pooled median to years when more than 30 steelhead were recaptured (χ^2 = 15.927, df=9, p = 0.067), indicating that environmental variables (e.g. Bulkley River discharge) effecting the migration behaviour of steelhead from the campground to the canyon have not caused statistically significant differences up to 2012. Thus the data from 2001-2012 has been pooled to calculate the expected distribution of delays in steelhead migration from the campground tagging location to the canyon sampling location (Table 6). With the addition of the 2012 results, the pooled median for the delay between tag application and recapture pooled has been reduced from 7.7 to 7.5 days due to a minor correction to the median for 2011 (i.e. 8.3 corrected to 6.6) and a median of 6.6 days in 2012. It will be important to incorporate and constantly test and update this temporal stratification into future mark recapture abundance estimates to account for early end dates of sampling and to acknowledge the uncertainties of the distribution (i.e. upstream or downstream of Moricetown) of overwintering steelhead in the Morice/Bulkley watershed.



Note: The number of recaptures used to assess the delay of steelhead migration at Moricetown Canyon have been corrected (i.e. Corrected R) to account for the different sample sizes of marked steelhead (M) that were sampled for recovery at the canyon for the different lengths of delay (i.e. Corrected $R_i = R_i * M_i / M_{max}$, where *i* is the # of days delayed).

Figure 9. Distribution of the corrected numbers of recaptured steelhead with different time delays when migrating from the campground/beach seine location to the canyon/dip net re-sampling location.

Table 6. Distribution of the time delay (days) and the median delay (red) for steelhead marked at the campground/beach seine location were recaptured at the canyon/dip net sampling location.

	Adjusted Number of Steelhead Recaptured (R) *[1]												Pooled Results		
Days to Recapture	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**Pooled Total**	**Proportion of Recaptures**	**Cumulative Proportion**
1	1.0	1.7	0.5	0.6	0.5	0.2	0.0	1.2	1.1	9.5	2.1	10.2	28.6	**0.038**	**0.03**
2	2.7	0.7	1.4	0.4	3.6	0.7	0.0	0.0	1.8	12.2	3.2	5.8	32.4	**0.042**	**0.072**
3	0.7	1.8	2.9	1.1	4.0	1.0	0.0	2.5	3.1	14.2	5.2	5.1	41.7	**0.055**	**0.127**
4	1.3	1.9	4.5	0.3	2.8	0.8	0.5	2.1	4.8	26.2	6.8	5.1	57.1	**0.075**	**0.202**
5	2.7	2.0	3.0	1.9	2.5	0.7	0.0	1.3	6.5	27.5	4.6	3.3	55.9	**0.073**	**0.275**
6	0.5	2.2	2.9	0.3	2.6	0.6	0.0	3.7	5.4	35.2	5.4	8.7	67.6	**0.089**	**0.364**
7	1.0	2.1	6.0	1.0	3.8	1.4	0.6	3.3	4.1	29.7	4.6	11.2	69.0	**0.091**	**0.455**
8	1.2	1.6	2.7	0.4	1.1	2.0	0.0	3.4	6.2	22.2	5.2	10.8	56.6	**0.074**	**0.529**
9	0.8	1.7	4.9	1.0	0.7	0.8	0.0	1.1	3.0	18.8	3.9	8.0	44.7	**0.059**	**0.588**
10	0.9	0.9	3.9	0.4	3.1	0.4	0.0	0.0	4.6	15.9	1.2	3.7	35.1	**0.046**	**0.634**
11	0.0	1.9	2.5	0.8	0.0	0.9	0.0	0.0	2.0	9.6	0.7	1.8	20.1	**0.026**	**0.660**
12	0.0	0.5	6.2	0.0	1.6	1.8	0.0	2.0	2.7	12.7	1.0	1.5	29.9	**0.039**	**0.699**
13	0.0	0.4	5.6	0.9	0.0	0.8	0.0	1.1	1.7	10.1	2.3	1.1	23.9	**0.031**	**0.731**
14	0.0	0.7	2.6	0.0	2.3	1.1	0.0	0.4	1.9	9.3	1.4	2.1	21.8	**0.029**	**0.759**
15	0.0	1.3	3.6	1.0	1.9	0.3	0.0	0.0	0.6	10.3	1.0	3.4	23.3	**0.031**	**0.790**
16	0.0	1.3	0.8	0.0	1.7	0.5	0.0	2.1	2.2	4.9	0.9	0.0	14.5	**0.019**	**0.809**
17	0.0	0.5	1.0	0.0	0.0	0.0	0.5	0.0	3.2	4.9	1.4	0.0	11.4	**0.015**	**0.824**
18	0.0	0.0	0.0	0.0	0.9	1.1	0.0	0.0	0.8	3.7	1.0	0.6	8.1	**0.011**	**0.834**
19	0.0	0.0	0.0	0.7	0.0	0.8	0.0	0.0	2.3	3.5	1.4	1.4	10.1	**0.013**	**0.848**
20	0.0	0.5	2.8	0.0	0.0	0.4	0.0	0.0	0.7	5.2	0.5	0.0	10.1	**0.013**	**0.861**
21	0.0	0.8	2.7	0.0	0.0	0.4	0.0	0.0	0.7	4.3	0.0	1.5	10.4	**0.014**	**0.874**
22	0.8	0.5	0.6	0.6	0.0	0.0	0.0	0.6	0.7	4.5	0.0	0.0	8.4	**0.011**	**0.885**
23	0.0	0.0	1.7	0.0	0.0	0.0	0.9	1.5	2.7	0.9	0.0	0.0	7.8	**0.010**	**0.896**
24	0.0	0.0	1.0	0.6	0.9	1.0	0.0	0.0	1.0	3.0	0.0	0.0	7.6	**0.010**	**0.906**
25	0.0	0.0	1.0	1.4	0.0	2.2	0.0	0.0	3.9	2.1	0.0	0.6	11.2	**0.015**	**0.920**
26	0.0	0.0	0.0	0.0	0.0	1.2	0.0	0.0	1.0	2.9	0.9	0.5	6.5	**0.009**	**0.929**
27	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.5	0.7	0.0	0.0	3.2	**0.004**	**0.933**
28	0.0	0.0	0.7	0.0	0.0	0.8	0.0	0.7	0.8	2.2	0.4	0.0	5.6	**0.007**	**0.940**
29	0.0	0.7	0.8	0.0	0.0	0.0	0.0	0.0	1.0	2.7	0.0	0.4	5.7	**0.007**	**0.948**
>29	0.0	0.0	1.0	0.0	2.0	2.0	0.0	2.0	3.0	17.0	5.0	2.0	34.0	**0.045**	**1.000**
Adjusted Total *[1]	13.4	25.6	67.2	13.3	36.0	23.8	2.5	29.0	76.3	326.0	59.9	88.9	**761.9**	**Adjusted Total Recaptures*[1]**	
Median	4.4	7.2	10.4	8.8	6.5	12.8		7.1	9.5	7.4	6.6	6.6	**7.5**	**Median Days to Recapture**	
Total	*21*	*65*	*101*	*32*	*57*	*69*	*7*	*54*	*107*	*451*	*138*	*123*	***1225***	***Total Recaptures***	

*[1] Number of recaptures are corrected for due to the lack of sampling on consecutive days throughout the study and because the tag application and canyon sampling ended on approximately the same dates of each year. The number of recaptures (R) for each length of delay (i.e. 1-29 days) are corrected down by multiplying each R by a correction factor (i.e. minimum number of marked steelhead sampled for any given time delay of each year/number of marked steelhead sampled for each lag time of the same year) to account for the different number of tagged steelhead that were sampled for the different time lags in the same year.

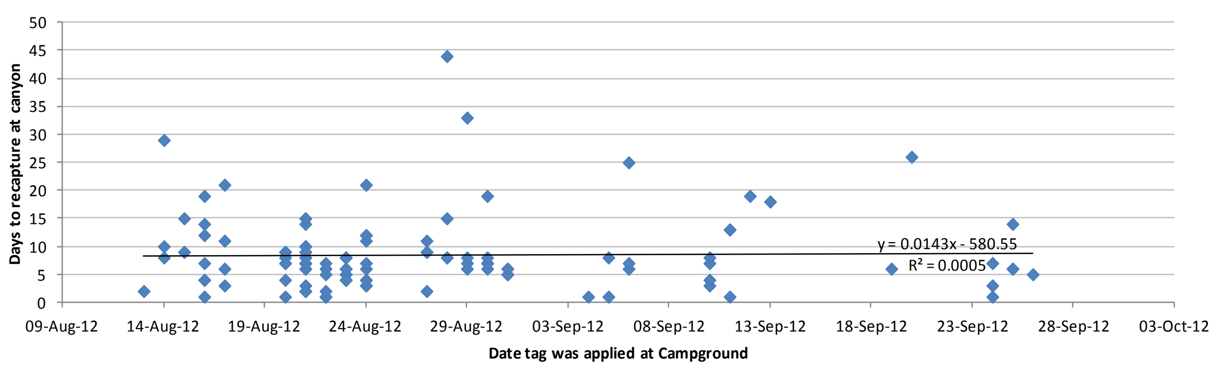


Figure 10. Correlation and regression analysis for the dates in 2012 when steelhead tags were applied at the Moricetown campground sites and time delay (days) to their recapture at the canyon.

3.3 OCEAN AGE COMPOSITION AND FORECASTS FOR 2013

A preliminary extrapolation of the data has been derived to approximate the ocean age distribution of steelhead in the 2012 return in attempt to describe the complexity of factors related to annual fluctuations in abundance estimates for steelhead arriving at Moricetown each year. Although no scale samples were obtained from the steelhead sampled at Moricetown in 2012, the bimodal distribution of fork length data appears to show a notable segregation between steelhead at sea for one winter versus two or more winters (Figure 11). Also helpful in defining the ocean age distributions for steelhead returning to Moricetown in 2012 was the recapture of 34 of 8,134 steelhead that were tagged at Moricetown in 2010. Interestingly, the fork lengths of steelhead that were identified to be repeat spawners from 2010 ranged from 60 -84 cm which shows a clear overlap of fork length distributions with fork lengths of first time spawners from 2010 smolts that spent two winters at sea (Figure 10). This may be good support for historical scale and otolith aging results, but comparison has not been incorporated into this short summary report. Based on the methods described in Section 2.3 of this report, the ocean age composition of steelhead returning to Moricetown in 2012 included the following:

2011 smolts → One Ocean Winter (OW) → **3,711 One-OW Returns**

$$= \frac{445(steelhead\ sampled\ with\ Fork\ Length < 60.5\ cm)}{3293\ (Sample\ Size\ with\ campground\ and\ canyon\ combined)} * 27{,}465$$

2010 smolts →Two Ocean Winters (OW) → **22,109 Two-OW Returns**

= 27,465 (Total estimated return) – 3,691 (1-OW Returns) – 1,645 (Repeat Spawners)

2010 Spawners → One Ocean Winters (0-OW) after previous return → **1,645 Repeat Spawners (RS)**

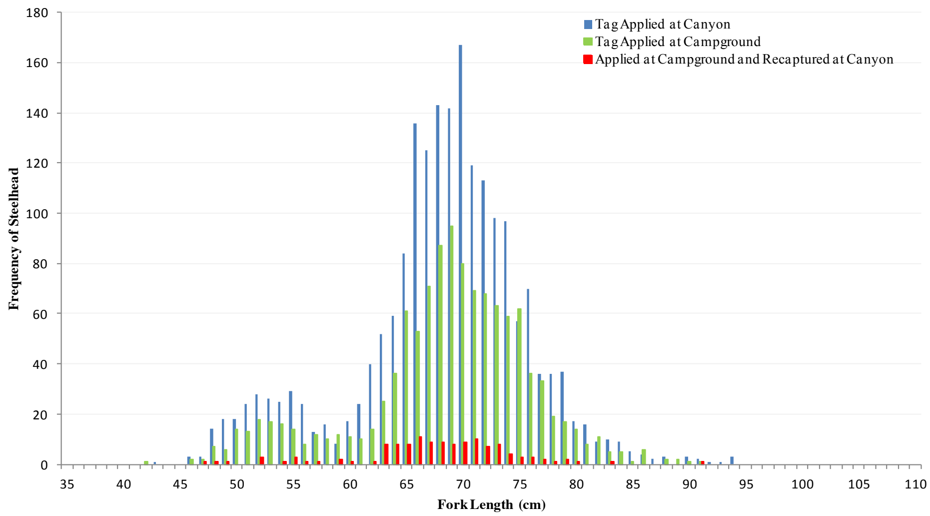
$$= \frac{1987\ (Tags\ applied\ at\ campground\ in\ 2012)}{125\ (Recptures\ at\ Canyon\ of\ Campground\ Tags)} * \frac{34\ (Recaptures\ of\ RS)}{8134\ (tags\ applied\ in\ 2010)} * 27{,}465$$

It appears noteworthy that the low estimated abundance of steelhead representing the 2011 smolts that returned to spawn after only one winter at sea (i.e. 3,711) suggests that the number of smolts in 2011 was also low and thus may result in below average return of steelhead with two ocean years in 2013. Interestingly, the pre-season forecast for steelhead returning to Moricetown in 2013 is for it to be at moderate level (i.e. <20,000) in the predicted range of 8,609 – 24,917, which is relatively low in comparison to the previously estimated returns that have ranged from 12,150 (i.e. Sept. 13th, 2003) to 41,140 (i.e. Oct. 22nd, 2010) since 1999. This forecast is presented in Appendix 3, and is only a simplistic evaluation based on the following:

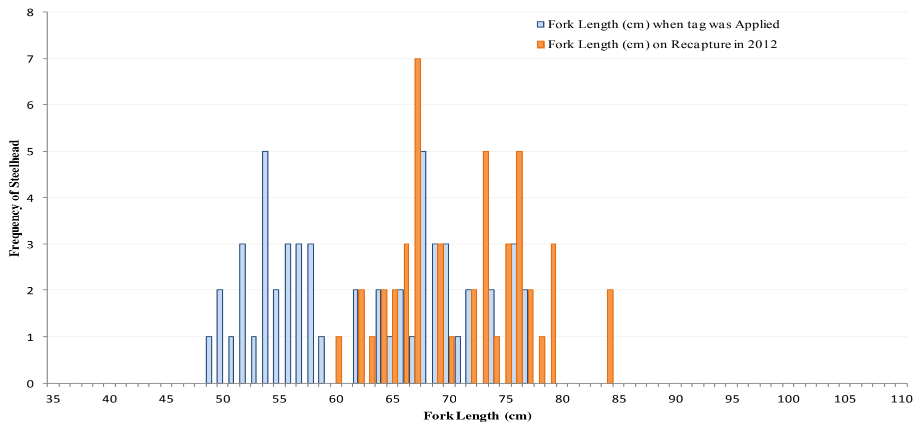
- how past abundance estimates are expected to influence smolt production of relevant years,
- the incorporation of ocean age compositions from the most recent and consecutively sampled years relevant to 2013 steelhead returns,
- the record low number of 2011 steelhead smolts that returned after one winter at sea in 2012, and
- the historical range of the ratio of smolts of a specific year spending one winter or two winters at sea (i.e. 1.4 to 3.9 since 2009).

Although several factors used in this forecast are obviously vulnerable to significant variability (e.g. difficulty in predicting ocean survival), it will be interesting to begin building on this forecast methodology, and even start incorporating more key factors such as winter and summer freshwater conditions that have significant influences on freshwater survival (e.g. measurable freshwater variations from available hydrometric data) which would influence smolt numbers (i.e. increased, average, or below average ratings) for assistance with forecasts within the predicted range for one winter at sea returns.

Fork Length Distributions 2012 Steelhead



Fork Length Distributions 2012 Recaptures of Repeat Spawners from 2010



Corelation of Fork Legths 2012 Recaptures of Repeat Spawners from 2010

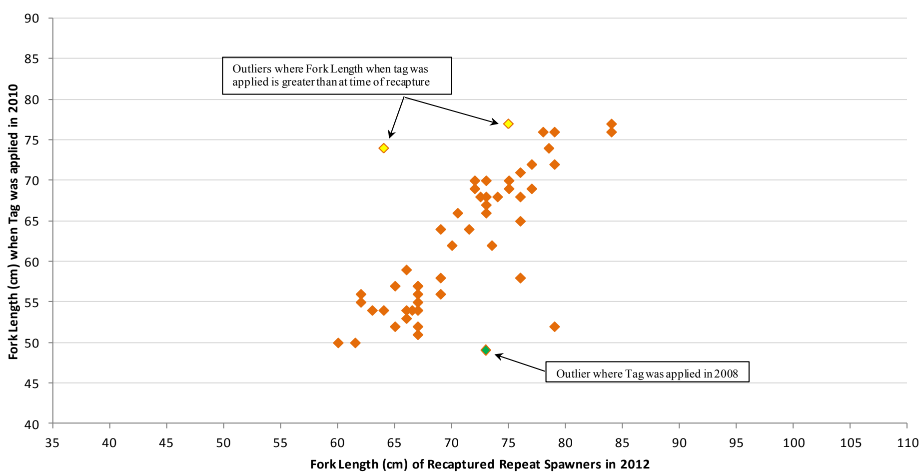


Figure 11. Presentation of 2012 fork length distribution (upper graph) with comparison of fork length distributions of recaptured steelhead identified to be repeat spawners (middle graph) including correlation of growth between different spawning years (middle and lower graphs).

3.4 MORICETOWN STEELHEAD ABUNDANCE ESTIMATES

Based on the available data, steelhead abundance estimates for the autumn arrival of summer-run steelhead at Moricetown have historically been derived using a pooled Petersen estimate due to relatively low catches. As the program has developed over the years, in conjunction with favourable sampling conditions, recently higher catches have allowed stratified estimates such as Schaefer and Maximum Likelihood Darroch methods to be considered. The presentation of steelhead abundance estimates for Moricetown is made under the standard assumptions concerning many population estimates, which are known to be violated to some degree. These estimates should likely be termed as an abundance index until the assumptions are tested and biases have been corrected. Key assumptions specific to this study design that require consideration for defendable inter-annual comparisons of abundance indices include that:

- the sampling time incorporates the entire migration time of steelhead through Moricetown Canyon,
- marked fish do not lose their marks (note: caudal punches insure no tag loss for Petersen estimates, and may provide a correction factor for stratified estimates in years with high numbers of recaptures),
- random samples of marked or unmarked fish are obtained (e.g. ensure sampling is not size selective, temporally biased),
- marked fish mix randomly with unmarked fish (e.g. assume that marked fish do not use the fishway more than unmarked fish),
- the ratio of mortalities for marked versus unmarked steelhead is consistent from year to year for stratified estimates (e.g. sampling is not more harmful to tagged fish in some years than other years),
- the ratio of fallback for marked and unmarked steelhead is consistent from year to year for stratified estimates (e.g. sampling does not impact migration of tagged fish differently in some years than other years), and
- mortality and fall back rates are consistent from year to year if estimating abundance upstream of Moricetown (e.g. sonic studies have already suggested some inter-annual variability of fallback), or annual fallback is measured annually.

In reiteration from past reports for the Moricetown Steelhead Tagging Project, not unlike almost all mark recapture studies that violate at least some of these assumptions to some degree, several of these violations are made with the Moricetown steelhead tagging project as well (*see* Schwarz and Bonner 2011). Fortunately, some estimators of abundance (e.g. pooled Petersen) are generally considered robust (Krebs 1999). Nevertheless, keeping the above assumptions in mind, the following sections summarize:

- inter-annual variability of abundance for steelhead arriving at Moricetown based on the historically presented Petersen estimate and stratified Schaefer and Maximum Likelihood Darroch estimates,
- necessary corrections for fallback, emigration and tagging mortality, and
- a comparison of Moricetown Petersen estimates to the Tyee Steelhead Abundance Index.

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3.4.1 Petersen Estimates

Historically, pooled Petersen estimates have been used to estimate steelhead returns to Moricetown Canyon due to the acquisition of only small numbers of recaptures and variable periods of sampling at the start of this study. A precautionary note when comparing Moricetown steelhead abundance estimates is to acknowledge the very small numbers of recaptures that occurred in 1999, 2000, and 2007 which resulted in estimates with very poor precision for those years. In 2012, the Petersen estimate for steelhead arriving at the Moricetown campground was 27,645 (95% C.I. = 23,709 – 33,167) which is within the historical range of estimates, but significantly lower than highest estimate of steelhead arriving at Moricetown in 2010 (41,140 with 95% C.I.: 38,058 – 44,934). In addition, the Petersen estimates for five of the 14 years sampled prior to 2012 were significantly lower than the estimate for 2012, although two of those years (i.e. 2003 and 2004) had relatively early end dates of sampling (Table 7).

Table 7. Petersen abundance estimates calculated for steelhead arriving at Moricetown Canyon.

Year of Study	Number of Steelhead			Petersen Estimate	95% Confidence Interval		Canyon Sampling End Date
	Marked (M)	Examined (C)	Recaptured (R)		Lower	Upper	
1999	164	1555	8	**28,527**	16,250	58,350	Oct. 25th
2000	225	734	3	**41,428**	18,876	103,819	Oct. 18th
2001	322	1184	23	**15,948**	10,920	24,040	Oct. 17th
2002	846	2068	68	**25,398**	20,890	33,481	Sept. 30th
2003	670	1864	102	**12,150**	10,388	14,908	Sept. 19th
2004	319	1615	32	**15,670**	11,425	23,126	Sept. 13th
2005	523	1697	57	**15,341**	12,459	20,753	Sept. 27th
2006	595	1777	69	**15,138**	12,511	19,767	Sept. 26th
2007	224	1101	12	**19,073**	11,621	32,258	Sept. 28th
2008	759	1988	54	**27,484**	22,097	37,856	Oct. 9th
2009	1390	2297	127	**24,973**	21,578	30,112	Oct.1st
2010	2946	6323	452	**41,140**	38,058	44,934	Oct. 22nd
2011	931	2896	140	**19,149**	16,709	22,725	Oct. 13th
2012	1196	2890	125	**27,465**	23,709	33,167	Oct. 18th

Note: Some minor corrections from previous reports included: inclusion of recaptures at canyon re-sample site, and exclusion of tags applied after the last day sampled at the Canyon.

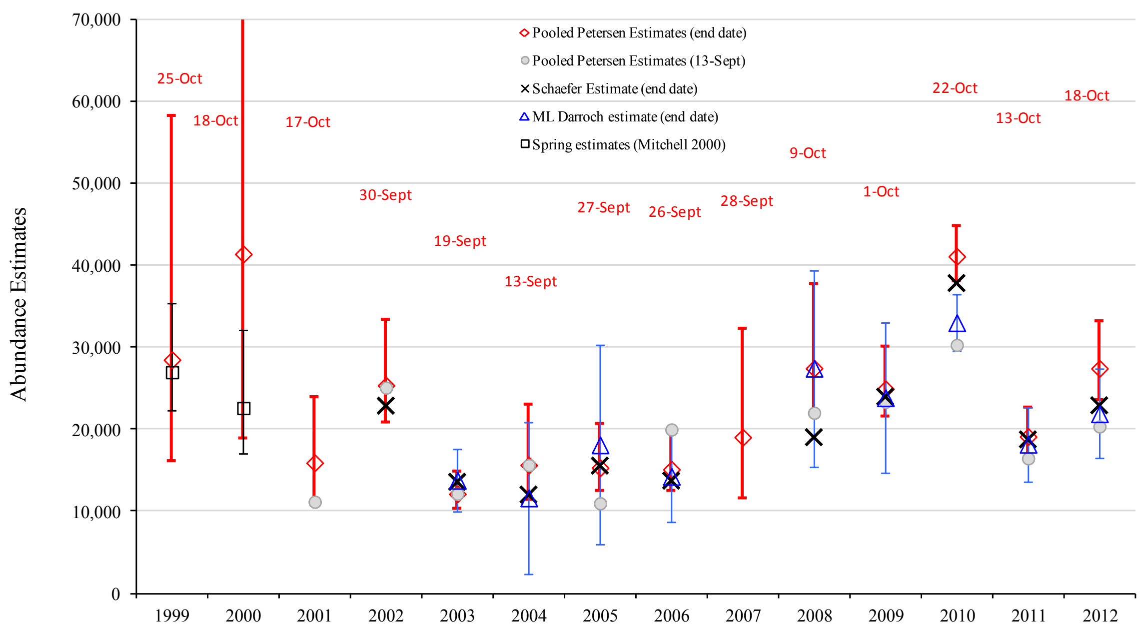
3.4.2 Stratified Abundance Estimates

From 2003 to 2012, a stratified population analysis tool (SPAS)(Arnason *et al* 1996) using a Schaefer estimate (Schaefer 1951) and a Maximum Likelihood Darroch estimate (ML Darroch) with arbitrary pooling to reduce the redundancy of temporal strata (Darroch 1961, Chapman and Junge 1956, Plante 1990) have been used to incorporate temporal stratification into the estimate and account for heterogeneity of catchability among the designated release groups (Appendix 4). For 2012, both capture (i.e. tags applied) and recapture strata (i.e. canyon sample) were grouped by 7 day intervals (i.e. week) and strata were pooled for Schaefer and ML Darroch estimates (Appendix 4). A summary of the end of season abundance estimates for steelhead comparing pooled Petersen (Table 7), Schaefer and ML Darroch results are presented in table 8 and figure 9. In 2012, tags were applied to 1196 steelhead at the campground sites, 2,890 steelhead were sampled at the canyon including 125 recaptures of tagged steelhead (note: two fewer recaptures than used for Petersen estimate due field data error). Based on results from previous years (SKR 2012) a 2.5% tag loss correction is used for the applied numbers of tags over each stratum. Somewhat different from past years, both the Schaefer (i.e. 22 931, *see* Appendix 4) and the ML Darroch (i.e. 21,926, *see* Appendix 4) estimates were notably lower than the pooled Petersen estimate for 2012 (i.e. 27,465, Table 7), with the ML Darroch also having slightly less precision (Table 8).

Table 8. Annual Comparisons of Steelhead Abundance Estimates using pooled Petersen, and stratified Schaefer and Darroch Maximum Likelihood (ML Darroch) Methods.

Study	Petersen Estimate*[1]	Schaefer Estimate		ML Darroch Estimate	95% Confidence Interval		Canyon Sampling End Date
					Lower	Upper	
Moricetown tagging 1999	**28,527**						Oct. 25th
Angling estimate spring 2000*[2]	**27,005**						N.A.
Moricetown tagging 2000	**41,428**						Oct. 18th
Sport fish estimate fall 2000*[3]	**22,627**						N.A.
Moricetown tagging 2001	**15,948**						Oct. 17th
Moricetown tagging 2002	**25,398**	**22,883**					Sept. 30th
Moricetown tagging 2003	**12,150**	**13,589**		**13,800**	9,928	17,673	Sept. 19th
Moricetown tagging 2004	**15,670**	**12,033**		**11,647**	2,398	20,897	Sept. 13th
Moricetown tagging 2005	**15,341**	**15,567**		**18,126**	5,969	30,284	Sept. 27th
Moricetown tagging 2006	**15,138**	**13,734**		**14,283**	8,795	19,771	Sept. 26th
Moricetown tagging 2007	**19,073**						Sept. 28th
Moricetown tagging 2008	**27,484**	**19,039**		**27,474**	15,487	39,461	Oct. 9th
Moricetown tagging 2009	**24,973**	**23,986**		**23,986**	14,639	33,136	Oct.1st
Moricetown tagging 2010	**41,140**	**38,064**		**33,047**	29,599	36,495	Oct. 22nd
Moricetown tagging 2011	**19,149**	**18,770**		**18,199**	13,692	22,707	Oct. 13th
Moricetown tagging 2012	**27,465**	**22,931**		**21,926**	16,456	27,395	Oct. 18th

*[1] for details on the Petersen estimates see Section 2.3 for methods and Table 7 for data summary and confidence intervals.
*[2] (Mitchell 2000)
*[3] (Mitchell 2001)



Note: Error bars indicate 95% confidence intervals with Poisson (<50 recaptures) or Normal approximation for Pooled Petersen Estimates (end date) in red and for Maximum Likelihood Darroch Estimates in blue.

Figure 12. Estimates of the number of Bulkley/Morice steelhead arriving at Moricetown Canyon from 1999 to 2012.

3.4.3 Corrections for Fallback and Mortality Based on Acoustic Telemetry

In order to estimate steelhead abundance upstream of Moricetown Canyon, a correction to the abundance estimates for steelhead arriving at the campground is required to account for the fallback and mortality of steelhead that arrive at the campground, but do not reach the re-sampling location. The Bulkley River sonic tagging studies have estimated the fallback of steelhead handled at the Moricetown campground (i.e. tagged steelhead not available for recapture) to approximately 34% in 2009 (Welch *et al*. 2009, 2010, Peard and Beere 2010). Accounting for the potential difference between fallback and mortality of tagged steelhead and untagged steelhead is a key factor for any abundance estimates, however there is currently no information available for the fallback or mortality of untagged steelhead from Moricetown Canyon. In addition, it is unknown if the behaviour of steelhead tagged with anchor tags and caudal punches differs from those tagged additionally with a sonic tag used in the sonic tagging studies. Based on the annual variability of fallback and unknown difference of mortality between tagged steelhead and untagged steelhead between the two years assessed, a range of corrections for the pooled Petersen estimates are presented in table 9, making the assumptions of a maximum expected difference in fallback and mortality (e.g. 40% of tagged steelhead will never reach the re-sampling location) through a range considering smaller differences in fallback that assumes bias and inter-annual variability (i.e. 20%, and 10% corrections to the abundance estimate) are also presented. Based on these correction factors, the corrected pooled Petersen estimates for steelhead upstream of Moricetown canyon as opposed to simply reaching Moricetown on October 18th in 2012 are from 16,479 (i.e. 40% fallback) to 24,178 (i.e. 10% fallback) (Table 9). To put this estimate into perspective, the lowest range of estimates on record for steelhead migrating upstream of Moricetown Falls has been as low as 7,297 to 10,935 as of September 19th in 2003 and as high as 24,684 to 37,026 as of October 22nd in 2010 (Table 9).

Table 9. Corrected pooled-Petersen Abundance Estimates with examples of adjustments to convert estimates of steelhead arriving at Moricetown campground to estimates of steelhead migrating upstream of Moricetown Canyon as of the end of sampling.

		Petersen Abundance Estimates			
Year	**End of sampling**	**No Correction**	***10% Fallback***	***20% Fallback***	***40% Fallback***
2001	Oct. 17th	15,948	*14,353*	*12,758*	*9,589*
2002	Sept. 30th	25,398	*22,858*	*20,318*	*15,251*
2003	Sept. 19th	12,150	*10,935*	*9,720*	*7,297*
2004	Sept. 13th	15,670	*14,103*	*12,536*	*9,422*
2005	Sept. 27th	15,341	*13,807*	*12,273*	*9,216*
2006	Sept. 26th	15,138	*13,624*	*12,110*	*9,083*
2007	Sept. 28th	19,073	*17,166*	*15,258*	*11,478*
2008	Oct. 9th	27,484	*24,736*	*21,987*	*16,505*
2009	Oct.1st	24,046	*21,641*	*19,237*	*14,435*
2010	Oct. 22nd	41,140	*37,026*	*32,912*	*24,684*
2011	Oct. 13th	19,149	*17,234*	*15,319*	*13,804*
2012	Oct. 18th	27,465	*24,178*	*21,431*	*16,479*
Range	***Variable end dates***	**12,150 – 41,140**	***10,935 – 37,026***	***9,720 – 32,912***	***7,297 – 24,684***

3.4.4 Comparison of Petersen Estimates to Tyee Test Fishery Index

The cumulative index for the mixed steelhead stock abundance at Tyee in the lower Skeena from 1999 to 2012 (Fisheries and Oceans Canada 2010) are presented (Figure 13) and compared to the Moricetown steelhead abundance estimates (Figures 14 & 15). This comparison is primarily an attempt to assess the potential for errors and the uncertainties related to steelhead abundance when sampling seasons at Tyee or Moricetown end early. The mix of steelhead stocks and sub-stocks returning to the Bulkley and Morice watersheds represent a meaningful proportion (i.e. up to 40%, Peard pers. comm. 2013) of steelhead that pass through the Tyee test fishery at the mouth of the Skeena River make it still useful to make this comparison to help assess the length of sampling required to incorporate the majority of steelhead returning each year and potentially detect differences in run timing of different stocks. From this comparison, it appears that the Tyee steelhead index and the abundance estimates at Moricetown have similar inter-annual rankings of abundance when comparing the status at the earliest end dates at each location (i.e. Aug. 23rd for Tyee and Sept. 13th for Moricetown, Figures 14 & 15), but then become less associated at the end of sampling. Variable lengths of sampling at the two locations and for different years appear to be the primary cause for this difference (e.g. Figure 13). Based on the available information it appears that the sampling period for summer run steelhead abundance should more consistently extend to at least mid to late September for the Tyee test fishery and approximately three weeks later (i.e. early to mid October) for the Moricetown Tagging project in order for these abundance estimates to consistently represent the annual fall returns of summer-run steelhead.

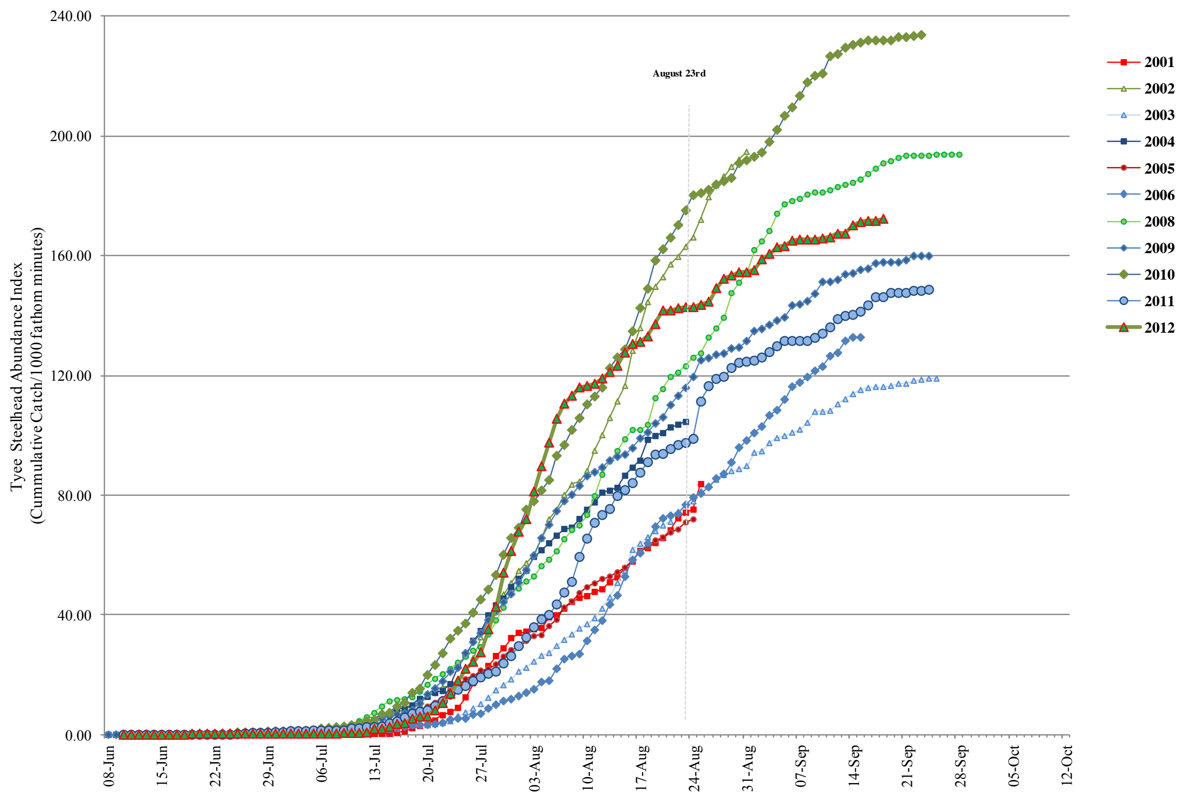


Figure 13. Intra-annual progression of the Tyee Steelhead Abundance Index for 2001 to 2012.

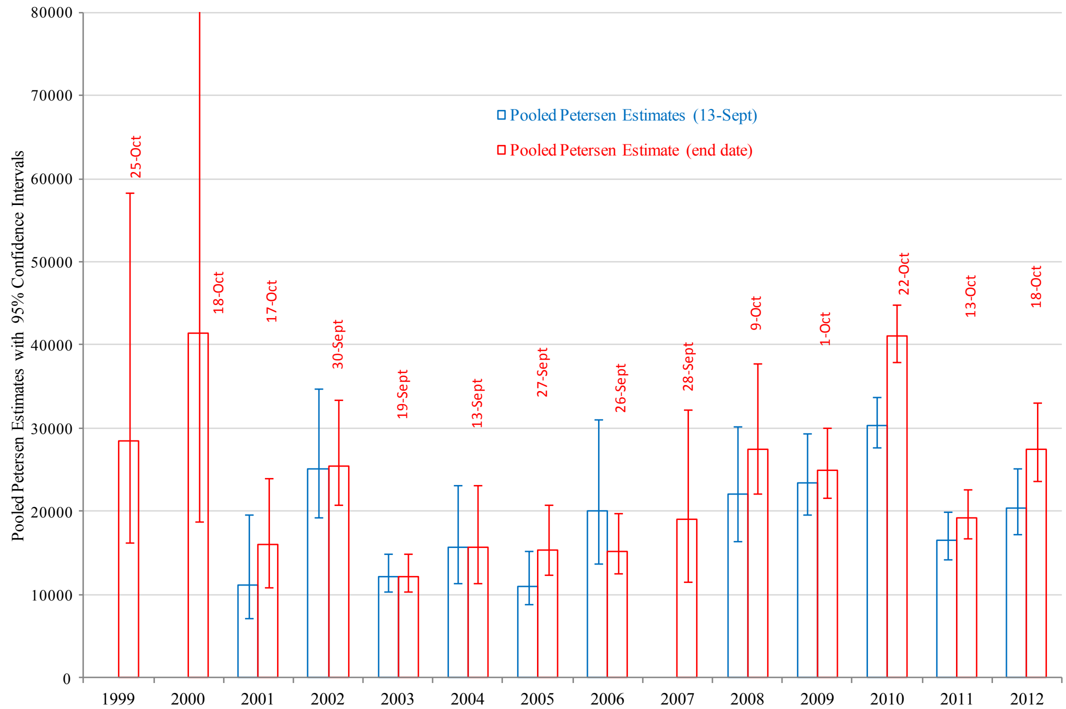


Figure 14. Pooled Petersen estimates of the number of Bulkley/Morice steelhead arriving at Moricetown Canyon 1999 to 2012.

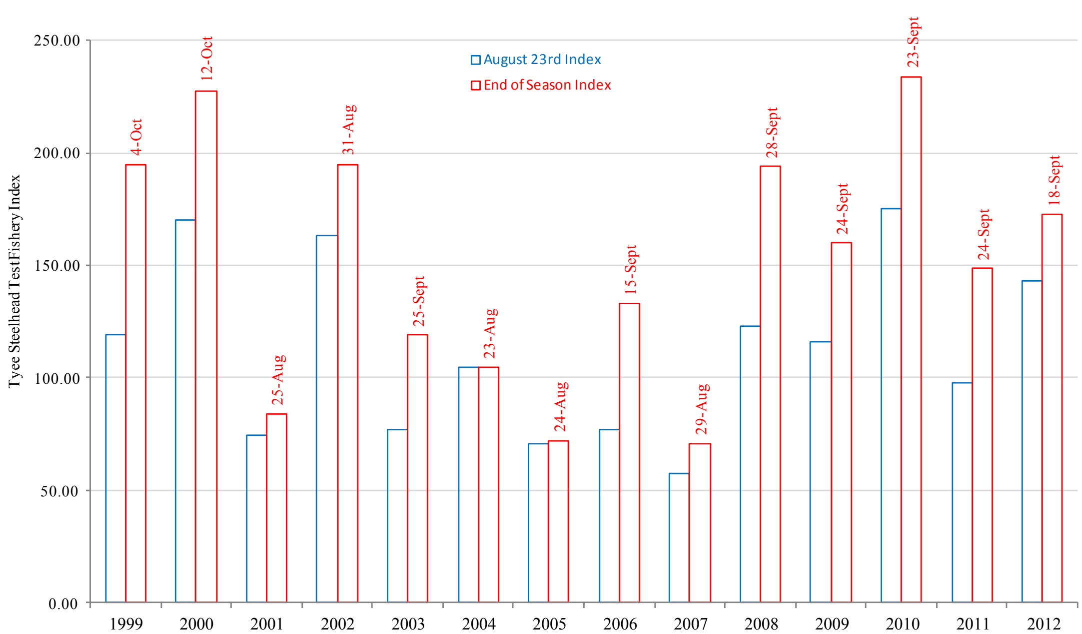


Figure 15. Tyee Test Fishery Skeena Steelhead Abundance Index from 1999 to 20121.

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List of Appendices