Wet'suwet'en Fisheries
Steelhead Tagging Project
at
Moricetown Canyon

July to October 2009

Data Summary and Recommendations

prepared by

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Executive Summary

During the summer and fall of 2009, Wet'suwet'en Fisheries continued the Moricetown Canyon steelhead tagging program that was initiated in 1999, in coordination with an ongoing coho, sockeye and chinook tagging program. Coho, sockeye and chinook data were analysed separately by Fisheries and Oceans Canada. The data collected for steelhead migration from July 27th to October 1st in 2009 and are summarized in this report. The continued objectives of this steelhead tagging program have been to standardize the sampling methodologies, to evaluate in-season population estimates or indices and to monitor the run-timing and relative returns of steelhead migrating upstream of Moricetown Canyon.

In 2009, 1390 steelhead were marked by beach seining downstream of Moricetown Canyon (i.e. campground) and 2297 steelhead, including 127 recaptures were handled at Moricetown Canyon for census. Tagging at the campground ended on September 25th, and tagging effort was reduced by one crew from September 22nd to September 25th. Sampling by dip net at the canyon ended on October 1st, but was reduced to one crew on September 21st. The Schaeffer estimate for steelhead abundance at Moricetown Canyon up to October 1st is 23,986 steelhead and the Maximum likelihood Darroch estimate for is 23,886 steelhead (95% confidence interval = 14,639-33,133). For comparison of 2009 abundance to historical records, the adjusted Petersen estimate for 2009 was also calculated and comes to 24,973 with a 95% confidence interval from 21,578 to 30,112. This estimate was only the fifth highest estimate since 1999, but is well within the 95% lower confidence interval of all the other higher estimates. However, this Petersen estimate is significantly greater than the Petersen estimates for 2003, 2005, and 2006 (i.e. 12150, 15341, and 15138) which suggest that the general ranking of this abundance is moderate and potentially high.

These estimates should be viewed in light of constraints of the study, including low recapture rates (2.8%), and non-random sampling at the beach seine and dipnet locations. The estimated number of steelhead moving through Moricetown Canyon in the study period is the highest estimate since 2001, when the numbers of recaptures increased from very low initial recapture rates in 1999 and 2000.

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Acknowledgements

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1.0 INTRODUCTION

Wet'suwet'en Fisheries has continued the annual steelhead tagging program on the Bulkley River at Moricetown canyon (about 30 km north of Smithers, B.C.) in 2009 to monitor run timing and abundance of steelhead (*Oncorhynchus mykiss*) arriving at Moricetown. This study is a continuation of previous tagging efforts at Moricetown Canyon since 1999 (SKR 2000a, 2001a, 2002a, 2003, 2004, 2006, 2009a, 2009b, 2009c). Steelhead tagging at Moricetown Canyon is conducted in conjunction with an extensive adult coho (*O. kisutch*) tagging program, and an adult sockeye salmon (*O. nerka*) tagging program; data for these species are analysed separately by the Department of Fisheries and Oceans Canada (Walter Joseph, Fisheries Manager, Office of the Wet'suwet'en, pers. comm.). In addition, chinook salmon (*O. tsawytscha*) have been tagged at Moricetown since 2002 (SKR 2003a, 2004, 2006, 2008). The steelhead tagging program at Moricetown Canyon was designed by Wet'suwet'en Fisheries, incorporating input from B.C. Environment (MoE) and the Department of Fisheries and Oceans (FOC). This report summarizes steelhead data collected from June 23rd, 2009 to October 1st, 2009.

The main objectives of this project were:

- to monitor timing of steelhead migrations arriving at Moricetown Canyon;
- to review, check, and summarize steelhead data collected at Moricetown Canyon; and
- to estimate the number of steelhead in the Bulkley River that arrive at Moricetown Canyon in the summer/fall of 2009.

2.0 MATERIALS AND METHODS

Methodologies employed during the Moricetown Tagging Program in 2009, were generally similar to those employed in previous years. Steelhead were captured using beach seines and dip nets. Beach seining was conducted about 350-400 metres downstream of the Moricetown Canyon, while sampling by dipnet was conducted at Moricetown Falls (Figure 1), using similar methods to those employed since 1999 (Wet'suwet'en Fisheries 2000, 2001, 2002, 2003, 2006, 2007, SKR 2009a, 2009b, 2009c). Sampling locations were consistent with all previous years (Figure 1), excluding the fish wheel that was unsuccessfully tested in 2000 and 2001 and has been abandoned. Wet'suwet'en Fisheries entered all data collected in the 2009 field season into a Microsoft Access 2000 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" entered as the tag status. Methods related to data quality assurance/quality control, steelhead sampling efforts, and steelhead abundance estimates are described in the following sections.

Photo from Google Earth 2009

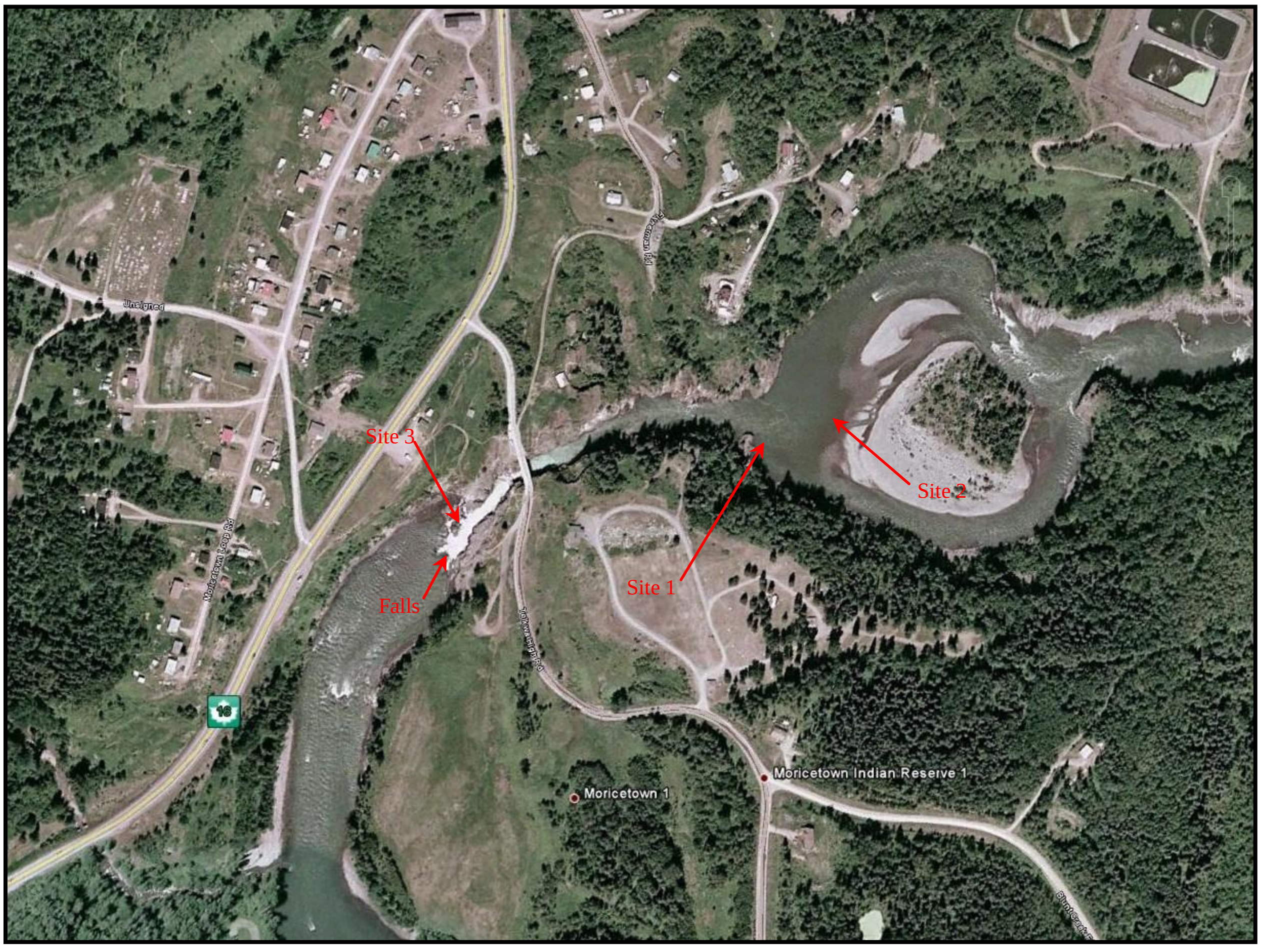


Figure 1. Aerial Photograph of Campground (Site 1) Campground/Island (Site 2) Beach Seine locations and the Canyon Dip Net location (Site 3) along the Bulkley River in Moricetown, B.C..

2.1 QUALITY ASSURANCE/QUALITY CONTROL

Quality assurance field checks were only conducted opportunistically in conjunction with sonic tagging activities (Welch *et al*,. 2010) throughout the steelhead sampling period. Field checks consisted of unscheduled visits to the beach seine and dipnet tagging sites, observation of species identifications, handling, tagging and record keeping activities. Field data sheets were copied and reviewed upon their submission to the Wet'suwet'en Fisheries office, and were later used for a detailed review of data entry to ensure data accuracy and fidelity. Entered data was compared to each original field data form prior to data analysis for this report. Queries were also designed to test for duplicate data, duplicate tag number applications, incorrect tag status recorded on forms, necessary corrections to the "caudal punch applied" field, incorrect dates entered, and incomplete data. Total sample sizes and numbers of recaptures from the campground and canyon locations (by beachseine and dipnet, respectively) in 2009 were also manually counted from the field data forms for comparison to the database prior to analysis.

2.2 STEELHEAD SAMPLING

Sampling for the Moricetown Tagging Project was conducted from July 23rd to October 1st, 2009. Steelhead were captured by beach seining downstream of the Moricetown Canyon (i.e. Site 1 and 2) and by dip net in the canyon (i.e. Site 3) (*see* Figure 1). Steelhead were tagged using a combination of individually numbered anchor tags (Table 1) and lower caudal punches at Sites 1 and 2 and upper caudal punches at Site 3 (*see* Figure 1). In conjunction with tagging at the beach seine location, a steelhead sonic tagging project was also implemented in 2009 and a total of 66 sonic tags were applied to steelhead in addition to anchor tags and caudal punches between August 4th and September 24th, 2009 (Welch *et al*, 2010). Sampling at the campground and canyon sites was conducted Monday to Friday, excluding one statutory holiday, but including 5 added weekend days in late August and early September. Two beach seine crews for the campground location (i.e. 5 persons/crew) and two dip net crews for the canyon location (i.e. 5 persons/crew) divided each of the work days into two shifts to ensure sampling throughout the majority of daylight hours at both locations

Table 1. Tag colours and numbers applied on steelhead from July to October 2009 for the Moricetown tagging program.

Location	Tag colour	Tag Numbers
Campground*	White	46501-46503
Campground*	Orange	47001-47622, 48501-48600, 48851-49000, 50001-50500, 51501-52000
Canyon*	Orange	43101-43618, 47951-48000, 50501-51500, 63208-68221, 68701-68711

* campground = sites 1 and 2 in Figure 1, Canyon = site 3 in figure 1

The beach seine crews tagged steelhead captured at the island or shore side immediately downstream of "Idiot Rock", located directly below the campground in Moricetown (*see* Figure 1; collectively referred to as "campground"). A trail leading from the campground to the beach was used to access the beach seine area on foot. A boat launch located downstream of the campground was utilized to access the beach seine area by boat. The beach seine was set at the campground side on most days (river right), and a beach on the island was used on some days as water levels changed the efficiency of each capture location. A 90 m long by 8 m deep net with a 5 cm (2") diagonal mesh size was used for beach seining purposes (Wet'suwet'en 2007, Brian Michell, Sr. Fisheries Technician, Office of the Wet'suwet'en, pers. comm.). The upstream side of the net was tied off to shore, and the net was spread out in a semicircle along the shore, and pulled into shore. A jet boat was used to set the net at varying lengths into the river dependent on river flow conditions. The net was pulled into shore, ensuring that the lead and float lines did not tangle. Captured fish were identified to species. Steelhead, coho, chinook and sockeye were measured (fork length), checked for tags (anchor tags, fin clips or punches), and their condition and gender was recorded. The Hallprint anchor tags used to mark steelhead captured at this location are summarized in Table 1. A secondary tag consisting of a lower caudal punch was also applied to assess tag loss. Tag colour and number of all recaptured fish were recorded. The beach seine location was allowed to rest for a minimum of 15 minutes between consecutive sets. The daily number of successful beach seine sets varied, and depended on several factors including day length, weather conditions, number of species caught (i.e. handling time), mending requirements, and potential twisting, tangeling or snagging during individual sets.

Each canyon crew consisted of two fishermen, a runner for transporting fish, a tagger and a recorder. Fish were captured by dip netting in the canyon from the outlet of the fishway on river left, upstream to the base of Moricetown falls on river left, and were transported to a tagging trough for processing. Fish species, fork length (cm), gender and comments on applied tags and fish condition were recorded on daily field data forms. Some anchor tags were applied to steelhead when available (Table 1) but not consistently in 2009. Anchor tags that were applied by canyon crews are summarized in Table 1. Tag colour and the number for each applied tag or tag on recaptured fish were recorded on daily field data forms. The daily effort and specific locations of dip netting were not recorded and appear to be biased by factors such as day length, weather, river conditions, mending requirements, and the ability of fisherman to be species selective using this sampling methodology.

2.3 STEELHEAD ABUNDANCE ESTIMATES

The population size of fish migrating upstream through Moricetown Canyon from June 23rd to October 1st, 2009 was determined using a Schaeffer estimate and an ML Darroch estimate, which are designed for open populations (Arnason *et al* 1996). A computer program designed by Arnason *et al.* (1996) for population analysis was used to calculate the ML Darroch and Schaeffer estimates. To calculate the Schaeffer and the ML Darroch estimate, the study period was divided into weeks, starting with the initial capture data for steelhead (July 27th, 2009) (Table 3). An adjusted Petersen estimate (Ricker 1975, Krebs 1999) and 95% confidence intervals (Krebs 1999) using poisson and normal approximations (i.e. <50 and >49 recaptures, respectively) are also calculated for inter-annual comparisons to previous studies, but is complicated by different end dates of sampling and inter-annual variability in timing of steelhead migration. In addition, both the mark sample (i.e. beach seine tagging), and the census sample (i.e. dip net sampling) were obtained in a non-random fashion (i.e. sampling days and times were not determined randomly, sampling period did not encompass entire migration period), thus this abundance estimate may be biased and does not represent the total return to the Bulkley/Morice watershed.

Table 2. Temporal stratification for the Moricetown steelhead data.

Week Number	Start Date	End Date
Week 1	July 27	August 2
Week 2	August 3	August 9
Week 3	August 10	August 16
Week 4	August 16	August 22
Week 5	August 17	August 23
Week 6	August 24	August 30
Week 7	August 31	September 6
Week 8	September 7	September 13
Week 9	September 14	September 20
Week 10	September 21	September 27
Week 11	September 28	October 1

3.0 RESULTS

The Moricetown Tagging Project was conducted for the eleventh consecutive year in 2009. In 2009, sampling commenced on June 23rd and ended on October 1st and resulted in the release of 1390 tagged steelhead at the Morictown campground tagging site and sampling of 2297 steelhead at the Moricetown Canyon for mark/recapture estimates of steelhead arriving at Moricetown en route to various overwintering locations in the Bulkley and Morice watersheds. The number of steelhead arriving at Moricetown as of October 1st using the Schaeffer estimate is 23,986 and using the ML Darroch estimate is 23,886 with a 95% confidence interval of 14,639 to 33,132. The adjusted Petersen estimate for the steelhead arriving at Moricetown to the end of sampling on October 1st, 2009 is 24,973 with a 95% confidence interval of 21,578 to 30,112. The following sections summarize the results from the data collection and analyses used to present some basic descriptions of steelhead migration, measures of abundance and sampling biases that may affect the accuracy of the abundance estimates, and some inter-annual comparisons of the 2009 results to previous studies.

3.1 QUALITY ASSURANCE/QUALITY CONTROL

Data sheets for 2009 obtained from the Wet'suwet'en Fisheries office appeared generally complete during site visits. Species identification was good by all crews, but gender identification was agreed to be difficult in some cases without harvesting and gonad inspection. Measurements of fork length were conducted quickly with the emphasis placed on reducing handling time over accuracy. Data entry was conducted by Wet'suwet'en Fisheries staff and digital data were submitted for quality assurance and corrections. Comparisons of field data forms and digital data revealed that few data entry problems were present. As previously identified, some difficulties determining the dates on individual sheets were identified (e.g. blank on last pages or incorrectly sequenced) and frequently caused incorrect entries. Another critical error on the data form was recording of incorrect tag status (e.g. "None Applied" instead of "Recaptured" despite recaptured tag number or alternate caudal punch recorded) which could significantly effect on the total recapture count and may be a significant influence on abundance estimate. Following removal of duplicate and incomplete records, corrections to data entry errors (e.g. wrong species entered), and insert of missing records, the total counts of steelhead records and recaptures from the field data forms matched data counts on the Moricetown Tagging Project database.

In total, 63 steelhead were recorded as harvested during the 2009 Moricetown steelhead tagging project. Most of these steelhead were harvested at the canyon (i.e. 61), and only two untagged steelhead were harvested in the beach seine fishery. None of the harvested steelhead had tags applied or were recaptures.

While no issues were identified in species identification during periodic field visits, some inconsistencies in species identification was noted when comparing initial to recapture species for recaptured fish. At total of 382 fish were recaptured and identified as steelhead upon initial capture, or upon recapture or both. Of these 382 fish. 366 (95.8%) were consistently identified as steelhead, three (0.8 %) were identified as chinook, coho or sockeye upon initial capture and steelhead upon recapture, and 13 (3.4%) were initially identified as steelhead, but were identified as chinook (2 fish) or coho (11 fish) upon recapture. This indicates some inconsistencies in species identification, however the error in species identification appears to be less than 5%. Inconsistently identified species were not used in the population estimates.

3.2 STEELHEAD SAMPLING

The sampling in 2009 resulted in the highest number of steelhead on record for both tags applied at the campground and for the census at the canyon (Table 4). A total of 1390 steelhead were tagged at the campground of which 127 were recaptured in a census of 2297 steelhead sampled at the canyon. Both the number of tags applied and the census sample size exceeded their targeted ranges to acquire Petersen estimates with less than 25% error (i.e. 600 to 1000 tags applied, 1000-2000 census sample, and the expected population size to be between 10,000 and 30,000, Ricker 1975). Interestingly, the ratio between tags applied and the number sampled in 2009 (i.e. 1:1.65, Table 4) was the lowest since the start of the project (i.e. 1:9.48 in 1999, Table 4) and suggests that the sampling method at the campground (i.e. beach seine) may be improving or that sonic tagging efforts may have made the beach seine sampling more selective for steelhead. This inconsistency of relative catch at these two locations suggests that daily catch counts should not be used for a cumulative abundance index without accounting for biases related to variables such as the number of settings, species selectivity in sampling, the quality of settings, the river conditions, the times of day, and even the day of the week.

The following sections summarize the results from steelhead sampling with regard to:

- the timing of steelhead arrivals at Moricetown,
- the time lags/fallback of steelhead from the campground before migrating to the canyon sampling location, and
- an assessment of the fallback of steelhead released upstream of Moricetown falls.

Table 3. Sampling ratios for steelhead tagging at the campground and sampling at the canyon for mark recapture estimates during the steelhead tagging program conducted at Moricetown Canyon from 1999 to 2009.

Year	Steelhead Tags applied at Campground	Steelhead sampled at Canyon	Sampling Ratio
1999	164	1555	1 : 9.48
2000	225	734	1 : 3.26
2001	322	1184	1 : 3.68
2002	846	2068	1 : 2.44
2003	670	1864	1 : 2.78
2004	319	1615	1 : 5.06
2005	523	1697	1 : 3.24
2006	595	1777	1 : 2.99
2007	224	1101	1 : 4.91
2008	759	1925	1 : 2.54
2009	1390	2297	1 : 1.65

3.2.1 Timing of Migration

The number of steelhead captured at the campground and canyon locations throughout the study period are presented in Figure 2. In 2009, the first steelhead was captured on July 27th at the canyon, and the first steelhead was captured at the campground on July 28th. The tagging program started well in advance of these dates, with the first Pacific salmon captured on July 3rd for the beach seine fishery at the campground location, and July 8th for the dip net fishery at the canyon location. This indicates that the timing of the mark-recapture study at Moricetown Canyon encompassed the start of the steelhead migration period. Capture dates for steelhead at the start of the migration season in 2009 coincide with capture dates in previous years of the study (i.e. usually the last week of July or first week of August). Daily campground catch increased gradually in the beginning of August, to a peak of 152 tags applied on August 23rd at the campground and 147 steelhead captured at the canyon on August 27th (Figure 2).

Overall, the relatively low daily catch of steelhead at the start and end of the study at the campground appears to suggest that the sampling protocol was successful in encompassing the fall steelhead migration period. However, the continued capture of some steelhead up to the last sampling day (i.e. 19 on October 1st) is a useful reminder that some late surges in October may still occur. Although bimodal distribution of catches at both locations are apparent based on sampling results in 2009 and may be related to run timing (e.g. different steelhead stocks), a poorly controlled fire and chainsaw activity in Moricetown Canyon to remove a large log jam from August 31st to September 4th more likely explains the decline of catch during that week.

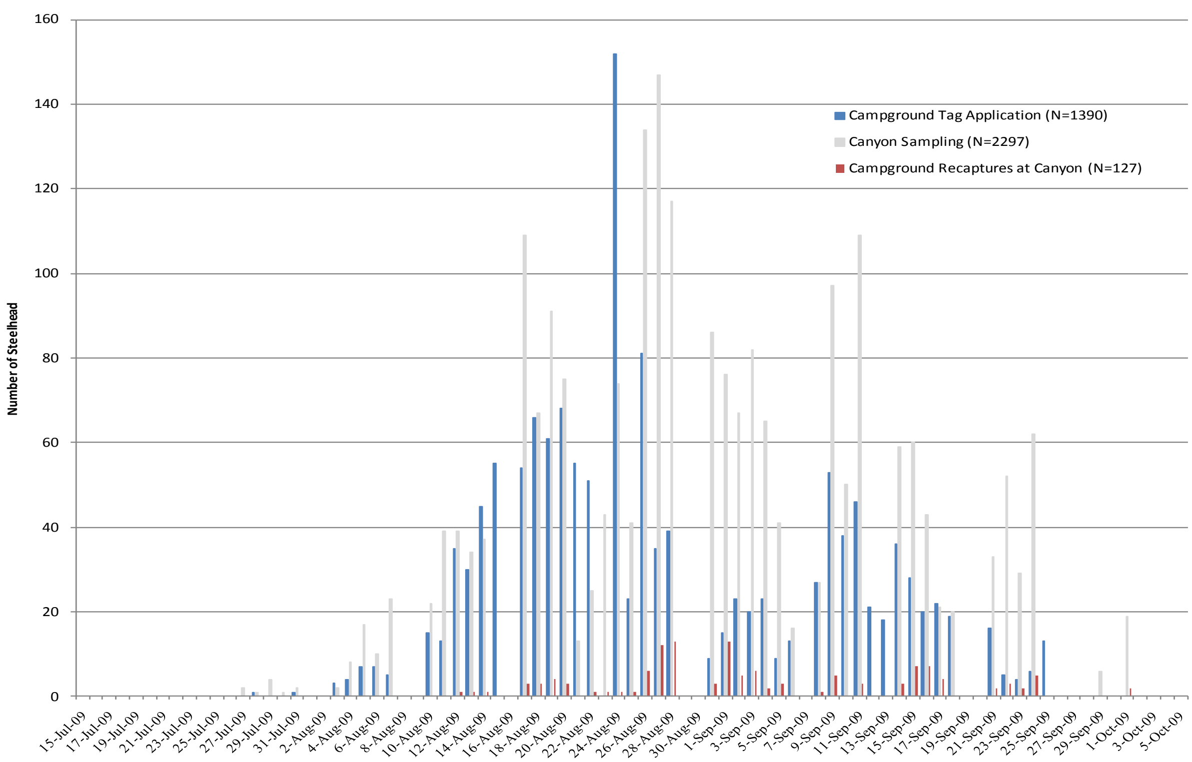
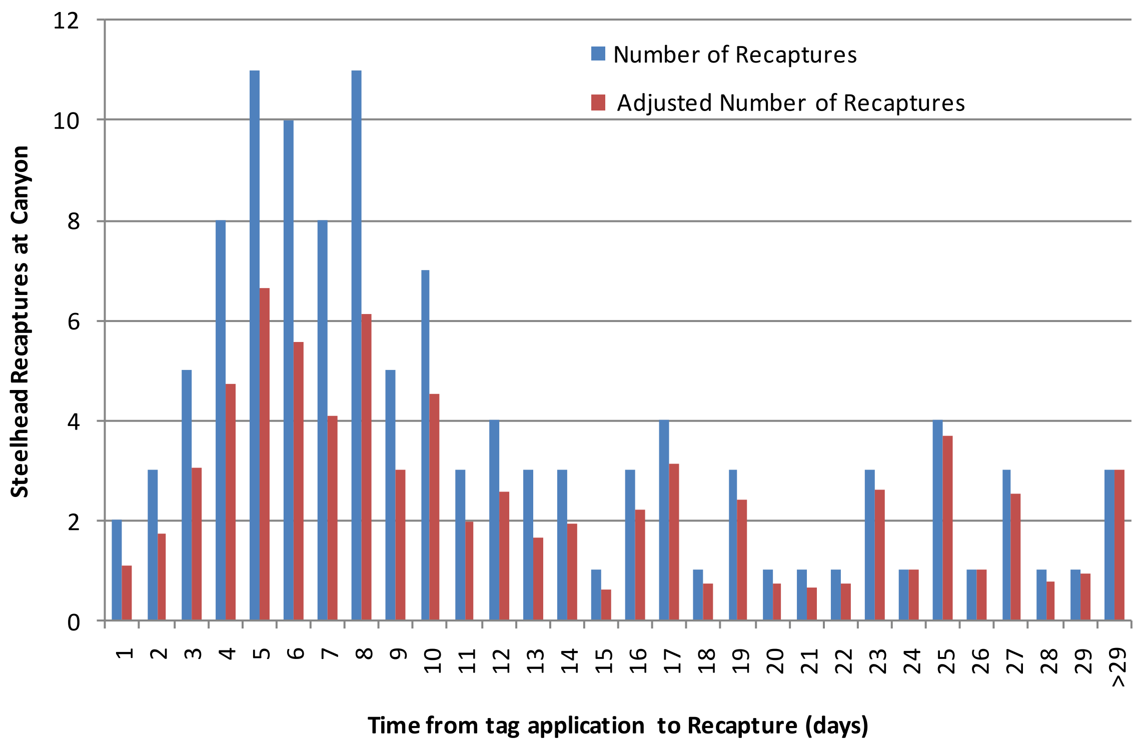


Figure 2. Temporal distribution of steelhead sampling results at the campground, canyon, and the recaptures of campground applied tags at the canyon.

3.2.2 Fallback and Migration from Campground to Canyon

Of the 2297 steelhead captured at the canyon, 127 steelhead were recaptures from the campground tagging locations. Based on 125 of the 127 steelhead recaptures (98.4 %, *see* Figure 3) occurring more than one day after tag application at the campground, it appears that the majority of steelhead hold up below the canyon (i.e. median = 9.3 days) before even attempting to pass Moricetown falls. Some surges in recaptures between 4 to 8 days, 16 to 19 days, and 23 to 28 days after tag application make the distribution of delays appear to be multi-modal, indicating a spatial pattern of fallbacks (e.g. multimodal distribution downstream) or possibly multiple attempts to pass the Moricetown falls (Figure 3). Interestingly, the Petersen estimate using recaptures of steelhead with campground applied tags at the campground locations (i.e. 20,879) is lower than for the canyon location (i.e. 24,973) which indicates that steelhead from the campground may be more vulnerable to recapture at the campground than the canyon (Table 4). However, the campground estimate is within the 95% confidence interval of the canyon estimate (21578-30112), indicating that the two estimates are not significantly different. A high number (28) and proportion (28%) of campground tagged steelhead recaptured on the same day at the campground is a bias likely related to the lower abundance estimate at the campground than the canyon. Despite the uncertainties, this skewed or multi-modal distribution time delay from the tagging location (i.e. campground) to the census location (i.e. canyon) clearly identifies the need to make temporal adjustments to the number of applied tags used for abundance estimates at the census location (i.e. canyon) to account for the spatial distribution and significant fallback of steelhead when they arrive at the Moricetown campground.



* The Adjusted Number of Recaptures are steelhead recaptures at the canyon made proportional to the number of recaptures with the lowest probability of recapture (e.g. 29 day delay) to correct for five day/week sampling and sampling at the canyon and campground being simultaneous.

Figure 3. Time delay from steelhead tag application at campground to their recapture at the canyon during the Moricetown Tagging Project, 2009.

Table 4. Summary of steelhead sampling during Moricetown tagging program in 2009.

	Campground (Beach Seine)	Canyon (Dipnet)
Steelhead Captured	1485	2297
Harvested	2	61
Caudal Punches	1390 (bottom punch)	2166 (top punch) (1106 or 51% caudal punch only)
Tags Applied or Recorded	1390	1060
Campground Recaptures Caudal punch only (%) Petersen Abundance Estimate*[1]	99 4 (4.0% due to tag loss or beach seine recapture) 20,879*[5]	127 10 (7.9% due to tag loss or dip net recapture) 24,973 (±5139)
Canyon Recaptures Caudal punch only (%) Estimate of Fallback	60 20 (33% had tag loss or caudal punch only) 656*[2] (30 % fallback of canyon tagged steelhead)	80 10 (13% had tag loss or caudal punch only) 876 *[3] (40% fallback of canyon tagged steelhead)

*[1] Adjusted Petersen Estimates
*[2] Estimated based on assuming the ratio of fallback recaptures to fallback estimate is equal to ratio of steelhead tagged at campground : campground recaptures at campground
*[3] Estimated based on assuming the ratio of fallback recaptures to fallback estimate is equal to ratio of steelhead tagged at campground to campground recaptures at canyon
*[5] no confidence interval provided due to significant proportion (30%) of same day recaptures.

3.2.3 Fallback from Canyon

Notable proportions of fallback have been identified after handling at the canyon and release of steelhead upstream of Moricetown falls (e.g. 48% in 2008, SKR 2009c). In 2009, assuming ratios equal to campground applied steelhead being recaptured at the canyon or campground, the number of steelhead falling back over the Moricetown falls and returning to the campground is estimated to be 656 of 2166 (30%) and 876 of 2166 (40%) to the canyon. The different proportions of steelhead at the two locations indicate that steelhead falling back over Moricetown falls may be more vulnerable to recapture at the canyon than the campground which is opposite to steelhead moving upstream from the campground. A high number (16) and percentage (20%) of the recaptures of canyon handled steelhead at the canyon on the same day of tagging suggests that these recaptures were exposed to sampling when falling back and then again when returning which would logistically give a negative bias in our estimate of fallback (i.e. underestimate of fallback). Conversely, this estimate of fallback from the canyon tagging site does not account for fish condition after handling or mortality which could cause a positive bias or overestimate of fallback. The estimated fallback from fish released upstream of the falls (i.e. 30 - 40%) being less than the fallback from the campground (98.4%) supports the assumption that the Moricetown falls is a natural obstruction and is a natural cause of fallback from the campground. However, the causes of fallback of steelhead released upstream of Moricetown Falls are unknown. Although a proportion of this fallback may be accounted for by a natural behavior, based on field observations and recorded conditions of steelhead when released upstream of the falls, there appears to be a notable effect of fish handling at the canyon location on steelhead migration. Although this anecdotal evidence would not bias abundance estimates using the canyon as the census location, it does present the possibility that similar effects of sampling and tag application at the campground may result in a positive bias of the adjusted Petersen estimate (i.e. overestimate).

3.3 STEELHEAD ABUNDANCE ESTIMATES

Steelhead abundance estimates for Moricetown Canyon represent the number of steelhead overwintering in the entire Bulkley and Morice watersheds that migrate at least as far upstream as Moricetown Falls. These estimates exclude steelhead that either stop downstream of Moricetown or fall back downstream from Moricetown campground and do not attempt Moricetown falls prior to the end of sampling at the canyon. The abundance estimates made using catch data from Moricetown Canyon (i.e. "census" sample for abundance estimates) do not represent the number of steelhead overwintering upstream of Moricetown falls, since the canyon sampling occurs downstream of this significant obstruction to fish migration. The following sections summarize end of season estimates using Schaeffer (Ricker 1975), ML Darroch (Arnason *et al* 1996), and adjusted Petersen methodologies (Ricker 1975, Krebs 1999) for steelhead abundance at Moricetown in 2009.

3.3.1 Schaeffer and ML Darroch Estimates

The Schaeffer (Ricker 1975) and Maximum Likelihood (ML) Darroch (Arnason *et al* 1996) estimates have been applied to the Moricetown Steelhead Tagging Project results since 2002, when the total number of recaptures at the canyon census location exceeded 50 for the first time of the study. The Schaeffer and ML Darroch estimates were selected since the levels of immigration and emigration are significant at this sampling location, and due to the lack of assumptions met using the Petersen estimate. The ML Darroch estimate is included, since confidence intervals can be determined for the ML Darroch estimate, while no confidence intervals are associated with the Schaeffer estimate. For these estimates, the daily data records have been pooled into weekly intervals, with tagging and recovery determined for each week (Appendix 4). To arrive at the Schaeffer and ML Darroch estimates, some additional pooling of weeks was required to provide a more equal distribution of tagged and recaptured steelhead for defined intervals. Data from weeks 1 to 2 for the campground tagging and weeks 1 to 3, 7 to 8, and 9 to 10 for the canyon census were pooled. This resulted in eight intervals of steelhead data for campground tag applications and six intervals of data for canyon census, and although some larger and non-sequential pooling of week intervals were tested, this distribution resulted in the smallest 95% confidence intervals of the ML Darroch estimate. A 5% tag loss has been applied to the estimate to compensate for steelhead that had lost their tags, as in previous years of the study. Tag loss of tags applied in the beach seine fishery in 2009 was estimated as 7.9%, however tag loss in previous years of the study have fluctuated around 5%, and this has historically been the standard correction for tag loss applied to mark-recapture data for this project. For the abundance of steelhead arriving at Moricetown Canyon up to October 1st, 2009, the Schaeffer estimate is 23,986 and the ML Darroch estimate is 23,886 with a 95% confidence interval of the ML Darroch estimate ranging from 14,639 and 33,133.

3.3.1.1 Assumptions and Biases in Estimate

Mortality resulting from predation, unknown harvest levels, or other causes, was not accounted for in the data. In addition, the effect of capture and tagging on survival rates or behaviour of steelhead was not determined in the study. As suggested by the evaluation of the fallback of steelhead released upstream of Moricetown falls to the canyon and campground sampling location (*see* Section 3.1.2), some reduction in the survival of steelhead after capture and tagging may exist, and if this reduction is significant, the abundance may be overestimated. Survival of captured and tagged fish could be evaluated to some degree by retaining a sub-sample of fish overnight, and determining their condition within 24 hours of capture and tagging. In addition, mark-recapture ratios could be evaluated upstream through angling, snorkel counts, fence counts (e.g. Toboggan Creek) or other methods to determine how the mark-recapture ratio changes. A change in mark-recapture ratio would indicate that differential mortality or downstream diversion may be occurring between the un-marked and marked group of steelhead.

3.3.2 Petersen Estimate

The adjusted Petersen estimate (Ricker 1975) of steelhead arriving at Moricetown was originally calculated to acquire an estimate of steelhead abundance for the Moricetown Steelhead Tagging Program despite the low proportions of recaptures in the initial three years of the study. It is important to note that the Moricetown Tagging Project does not meet the assumptions related to the Petersen method, thus caution should be stated when presenting these results. However, for comparisons to previous years, an adjusted Petersen estimate has been calculated based on 1390 steelhead tagged with caudal punches at the campground and 127 recaptures of the 2297 steelhead sampled at the canyon census location. For steelhead migrating to the base of Moricetown falls (i.e. canyon) from June 23rd to October 1st in 2009, the adjusted Petersen estimate is 24,973 steelhead with the 95% confidence interval from 21,578 to 30,112.

3.3.2.1 Assumptions and Biases in Estimate

Mark-recapture estimates assume random samples of marked or unmarked fish, or that marked fish mix randomly with unmarked fish, that immigration, emigration, mortality and natality are negligible during the study, that marked fish are in every way the same as un-marked fish, and that marked fish do not lose their marks (Bagenal 1978, Krebs 1999). Almost all mark recapture studies violate at least some of these assumptions to some degree, which results in decreased accuracy of the estimate. If violations are severe, resulting estimates can be misleading. Therefore, it is important to evaluate to what extent the underlying assumptions of the mark-recapture study are violated, and if adjustments can be made to compensate for these violations. The potential presence of sampling biases and low recapture ratios (i.e. 5.5% of censused fish in 2009) affects the accuracy and precision of the Petersen estimate, and must be taken into consideration when refining this study.

Differences in capture rates of sampling gear over time, fork length and sex ratio comparisons can indicate selectivity in capture methods, which influence the validity of population estimates (Ricker 1975, Bagenal 1978, Krebs 1999). As in previous years, some temporal and gear biases may exist in the data obtained for the 2009 Moricetown tagging program, but these biases were less severe than in the initial two years of the study. While temporal biases in capture rates between dip net and beach seine sampling observed in 1999 and 2000 have been reduced in 2001 to 2009, systematic sampling on weekdays for dipnet crews and beach seine crews still results in non-random sampling, which violates an assumption for the Petersen estimate. Spreading the available crew time equally over 7 days per week may improve this sampling design as long as the majority of daylight hours and key migration hours of each day are consistently sampled. A test of steelhead migration for a sub-sample of twenty four hour periods may also be useful toward designing the sampling schedule for this project.

A potential for different selectivity of steelhead sampling between sampling methods (i.e. beach seine and dip net) and locations of sampling (i.e. campground and canyon) was noted in 2008 (SKR 2009c) to potentially bias abundance estimates. Because gender was not consistently and accurately assigned, fork lengths of male and female steelhead have been grouped together to test for differences in size selection of the different sampling methods (i.e. beach seine and dip net) and locations (i.e. campground and canyon). In 2009, the mean fork lengths of steelhead captured at the campground (beach seine Mean = 66.17, SE = 0.28) was not significantly different from the fork lengths of steelhead captured canyon (dip net Mean = 66.52, SE=0.226, Mann Whitney U statistics = 1663021.00, p=0.270) in 2009. Although the largest fish are noted to be consistently captured at the canyon, it does not appear that different sampling techniques at the two locations will bias this Petersen estimate.

3.4 INTER-ANNUAL COMPARISONS

Inter-annual comparisons of the historical results from Moricetown steelhead tagging project are intended to provide a very general overview and insight into future assessments of results that are based on this sampling design. The following sections summarize the inter-annual variability of the timing of steelhead migration at Moricetown, the different abundance estimate methodologies investigated, the abundance rankings based on Petersen estimates, and the relationship of Moricetown Petersen estimates to the Tyee Steelhead Abundance Index.

3.4.1 **Timing of Migration**

The cumulative catch of steelhead at the Moricetown Canyon dip net sampling location provides a general overview of the temporal distribution of steelhead catch with some insight of how total catch may be associated with run timing at Moricetown (Figure 4). Sampling results from the campground tagging site is not presented due to its less consistent efforts and methodologies throughout the study. In order to provide some evaluation and inter-annual comparisons of the run timing of steelhead arriving at Moricetown, daily catch is combined to give weekly total catch as a less variable unit. For eight of the eleven years sampled, the peak weeks of steelhead catch at the canyon occurred within the last ten days of August. Interestingly, the earliest peak week of steelhead catch has occurred as early as mid August (e.g. 2004 and 2005), but resulted in the third and fourth lowest Petersen abundance estimates (i.e. 15,670 and 15,341, respectively, *see* Table 5). The latest peak week of catch at the canyon occurred in 2007 when the Bulkley River experienced extensive and prolonged flooding into the study period which significantly decreased the efficiency of sampling through most of August. Secondary surges in weekly catches have also been evident as indicated by increased catch in the second week of September in 1999 and 2009, and even as late as the third week of September in 2006 (Figure 4). Although the catch results from the canyon location suggest that steelhead have ended their migration to Moricetown Canyon by October 1st, it would be useful to extend canyon census sampling into October to account for the delayed migration of steelhead from the campground and potentially later surges in arrivals. If extended sampling is not feasible, implementation of any monitoring system of steelhead activities at the Moricetown falls into October (e.g. visual observations) would be beneficial to acquire some certainty for using the fall abundance estimate as an estimate of annual return.

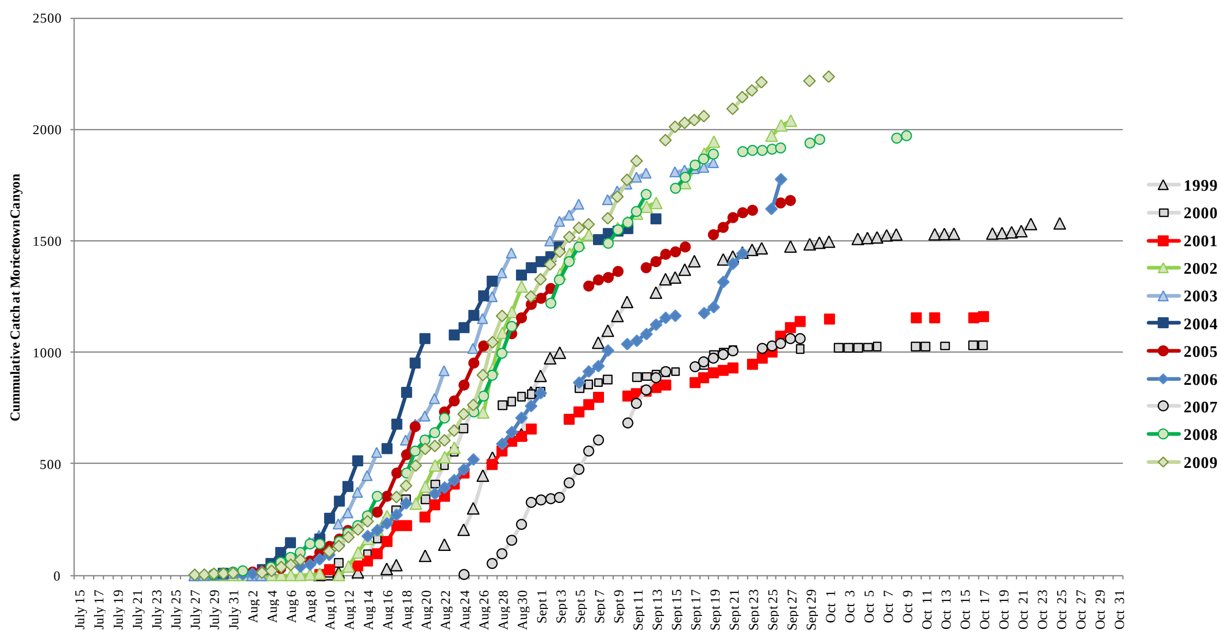
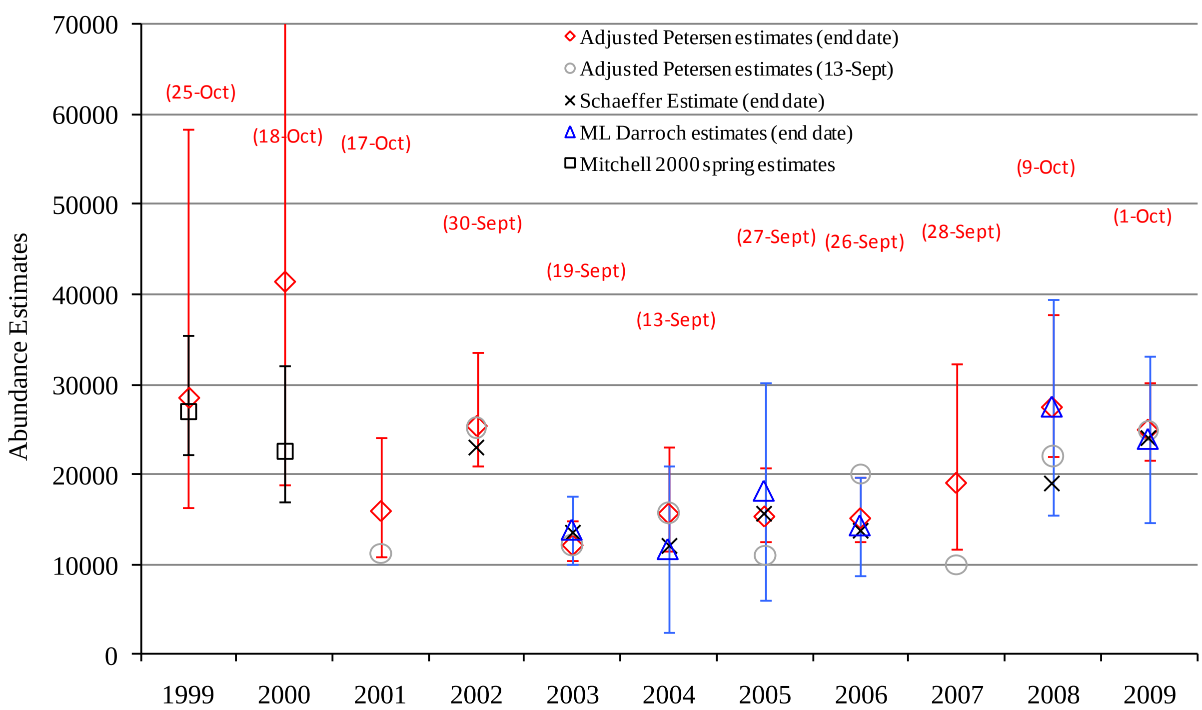


Figure 4. Cumulative catch of steelhead at Moricetown Canyon by dip net from 1999 to 2000.

3.4.2 End of season Abundance Estimates

Steelhead abundance estimates based on Petersen, Schaeffer and ML Darroch methodologies are presented in Figure 5 and no significant differences among any intra-annual comparisons of different estimates were observed. There are no significant differences between years comparing ML Darroch estimates, although this appears related to complications calculating the confidence intervals using this method. It is unfortunate that the campground tag application was minimal in 1999 and 2000 (ie. 164 and 225, respectively), as the spring estimates (Mitchell 2000, 2001) are therefore primarily dependent on the canyon applied steelhead as opposed to the campground applied tags used for other Moricetown estimates. The present data has confirmed that steelhead released from the campground respond differently to handling and tag application than steelhead handled and tagged at the Moricetown campground, thus requiring a correction for a presently unmeasured bias and complicating direct comparisons of angling abundance estimates to Moricetown estimates. The Petersen abundance estimates for the earliest end date of sampling (September 13th) are also displayed in figure 5 to examine the complications with having variable end dates of sampling each year. The higher Petersen abundance estimate for September 13th (i.e. 20,005) than September 26th (i.e. 15,138) in 2006 is a useful reminder of the weakness of abundance estimates (i.e. over-estimation) when temporal distribution is omitted. The consistency of Schaeffer estimates being lower than the Petersen estimates, for the seven years it has been calculated, also implies that the Petersen estimate may be an overestimate. Nevertheless, a number of significant differences among inter-annual Petersen estimates of steelhead abundance at Moricetown have been identified and this method may continue to provide useful inter-annual rankings of steelhead abundance if less than 25% error can be maintained.



Note: Error bars indicate 95% confidence intervals with Poisson (<50 recaptures) or Normal approximation.

Figure 5. Estimates of the number of Bulkley/Morice steelhead arriving at Moricetown Canyon (above), and Tyee Test Fishery Skeena Steelhead Abundance Index (below) from 1999 to 2009.

3.4.3 Adjusted Petersen Estimates

The adjusted Petersen estimate for steelhead abundance at Moricetown Canyon until October 1st in 2009 is 24,973 with a 95% confidence interval from 21,578 to 30,112. A precautionary note when assessing the Moricetown steelhead abundance estimates is to acknowledge the very small numbers of recaptures that occurred in 1999, 2000, and 2007 which resulted in more than 40% error for those years. Interestingly, the steelhead abundance estimate for Moricetown in 2009 is only the fifth highest estimate on record since 1999, despite having the highest catch of steelhead on record (Table 5). It is more statistically significant to note that this estimate is well within the lower 95% confidence interval of all of the years with higher estimates (i.e. 1999, 2000, 2002 and 2008) and is significantly higher than the three lowest estimates on record (i.e. 2003, 2005, and 2006, Table 5) indicating that the steelhead return in 2009 has a moderate and possibly high ranking of abundance.

Table 5. Adjusted Petersen abundance estimates calculated for steelhead sampled at Moricetown Canyon from 1999 to 2009.

Year	Sample size (N)			Adjusted Petersen Estimate	95% Confidence Interval	
	marked	examined	recaptured		Lower	Upper
1999	164	1555	8	**28,527**	16,250	58,350
2000	225	734	3	**41,428**	18,876	103,819
2001	322	1184	23	**15,948**	10,920	24,040
2002	846	2068	68	**25,398**	20,890	33,481
2003	670	1864	102	**12,150**	10,388	14,908
2004	319	1615	32	**15,670**	11,425	23,126
2005	523	1697	57	**15,341**	12,459	20,753
2006	595	1777	69	**15,138**	12,511	19,767
2007	224	1101	12	**19,073**	11,621	32,258
2008	759	1988	54	**27,484**	22,097	37,856
2009	1390	2297	127	**24,973**	21,578	30,112

3.4.4 Comparison of Adjusted Petersen Estimates to Tyee Test Fishery Index

The data from the mixed steelhead stock abundance indices at Tyee in the lower Skeena from 1999 to 2009 (Fisheries and Oceans Canada 2010) are presented for a general comparison to the Moricetown steelhead abundance estimates (Figures 6 and 7). This comparison is primarily an attempt to assess the potential for errors and the uncertainties related to steelhead abundance when sampling seasons at Moricetown are ended early. Although the mix of steelhead stocks and sub-stocks returning to the Bulkley and Morice watersheds do not represent the majority of steelhead that pass through the Tyee test fishery at the mouth of the Skeena River, it still appears useful to make this comparison to help assess the length of sampling required to incorporate the majority of steelhead returning each year. 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), 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 (Figures 6 and 7). Based on the available information it appears that the optimum sampling period for summer run steelhead abundance should more consistently extend to mid to late September for the Tyee test fishery and early to mid October for the Moricetown Tagging project in order for these abundance estimates to consistently represent the annual returns of summer-run steelhead.

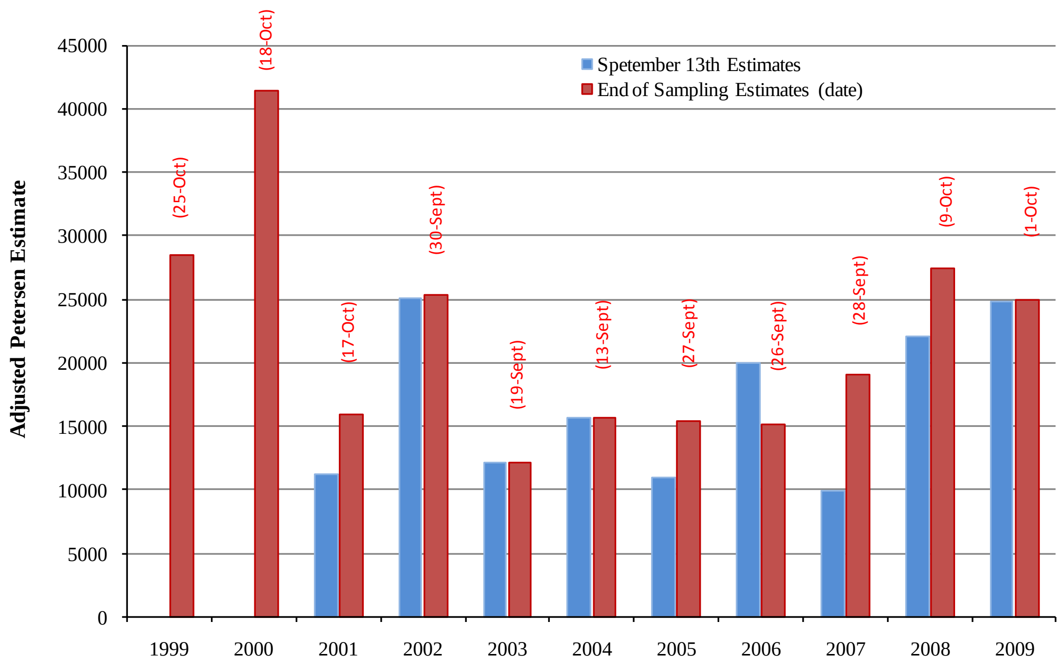


Figure 6. Adjusted Petersen estimates of the number of Bulkley/Morice steelhead arriving at Moricetown Canyon 1999 to 2009.

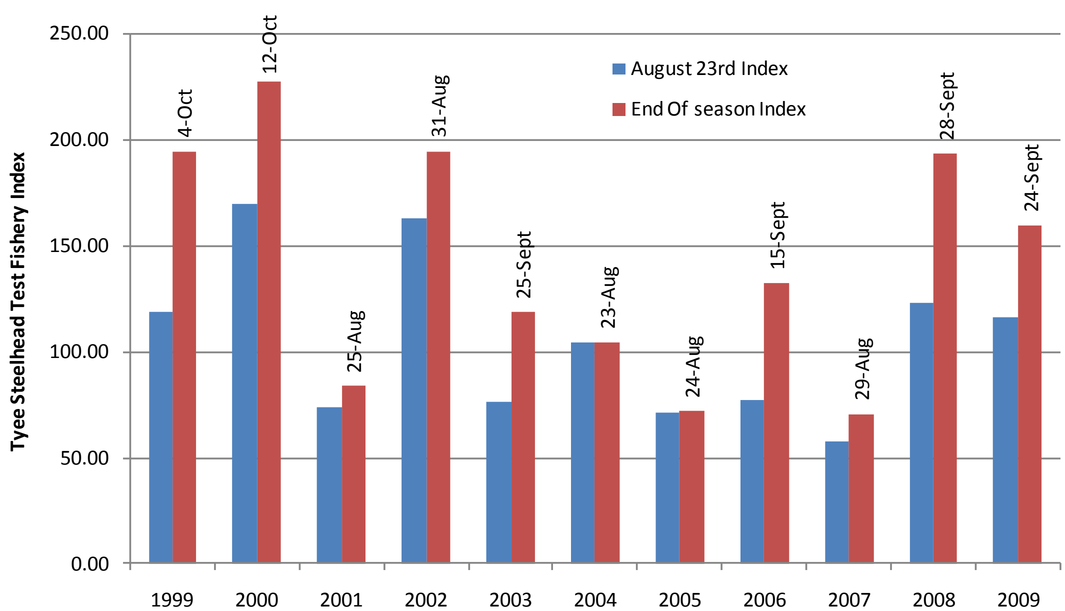


Figure 7. Tyee Test Fishery Skeena Steelhead Abundance Index from 1999 to 2009.

4.0 RECOMMENDATIONS

The Wet'suwet'en Fisheries steelhead tagging program has improved continuously since its onset, but has primarily been developed as a by-product of the Salmon Tagging Program. The potential for this program to obtain useful annual steelhead abundance estimates for ongoing management of this highly valued freshwater resource emphasizes the importance of refining the study design. To rank the priority for the following recommendations it may be important to determine the value and estimate the number of years of data that would be desired for future assessments of the collected data with regards to co-relations of Bulkley/Morice river steelhead returns to the Tyee Test Fishery cumulative index, harvest activities and steelhead life history characteristics (i.e. iteroparity). If the steelhead tagging project is proposed to proceed for more than just a few years, applications for annual base funding to help subsidize the steelhead portion of this program will be critical toward the refinement of the study design, improving the presentation and efficiencies of the overall tagging program, and fostering co-management of this fisheries resource. In addition, it would be advantageous for Wet'suwet'en Fisheries, BC Fisheries, FOC, and other interested parties to meet annually to ensure that funding and feasibility are integrated into the project design with defined objectives.

Since the initiation of the steelhead tagging program, the main objectives have been to monitor the timing of steelhead migration through Moricetown Canyon and to acquire an abundance estimate for the Bulkley/Morice River populations. Especially if this project is proposed to continue for more than just a few years, a number of modifications to the program have been identified with the intent to improve the aesthetics, operation, and data results. The following sections summarize the recommendations for potential improvements to the *Moricetown Canyon Tagging Facilities*, *Sampling Schedule*, *Sampling Methodologies*, *Data Records*, *Quality Assurance*, application of the *Moricetown Steelhead Abundance Index*, and some potential *Future Studies* that may identify some biases in the Bulkley/Morice steelhead abundance indices.

4.1 MORICETOWN CANYON FIELD FACILITIES

As short term facilities, the tag application and re-sampling sites for this project have been sufficient, but some suggestions are provided to improve both the beach seine tagging and dip net re-sampling facilities. For these recommendations it is critical to consider that the site of the project is highly exposed to the public eye along Highway 16 at a popular tourist rest stop.

Tagging Facility

The Moricetown campground tag application facility located on river right, just downstream of the canyon, could benefit from the following:

- addition of a portable, but theft resistant, dry storage building for extra gear and safety equipment,
- rental of a portable toilet for the beach seine location,
- provide suitable heating apparatus for the dry storage building and staff if sampling is extended into October,
- placement of temporary level footings for the tables, covered area and storage building
- addition of secure shoreline anchors to tie the boats to, and
- acquisition of a number of large portable coolers for temporary storage and transport of harvested fish.

Re-sample Facility

The Moricetown Canyon re-sampling facility located on the fishway on river left could benefit from the following:

- a portable, but theft resistant, dry storage building for extra gear and safety equipment,
- Provide suitable heating apparatus for the dry storage building and staff if sampling is extended into October,
- a water supply pump securely, but temporarily placed to provide an approximately 3 inch water supply hose to allow for continuous recycling of water through holding tanks and for cleaner harvest activities,
- temporary, but secure supply of electricity to ensure lighting if night work is conducted and to allow use of an environmentally safer and quieter water pump,
- inset of bolt anchors drilled into rocks for supporting, securing and allowing easier adjustments of walkways to different river levels,
- inset of bolt anchors and construction of small aluminum platforms for sampling and at convenient locations for fish holding tanks, and
- waste water disposal system to avoid dumping of discoloured water into the fish way or middle pool at low flows.

4.2 SAMPLING SCHEDULE

The starting date for sampling has always been dictated by the arrival of salmon, thus has consistently encompassed the initial arrival of steelhead at Moricetown Canyon, but could be delayed to August 1st if this tagging program is only focused on steelhead in future years. The ideal end date for future years of sampling appears to be the second or third week of October, but this could be shortened for the occasional year when early and precise estimates of adequate returns are confirmed, or due to budget constraints. Acquisition of at least a sub-sample of abundance estimates with sample periods extending to October 15th or later will be valuable in helping recognize the biases of abundance estimates at various end dates of sampling. For the purpose of reducing bias for in-season abundance estimates and improving its precision, the following suggestions related to the sampling schedule should be considered:

- sampling 7 days per week would provide the best results even if the effort per day is strategically decreased (e.g. two crews working 4 days on/4 days off with 10 hour days during the peak migration) for the entire study period,
- increase beach sampling intensity from August 7th to 21st in attempt to improve precision of abundance indices throughout the study and to acquire better precision earlier in the season as reliable indicator of low or high abundance years (e.g. potentially two crews working simultaneously at slightly different, and steelhead preferred, locations), and
- avoid increasing sampling effort when arrivals of steelhead are high, but continue weekend sampling (i.e. continuous) if funding is available.

It may also be useful, for management purposes, to begin establishing an emergency fund to ensure that, when in-season indices are low, sampling effort can be increased and continued into October in attempt to acquire as accurate and precise estimations of the lower abundance years as possible.

4.3 SAMPLING METHODOLOGY

The sampling methodologies developed throughout this project have been effective, but the following suggestions are provided for the beach seine and dip net operations with the intents to improve aesthetics, reduce the effects of handling on fish condition, and to possibly help establish a measurable unit of sampling effort that may be useful toward establishing catch per unit effort (CPUE) that could later replace mark recapture abundance estimates. The following suggestions for any modifications to the existing scientific experimental design of the Moricetown Tagging Program should be prepared and clearly presented to Wet'suwet'en Fisheries and FOC for discussion and refinement prior to implementation.

Beach Seine Sampling

Beach seine sampling has been improving in conjunction with field crew experience, but training will remain critical as staff members are replaced. A new net should be provided each year to help maintain the consistency of effort, as well as the net lengths used for each set should be recorded. It may also be helpful for cumulative index calculations if the initial setting of each crew or for the settings at 08:00 and 18:00 hr (next setting if overturned) are made to target steelhead in conjunction with sampling seven days per week. It may also help reduce the impact of beach seining on steelhead if fish are less exposed to air when the net is dragged onto the beach, crews continue to handle steelhead first, and that constant reminders are given for the removal of gloves prior to handling any species.

Dip Net Sampling

Dip net sampling has been efficient and effective since the initiation of the study, but refresher and initiation training meetings should be provided at the start of each year and especially as staff are replaced. The primary concern related to dip net activities has been with regard to the long handling time required to catch, transport to the tag application site, and release the fish. Notable impacts of handling have been observed based on more scale loss and slower recoveries after release than appear to occur on steelhead released after beach seine capture and tag application. There have not been any simple ideas for reducing the stress imposed on fish at the re-sample location, but some suggestions to be considered include the following:

- establish secure and adjustable holding containers at three dip net sampling sites to allow faster transfer of fish from nylon mesh dip nets to a conveniently located holding tank,
- design the holding tanks to allow gentler release of fish from the dip nets into the holding tanks as possible and easily remove untargeted species,
- design the holding tanks to allow more gentle transfer of fish to the mark and release location, possibly with carrying devices designed to easily insert, remove and transport with up to 4 fish,
- design a fish carrying device made with a smoother coating or material with less flex to reduce entanglement and loss of scales and protective mucous coating,
- design and use several less flexible and abrasive carrying structures to replace the existing dip nets that have been used for transporting fish from the dip net to the mark and release location,
- consider construction of a floating platform on the river left side of the fishway for the mark and release to standardize the impacts of fish release at different river levels and reduce the stress on fish that has resulted in the past during lower water levels,
- add fish release methods to the training session to reduce the stress and enhance the recovery of released fish,
- consider installation of a protected holding area at the release location to allow monitoring of fish in poor condition and reduce the fallback of releases over the falls or into the fishway,

- design the measuring trough at the marking location to have containment with a non-abrasive material and to contain flowing water to reduce suffocation and stress to the fish during tag application and data recording,
- ensure that any fish handled are released at a location in the river that is suitable for up to 30 minutes rest with limited risk for the fish to immediately fall back into the fishway or over the falls (e.g. temporarily install a dark, low gradient fishway perpendicular to the existing fishway on river left that is impassable at the downstream end, but has suitable flow for fish to recover),
- a pre-season preparation meeting with all employees should be held to review the objectives, sampling methodologies, fish condition topics, and for input on any proposed design changes, and
- the motivation for dip net crews based on tag application should be modified to something that will risk less bias on sampling efforts such as number of days with the highest steelhead catch.

Tag application

Tag application methods appear to have been successful, but more practical consideration of colour and number sequences distributed from year to year and among species may be an asset. Some suggestions for helping to standardize the tag application methodology include the following:

- the Moricetown Tagging Program should work toward designating a specific and consistent colour tag for salmon from year to year (e.g. chinook- white, sockeye – yellow, coho – blue), and for steelhead using alternate colours from year to year (e.g. red and orange), to help incorporate the iteroparous life history of steelhead and help more easily identify recaptures from previous years of study in the field.
- continue the application of upper caudal punch to allow monitoring of fallback and recapture of fish sampled at the canyon re-sampling location, but omit application of dorsal tags at the canyon unless upstream sampling is to be conducted and a higher number of applied tags is desired,
- continue to apply dorsal fin tags if there is potential funds for upstream sampling (e.g. Toboggan Creek adult fish fence) or snorkel counts,
- ensure a different colour tag is applied at the dip net from the beach seine to provide the option of later comparisons of survival and fall back between sampling locations.
- attempt to apply up to 1500 numbered tags each year at the beach seine in conjunction with lower caudal punch, but consider omitting or reducing application of numbered tags if the time delay from tag application to recapture remains constant or there are budget constraints on occasional years,
- Design a tagging trough directly attached to the holding tank that can eliminate the necessity of dip net transfer and handling of steelhead in netting for measuring, tag application and release.

4.4 DATA RECORDS

Some valuable field data potentially related to the time delays of steelhead moving from the tag location to the canyon re-sampling location has not been or has been inconsistently collected. Data loggers for water temperature, turbidity and discharge could provide valuable insight of their potential correlation with steelhead migration. Some suggestions for modifications to the field datasheets that may be useful or help improve field entries and data entry include:

- daily weather and water conditions should be moved from the detailed data sheets to the daily summary cover sheet,
- date format should be presented (i.e. year/mm/dd) on each form and an indicator of the day of the week (i.e. M/T/W/TH/F/SA/SU) could be added as a check method for dates recorded
- an additional field should be added to the detailed data sheet to clarify between "caudal punch present" and "caudal punch applied",
- the daily summary sheet should include a table with fields for *species, pages, total captured, total harvested, tags/caudal punches applied, beach seine recaptures, and other recaptures*,
- the beach seine daily summary page should be reviewed and updated to any modifications to the sampling methodology and data requirements.

4.5 QUALITY ASSURANCE

Guidelines for pre-field training should be developed and annually updated to ensure that all staff are knowledgeable with regard to the project objectives, background information, and are familiar with sampling and record keeping methods. The training program should be provided annually prior to the start of the field season, to better ensure the commitment of staff to the entire project. Data records from each crew should be reviewed within the initial two weeks of each year to modify or incorporate any modifications to the sampling and record keeping methodologies. Regular visits by a consistent monitor, in conjunction with occasional visits from the appropriate agencies and Wet'suwet'en Fisheries, will be integral in maintaining data quality and positive motivation of the field crews. Quality assurance of the summary data entered in-season should be conducted weekly and a complete check of all data should be done when all of the detailed data has been entered to check on the summary data results and for more detailed analyses of the data.

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Appendix 1. Steelhead data obtained by beach seining.

Appendix 2. Steelhead data obtained by dipnetting.

Appendix 3. Steelhead Recaptures obtained during the 2008 Moricetown tagging program.

Appendix 4. Breakdown of mark-recapture data for calculation of the Schaeffer estimate