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 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.

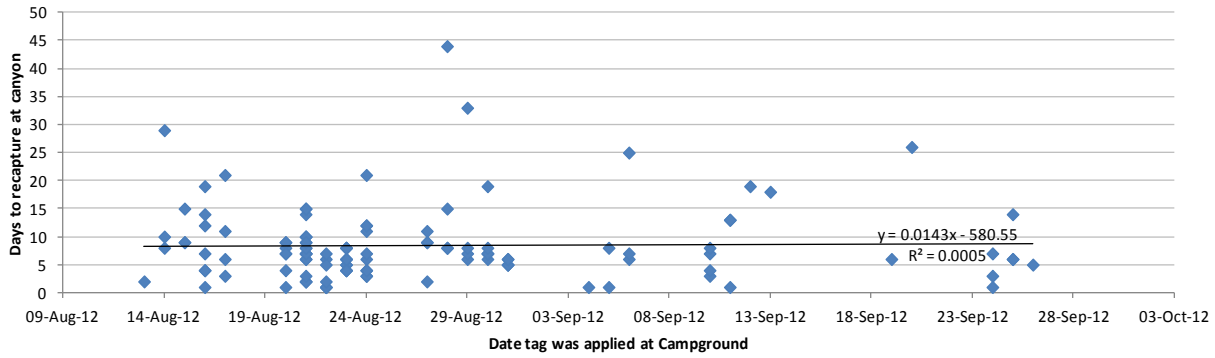


Figure 10. Correlation and regression analysis for the dates in 2012 when steelhead tags were applied at the Moricetown campground sites and time delay (days) to their recapture at the canyon.

3.4.1 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.

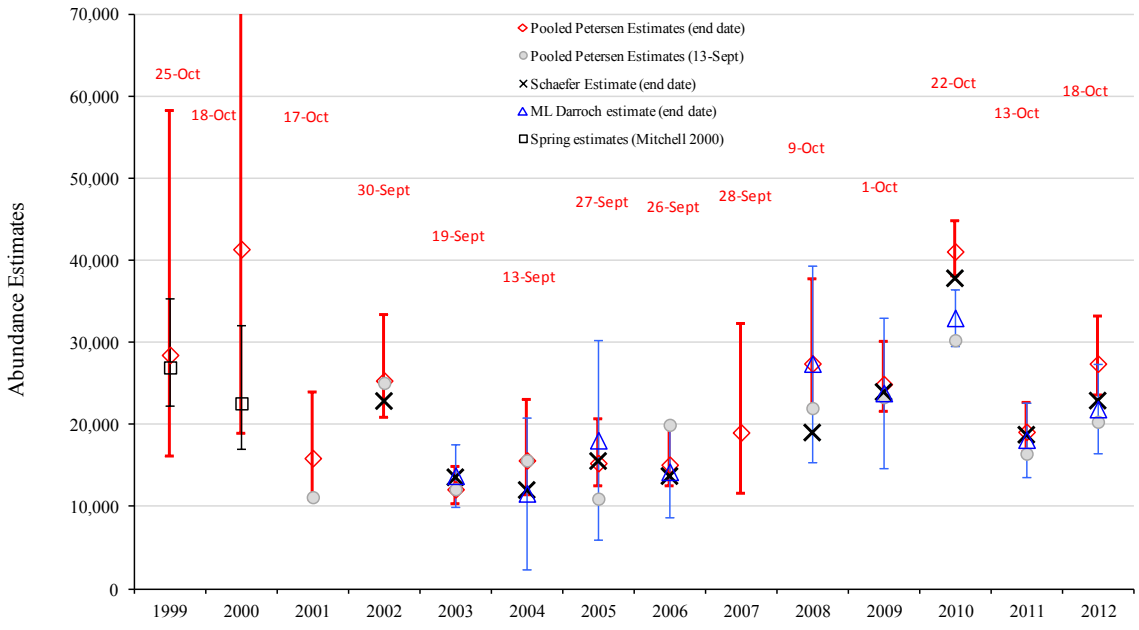
3.4.2 Stratified Abundance Estimates

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***