Walter Hardman Project Water Use Plan

Lower Cranberry Creek: Rainbow Trout Biology/Abundance Monitoring

Implementation Year 4

Reference: WHNMON-5

Study Period: 2011-2012

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July 3, 2012

Triton Project 4545

Lower Cranberry Creek: Rainbow Trout Abundance/Biology Monitoring

WHNMON-5

Year 4 (2011) of 5

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DISCLAIMER

This report is rendered solely for the use of BC Hydro in connection with the Walter Hardman Project Water Use Plan Monitoring Program (WHNMON-5: Lower Cranberry Creek Rainbow Trout Abundance/Biology Monitoring Program), and no person may rely on it for any other purpose without Triton Environmental Consultants Ltd.'s prior written approval. Should a third party use this report without Triton's approval, they may not rely upon it. Triton accepts no responsibility for loss or damages suffered by any third party as a result of decisions made or actions taken based on this report.

- The objective of this report is to address the following scope requirements: To determine how increases in minimum flow affect rainbow trout populations in Cranberry Creek, for BC Hydro. This will be accomplished by quantitatively determining the age composition, individual size, density and biomass of rainbow trout at various sites, and by qualitatively assessing fish habitat use within the creek.

- This report is based on facts and opinions contained within the referenced documents and facts. We have attempted to identify and consider relevant facts and documents pertaining to the scope of work, as of the time period during which we conducted this analysis. However, our opinions may change if new information is available or if information we have relied on is altered.

- We applied accepted professional practices and standards in developing and interpreting data obtained by our field measurement, sampling and observation. While we used accepted professional practices in interpreting data provided by BC Hydro or third party sources we did not verify the accuracy of data provided by BC Hydro or third party sources.

- This report should be considered as a whole and selecting only portions of the report for reliance may create a misleading view of our opinions.

EXECUTIVE SUMMARY

Lower Cranberry Creek is a small tributary of the Arrow Lakes Reservoir - the lower reaches being valuable habitat to resident Rainbow Trout. The Walter Hardman Hydroelectric facility (25 kms south of Revelstoke, BC) is a run-of-river generating station that is located on Cranberry Creek, approximately 11.5 kms upstream of the confluence with Upper Arrow Lake. Under the Walter Hardman Project Water Use Plan (2006), the Walter Hardman Water Use Planning Consultative Committee developed several programs designed to monitor outcomes of the recommended operational changes and changes to physical works at the generating facility.

This report summarizes the findings of year 4 (of 5) of WHNMOM-5 Lower Cranberry Creek Rainbow Trout Abundance/Biology monitoring program. This particular program was developed to determine the effect of changes in minimum flow in Lower Cranberry Creek, from Walter Hardman facility, on the resident Rainbow Trout population.

Similar to previous years of the program eight sites were monitored along a 5.47 km section of creek between the impassable falls 2.30 km upstream of the mouth of the creek to an unnamed tributary 7.73 kms upstream from the mouth. These sites were sampled by electrofishing and assessed for fish habitat values.

In total 146 Rainbow Trout were captured by electrofishing in 2011 representing 4 age classes (0+: fry to 3+: adults). Fish health indicator analysis showed that the majority of the fish were within normal size limits of healthy fish (mean K value of 1.13). Measured abundance in 2011 was higher than all previous years (2007 and 2008). Similar to previous years of the program (Davis 2009), the habitat quality in Lower Cranberry Creek in 2011 was found to be suitable for Rainbow Trout. However, instituting a minimum flow would likely benefit the Rainbow Trout population by increasing available spawning, rearing and overwintering habitat.

WHNMON-5 STATUS of OBJECTIVES, MANAGEMENT QUESTIONS and HYPOTHESES after year 4 (2011)

Objectives	Management Questions	Management Hypothesis	Year 4 (2011) Status
To determine the effect of changes in minimal flow on the resident Rainbow Trout (RB) population in lower Cranberry Creek by: Providing auxiliary information on the status of the Rainbow Trout population in lower Cranberry Creek in order to support habitat assessments of the fisheries benefits of minimum flow release from the diversion weir. Providing baseline Rainbow Trout abundance data against which future monitoring studies can measure a response	What is the status of the current RB population in lower Cranberry Creek? How do increases in minimum flows affect the RB population and what are the potential benefits of establishing a minimum flow? What is the qualitative capacity of the population to respond to potential habitat improvements resulting from minimum flow releases?	There is no direct management hypothesis associated with this particular study. Rather, this study is intended to better inform existing fish population status and biology, the response of fish to operational changes, and, in conjunction with Rainbow Trout habitat monitoring (Monitoring Program No. WHN-2 Rainbow Trout Rearing Habitat in lower Cranberry Creek) to qualitatively judge the degree to which low limits populations.	The Rainbow Trout population in lower Cranberry Creek likely is made up of 4 age classes: 0+ to 3+. Health indicator analysis shows a relatively "normal" level of health (K value) The capacity of the population to respond to habitat improvements through minimum flow releases is likely high. Minimum flow release would likely improve RB habitat in lower Cranberry Creek.

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1. INTRODUCTION

Triton Environmental Consultants Ltd. (Triton) was retained in 2011 by BC Hydro to complete the remaining 2 years of a 5 year Rainbow Trout monitoring program on lower Cranberry Creek. The program is one of several described by the Walter Hardman Water Use Plan (WUP) which is designed to monitor the outcomes of operational changes and changes to physical works, and provide information on which to base future operating decisions (WUP Terms of Reference (TOR) 2006).

The Walter Hardman Hydroelectric project is located on Cranberry Creek, within the Columbia-Shuswap Regional District. The generating station is approximately 25 km south of Revelstoke, B.C. and uses water diverted from Cranberry Creek to generate power. When creek flows are greater than plant capacity of ~4.3 m^3s^{-1}, the excess water is released to Lower Cranberry Creek; however when flows are less than plant capacity no water is released into Lower Cranberry Creek.

Rainbow Trout are resident in Cranberry Creek throughout the year and it was hypothesized by the Water Use Planning Consultative Committee that a lack of minimum flow would limit the available habitat and reduce productivity of the system (WUP TOR 2006). A water diversion pipe was installed to maintain a minimum flow of 0.1 m^3s^{-1} during times of the year when discharge is less than the generating plant's capacity. This minimum flow is anticipated to improve fish habitat downstream during periods of low discharge.

Rainbow Trout habitat in British Columbia is widely varied. Among the species there are five general habitat-types: Anadromous, lacustrine, large river, stream residents, and headwater habitats (Keeley et al. 2005 as cited in McPhail 2007). In lower Cranberry Creek and within the limits of this study area, it is likely the RB population fits into the stream and possibly the lacustrine habitat types, as it is possible for individuals to be "washed" downstream from upstream of the Walter Hardman head pond during freshet or flood events and end up residing in lower Cranberry Creek.

The Lower Cranberry Creek Rainbow Trout Abundance/Biology Monitoring program (WHNMON-5) has two objectives: It is intended to provide auxiliary information on the status of the resident Rainbow Trout population to support habitat assessments of fisheries benefits of minimum flow release from the diversion weir; it will also provide baseline Rainbow Trout abundance data against which future monitoring studies can measure a response. The overall goal of the program is to determine the effect of changes in minimal flow on the resident Rainbow Trout (RB) population in Cranberry Creek through the investigation of the following management questions:

- What is the status of the current RB population in lower Cranberry Creek?
- How do increases in minimum flows affect the RB population and what are the potential benefits of establishing a minimum flow?
- What is the qualitative capacity of the population to respond to potential habitat improvements resulting from minimum flow releases?

This report provides a qualitative analysis of fish habitat use as well as a population estimate for the resident Rainbow Trout population. It includes a description of age and size class, instantaneous growth rate, health indicators, and habitat use at low flows. Data collected is compared with previous studies where possible and applicable. These studies include: Summit (2000) and Davis et al. (2009). In 2000, Summit Environmental Consultants Ltd completed a study titled *Cranberry Creek Fisheries and Hydrology Study*. Similar to WHNMON-5, Summit's report, in part, investigated fish habitat quality under different flows (high, medium and low). Rainbow Trout were captured, enumerated, analyzed for health status and segregated into length-age categories. Where comparisons were made, data from Summit's *Site 5* was used as its location was likely very near (within 50 m) Triton sites 7 and 8. The Davis (2009) study was year 2 of WHNMON-5 with the same reach of lower Cranberry Creek being utilized for the study.

2. METHODS

The methodology for the Lower Cranberry Creek Rainbow Trout Abundance/Biology Monitoring program mirrored the BC Hydro Terms of Reference and the Year 2 report (Davis 2009) where appropriate, and adhered to the Resources Information Standards Committee (RISC) Fish and Fish Habitat Inventory (RISC 2000), and the Fish Collection Methods and Standards (RISC 1997). Year 4 of the program involved further sampling for fishes, and the associated data entry and reporting described in the following sections.

2.1 FIELD STUDY

The study area is located along a 5.47 km section of Cranberry Creek between the impassable falls 2.30 km upstream of Upper Arrow Lake, and an unnamed tributary located 7.73 km upstream of the lake (Figure 2-1). An initial reconnaissance trip was completed late August, 2011 to ensure that existing sites were relevant and to select new sites if needed. Sites were selected to ensure similar habitat values among transects and to ensure capture of enough fish to be able to comment on the population. New sites were staked and flagged with company name, site number and Universal Trans Mercator (UTM) coordinates (NAD83) recorded on the flagging.

A total of eight sites were used sampled within the study area. Seven sites were new sites selected by Triton while one site (Site 4) corresponded to Davis 2009 site LCSN06. It shall be noted that Summit Environmental "*Site 5*", was within the study area (Table 3-1). As Summit (2000) did not report specific UTMs of *Site 5 – Highway Zone*, the degree of overlap with Triton sites 7 and 8, if any, cannot be determined. Rough scaling from **Figure 1.1 of Section 1.3** (Summit main report) likely places Summit *Site 5* between Triton Sites 7 and 8.

Closed-site, multi-pass electrofishing was completed at all eight sites using a Smith-Root Model 12B backpack electrofisher with pulse frequency of 60 Hz and pulse width of 6 ms. Voltage settings varied from 300 to 400 volts depending on water conductivity. Sampling was conducted using the three-pass depletion method (three consecutive passes resulted in decreasing numbers of individuals). Stop-nets with 5 mm mesh size were set up at each site approximately 30 m apart to isolate a section of the stream prior to electrofishing. Specific placement of the stop-nets was determined on-site to select for high habitat values to maximize fish catch potential. One crew member with the electrofisher and two crew members with dip nets would then sample the length of the enclosure placing all captured fish in buckets. Fish were weighed to the nearest 0.01 gram and measured to the nearest 1 mm (fork length: FL) following each pass. All fishes captured were anaesthetized using a solution of clove oil and creek water (0.03g clove oil per L water) as recommended by Anderson et al. (1997) to reduce handling stress before being enumerated and measured. Fishes were then placed in an aerated recovery container with fresh creek water and an aerator. Sampling passes were carried out until three successive passes yield declining numbers of fish (or only two passes when no fishes were captured on the second pass). Fishes were monitored for signs of stress throughout the handling process, and once fully recovered, were released back into the creek within the vicinity of capture.

Scale samples were taken from 9 of the 146 Rainbow Trout captured and sent to *North/South Consultants Inc.* to be aged. Note that the terms “fry” and “young-of-year” represent the same age class in this study. These are individuals that hatched in the spring of 2011.

Fish habitat assessment followed the standards and procedures established by the Resources Inventory Committee (1998). Data collected including water depth and velocity, substrate composition and description of available cover for fish were recorded. Water quality data including water temperature, pH, and conductivity were measured at each site as well as site length, stream gradient and UTM location. Photographs were also taken to document site conditions during the study period.

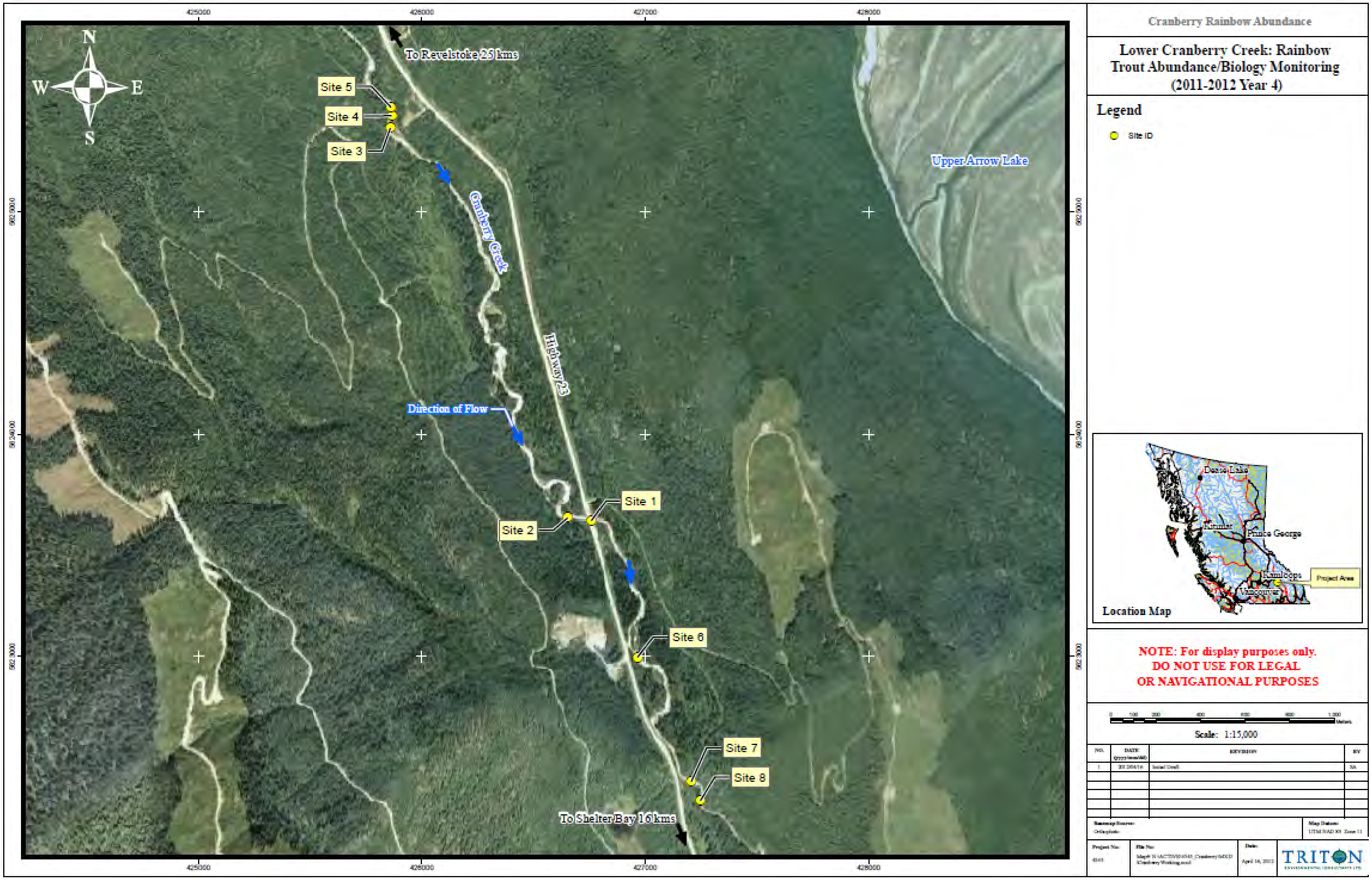

Figure 2-1. WHNMON-5 Study Area, Triton 2011

2.2 DATA ANALYSIS

All data collected was entered into a spreadsheet using MS Excel for analysis and comparison of the following parameters:

- Population estimate and density (using software MicroFish 3.0)
- Fish size and age composition
- Biomass per site
- Comparison of results from Summit (2000) report
- Habitat use and availability at various flows

2.2.1 Population Estimate and Density

Electrofishing data were used to calculate population and density of Rainbow Trout. Site density was calculated under the Maximum-likelihood Estimation method (MLE; Zippin, 1956, Seber, 1982)) using the software MicroFish 3.0 (Van Deventer, 1989). MLE is a commonly used method of estimating unknown parametric values, under a particular statistical model (*i.e.* normal distribution), given a particular data set. MLE was used here in conjunction with the triple-pass removal fish sampling method to estimate the local population (*i.e.,* the number of fish captured if sampling continued until no fish were remaining in the site). Observed fish density (fish/100 m^2) was also calculated from collected field data. Simply calculated in Equation 1:

$$\text{Observed density (fish per } 100\text{m}^2) = \frac{\text{number of fish captured}}{\text{measured site area (m}^2)}(100) \qquad \textbf{(Eq.1)}$$

As in Davis (2008); where there were only 2 passes performed (site 7) equations 2 and 3 were used (Hayes et al. 2007).

Population Estimate:

$$N = \frac{n^2_1}{(n_1 - n_2)} \qquad \textbf{(Eq.2)}$$

Variance:

$$V = \frac{n_1^2 n_1^2 (n_1 + n_2)}{(n_1 - n_2)^4} \qquad \textbf{(Eq.3)}$$

Where, N = Population Estimate (number of individuals)

n_1 = number of fish caught on first pass

n_2 = number of fish caught on second pass

V = Variance

2.2.2 Age Composition - Length-Weight Relationship – Biomass

Nine Scale samples were collected during sampling and analyzed for age. Samples from fish were carefully taken from the widest size-range of fish possible to obtain relevant data. These data were used in conjunction with length-weight field data to delineate a likely age structure. Biomass at each site was calculated thusly:

$$\text{Biomass (grams/m}^2\text{)} = \frac{\text{sum of all recorded weights of captured RB (grams)}}{\text{measured area of the site (m}^2\text{)}} \qquad \textbf{(Eq.4)}$$

2.2.3 Growth Rate and Fish Condition

Growth rate was calculated by using the mean FL in each age class plotted against age. The slope of the best-fit line corresponds to growth rate. Fish condition was quantified as it is possible for there to be a wide variation in the length-weight relationship depending on the health of individual fish. As cited in Davis (2009), condition indices can provide a relevant measurement of individual fish health based on their length and weight (Anderson and Neumann 1996). Fulton's condition factor (Ricker 1975) was used to quantify the relative condition or well-being of captured fish. The coefficient of condition (K) was calculated using the following equation:

$$K = \frac{10^5 W}{L^3} \qquad \textbf{(Eq.5)}$$

Where W is equal to mass in grams (g) and L is equal to fork length in millimeters (mm). Typical condition factor range for salmonids is 0.8 to 2.0. Barnham and Baxter (1998) proposed a grading scale for fish condition factor in which a value of 1.2 suggests "a fair fish, acceptable to many anglers", whereas a value of 1.4 suggests "a good, well-proportioned fish". Values less than 1.0 are considered "poor" and are characterized by long, thin bodies.

3. RESULTS AND DISCUSSION

3.1 RECONNAISSANCE SURVEY

The reconnaissance survey for WHNMON-5 was carried out at the end of August 2011 to delineate suitable sites for sampling. Sites were selected to ensure similar habitat values among transects and to ensure capture of enough fish to be able to comment on population dynamics. New sites (7 Triton sites) were staked and flagged with site number and UTM coordinates recorded on the flagging. Summit Environmental (2000) site-5 was not located during the reconnaissance. However, from Summit's project maps, it is likely Summit-site 5 was located between Triton sites 7 and 8. Table 3-1 summarizes the eight sample sites chosen in 2011 and section 3.1.1 provides habitat description and representative site photographs.

Table 3-1 Rainbow Trout Abundance Sample Sites, Triton 2011

Site ID	UTM 11U Coordinates (NAD83)		Elevation (m)	Site Length (m)	Comment
	Easting	Northing			
Site 1	426760	5623613	597	57	Triton site - Hwy. 23 crossing
Site 2	426653	5623625	598	40	Triton site
Site 3	425859	5625378	629	45	Triton site
Site 4	425866	5625434	629	40	Corresponds to Davis LCSN06 (year 2)
Site 5	425862	5625472	630	41	Triton site
Site 6	426967	5622997	591	45	Triton site. Near LCSN04 (Davis year 2)
Site 7	427207	5622437	586	40	Triton site. Near LCSN02 (Davis year 2)
Site 8	427248	5622350	583	47	Triton site

3.1.1 Descriptions and Representative Site Photographs for 2011 Sampling Program

Site1

This 57 meter long site, at the Highway 23 bridge crossing, consisted of a glide with cobble/boulder riffles at both the upstream and downstream ends. Habitat values for rearing, overwintering and spawning were moderate/high (rip rap cover), moderate (0.6 meter deep residual pool) and low (substrate too course), respectively. Stream stage (discharge) was assessed as low (0-30% of Bankfull Channel depth) and total cover was assessed as moderate (5-20%).

Plate 1. Site 1: View downstream of left margin pool from right bank upstream of Hwy. 23 Bridge.

Site 2

This 40 meter long site was located approximately 94 m upstream of the Highway 23 bridge crossing and consisted of a glide with cobble/boulder substrates. The right margin was dominated by rip rap, providing the majority of good habitat, while the left bank was shallow-sloped and cobble-dominated. Habitat values for rearing, overwintering and spawning were moderate (rip rap and overhanging vegetation cover), moderate (0.9 meter deep residual pool) and low (substrate too course), respectively. Stream stage (discharge) was assessed as low and total cover was assessed as moderate.

Plate 2. Site 2: View upstream of right margin pool from creek centerline.

Site 3

This 45 meter long site was located approximately 1.9 km upstream of the Highway 23 bridge crossing. The upstream half of the site consisted of a bedrock-dominated pool (0.95 m deep) while the downstream half was a shallow boulder/cobble riffle. Habitat values for rearing, overwintering and spawning were moderate (rip rap and pool cover), moderate/high (0.95 meter deep residual pool) and low (small percentage of suitable-sized gravel), respectively. Stream stage (discharge) was assessed as low and total cover was assessed as moderate.

Plate 3. Site 3: View downstream of right margin pool from upstream-end riffle.

Site 4

This 40 meter long site was located approximately 2 km upstream of the Highway 23 bridge crossing and consisted of a glide with boulder/cobble riffles at the upstream and downstream ends. Habitat values for rearing, overwintering and spawning were moderate (substrate and overhanging vegetation cover), low (1 – 0.5m deep residual pool) and low (no suitable spawning gravel observed) respectively. Stream stage (discharge) was assessed as low and total cover was assessed as moderate.

Plate 4. Site 4: View upstream of left margin pool from downstream riffle.

Site 5

This 41 meter long site was located approximately 2.06 km upstream of the Highway 23 bridge crossing and consisted mainly of a boulder/cobble riffle. Habitat values for rearing, overwintering and spawning were moderate (substrate and overhanging vegetation cover), low (insufficient pool depth) and low (low representation of suitable spawning gravel) respectively. Stream stage (discharge) was assessed as low and total cover was assessed as moderate.

Plate 5. Site 5: View upstream of right margin from downstream end of site.

Site 6

This 45 meter long site was located approximately 662 m downstream of the Highway 23 bridge crossing and was riffle/pool morphology. Habitat values for rearing, overwintering and spawning were moderate/high (instream woody debris and overhanging vegetation cover), low (insufficient pool depth) and low (no suitable spawning gravel observed) respectively. Stream stage (discharge) was assessed as low and total cover was assessed as moderate.

Plate 6. Site 6: View downstream of right margin pool from upstream end of site.

Site 7

This 40 meter long site was located approximately 1.31 km downstream of the Highway 23 bridge crossing and was glide morphology with boulder/cobble substrate. Habitat values for rearing, overwintering and spawning were low/moderate (limited cover and complexity), moderate (several pools with > 0.5m depth) and low (no suitable spawning gravel observed) respectively. Stream stage (discharge) and total cover were assessed as low.

Plate 7. Site 7: View upstream of right margin pool from downstream end of site.

Site 8

This 47 meter long site was located approximately 1.42 km downstream of the Highway 23 bridge crossing and was riffle/pool morphology with a cobble/gravel riffle at the downstream end, a bedrock pool mid-site and a boulder/cobble riffle at the upstream end of the site. Habitat values for rearing, overwintering and spawning were moderate (good habitat complexity with moderate cover), low (pool depth limited) and low (no suitable spawning gravel observed) respectively. Stream stage (discharge) was assessed as low and total cover was assessed as moderate.

Plate 8. Site 8: View downstream of right margin pool from upstream end of site.

3.2 POPULATION DYNAMICS

Electrofishing-sampling yielded Rainbow Trout (RB) captures at all eight sites in 2011. In total, 146 RB were captured including 3 fry (young-of-year), 137 juveniles and 6 adults. Site 3 had the most fish captured (n=32; all juveniles) while Site 7 had the least (n=6; all juveniles). The mean number of fish captured between all sites was 18.3 (stdev=8.3).

The ability to compare population dynamics data between the 2011 and 2008 results (Davis 2009) and draw meaningful conclusions is somewhat limited as only 3 RB were captured by electrofishing in 2008 at one site versus 146 RB captured in 2011 at eight sites. As well, 2011 sampling took place 1 month later in the year than in 2008. Creek discharge was higher in 2008 during the time of sampling than it was in 2011. Water depth and velocity as well as creek morphology (accessibility to different habitats for fish) affects habitat suitability.

3.2.1 Population Estimate and Density

The software *MicroFish version 3.0* (Van Deventer 2012) was used to obtain the Maximum Likelihood Population Estimate (MLE), corresponding confidence range (95% confidence interval) and capture probability at sites where three consecutive passes were performed. Where two passes were performed (site 7), the methodology follows Hayes et al. (2007) as cited in Davis (2009) where equations 2 and 3 in section 2.2.1 of this report. Table 3-2 summarizes capture data by site and the resulting MLE.

Table 3-2 Rainbow Trout Population Estimate, Triton 2011

Site ID	Pass	Effort (EF sec)	Number Fish Captured	Pop'n Est. (n) (as per MicroFish 3.0)	Confidence Range(95% CI) (+/- %)	Capture Probability (q)
1	1	552	18	27	7.4	0.71
1	2	505	7			
1	3	562	2			
2	1	453	11	20	20.0	0.59
2	2	305	6			
2	3	429	2			
3	1	586	25	32	3.1	0.78
3	2	573	5			
3	3	498	2			
4	1	464	12	23	26.1	0.53
4	2	408	5			
4	3	356	4			
5	1	390	10	14	7.1	0.74
5	2	368	3			
5	3	not recorded	1			
6	1	450	9	12[B]	8.3	0.75
6	2	464	1			
6	3	410	2			
6	4	411	1[A]			
7	1	411	6	6[C]	100[C]	n/a[C]
7	2	445	0			
7	3	-	-			
8	1	358	9	14	14.3	0.67
8	2	377	3			
8	3	328	2			

[A] This was a visual observation. There were no fishes captured in the fourth pass.
[B] Pass "two" was omitted from the estimate and passes 1, 2 and 4 were used to obtain MLE. The MLE here is therefore an underestimate.
[C] Where 2 passes were performed; refer to equations 2 and 3 in (section 2.2.1) for population estimate and corresponding variance. Variance was then converted to a percent of the population estimate. Capture probability is not calculated by equations 2 and 3.

Table 3-3 Rainbow Trout Density Results, Triton 2011

Site ID	Pop'n Est. (n fish)	Estimate Confidence Interval$_{95\%}$ (+/- n fish)	Site Length (m)	Mean Wetted Width (m)	Measured Area (m^2)	Fish Density ($fish/100m^2$)	Density Confidence[B] Interval$_{95\%}$ (+/- n fish)
1	27	2.0	57	6.93	395.01	6.84	0.51
2	20	4.0	40	7.40	296.00	6.42	1.28
3	32	0.99	45	5.20	234.00	13.68	0.42
4	23	6.0	40	6.37	254.80	8.24	2.15
5	14	0.99	41	6.43	263.63	5.31	0.38
6	12	1.0	45	5.40	243.00	4.94	0.41
7	6[A]	6[A]	40	10.27	410.80	1.46	1.46[A]
8	14	2.0	47	7.75	364.25	3.85	0.55

[A] Site 7 values were calculated using Eq 2 and 3 (section 2.2.1) to obtain population estimate and corresponding variance.
[B] Confidence Interval here is calculated from first converting MLE CI into a percent then multiplying that value by fish density and multiplying the result by 100.

Of the seven sites sampled by Davis in 2008, only one site (site LCEF05.5) yielded RB through electrofishing (n = 3). Fish size and abundance data for the remaining six sites, of which only 3 sites contained RB, was gathered through snorkel surveys with only density calculations carried out during reporting. Population estimate and density calculations were employed for site LCEF05.5 only. Population, density, biomass and condition factor data form Davis (2009) is summarized in Table 3-4 below. It should be noted that, for posterity, Table 3-4 was recreated faithfully from *Tables 3 and 4*, in text, grammar and content, with respect to the Davis (2009) report. However densities were converted from "$fish/m^2$" to "$fish/100m^2$" for comparison purposes.

Table 3-4 Summary of Davis 2008 sampling results (see Tables 3 and 4, Davis 2009)

Site ID	Sampling Method	# Obs	Length (cm)	Weight (grams)	Pop'n Estimate	Density ($fish/100m^2$)	Biomass (g/m^2)	Condition Factor - K
LCSN01.5	Snorkel	3	0-15	nr	nr	1.09	nr	nr
LCSN03	Snorkel	3	0-30	nr	nr	3.57	nr	nr
LCSN04	Snorkel	1	0-10	nr	nr	0.23	nr	nr
LCEF05.5	EF	3	16.37[A]	34.40[A]	4	4.00	1.23	0.82

[A] These were the calculated means (mass assumed to be grams): (14.6cm, 30.4g, K=0.98), (14.5cm 28.3g, K=0.93) and (20.0cm, 44.5, K=0.56).
nr – "not reported"

In terms of density of fish per unit area, 2011 results showed higher RB densities than 2008 results. It should be noted that the strength of comparison is limited as sampling methodologies differed from 2008 to 2011 (snorkel surveys vs. electrofishing). From Table 3-4 adding the densities from the four Davis sites, the mean is 2.22 fish/100m^2 (stdev = 1.85) while, from Table 3-3, adding the densities from the eight Triton sites, mean density was 6.34 fish/100m^2 (stdev = 3.60).

Comparing Triton population and density results to Summit (2000) results (August 25-28, 1998 – low-flow survey) we see Summit *Site 5*, which was likely between Triton Sites 7 and 8, had a population estimate of 30 RB compared to 6 RB and 14 RB for Triton Sites 7 and 8. As well, RB density was greater at *Site 5* in 2000 than at Sites 7 and 8 in 2011 (4.97 fish/100m^2 vs 1.46 and 3.85 fish/100m^2). Additionally, *Site 5* was reported to have the largest measured population between all the sites sampled in 1997 and 1998 (Summit 2000).

3.2.2 Age Composition - Length-Weight Relationship – Biomass

Of the 146 RB captured, 9 representative scale samples were collected and sent for age analysis to *North/South Consultants Inc*. From measured fork lengths (FL) of all captured RB the following length-frequency histogram was generated (Figure 3-1).

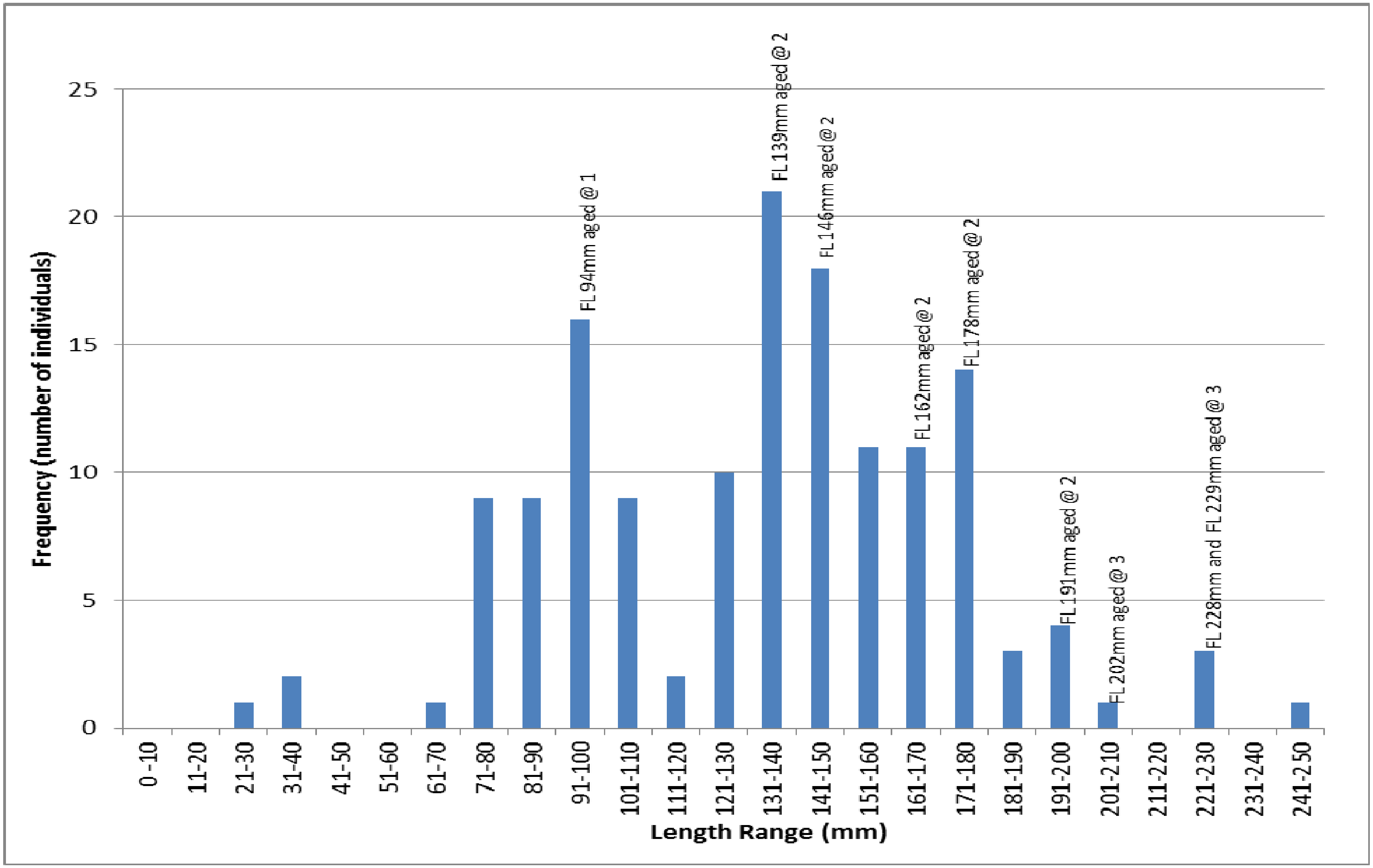

Figure 3-1. Frequency of Length ranges for Rainbow Trout captured during the 2011 field program (N = 146). Those bars with annotated lengths and ages (N = 9) are the 9 scale samples that were aged and the ranges in which they belong.

Based on Figure 3-1, it is estimated that 0+ (young-of-year) fishes range in length from 0 to 60 mm FL, 1+ fishes range from 60 to 120 mm, 2+ fishes range from 120 to 200 mm and 3+ range from 200 to 230 mm.

For all RB captured a length weight regression was also plotted to investigate strength of the relationship and is presented in Figure 3-2.

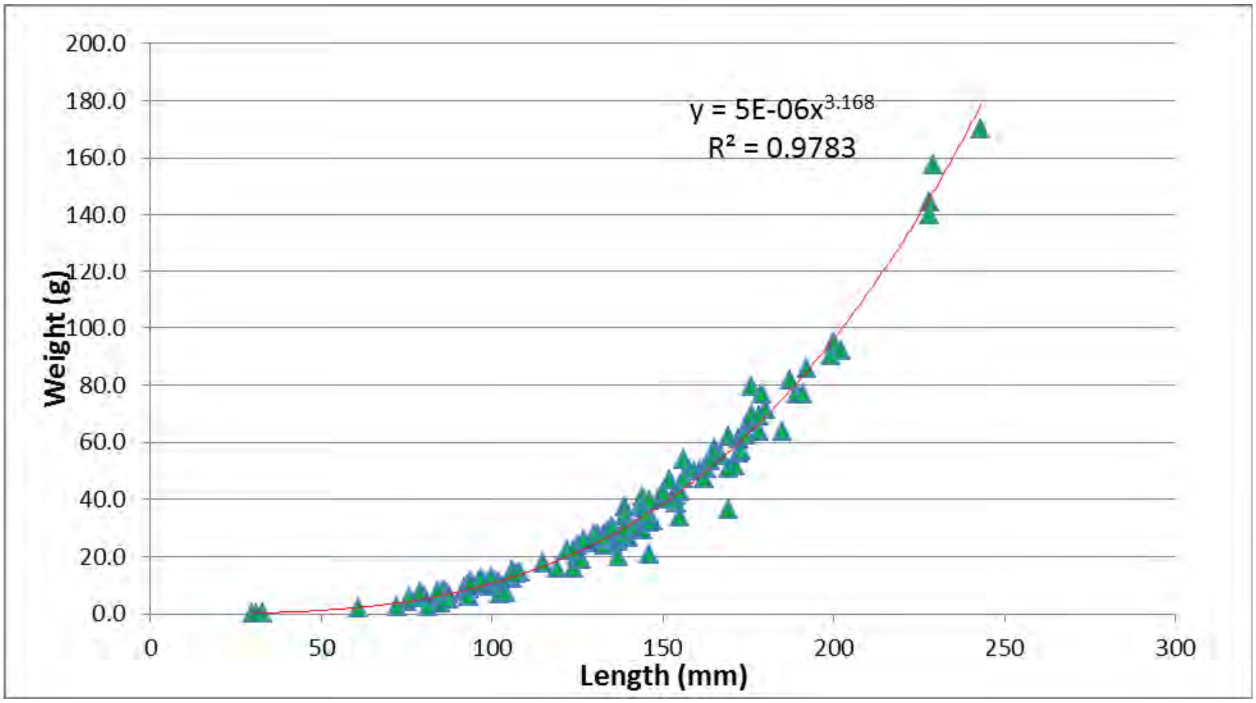

Figure 3-2. Length-Weight regression for Rainbow Trout captured during the 2011 field program (N = 146).

For captured RB in 2011, there is a strong correlation between fish weight and length (R^2 = 0.98).

As stated in Davis 2009, due to the small number of fish caught during the 2008 program a length weight regression was no performed. Therefore, no comparison between Triton 2011 data and Davis 2008 data can be made in that regard. Alternatively, Summit Environmental (2000) produced an *Average Rainbow Trout Fork Length by Age Class* histogram which included data from *Site 5*, which was likely between Triton sites 7 and 8. Figure 3-3 is the histogram as it appeared in the Summit final report in 2000.

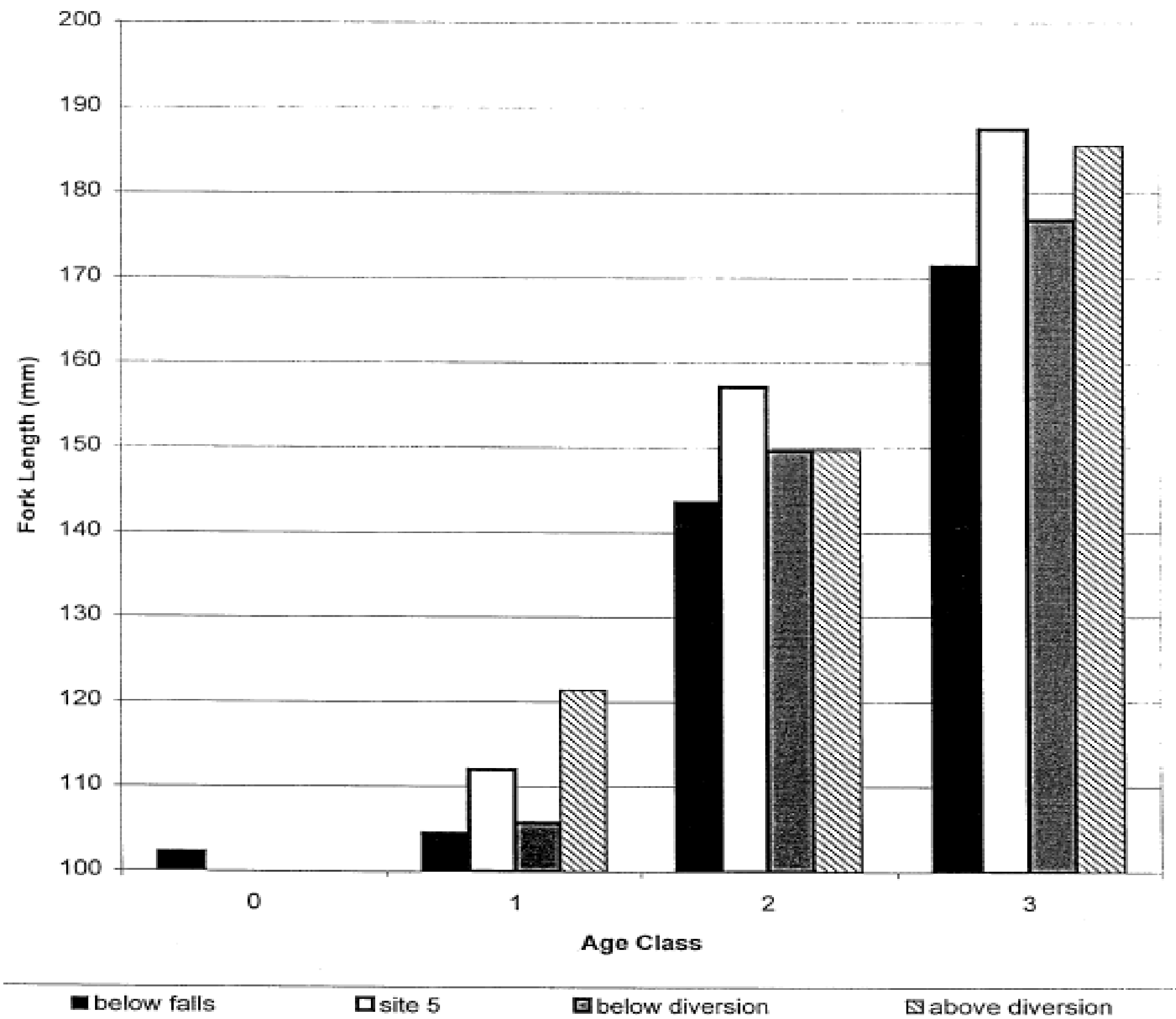

Figure 3-3. ***Average Rainbow Trout Fork Length by Age Class*** **– Summit, 2000**

Age class delineations were similar in 1998 Summit results compared to Triton 2011 results. Comparison of FL averages is displayed in Table 3-5 on the following page.

Table 3-5. Average Rainbow Trout Fork Length by age Class: Summit *Site 5* and Triton Sites.

Age Class	Summit *Site 5* mean FL (mm)	# Fish captured	Triton All Sites: mean FL (mm)	# Fish captured	Triton Sites 7 and 8 (mm)	Fish captured
0	NFC	0	31	3	NFC	0
1	112	n/a	91	45	98	8
2	157	n/a	151	91	150	10
3	187	n/a	218	7	199	1

Note: Summit (2000) reported that scales samples from a sub set of 81 RB were aged from all RB caught in Cranberry and South Cranberry Creeks in August 1998 (during low flow period). They did not specify how many samples from each class there were.

Comparison of Summit's data and Triton's show similar average FLs within the age classes.

Biomass was also calculated for each site as the total weight of all captured RB divided by the measured area of the site to yield grams per square meter. Biomass by site is displayed in Figure 5 below.

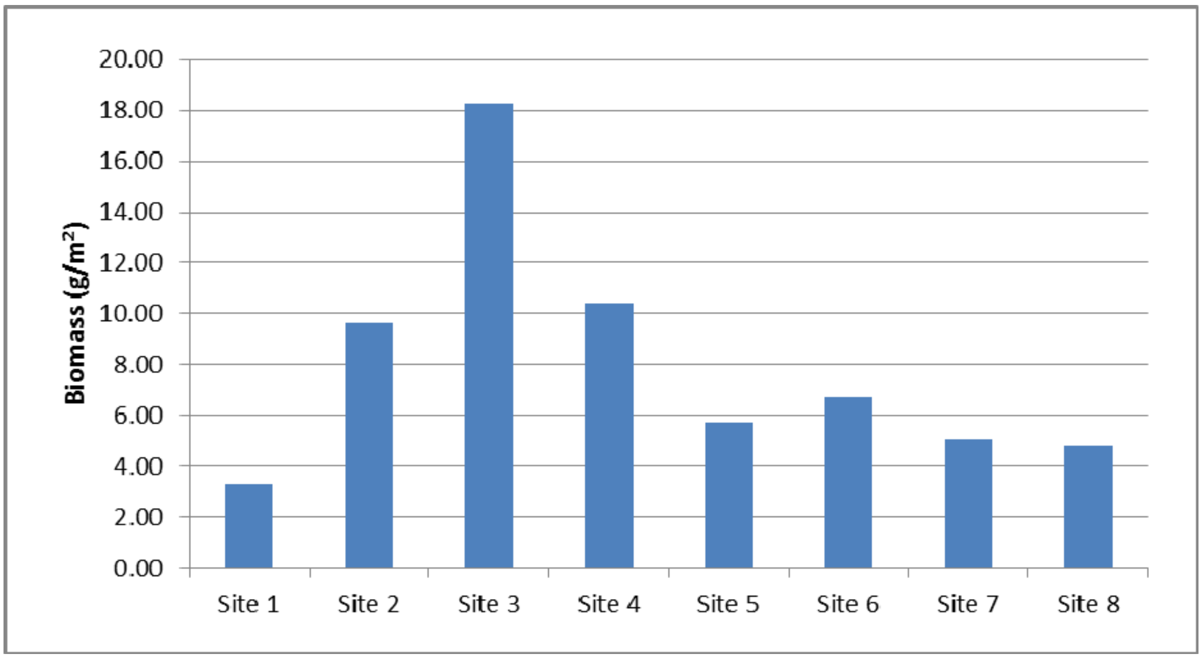

Figure 3-4. Biomass by site for Rainbow Trout captured during the 2011 field program.

Compared to 2008 sampling results (Davis 2009), biomass in 2011at all 8 Triton sites was higher with values ranging from 3.33 g/m^2 to 18.25 g/m^2 (mean = 8.00, stdev = 4.79) compared to 1.23 g/m^2 for site LCEF05.5.

3.2.3 Growth Rate and Fish Condition

Classically growth rate is attained through standard mark-recapture studies. Individuals are *tracked* over a period of time – their length and weight measured through the different life stages. This results in an accurate estimation of growth rate. "Growth rate" values for this study are fundamentally different. Instead of a classic change-of-length over time, we are taking an instantaneous snapshot and are forced to compare between age classes rather than between individuals over time. Through each life stage, growth rate is variable – depending on water temperature and depth (adults preferring 7-18 ^{o}C), availability of food, predation and habitat suitability (Raleigh et al., 1984 as cited in McPhail, 2007).

As previously tabulated in Table 3-5, average FL was calculated for each age class. The average difference between the age classes are as follows: 0+ to 1+; 60mm, 1+ to 2+; 60mm and 2+ to 3+; 67 mm. Based on this result there appears to be relatively linear growth from young-of-year to 3 years of age for captured RB in Lower Cranberry Creek. Fish condition was calculated for RB caught in 2011 and subsequently compared with Davis 2009 data. Comparison data is displayed below in Table 3-6.

Table 3-6. Condition Factor for Rainbow Trout captured during the 2011 field program compared to results of site LCEF05.5 (Davis 2009).

Site	Fish captured	Min K	Max K	Mean K	StDev K	Mean K YOY	Mean K Juv	Mean K Adult
1	27	0.97	1.46	1.16	0.11	n/a	1.16	1.20
2	19	0.92	1.29	1.11	0.10	n/a	1.11	n/a
3	32	0.83	1.40	1.16	0.13	n/a	1.16	n/a
4	21	1.03	1.34	1.18	0.09	n/a	1.18	1.18
5	14	0.51	1.48	0.89	0.33	n/a	0.89	n/a
6	12	0.67	1.38	1.15	0.20	0.76	1.22	n/a
7	6	1.10	1.28	1.21	0.07	n/a	1.21	n/a
8	14	0.83	1.32	1.15	0.12	0.83	1.18	n/a
LCEF05.5	3	0.56	0.98	0.82	n/r	n/r	n/r	n/r

Condition factor for fishes at the majority of sites sampled was similar (seven or eight sites at 1.1 or 1.2). Site 5 was somewhat lower with several of the 14 measured RB having uncharacteristically low weights for their lengths compared to the majority of the RB captured across all sites. Whether this is indicative of their individual life history thus far or a result of field notes or scale error is unclear at this time. Compared to Davis 2009, mean K in 2011 was higher at all sites than at Site LCEF05.5. However, difference in sample size (146 RB in 2011 vs. 3 in 2008) limits our ability to draw meaningful conclusions in this regard.

3.3 FISH HABITAT CONDITIONS

3.3.1 Water Temperature - Water Depth – Water Velocity

Water temperatures during sampling ranged from 9.6 ^{0}C at Site 3 to 16.8 ^{0}C at Site 5. The mean temperature across all sites was 12.8 ^{0}C. This is well within normal preferred range for Rainbow Trout (Raleigh et al. 1984 as cited in McPhail 2007).

Discharge of Cranberry Creek at time of sampling was characterised as *Low*; characterized as riffle-pool morphology with only a small degree of connectivity between pool sections. Water velocities were consequently low (ranging from 0 – 0.27 m/s) and on most site transects, velocities were less than 0.01 m/s. Water depths varied within and between sites. Depths ranging from 0.03 to 0.11 m at inlets and tail-outs to pooled areas while residual pool depths ranged from 0.12 m – 0.95 m between sites. Mean residual pool depths across all sites was 0.57 m for the study area.

3.3.2 Spawning – Rearing – Overwintering Habitat Quality

The majority of sites (5 of 8) had no observable suitable spawning habitat for resident RB. Boulder/cobble substrates dominated these sites with low representation of gravel-size class preferred by RB. The remaining 3 sites (sites 1, 3 and 4) were characterized as having limited spawning habitat.

Rearing habitat for fry and juveniles is characterized by mainly cobble-boulder substrates with an abundance of in-stream (boulders, undercut banks, large woody debris) and overhanging vegetation cover (McPhail 2007). The majority of sites (5 of 8; Sites 2 – 5, and 8)) were characterized as having moderate rearing value, with total cover (substrate, large and small woody debris and overhanging vegetation) also characterized as moderate. Two of the eight sites (Sites 1 and 6) were characterized as having moderate-high rearing value due to good habitat complexity while Site 7 contained low-moderate value due to limited amount of instream and overhanging riparian vegetation.

Ideal overwintering habitat is characterized by an abundance of cover, pool depths > 0.5 m and a steady supply of dissolved oxygen, either by seasonal flow or groundwater influence. The majority of sites (6 of 8; Sites 1 – 5 and 7) had moderate-value overwintering habitat while Site 6 had no potential for overwintering (lack of deep pools) and Site 8 had low overwintering value (shallow residual pool).

4. CONCLUSIONS

The objective of this monitoring program is to determine the potential benefits of minimum flows for Rainbow Trout in lower Cranberry Creek. In particular, the purpose of this study is to provide additional baseline data on how the resident Rainbow Trout population may respond to future changes in minimum flows (BC Hydro Terms of Reference 2010).

The analysis of population dynamics and overall health status of the captured fish in lower Cranberry Creek suggests a relatively healthy (mean K = 1.13) Rainbow Trout population (Barnham and Baxter 1998). However, as the study area is not *closed* (truly fluvial), designation of what type of RB population resides in the study area remains to be definitively determined. The influence of lacustrine individuals (typically larger than fluvial individuals) from upstream of the study area could lead an overestimate of the health of the population within the study area if one mistakenly assumes a closed population. As flow regime decisions will likely consider the ability of the population to adapt to them, we must be careful to delineate the influence upstream populations may have on the lower Cranberry Creek population. It may be necessary to expand the scope of the study to investigate this possibility.

As previously stated in section 3.2 the ability to directly compare results in 2011 to results from Davis 2009 is limited. Different sampling methodologies and higher creek discharge during data collection in 2008 prevent meaningful estimations of population dynamics. However, habitat quality and biological potential was inferred in 2008 as being suitable for Rainbow Trout as was the case in 2011. The low discharge in 2011 and subsequent fracturing of pool habitats likely was the determining factor in how fishes were distributed. Without adequate water depth to allow foraging juveniles and adults to move freely upstream or downstream, they are forced to “hold” wherever they are able as seasonal flows decrease. Instituting a constant minimum flow, sufficient to connect these areas, would likely increase the overall quality of habitat and be of benefit for the resident Rainbow Trout population in lower Cranberry Creek during the months when natural discharge is lowest.

5. RECOMMENDATIONS

The 2012/2013 sampling program should follow methodologies established during the 2011/2012 program to strengthen the baseline data needed for management decisions regarding minimum flow in lower Cranberry Creek. The same sites should be revisited, and the same sampling methodology followed. To more accurately place captured fish into age classes, additional scale samples should be collected and analysed.

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