Jordan River Project Water Use Plan

Jordan River Diversion Reservoir Fish Indexing

Implementation Year 6

Reference: JORMON-4

Study Period: 2010

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Jordan River
Water Use Plan Monitoring Program

Diversion Reservoir
Fish Indexing - 2010

prepared for:

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Contents

Summary

- The Jordan River Water Use Plan included a 6-year monitoring period to assess the biological response to the set limits of reservoir drawdown at Diversion Reservoir. The original study design was to collect 5 years of baseline information on key indicators that were used to assess aquatic productivity in Diversion Reservoir, and then evaluate the effects of a treatment year with a greater drawdown during Year 6. The indicators that were monitored included Secchi depth, nutrients, chlorophyll, rainbow trout catch rates and rainbow trout condition. BC Hydro was unable to provide the conditions necessary for the treatment year in 2010, so a sixth year of baseline data was collected in place of the treatment data.

- MJL Environmental Consultants carried out annual field studies at Diversion Reservoir during the 6-year monitoring period from 2005 to 2010. The purpose of this document is to report on the findings from the 2010 field studies and to then examine the collective data from the 6-year sampling period to detect trends in the key indicators.

- Water temperature and dissolved oxygen profiles in 2010 found that similar to previous years, the reservoir was clinograde with stratification at a depth of approximately 10 m. The effects of stratification were less pronounced in the east basin since most of the east basin is shallower than 10 m. Sampling found that the hypolimnion was anoxic and lethal to fish during the summer stratification period. Also, in 4 of the 6 study years the dissolved oxygen levels in portions of the epilimnion did not meet the BC provincial criteria of 8 mg/l deemed necessary to avoid negative effects on growth and survival. It is difficult to assess how pronounced the negative effects to fish production may have been since it is not known how long these marginal or substandard conditions persisted.

- In 2005 and 2008 the limnological conditions of the reservoir resulted in the trout being „sandwiched‟ between warm, stress-inducing temperatures near the surface and the uninhabitable anoxic layer near the bottom. Under such conditions, the trout are highly vulnerable to BCH drafting operations since the hollow cone valve (HCV) intake at Diversion Reservoir Dam can potentially draw water from the mid-layer of the water column that is most suitable for fish rearing.

- The first order productivity indicators (Secchi depth, total phosphorous, dissolved phosphorous and chlorophyll *a* levels) were monitored over the 6-year period of reduced reservoir drawdown. The results were mixed, with statistically significant decreases observed in Secchi depth and total phosphorous trends while significant increases were observed in dissolved phosphorous and chlorophyll *a* trends. Analysis of pooled data found that some first order parameters showed an increasing trend while others showed a decreasing trend but collectively, they all showed significant changes during the study period. Despite the fact that the fluctuations were at times statistically significant, the levels generally stayed within a range that is typical of oligotrophic lakes on Vancouver Island.

- Rainbow trout sampled from Diversion Reservoir in 2010 had a Fulton‟s Condition Factor value of 1.07, which is within the expected normal range of 1.00 to 1.15 for rainbow trout from lakes on Vancouver Island. The physical condition of the rainbow trout remained remarkably stable during the 6 years of sampling with no significant differences between the 6 years of sampling. Analysis of pooled data found a slightly decreasing trend in condition over the study period.

- The catch rate (catch per unit effort) of rainbow trout in gillnets during 2010 was 26 fish/hr. Even though this was one of the highest catch rates over the 6 years of sampling, ANOVA tests found that the difference was not statistically significant from the previous years of study. However, an alternative assessment using correlation analysis found that the catch

rates showed a significant increasing trend over the sample period, indicating an increasing abundance of rainbow trout during the study period of reduced drawdown magnitude.

- Study results indicate that the rainbow trout population appears to be limited by the limited food and space for the rapidly growing 2 year old fish during their period of rapid growth during the critical summer period in the reservoir. We concluded that the abundance of trout increased over the study period but that the larger population continued to be constrained by limited food and space resources, albeit at a level of greater abundance.

- Despite the lack of a treatment year for comparison, the 6 years of baseline data does allow for the testing of some of the hypotheses that were stated in the Terms of Reference as follows:

H_1: Reduced reservoir drawdown does not increase rainbow trout condition.

H_{1a}: Changes in reservoir first order productivity indicators occur independently of reservoir operation.

H_{1b}: Changes in fish condition occur independently of reservoir first order productivity indicators.

Regarding H_1: The analysis found no significant increases in rainbow trout condition between any of the 6 study years and the analysis of pooled data over the 6-year study period detected only a very slight declining trend in fish condition. Together these analyses indicate that there was no significant increase in rainbow trout condition over the 6-year period of reduced reservoir drawdown. Accept H_1.

Regarding H_{1a}: Since there was no treatment year in the study, the wording of “reservoir operation” in the hypothesis was interpreted as “reduced reservoir drawdown”. The first order productivity indicators (Secchi depth, total phosphorous, dissolved phosphorous and chlorophyll *a* levels) were monitored over the 6-year period of reduced reservoir drawdown. The results were mixed, with statistically significant decreases observed in Secchi depth (inverted) and total phosphorous trends while significant increases were observed in dissolved phosphorous and chlorophyll *a* trends. Analysis of pooled data found that some first order parameters showed an increasing trend while others showed a decreasing trend but collectively, they all showed significant changes during the period of reduced drawdown. Therefore, changes in primary production indicators occurred independently of reservoir operation. Accept H_{1a}.

Regarding H_{1b}: The analysis found no significant increases in rainbow trout condition between any of the years over the 6-year study period. Over the same period, the first order productivity indicator trends were mixed and collectively showed no clear trend. With no clear change in fish condition and no clear trend in first order indicators, a clear association is difficult to evaluate. Therefore H_{1b} cannot be addressed.

- The hypotheses for this study focus on the condition factor of rainbow trout as the critical parameter for evaluating the production of fish in the reservoir. However, study findings suggest that trout abundance may be a better reflection of overall trout production in the reservoir. The trend in fish abundance increased significantly over the 6-year study period, which is interpreted as an increased benefit to fish. The study findings therefore do not support revisiting the recommendations for more flexible operating options.

- Recommendations include developing operational precautions associated with HCV use during the summer. Opportunities to alleviate limitations to trout production in the Diversion Reservoir include lake aeration and nutrient enrichment. Overview concepts are discussed.

1.0 Background

The Jordan River Water Use Plan (WUP) project was initiated by BC Hydro (BCH) in April 2000 and concluded in November 2001. The WUP included a 6-year monitoring period. The WUP recommended an operational change that was hypothesized to elicit biologically significant measurable responses in the resident fish populations in Diversion Reservoir (BC Hydro 2002). Specifically, this operational change included limiting reservoir drawdown flexibility (and ultimately active storage) by imposing the following operational constraints:

- Minimum normal elevation of 376 m: 1 July - 30 September
- Minimum normal elevation of 372 m: 1 October - 30 June

It was hypothesized that the decrease in seasonal and daily reservoir fluctuation and the decrease in pelagic volume would increase both the establishment of an effective littoral zone and mitigate the negative influences that reduce the condition factor of rainbow trout. Condition factor of rainbow trout was assumed to be coincidental with drawing down the reservoir and associated exposure to high temperatures and low oxygen levels during summer months.

In September 2005, MJL Environmental Consultants (MJL) carried out the first year of field studies for the 6-year monitoring period at Diversion Reservoir. The objective was to collect baseline information for key indicators that will be used to assess aquatic productivity in Diversion Reservoir. These indicators include chlorophyll a, phosphorous, temperature and fish condition, which would be monitored for change during a planned treatment year when reservoir levels exceed the WUP operational constraints.

MJL repeated the field studies each September for 4 more years (2006 to 2009) to augment the baseline information collected in 2005. The study design called for the treatment year in the final year of the study in 2010. The treatment year called for a drawdown of Diversion Reservoir beyond the lower limits of the operational constraints of 376 m to investigate the response in aquatic productivity. BC Hydro was unable to provide the conditions necessary for the treatment year in 2010, so a sixth year of baseline data was collected in place of the treatment data.

The purpose of this document is to report on the findings from the 2010 field studies and to examine the collective data from the 6-year sampling period to detect trends in the key productivity indicators.

2.0 Methods

Field studies took place at Diversion Reservoir during September 8 to 10, 2010. The water level of Diversion Reservoir was El. 380.3 m at the start of the field sampling on September 8, 2010, similar to previous sampling periods. (**Table 2.1**).

Table 2.1 Surface elevations at Diversion Reservoir during field sampling periods, 2005-2008.

	Reservoir Water Level During Sampling		Comments
	Max Elevation	**Min Elevation**	
2005	378.1 m	378.1 m	- -
2006	378.3 m	378.3 m	- -
2007	377.1 m	377.0 m	- -
2008	378.0 m	376.2 m	unscheduled drafting event during sampling
2009	380.3 m	379.1 m	heavy rain and inflows
2010	380.3 m	380.1 m	- -

The indicators of aquatic productivity selected for this study are Secchi depth, total phosphorous, dissolved phosphorous, chlorophyll *a*, CPUE for lentic rainbow trout and Fulton"s condition factor for rainbow trout.

2.1 Limnology

Limnology stations, fish sample sites and photo documentation sites were geo-referenced to allow sampling at the same locations in each of the 6 years of the study. A Magellan Pro Marine GPS unit was used to establish UTM coordinates in the field in 2005. The same UTM coordinates were used to establish the sample sites at the same locations each year.

The water quality sampling work plan was based on the methods described in the RISC manual *Ambient Fresh Water and Effluent Sampling Manual* (Cavanagh et al 1997). All sampling in the West Basin of Diversion Reservoir was included in Site 1 and all sampling in the East Basin was included in Site 2. Limnology Station 1 was located in the deepest portion of the West Basin and Limnology Station 2 was located in the deepest portion of the East Basin (**Figure 2.1**).

Figure 2.1 Location of limnology stations at Diversion Reservoir, September, 2005-2010.

A 5 m aluminum skiff equipped with a Lowrance X-16 depth sounder and GPS were used to re-locate the limnology sites used in the previous years, and collect the limnology data. Replicate water chemistry samples were collected at the 2 limnology sites and at the 2 gillnet sites (*see* Biological Sampling). A vertical Beta Sampler was used to collect the water samples from a depth of 1 to 2 m. The chilled water samples were delivered to MB Labs (Victoria) for analysis within 24 hours of collection.

Field limnology data was collected at the same time as the lab water chemistry samples. A YSI Model 85-10 water temperature/dissolved oxygen meter (accuracy: ±0.3 mg/l) with a 30 m probe, was used to record the temperature and dissolved oxygen (DO) profile of the lake at 1 m intervals. The data was recorded on a standard Temp/DO profile chart for later entry into an Excel spreadsheet. A standard limnology Secchi disc was used to obtain Secchi depths and water color information at the 2 limnology sites and the 2 gillnet sites. Water and air temperature, weather conditions, time, date, reservoir level and estimated stream inflows were recorded when the water samples were collected.

2.2 Biological Sampling

A Provincial scientific collection permit was obtained prior to commencement of the fieldwork. The methods for fish sampling described in the RISC manual *Fish Collection Methods and Standards, Version 4.0* (BCMELP-FIU 1997) were used for this study.

Fish sampling locations were chosen in 2005 to target habitats used by each life history stage of trout, including littoral habitat, tributary mouth and instream habitat. The same locations were used for fish sampling in the following 5 years (**Figures 2.2 and 2.3**).

Fish samples were collected using a combination of standard variable-mesh lake gillnets and baited minnow traps. Two 91.5 m long by 2.4 m deep gillnets made up of standard gillnet gangs, one sinking and one floating, were set during the day at each of the gillnet sites. Care was taken to ensure that the sinking gillnets were not deployed in the anoxic hypolimnion.

The minnow traps were baited with salmon roe. One instream minnow trap was deployed in a pool near the mouth of Walker Creek. The 2 additional minnow trap sites (MT 11 and MT 12) that were added in 2006 were sampled again in the following 4 years in an attempt to increase the fry component of the fish sample.

The Jordan River Water Use Plan Monitoring Program Terms of Reference (Attachment B) for Diversion Reservoir suggest that fish samples should be measured using standard length (Equation 1). Following discussions with BCH personnel (Dodd pers. comm.) it was agreed that fork length was preferable, so that the data could be compared to regional data or historical data from Diversion Reservoir. Fish collected that were larger than fry size were weighed to the nearest gram using an Ohaus Model LS 2000 portable electronic balance, measured for fork length to the nearest millimeter on a fish measuring board, inspected for gonad maturation, and photographed. Fry were weighed to the nearest 0.1 gram using an Ohaus SP-401 portable electronic balance. Fish scales were collected from each sampled fish, except for the fry caught in the minnow traps, and otoliths were collected from approximately 1 in every 5 fish that were aged from scale samples. A CCD ST-30 10X-60X stereo microscope was used for scale and otolith analysis. Scales and otoliths were retained and archived after analysis.

2.3 Analysis

Analysis of variance (ANOVA) and correlation analyses were done using SPSS software.
Tabular calculations and graphic plots were done using MS Excel software.

2.4 Photodocumentation

Digital photographs of sample sites and sampled fish were collected each year. Images were archived and details of the photo documentation were summarized on a standard data collection form (**Appendix 5**).

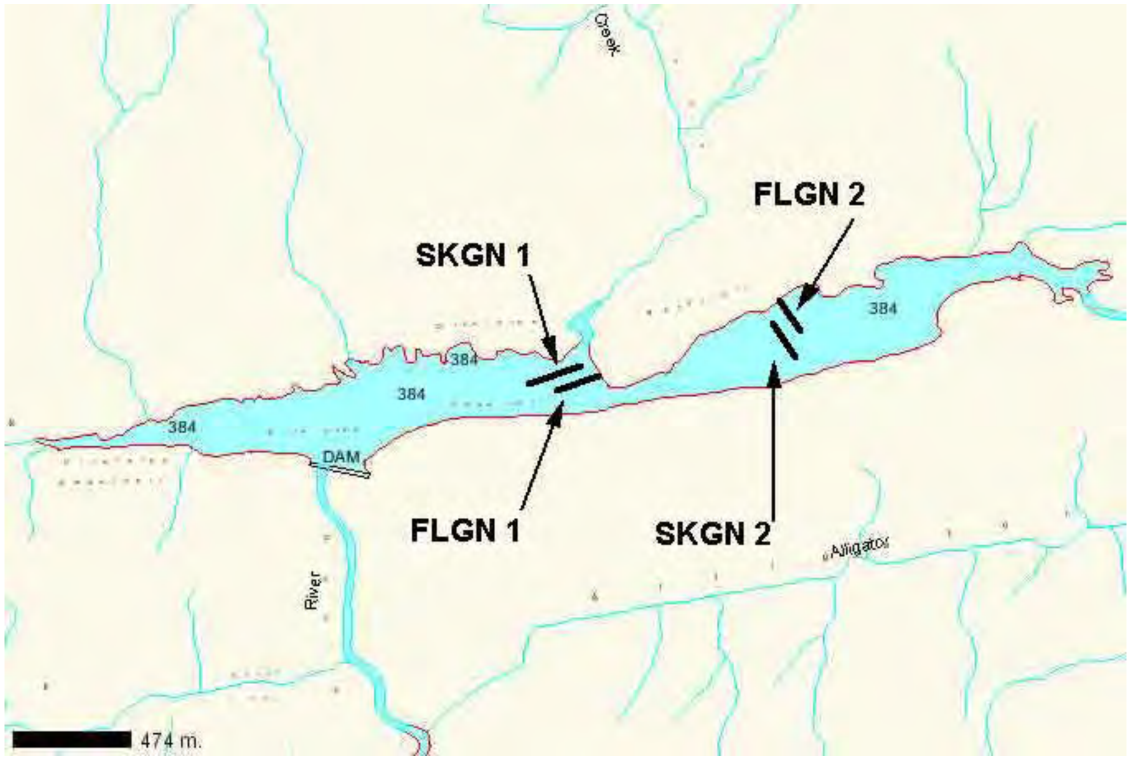

Figure 2.2 Location of floating (FLGN) and sinking (SKGN) gillnet sites at Diversion Reservoir, September 2005 to 2010.

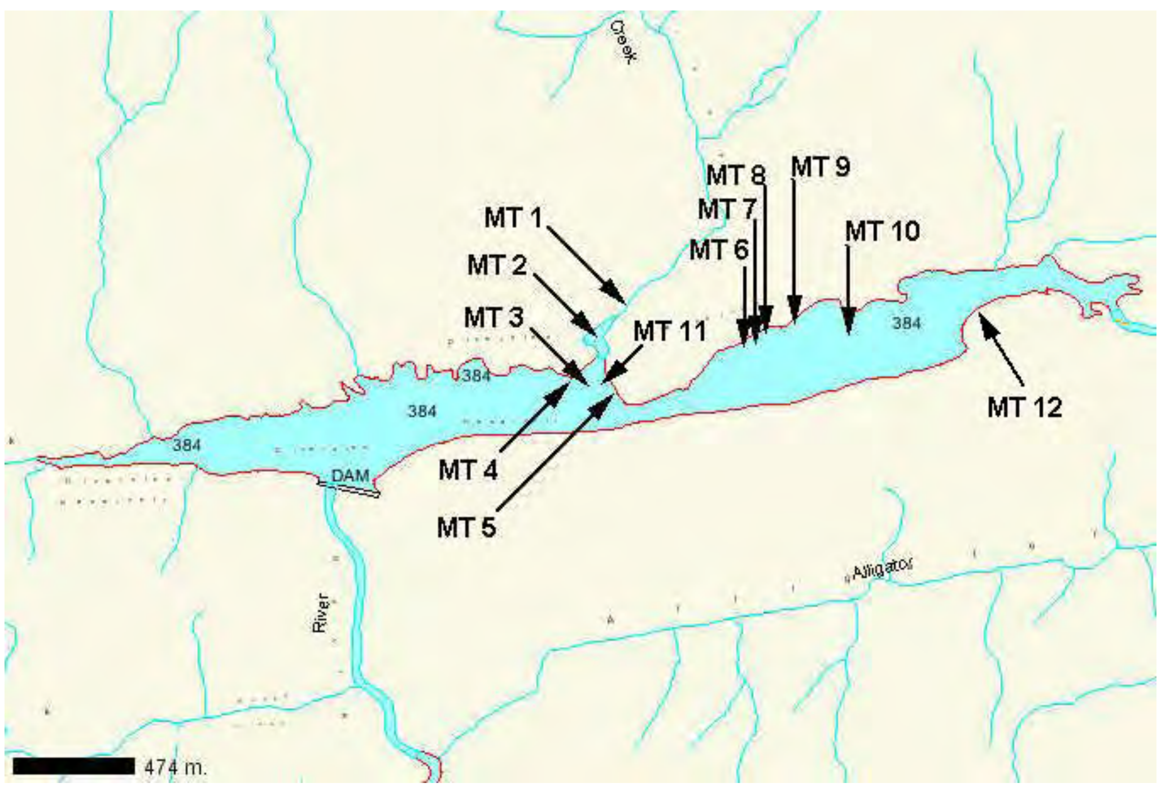

Figure 2.3 Location of baited minnow trap sites at Diversion Reservoir, September 2005 to 2010.

3.0 Results and Discussion

3.1 Limnology

3.1.1 Reservoir Levels

Reservoir operations and therefore water levels varied between years according to factors such as operational requirements and weather. The surface elevation levels for Diversion Reservoir in 2005 to 2010 are summarized in **Figure 3.1**. The reservoir has generally been operated within the operational limits of the WUP during the 6 study years since 2005, with the exception of September 16-19, 2008 when reservoir levels dropped to El. 375.8 m during a brief drafting event.

Efforts were made during all of the study years to conduct field sampling between El 377 m and 378 m to maintain as consistent sampling conditions as possible. However, operational constraints have not always allowed these target levels to be available during the sampling window and the actual range of water levels on the day of limnology sampling over 6 years has ranged from El 376.2 m to 380.3 m. During field sampling in 2010, the surface elevation of Diversion Reservoir was relatively stable between El. 380.1 and 380.3 m.

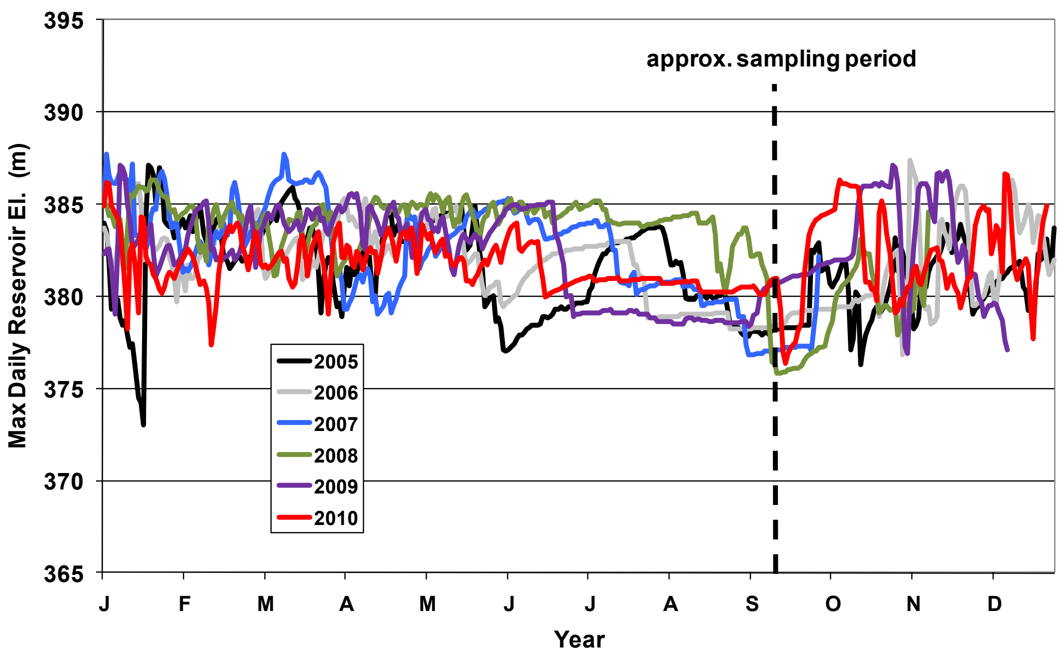

Figure 3.1 Surface elevations of Diversion Reservoir in 2005 to 2010 (Source: BC Hydro).

3.1.2 Water Temperature and Dissolved Oxygen

The reservoir was thermally stratified at the time of sampling in 2010, although the thermocline was only evident in the deeper West Basin. The thermocline was at a depth of 10 m, which was shallower than any of the previous 5 years of sampling (**Table 3.1**). Water temperatures in the deeper West Basin decreased from a maximum of 16.6^{o} C at the surface to a minimum of 9.7^{o} C at a depth of 23 m. The thermal stratification in the shallower East Basin was less pronounced, since most of this basin is shallower than the 10 m thermocline **(Figures 3.2 and 3.3)**.

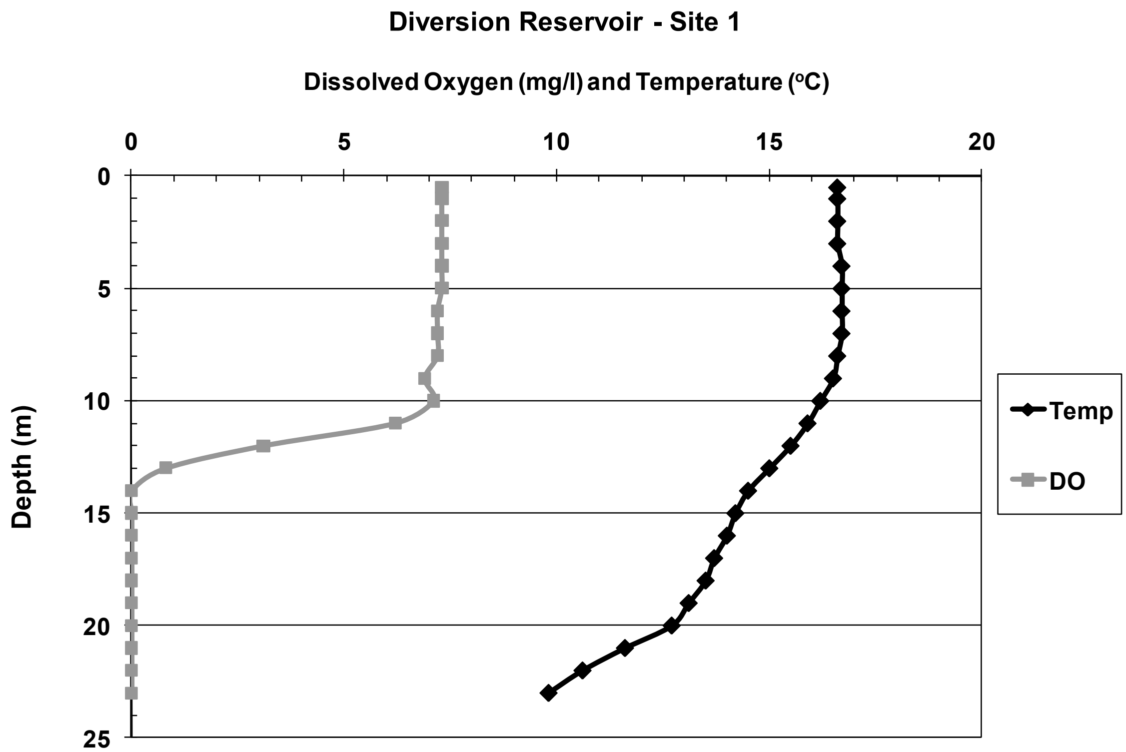

Figure 3.2 Water temperature and dissolved oxygen profiles at Limnology Station 1 (West Basin), Diversion Reservoir on September 10, 2010.

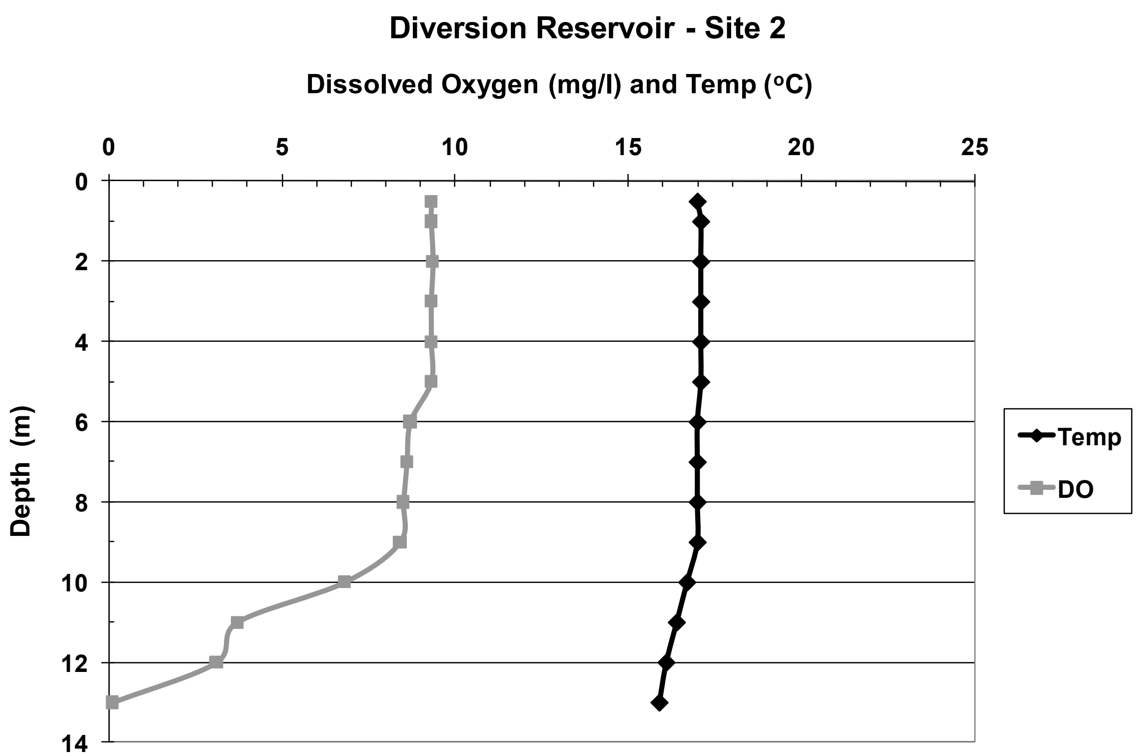

Figure 3.3 Water temperature and dissolved oxygen profiles at Limnology Station 2 (East Basin), Diversion Reservoir on September 9, 2010.

Table 3.1 Summary of thermocline depth and the depth of the upper extent of the hypolimnion in the West Basin at Diversion Reservoir, 2005 to 2010.

Year	Thermocline Depth (m)
2005	15
2006	12
2007	16
2008	16
2009	20
2010	10

The optimum water temperature for rainbow trout growth is approximately 12 ^{o}C. Higher water temperatures can be tolerated but trout avoid temperatures higher than 19 ^{o}C and cannot survive water temperatures of 25 ^{o}C (Bell 1973). The provincial water quality guidelines for BC recommend that to avoid negative effects on rainbow trout growth and survival, the mean weekly maximum water temperature should not exceed 18 ^{o}C and the maximum daily temperature should not exceed 19 ^{o}C (Oliver and Fidler 2001).

In 2010 the upper 10 m of the epilimnion ranged from 15 to 17 ^{o}C, suggesting that surface water temperatures were suitable for trout rearing. However, sampling in previous years found that this is not always the case. In 2005 the water temperature of the upper 12 m of the water column ranged from 18 to 19 ^{o}C and in 2008 the water temperatures of the upper 1 m ranged from 18 to 20 ^{o}C. These temperatures marginally exceed the provincial standards but it is not clear if these conditions persisted long enough to exert negative influences on growth and survival of the trout. In 2008 for example, the trout could take refuge from the warm surface layer by retreating to the deeper, cooler water, although such a strategy has a cost of spending less time foraging in the productive surface layers of the reservoir. This avoidance behaviour further reduces the space and resources available to the trout, even if only temporarily. As the US Environmental Protection Agency has cautioned; if space or food resources are limited, avoidance could affect fish almost as seriously as direct mortality (BCMOE 2011).

Thermal stratification of lakes during the summer is not unusual and is typical of many lakes and reservoirs on Vancouver Island. Lakes deeper than approximately 10 m and with limited inflows and circulation are often candidates for summer stratification on Vancouver Island. Once stratified, oxidative processes occur in the hypolimnion, with an intensity that is proportional to the amount of organic matter in the hypolimnion. Oxygen is consumed during this process and the result can be an anaerobic hypolimnion that is lethal to fish. In Diversion Reservoir the major consumption of oxygen from this layer is probably associated with bacterial decomposition of organic matter such as the numerous inundated trees and stumps that remained when the reservoir was created.

DO sampling found that Diversion Reservoir was clinograde at the time of sampling in 2010. The deeper West Basin was found to have an anoxic hypolimnion as it has consistently displayed in each year of study since 2005. In 2010 the DO levels in the epilimnion ranged from 7.3 to 6.2 mg/l but at a depth of 10 m the DO levels rapidly declined to 0 mg/l. The hypolimnion between the depth of 11 m and 23 m was anoxic and uninhabitable by fish.

The DO levels in the East Basin exceeded 8 mg/l in the upper 9 m of the water column but showed a marked decline below the depth of 10 m, with a thin anoxic layer near the bottom in the deepest portion of the reservoir. Since much of the East Basin is shallower than 10 m, the deep anoxic layer was not as pronounced at this end of the reservoir.

Rainbow trout can survive DO levels as low as 3 or 4 mg/l for brief periods (Matthews and Berg 1996), but the BC provincial criteria for ambient water quality stipulate that longer term DO levels should be 8 mg/l or more to avoid negative effects on growth rates (BCMOE 2011). Therefore, in 2010 the epilimnion of the West Basin had DO levels that were marginal or low enough have a negative influence on trout growth, while the hypolimnion was anoxic and lethal to trout. Trout in the East basin had suitable conditions in the upper 9 m of the water column but were also not able to inhabit the anoxic waters that were deeper than 10 m.

DO levels were also below provincial standards in 4 of the 6 study years (**Table 3.2**). Diversion Reservoir was clinograde in all of the 6 years, with an anoxic hypolimnion established at depths ranging from 5 m to 15 m, depending on the year. Therefore sampling in 4 of the 6 sample years found that the DO levels in the hypolimnion were anoxic and the DO levels in portions of the epilimnion did not meet the BC provincial criteria of 8 mg/l that is necessary to avoid negative effects on growth and survival. It is not clear how long these conditions persisted and therefore difficult to clearly understand the magnitude of the negative effects on trout growth.

Table 3.2. Portion of the epilimnion with suitable DO levels for aquatic production and interface depth of the anoxic hypolimnion, 2005 to 2010.

Year	Meters of Water Column in Epilimnion with DO Levels >8 mg/l	Upper Interface of Anoxic Hypolimnion
2005	0 m	10 m
2006	0 m	11 m
2007	0 m	12 m
2008	7 m	15 m
2009	0 m	5 m
2010	10 m [a.]	10 m

a. East Basin only.

In 2005 and 2008 similar stratified conditions resulted in the trout being „sandwiched‟ between warm, stress-inducing temperatures of 18 to 20 ^{o}C near the surface and the uninhabitable anoxic layer near the bottom. Under such conditions, the trout are highly vulnerable to BCH drafting operations since the hollow cone valve (HCV) intake at Diversion Reservoir Dam can draw water from the layer of the water column that is inhabited by the fish. A drawdown using the HCV in this situation could reduce the layer of suitable trout rearing water and result in significant impacts to the trout population that is confined to this layer (**Figure 3.4**).

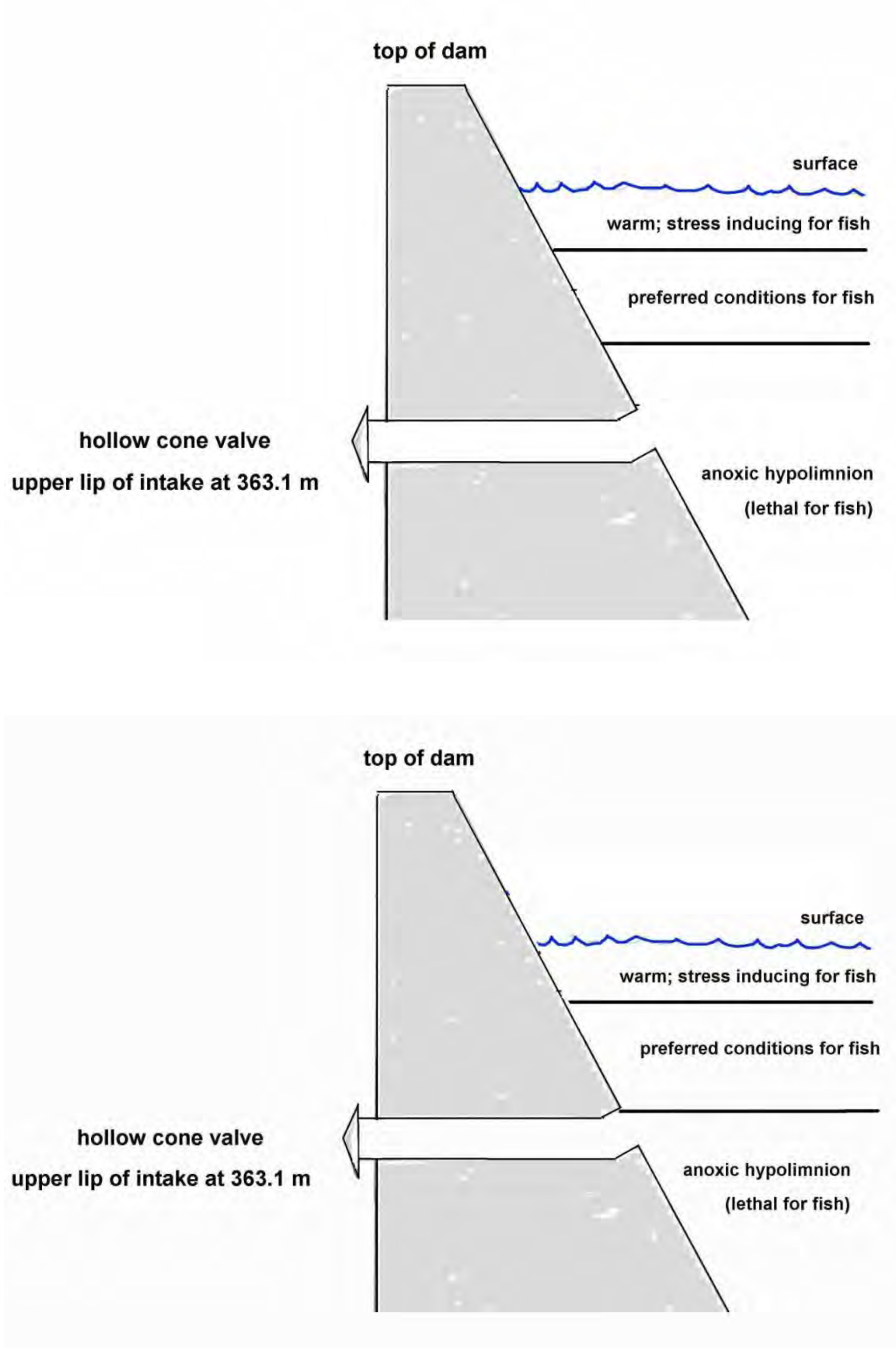

Figure 3.4 Section view of Diversion Reservoir Dam showing conceptual conditions before and after the unscheduled drafting event, Sept. 12-13, 2008. The top drawing shows conditions that were not documented, but likely present prior to drafting on Sept. 12. The bottom drawing shows that drafting had reduced the hypolimnion and was at the threshold of extracting water from the preferred layer for fish when drafting activities were terminated.

3.1.3 Secchi Depth and Water Color

Secchi depths and water color at the 2 limnology stations and the 2 gillnet sites are summarized in **Table 3.3**. In 2006, 2 additional sites (Gillnet Sites 1 and 2) were added to the 2005 sampling protocol and replicate samples were taken at each of the 4 sites to allow for more robust statistical comparisons between years.

Table 3.3 Secchi depths and water color at Diversion Reservoir September 2005 to 2010.

	2005	2006	2007	2008	2009	2010
Sample date	Sept 8	Sept 14	Sept 16	Sept 13	Sept 9	Sept 10
Mean Secchi depth (m)	3.3	3.5	3.4	3.0	3.1	4.5
SD	0.4	0.2	0.2	0.1	0.2	0
N	2	8	8	8	8	8
Color	brown	brown	brown	brown	brown	brown

Secchi depth remained between 3.0 m and 3.5 m during the first 5 years of study then increased to 4.5 m in the sixth year. An analysis of variance (ANOVA) and Scheffe tests of the study data over 6 years found that the Secchi depth of 4.5 m in 2010 was significantly higher than all the previous study years (p=0.00) (**Figure 3.5**). Correlation analysis of the pooled data over the 6 year period found that there was an increasing trend over the 6 year study (**Figure 3.6).**

Secchi depth is often inversely related to algal biomass which, in this case might suggest that there was a significant decrease in primary production during the study period. A review of historical data found that a 2002 study (Stewart et al., 2002) also documented a Secchi depth of 4.5 m in Diversion Reservoir, indicating that similar fluctuations occurred prior to the study and may not be attributable to periods of restricted drawdown alone.

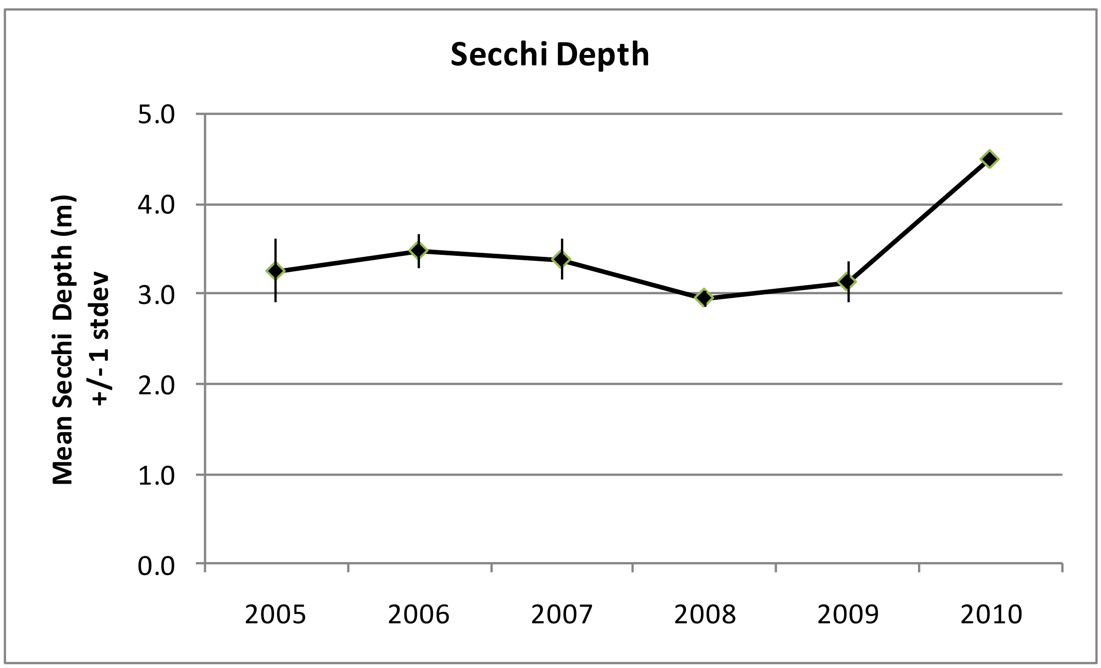

Figure 3.5 Mean annual Secchi depths at Diversion Reservoir, 2005 to 2010.

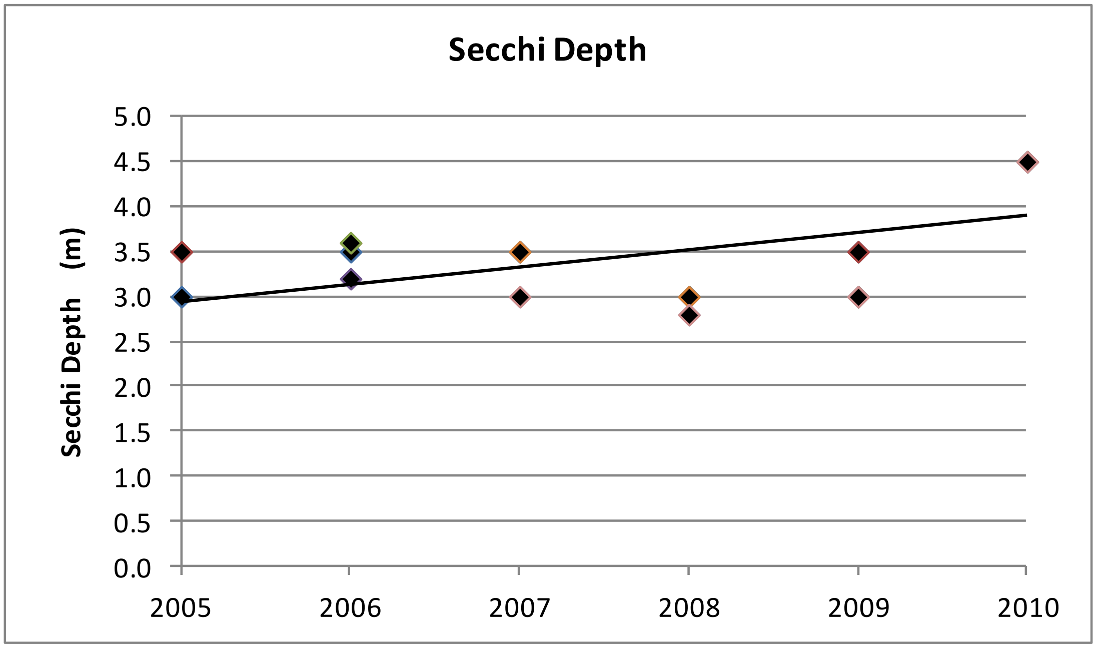

Figure 3.6. Correlation trend for pooled Secchi depths from 2005 to 2010.

3.1.4 Nutrients

Total phosphorous and dissolved phosphorous levels were collected at the 2 limnology stations and the 2 gillnet sites for the 6 study. Two replicate samples were taken at each of the 4 sites so that there were a total of 8 samples for each parameter (**Appendix 2**).

Total Phosphorous

The mean total phosphorous level in 2010 was 8.5 ug/l; near mid-range for the levels collected since 2005 (**Table 3.4 and Figure 3.7)**. ANOVA and Scheffe tests between the sampled years found that there were significant differences in total phosphorous levels during the 6 years of sampling with total phosphorous levels in 2009 being significantly lower than 2005 (p=0.00) and 2010 (p=0.019). Correlation analysis of the pooled data also found that there was a decreasing trend in total phosphorous levels over the study period (**Figure 3.7).**

Table 3.4 Mean total phosphorous levels at 4 sites in Diversion Reservoir, 2005 to 2010.

	2005	2006	2007	2008	2009	2010
Sample date	Sept 8	Sept 14	Sept 16	Sept 13	Sept 9	Sept 10
Mean total phosphorous (µg/l)	9.4	6.5	7.3	10.4	3.2	8.5
SD	2.3	2.6	1.8	4.3	2.4	4.3
Range	6.1 - 12.7	3.7 - 10.6	5.8 – 10.3	1.1 – 16.0	0.5 – 7.7	4.9 – 16.7
n	8	8	8	8	8	8

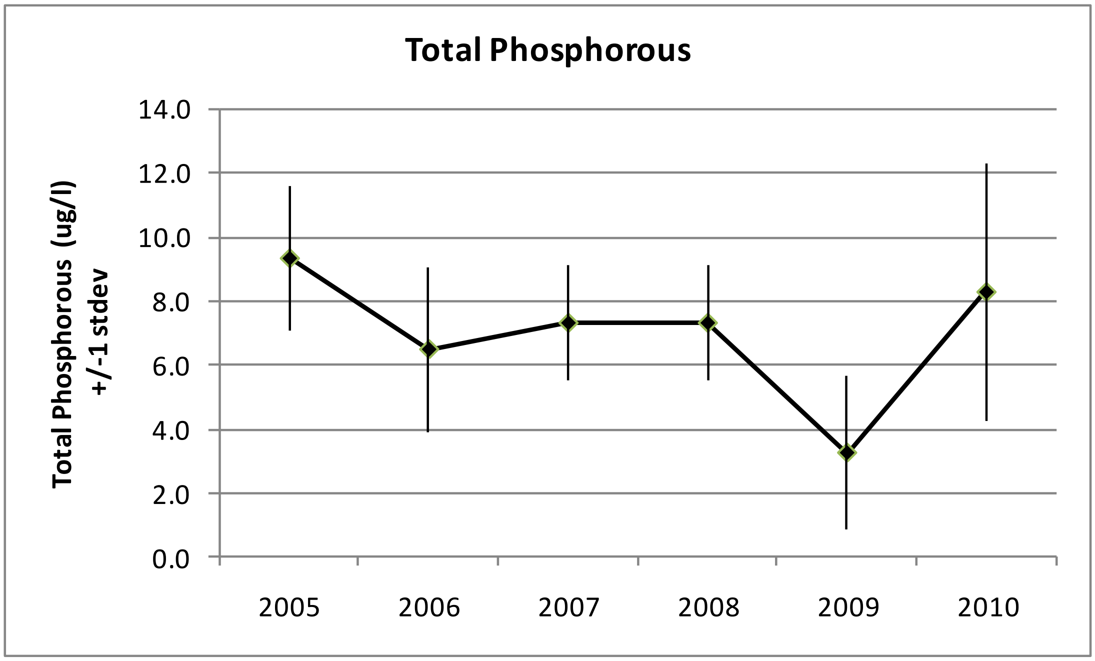

Figure 3.7 Mean total phosphorous levels at Diversion Reservoir, 2005 to 2010.

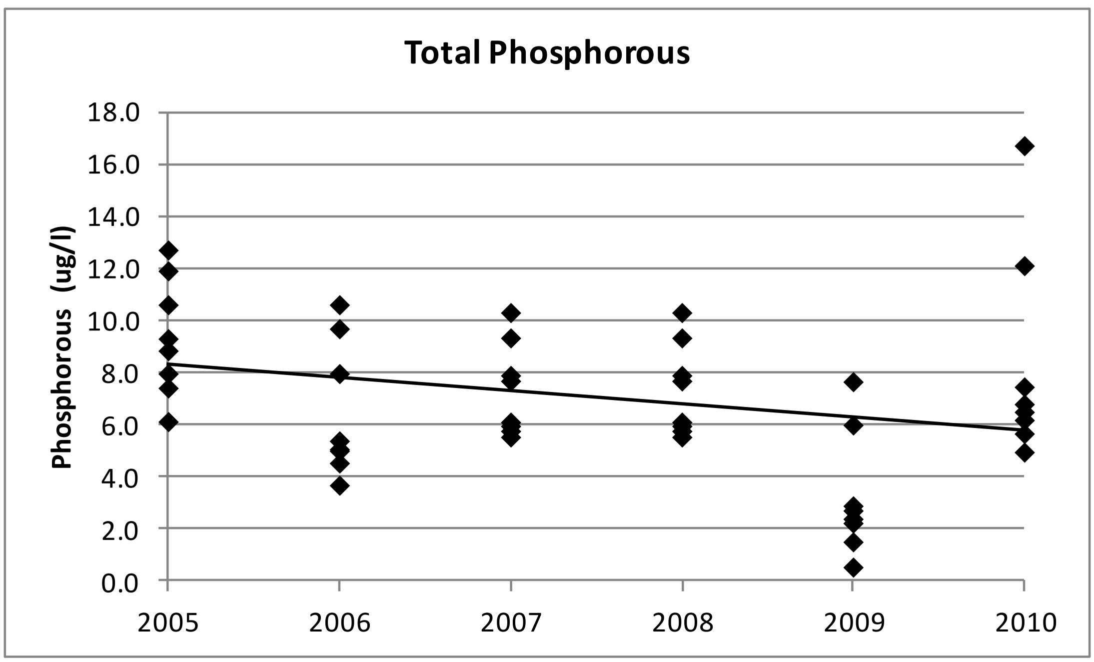

Figure 3.8. Correlation trend for pooled total phosphorous levels from 2005 to 2010.

Phosphorous is typically the least abundant nutrient and is commonly the first nutrient to limit biological production (Wetzel 2001). Even though there were fluctuations including significant decreases in total phosphorous over the 6 study years, all years fall in the range of 0.003 mg/l to 0.017 that is typical of oligo-mesotrophic reservoirs such as Diversion Reservoir (Wetzel, 2001).

Total Dissolved Phosphorous

In 2010 the mean total dissolved phosphorous (TDP) was 6.1 ug/l which is approximately mid-range in the 6 years of sample data (**Table 3.5 and Figure 3.9)**. ANOVA and Scheffe tests found that TDP levels in 2009 were significantly higher than 2010 (p=0.007). Correlation analysis of the pooled data also found an increasing trend over the 6 year study period (**Figure 3.10**)

The reason for the higher TDP levels in 2009 is not clear, other than TDP is typically taken-up rapidly during the process of primary production, and levels can fluctuate rapidly depending on an increased input into the system as might be due to elevated inflows and nutrients. Such conditions did occur during a heavy rain inflow event during the sampling period in 2009.

Table 3.5 Mean dissolved phosphorous levels from 4 sites in Diversion Reservoir, 2005 to 2010.

	2005	**2006**	**2007**	**2008**	**2009**	**2010**
Sample date	Sept 8	Sept 14	Sept 16	Sept 13	Sept 9	Sept 10
Mean dissolved phosphorous (µg/l)	6.4	2.4	5.9	8.4	8.8	6.1
SD	2.3	1.0	1.1	2.8	0.65	1.59
Range	4.7 - 11.2	1.2 - 4.1	3.9 - 7.4	6.2 – 14.5	7.6 – 9.8	4.4 – 8.3
n	8	8	8	8	8	8

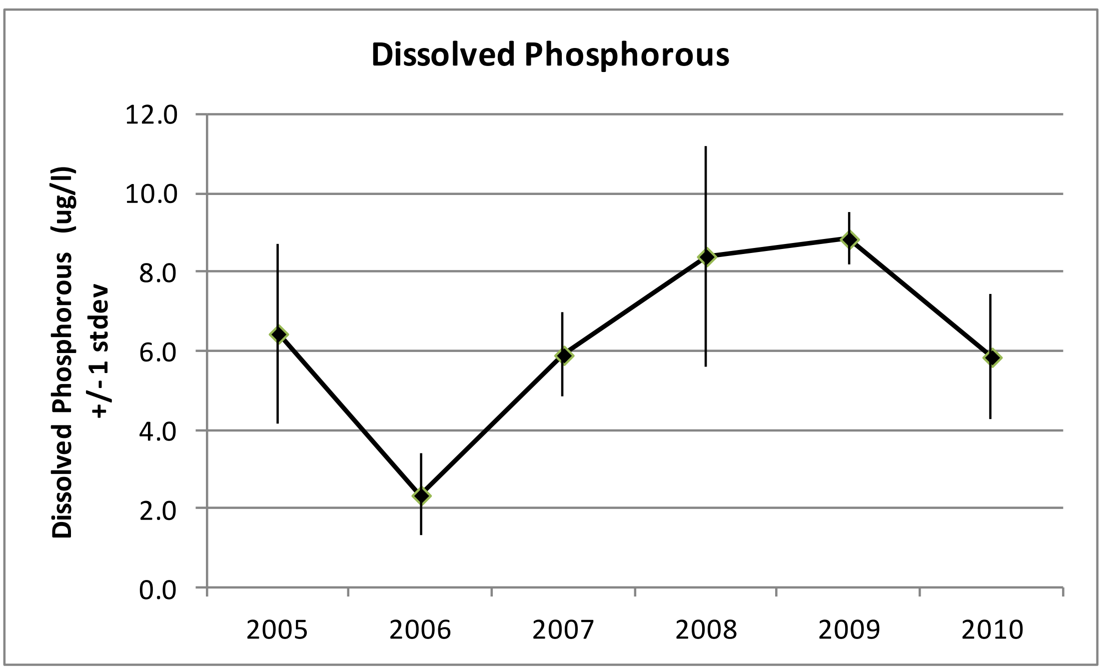

Figure 3.9 Mean dissolved phosphorous levels at Diversion Reservoir, 2005 to 2010.

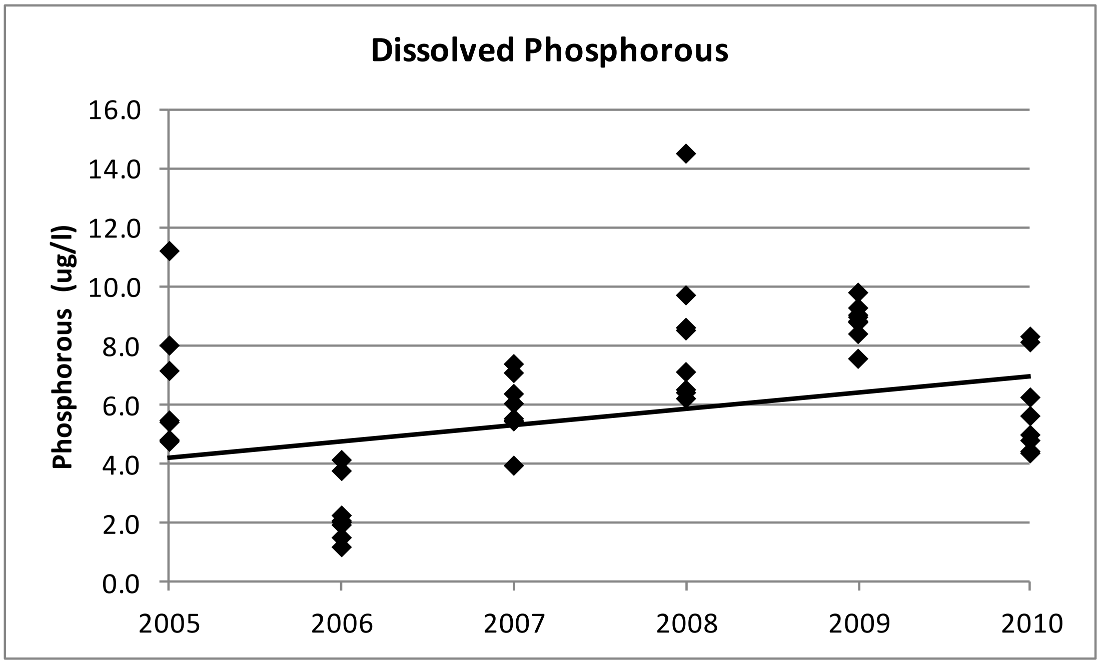

Figure 3.10. Correlation trend for pooled dissolved phosphorous levels from 2005 to 2010.

3.1.5 Phytoplankton

Chlorophyll *a* levels over the 6 year study period are summarized in **Table 3.6 and Figure 3.11**. Two replicate samples were taken at each of the 4 sites so that there were a total of 8 samples (**Appendix 3**). ANOVA and Scheffe testing found that there was a significant increase in the observed chlorophyll *a* levels among years, with 2009 (11.7 mg/m^3) being significantly higher than 2010 (3.1 mg/m^3)(p=0.00). Despite the drop in chlorophyll levels in the 2010 sample, correlation analysis of the pooled data found a generally increasing trend over the 6 year study period (**Figure 3.12**), similar

Table 3.6 Mean chlorophyll *a* levels in Diversion Reservoir in September 2005 to 2010.

	2005	2006	2007	2008	2009	2010
Sample date	Sept 8	Sept 14	Sept 16	Sept 13	Sept 9	Sept 10
Mean chlorophyll *a* (mg/m^3)	2.3	3.0	2.1	12.8	11.7	3.1
SD	0.8	0.6	0.7	3.47	4.5	0.59
Range	1.4 - 3.1	2.3 - 3.9	1.1 - 3.0	4.7 – 15.5	6.3 – 17.8	2.4 – 3.9
n	8	8	8	8	8	8

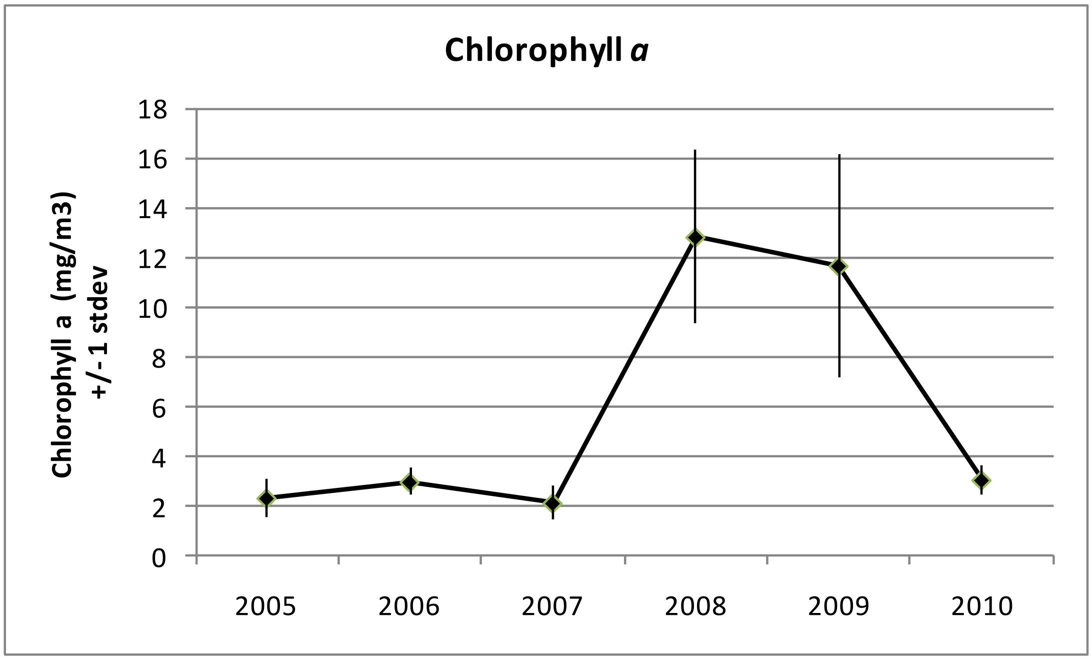

Figure 3.11 Mean chlorophyll *a* levels at Diversion Reservoir, 2005 to 2010.

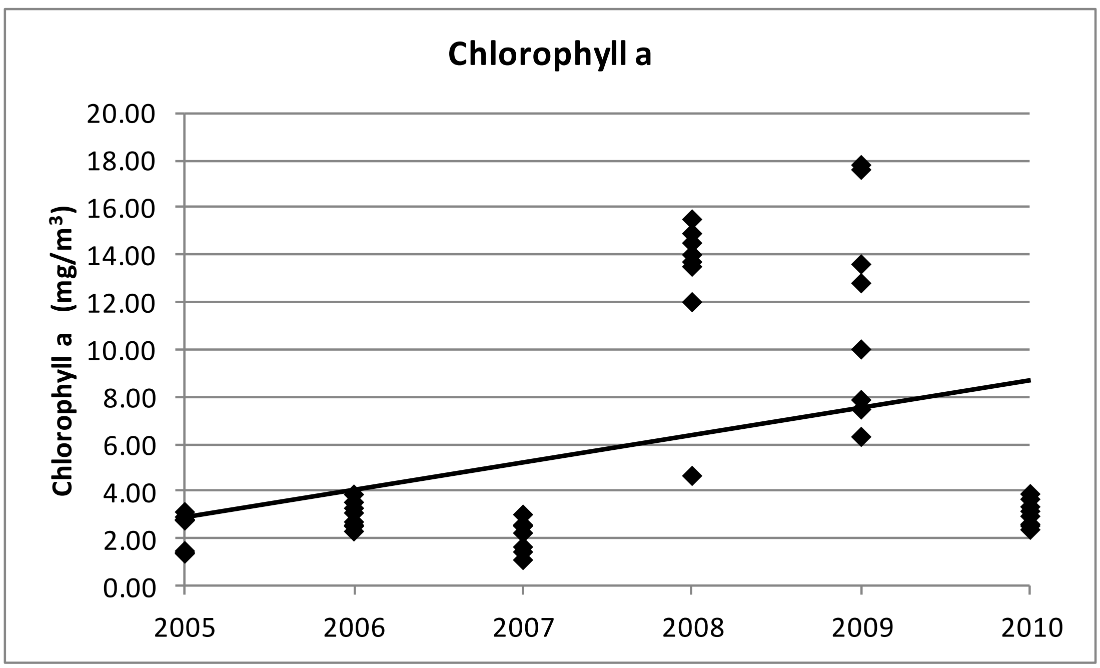

Figure 3.12. Correlation trend for pooled chlorophyll *a* levels from 2005 to 2010.

Chlorophyll biomass and production have been shown to respond to phosphorous loading as described in numerous studies by Wetzel (2001). The observed increasing trends in TDP and chlorophyll *a* in Diversion Reservoir suggest that there could be an association between the 2 parameters over the 6 study years. The analysis of seasonal phytoplankton growth characteristics and abundance can sometimes be difficult because of the array of environmental and physiological factors involved. Some important factors regulating phytoplankton growth and succession are (Wetzel 2001):

- Light and temperature
- Inorganic nutrient factors
- Organic nutrient factors and their interactions with inorganic nutrient availability
- Biological factors of competition for resources and predation
- Buoyancy regulation of the phytoplankton so as to stay in the photic zone

The significant drop in chlorophyll *a* levels in 2010 might be explained by related contributing factors such as temporal variations in the peak levels that could have been missed during sampling or by variations in reservoir management during BCH operations. For example, BCH operations can influence water temperatures when reservoir drawdowns either spill warmer water from the surface or extract cooler water through the deeper HCV.

3.2 Fish

Numerous trout in the gillnet sample showed indications of hybridization. These fish exhibited a continuum of identification traits between rainbow trout and cutthroat trout, with no clearly defined threshold between the 2 species and the hybrids. In many cases these traits were weak, such as a rainbow trout with a faint orange slash on the throat. Hybridization has been noted in historical studies at Diversion Reservoir (Stewart et al. 2002), where such fish were identified as a distinct hybrid population that were analyzed separately from the rainbow or cutthroat trout. We did not follow this approach for the following reasons:

- The genetic integrity of the native cutthroat trout population has been compromised by hatchery stocking, making it difficult to show that a pure rainbow or cutthroat population remains. Even if great care is taken to classify fish according to their phenotype, the actual genotypes may not correspond to such groupings. It is possible that no pure cutthroat or rainbow trout remain in Diversion Reservoir.
- Accurate and consistent species identification is difficult in the hazy continuum between rainbow, hybrid and cutthroat trout.
- Inclusion of a third group of fish (hybrids) would split the fish samples into smaller groups and make for less robust statistical analysis.
- Adult trout and parr were speciated according to their most dominate identification traits. Handled in a consistent manner, this allowed for larger sample sizes and more robust analyses.

3.2.1 Netting and Trapping

Gear effort, catch and catch per unit effort (CPUE) for the gillnetting and minnow trapping are summarized in **Table 3.7**. The individual fish data is included in **Appendix 4**. A total of 46 fish were sampled in 2010, 43 from Diversion Reservoir and 3 juvenile trout from Walker Creek. One of the juveniles from Walker Creek was too small to accurately speciate, so it was included in the rainbow trout sample because it was small (suggesting late emergence) and because numerical abundance suggests that their parents were more likely to be rainbow trout. Thirty-six (84%) rainbow trout and 7 (16%) cutthroat trout were sampled from the reservoir using gillnets and minnow-traps. Thirty-five fish that appeared to be in healthy condition after sampling were released live at the point of capture (**Table 3.8**).

Table 3.7 Summary of fishing effort and catch at Diversion Reservoir September 8 - 9, 2010.

Date of Deployment	Gear Type	Effort (hours)	Catch	CPUE
Sept. 9, 2010	FLGN 1	0.1	2 CT, 1 RB	30.0 fish/hr
Sept. 9, 2010	SKGN 1	0.4	3 CT, 14 RB	42.5 fish/hr
Sept. 9, 2010	FLGN 2	0.2	2 CT, 10 RB	60.0 fish/hr
Sept. 9, 2010	SKGN 2	0.2	2 RB	10.0 fish/hr
Sept. 8, 2010	MT 1	16.8	1 CT, 2 RB	0.18 fish/hr
Sept. 8, 2010	MT 2	16.5	0	0 fish/hr
Sept. 8, 2010	MT 3	16.3	0	0 fish/hr
Sept. 8, 2010	MT 4	15.8	2 RB	0.13 fish/hr
Sept. 8, 2010	MT 5	16.8	3 RB	0.18 fish/hr
Sept. 8, 2010	MT 6	20.7	3 RB	0.15 fish/hr
Sept. 8, 2010	MT 7	20.6	0	0 fish/hr
Sept. 8, 2010	MT 8	20.6	1 RB	0.05 fish/hr
Sept. 8, 2010	MT 9	20.6	0	0 fish/hr
Sept. 8, 2010	MT 10	20.6	0	0 fish/hr
Sept. 8, 2010	MT 11	20.6	0	0 fish/hr
Sept. 8, 2010	MT 12	20.6	0	0 fish/hr

FLGN = floating gillnet, SKGN = sinking gillnet, MT = minnow trap

Table 3.8 Fate of fish sampled at Diversion Reservoir September 8 - 9, 2010.

Species	Killed	Released	Total
Rainbow trout	10	28	38
Cutthroat trout	1	7	8
Total	**11**	**35**	**46**

3.2.2 Catch Per Unit Effort

CPUE is often used as an indicator of fish abundance. We compared the combined mean CPUE for rainbow trout in the 4 variable-mesh gillnet sets (2 floating gillnets, 2 sinking gillnets) made each year to establish trends in fish abundance over the study period. The CPUE data for rainbow trout sampled using gillnets in 2005 to 2010 are summarized in **Table 3.9**, **Figure 3.13** and **Appendix 6**.

Table 3.9 Mean CPUE values for rainbow trout (all nets combined) with ANOVA and Scheffe test results for differences among years in Diversion Reservoir, 2005 to 2010.

Year	n	Mean CPUE (Fish/hr)	SD	ANOVA Test (Scheffe) Results for Differences Between Years
2005	4	6.50	2.29	Not significant
2006	4	6.95	1.87	Not significant
2007	4	18.55	4.99	Not significant
2008	4	26.75	15.40	Not significant
2009	4	21.00	7.57	Not significant
2010	4	26.25	19.74	Not significant
Total	24	17.67	12.83	Not significant

ANOVA: F=2.725, df between = 5, df within = 18 significance = .053

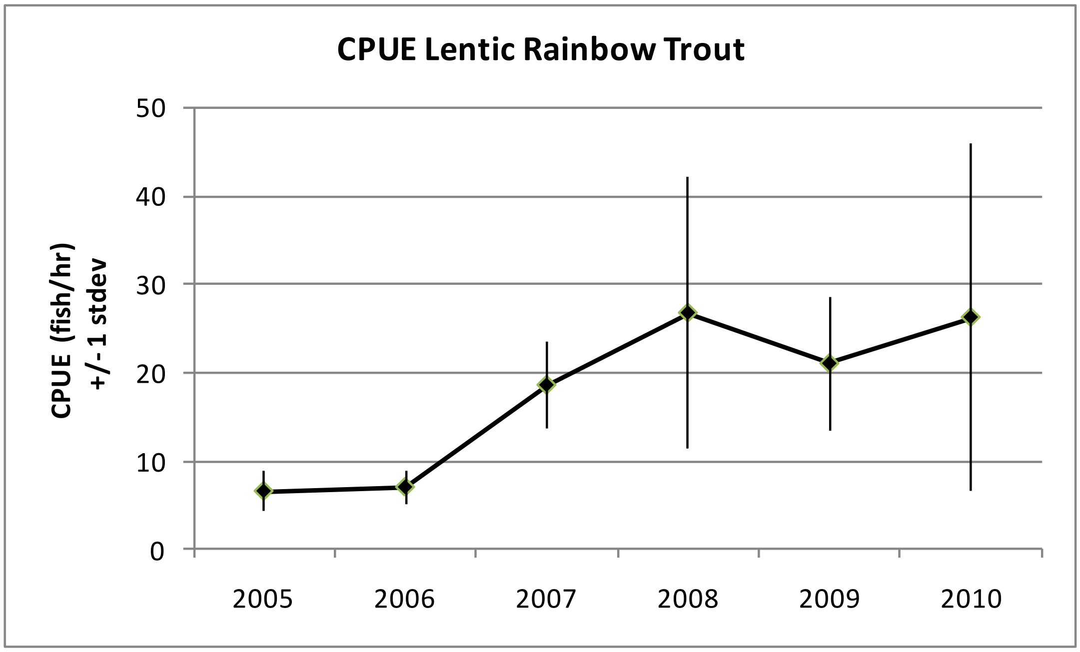

Figure 3.13 Mean catch per unit effort (CPUE) of floating and sinking gillnets combined, for lentic rainbow trout in Diversion Reservoir, 2005 to 2010.

The CPUE for rainbow trout increased from 6.5 fish/hr in 2005 to 26.25 fish/hr in 2010. Even though ANOVA and Scheffe tests found that the observed increase in catch rate between each year was not statistically significant (p=0.53), correlation analysis of the pooled data over the entire study period found that the overall increase in CPUE was statistically significant (p=0.003, Pearson"s R) despite considerable variance in the 2008, 2009 and 2010 samples. The correlation analysis therefore indicates a significant increase in the abundance of rainbow trout during the 6 year study period with reduced reservoir drawdown (**Figure 3.14**).

Comparisons of our baseline fish data with historical data from Diversion Reservoir were confined primarily to rainbow trout because the sample sizes for historical cutthroat trout samples were either null or too small for meaningful comparisons. Historical gillnet sampling data showed a CPUE of 10.4 fish/hr in 1994 (Griffith 1996) and a CPUE of 3.8 fish/hr in 2002 (Stewart et al., 2002). These results are similar to the early years of this study period but are less than half of the latter years of our study period, which is consistent with the increasing trend that was indicated by the correlation analysis.

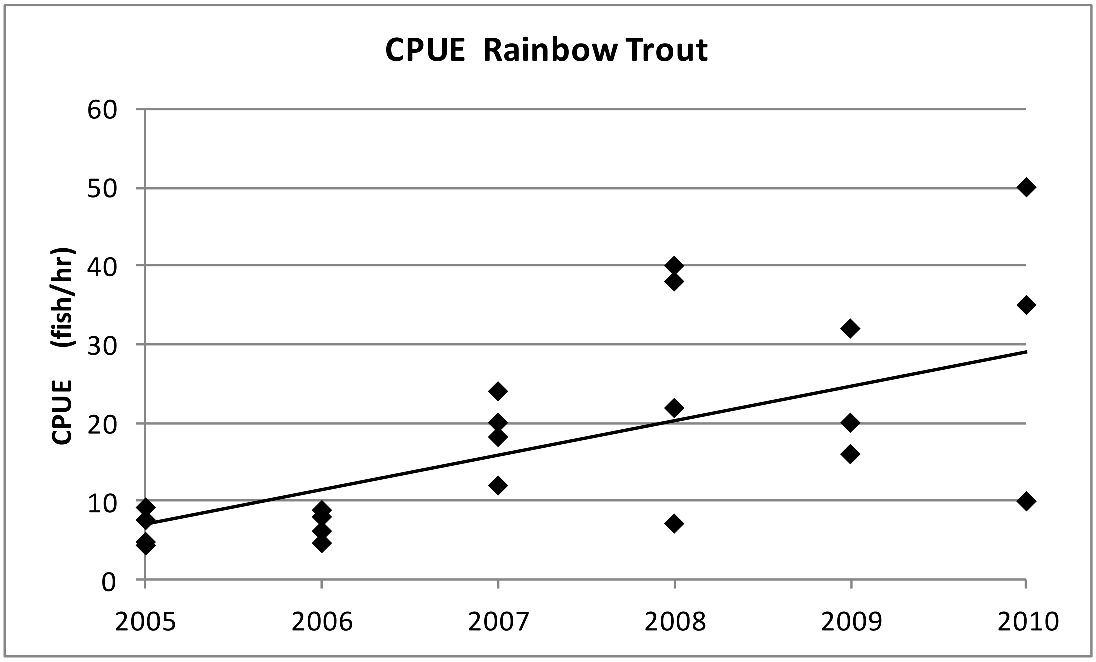

Figure 3.14 Correlation trend for pooled rainbow trout CPUE in gillnets from 2005 to 2010.

3.2.3 Length Frequency Distribution

The length frequency distributions of rainbow and cutthroat trout sampled in Diversion Reservoir and Walker Creek in 2010 are summarized in **Figure 3.15**.

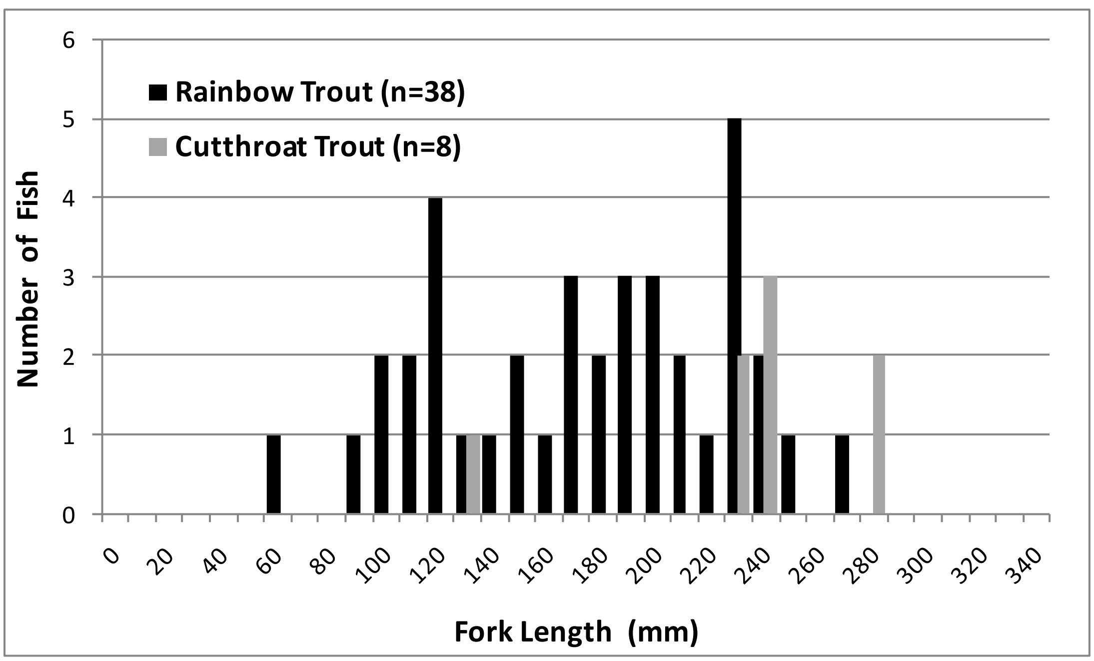

Figure 3.15 Length frequency distribution of fish sampled from Diversion Reservoir Sept. 9, 2010.

3.2.4 Age

Scale analysis was used to age a total of 42 trout of which 11 were also aged using otoliths. Age determinations from the otolith samples were used to validate the age determinations from the corresponding scales. In addition, 4 juveniles that were released after sampling were aged using the length frequency distribution for rainbow trout. The ages of rainbow and cutthroat trout sampled in 2010 are summarized in **Table 3.10**.

Table 3.10 Number of fish in each age group for rainbow trout and cutthroat trout sampled from Diversion Reservoir on September 9, 2010.

Age Group	0+	1+	2	3+	4+	5+
Rainbow (n=38)	1 (3%)	11 (29%)	14 (37%)	9 (24%)	2 (5%)	1 (3%)
Cutthroat (n=8)	0 (0%)	1 (12%)	0 (0%)	5 (62%)	2 (25%)	0 (0%)

Rainbow trout and cutthroat trout populations have different age structure due largely to their differing life histories. For consistency, we focused the age analysis on rainbow trout which accounted for the largest portion (83%) of the sample.

The dominant age group in the 2010 rainbow trout sample was the 2+ fish that accounted for 37% of the sample. Over the 6 years of sampling the proportion of 0+ and 1+ juveniles varied widely. In comparison, the sexually mature 2+ component remained relatively stable, accounting for 25%-41% of the sample over the study period with no obvious dependence on juvenile recruitment levels (**Figure 3.16**).

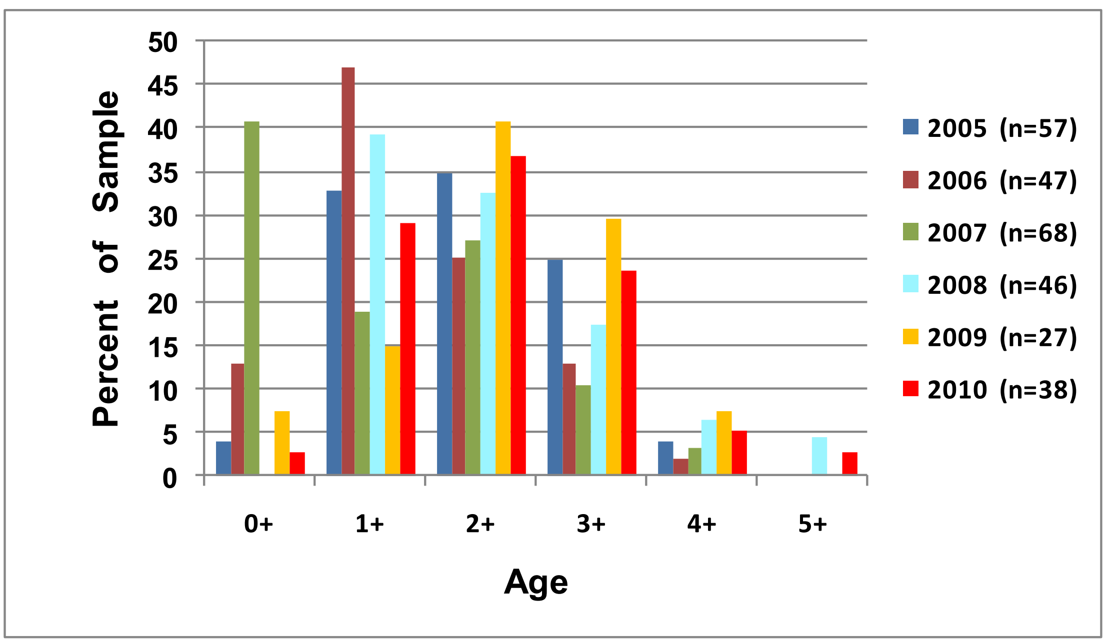

Figure 3.16 Comparison of age structure of sampled rainbow trout from 2005 to 2010.

For example, the highest abundance of 1+ parr observed in 2006 translated into one of the lowest abundances of 2+ adults the following year, and the lowest abundance of 1+ parr in 2009 translated into one of the highest abundance of 2+ adults the following year. This is not unusual since juvenile survival rates are often density-dependant due to competition for limited resources such as food and space. Such a population structure suggests that the limiting life stage for rainbow trout in Diversion Reservoir is the transition to 2+ adults. This is a time of rapid growth and energy requirements for sexual maturity that may be limited by competition for finite resources during the critical summer growth period. During the summer the reservoir is typically at low pool with a reduced surface area and is also stratified with only limited portions of the water column suitable for rearing rainbow trout.

3.2.5 Length-Weight Regressions

The slope of the length-weight regression curve can be used to describe the condition of the rainbow trout that were collected with gillnets at Diversion Reservoir. A comparison of length-weight regressions from fish sampled from 2005 to 2010 show similar slopes, suggesting that the condition of the rainbow trout appears to have varied little between the 6 years of sampling (**Figure 3.17**).

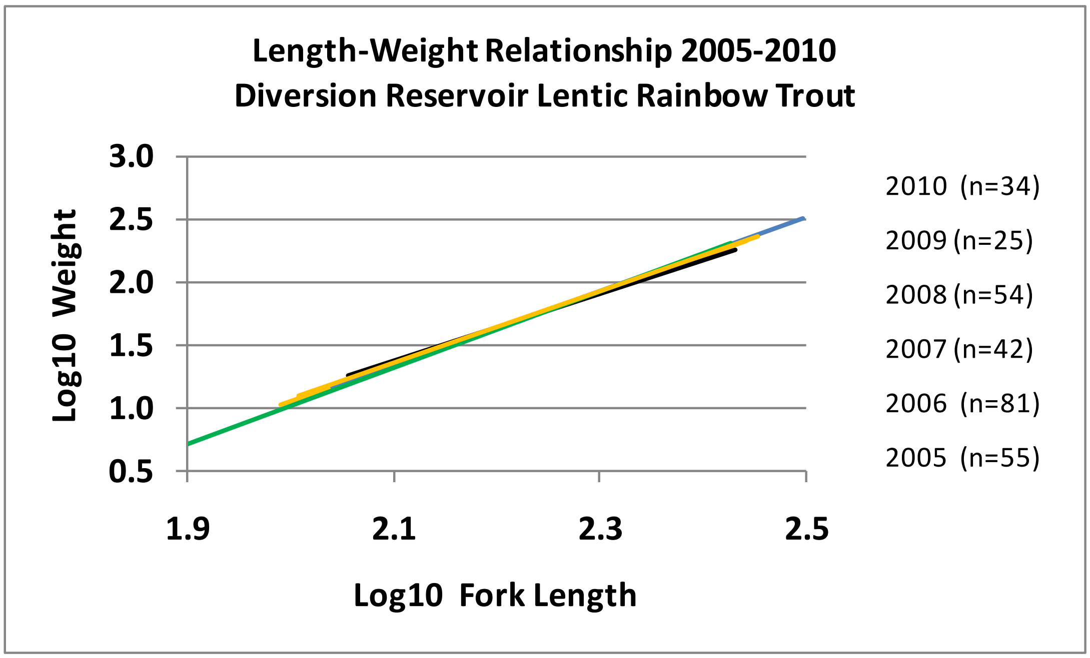

Figure 3.17 Comparison of the length - weight regressions for lentic rainbow trout samples from 2005 to 2010.

3.2.6 Condition Factor

Fish length and weight were integrated into Fulton"s condition factor (K) using Equation 1 (Ricker 1975):

$$K=w/l^3 \qquad \text{Equation 1}$$

where:

K = Fulton"s condition factor
w = wet weight in grams * 10^5
l = fork length in millimeters

Fulton‟s condition factor (K) is a similar method of describing the condition of sampled fish based on the length and weight of the fish. Analysis of K from sampled fish considered only those fish captured using lake gillnets in order to best represent the growth conditions in the reservoir. The 0+ fry sampled from Walker Creek were not included in the lentic sample since these fish would not reflect growth conditions in the reservoir.

The mean K of Diversion Reservoir rainbow trout sampled in 2010 was 1.07, SD=0.09 (**Table 3.11, Figure 3.18**), which is within the expected normal range of 1.00 to 1.15 for rainbow trout from lakes on Vancouver Island and is typical of many Vancouver Island lakes with high flushing rates, low nutrient levels and relatively low aquatic production (Ptolemy, pers. comm.). The similar condition of the trout population and a correspondingly similar and stable K therefore seems consistent with the relatively low aquatic production of coastal BC lakes.

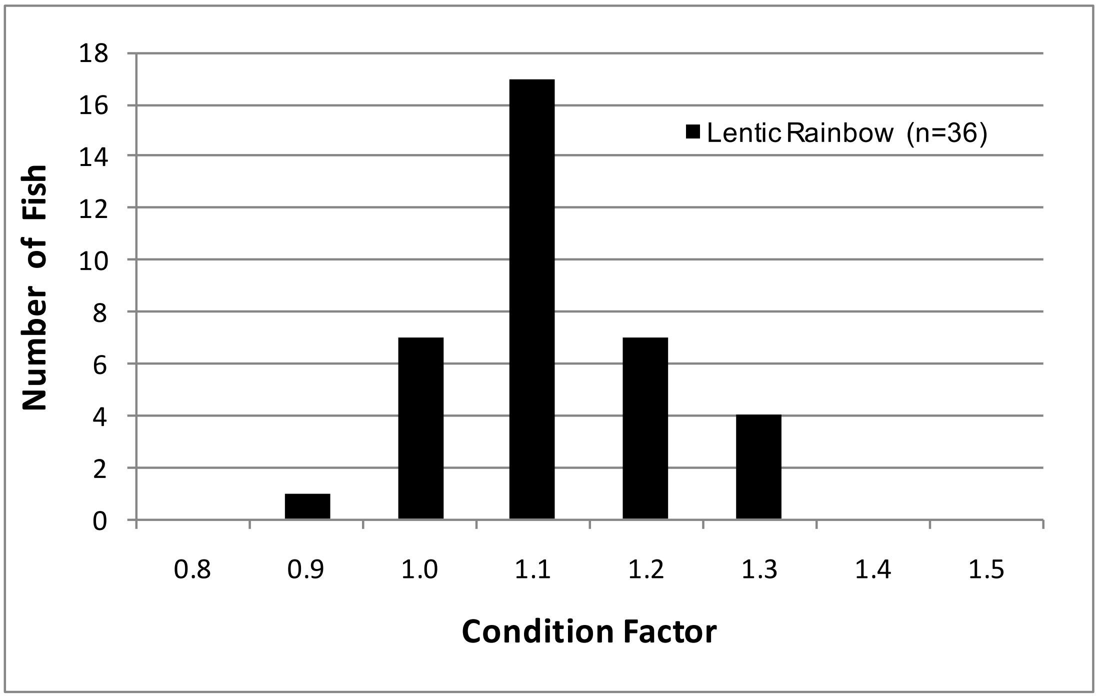

Figure 3.18 Frequency distribution of condition factor K-values for lentic rainbow and cutthroat trout sampled from Diversion Reservoir, September 9, 2010.

Table 3.11 Summary of Fulton‟s condition factor values (K) for Diversion Reservoir rainbow trout sampled in 2005 to 2010.

Year	Sample Date	N	K	SD
2005	Sept 7-8	55	1.10	0.11
2006	Sept 12-14	81	1.10	0.12
2007	Sept 15-16	38	1.07	0.14
2008	Sept 12-13	46	1.08	0.07
2009	Sept 8-9	25	1.03	0.11
2010	Sept 9	26	1.07	0.09

The physical condition of the rainbow trout (Fulton‟s Condition Factor K) remained remarkably stable during the 6 year study. ANOVA and Scheffe tests found that there were no significant differences in K between the study years (**Figure 3.19**). Correlation analysis of the pooled data from all years found a significant (*p*=0.008) but very slight decline in K over the study period indicating a slight, almost negligible decline in fish condition during the 6-year period of reduced drawdown (**Figure 3.20**).

The observed mean K values of 1.03 to 1.10 were all within the range observed at other lakes on the west coast of Vancouver Island. Historical sampling found slightly lower K values of 1.1 in 1994 (n=161)(Griffith 1996) and 1.06 in 2002 (n=47), which were also in the expected normal range for Vancouver Island (Stewart et al., 2002).

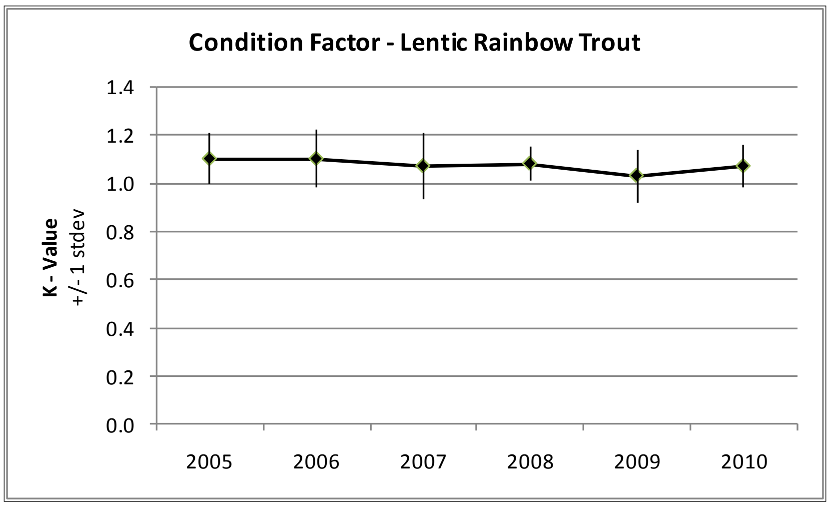

Figure 3.19 Mean annual Fulton‟s Condition Factor (K) of lentic rainbow trout, 2005 to 2010.

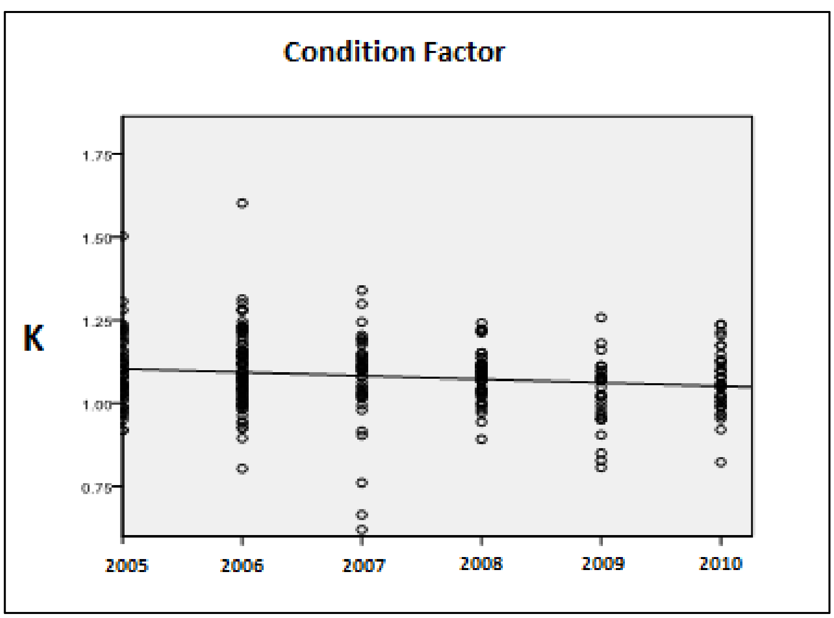

Figure 3.20. Correlation trend in Fulton‟s Condition Factor (K) of lentic rainbow trout using pooled data over the 6 study years from 2005 to 2010.

4.0 Conclusions

The original study design for this project was to assess aquatic productivity by collecting 5 years of baseline data to establish normal levels of aquatic production indicators. A sixth year of study was planned as a treatment year that called for a drawdown of Diversion Reservoir beyond the lower limits of the operational constraints of 376 m to investigate the response in aquatic productivity. However, BC Hydro was unable to provide the conditions necessary for the treatment year in 2010, so a sixth year of baseline data was collected in place of the treatment data. This report therefore documents 6 years of baseline data with no treatment year.

Despite the lack of a treatment year for comparison, the 6 years of baseline data does allow for the testing of some of the hypotheses that were stated in the Terms of Reference as follows:

H_1: Reduced reservoir drawdown does not increase rainbow trout condition.

H_{1a}: Changes in reservoir first order productivity indicators occur independently of reservoir operation.

H_{1b}: Changes in fish condition occur independently of reservoir first order productivity indicators

Regarding H_1: The analysis found no significant increases in rainbow trout condition between any of the 6 study years and the analysis of pooled data over the 6-year study period detected only a very slight declining trend in fish condition. Together these analyses indicate that there was no significant increase in rainbow trout condition over the 6-year period of reduced reservoir drawdown. Accept H_1.

Regarding H_{1a}: Since there was no treatment year in the study, the wording of “reservoir operation” in the hypothesis was interpreted as “reduced reservoir drawdown”. The first order productivity indicators (Secchi depth, total phosphorous, dissolved phosphorous and chlorophyll *a* levels) were monitored over the 6-year period of reduced reservoir drawdown. The results were mixed, with statistically significant decreases observed in Secchi depth (inverted) and total phosphorous trends while significant increases were observed in dissolved phosphorous and chlorophyll *a* trends. Analysis of pooled data found that some first order parameters showed an increasing trend while others showed a decreasing trend but collectively, they all showed significant changes during the period of reduced drawdown. Therefore, changes in primary production indicators occurred independently of reservoir operation. Accept H_{1a}.

Regarding H_{1b}: The analysis found no significant increases in rainbow trout condition between any of the years over the 6-year study period. Over the same period, the first order productivity indicator trends were mixed and collectively showed no clear trend. With no clear change in fish condition and no clear trend in first order indicators, a clear association is difficult to evaluate. Therefore H_{1b} cannot be addressed.

The hypotheses for this study focus on the condition factor of rainbow trout as the critical parameter for evaluating the production of fish in the reservoir. However, study findings suggest that trout abundance may be a better reflection of overall trout production in the reservoir. Abundance in this study was measured as CPUE, and the CPUE data indicates that the abundance of rainbow trout increased significantly over the study period. Despite the fact that the condition of the trout did not improve during the study period, the abundance of fish increased, suggesting an overall increased benefit to the trout production as a result of reduced reservoir drawdown.

BC Hydro Terms of Reference for this study state:

> "If the monitoring program finds that *no increased benefits* to fish were observed by introduction of reservoir constraints, the recommendations could be revisited for more flexible operating options at the end of the review period."

Since the 6-year monitoring program noted increased benefits to fish, the study findings do not support revisiting the recommendations for more flexible operating options.

5.0 Recommendations

5.1 BC Hydro Operations

Drawdown of Diversion Reservoir during the summer stratification period can have potentially negative effects on fish and fish habitat (*see* **Section 3.1.2**). If BCH operational plans include a summer drawdown, it is recommended that a temp-DO profile be established at Limnology Station 1 prior to the event. The temp-DO profile would establish which portion of the water column is suitable fish habitat and where this lies in relation to the HCV, thereby providing a basis for assessing the potential impacts.

5.2 Mitigation Opportunities

Findings from this study indicate that the limiting factors to rainbow trout production are the finite resources of food and space for 2+ adults during the critical summer growth period. Lake aeration and nutrient enrichment are two methods that could be used to alleviate the limited resources, although additional limnological information is needed to evaluate whether or not such projects would be beneficial at Diversion Reservoir. For example, with lake aeration it is not clear how long the sub-standard conditions persist during the summer months, how pronounced the negative effects to trout are, and whether such a project would be warranted. Data requirements needed to assess these opportunities include regular limnological sampling during the year to determine the duration of stratification and how the conditions fluctuate during the year. A brief description of the 2 methods is as follows:

Lake Aeration

Marginal surface water temperatures and lethal DO conditions in the hypolimnion combine to reduce the suitable rearing habitat during the summer months. Lake aeration is one option that can address these conditions by using a compressor to force air bubbles into the deep hypolimnion where they rise to the surface, thereby mixing the stratified layers of the reservoir. The desired result is to produce a monomictic water column that is suitable for fish from top to bottom.

Nutrient Enrichment

Existing nutrient levels in Diversion Reservoir can be augmented with the addition of key nutrients that can in turn increase aquatic production and ultimately the food supplies for trout. Nutrient enrichment projects have been used successfully on BC lakes. The application of nutrients typically takes place during the spring and summer growth period when flushing rates are lowest and water temperatures are highest.

6.0 References

BC Ministry of Environment. 2011. Provincial Dissolved Oxygen Criteria for Aquatic Life for Fresh, Marine and Estuarine Waters, and Sediments. Accessed online Nov. 7, 2011 at: http://www.env.gov.bc.ca/wat/wq/BCguidelines/do/do-03.htm.

BC Hydro. 2002. Jordan River Water Use Plan Consultative Report. Prepared for BC Hydro Jordan River Water Use Plan Project. Burnaby, BC.

[BCMELP-FIU] British Columbia Ministry of Environment, Lands and Parks, Fish Inventory Unit. 1997. Fish Collection Methods and Standards, Version 4.0 [Prepared for British Columbia Resources Information Standards Committee]. Accessed online Dec. 2, 2010 at: http://www.gov.bc.ca/risc/pubs/aquatic/fishcol/index.htm

Bell MC. 1973. Fisheries handbook of engineering requirements and biological criteria. Fisheries Engineering Research Program. US Army Corps of Engineers, North Pacific Division, Portland, Oregon.

Cavanagh N, Nordin RN, Swain LG, Pommen LW. 1997. Ambient fresh water and effluent sampling manual. British Columbia Resources Inventory Standards Committee. Available at: http://ilmbwww.gov.bc.ca/risc/pubs/aquatic/ambient/index.htm#TOC

Griffith RP. 1996. Biophysical assessment of fish production within the Jordan River Drainage in 1994. BC Hydro and Power Authority, Environmental Affairs, Burnaby, BC.

Matthews KR, Berg NH. 1996. Rainbow trout response to water temperature and dissolved oxygen stress in two southern California stream pools. J of Fish Biology (1997) 50:50-67.

Lough MJ, Hay SE and Rutherford SE. 2000. Reconnaissance (1:20,000) inventories of 93 lakes in the Sayward Forest. Prepared by MJ Lough and Associates for BC Ministry of Environment, Lands and Parks, Nanaimo, BC.

Oliver GG, Fidler LE. 2001. Towards a water quality guideline for temperature in the Province of British Columbia. Prepared for BC Ministry of Environment, Lands and Parks, Victoria, BC by Aspen Applied Sciences Ltd., Cranbrook, BC. Accessed online at: http://www.env.gov.bc.ca/wat/wq/BCguidelines/temptech/temperaturetech-07.htm

Ricker WE. 1975. Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Board. Ca. Bulletin 191: 382 p.

Stewart S, Shon M, McHale R, Francis A. 2002. The limnological assessment of two Jordan River reservoirs (Phase II). Prepared for Royal Roads University, Sooke, BC.

Wetzel RG. 2001. Limnology. Lake and river ecosystems, Third edition. Academic Press.

7.0 Personal Communications

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Ptolemy R. Fish biologist, Aquatic Ecosystems Science Section, BC Ministry of Environment, Victoria, BC.

Appendix 1 Diversion Reservoir Field Data - Temperature - Dissolved Oxygen Profile 2010

Water Temperature and Dissolved Oxygen Profiles on September 10, 2010

Limnology Station 1

DO (mg/l)	Temp (c)	Depth (m)	
7.3	16.6	0.5	
7.3	16.6	1.0	
7.3	16.6	2.0	
7.3	16.6	3.0	
7.3	16.7	4.0	
7.3	16.7	5.0	
7.2	16.7	6.0	
7.2	16.7	7.0	
7.2	16.6	8.0	
6.9	16.5	9.0	
7.1	16.2	10.0	
6.2	15.9	11.0	
3.1	15.5	12.0	
0.8	15.0	13.0	
0.0	14.5	14.0	
0.0	14.2	15.0	
0.0	14.0	16.0	
0.0	13.7	17.0	
0.0	13.5	18.0	
0.0	13.1	19.0	
0.0	12.7	20.0	
0.0	11.6	21.0	
0.0	10.6	22.0	
0.0	9.8	23.0	
0.0	9.7	24.0	Bottom

Limnology Station 2

DO (mg/l)	Temp (c)	Depth (m)	
9.3	17.0	0.5	
9.3	17.1	1.0	
9.4	17.1	2.0	
9.3	17.1	3.0	
9.3	17.1	4.0	
9.3	17.1	5.0	
8.7	17.0	6.0	
8.6	17.0	7.0	
8.5	17.0	8.0	
8.4	17.0	9.0	
6.8	16.7	10.0	
3.7	16.4	11.0	
3.1	16.1	12.0	
0.1	15.9	13.0	Bottom

Appendix 2 Diversion Reservoir Field Data - Phosphorous 2010

Results of lab analysis of phosphorous levels at 4 sites in Diversion Reservoir, September 10, 2010. Replicate samples (A and B) were taken at each sampling location.

Site	TP (μg/l)	DTP (μg/l)
Limnology Station 1A	6.8	4.4
Limnology Station 1B	5.7	4.4
Limnology Station 2A	6.2	5.6
Limnology Station 2B	4.9	4.8
Gillnet Site 1A	12.1	8.1
Gillnet Site 1B	16.7	8.3
Gillnet Site 2A	7.5	6.2
Gillnet Site 2B	6.5	5.0

Appendix 3 Diversion Reservoir Field Data - Chlorophyll

Site	Date	Time	Chlorophyll A	Chlorophyll B	Chlorophyll C	Total Chlorophyll	Phaeophytin
Limno 1A	10/9/10	9:30	2.94	0.25	5.38	8.57	6.50
Limno 1B	10/9/10	9:30	3.66	15.80	15.80	35.26	7.74
Limno 2A	10/9/10	19:45	2.60	0.00	3.33	5.93	5.12
Limno 2B	10/9/10	17:45	2.37	0.00	12.30	14.67	7.08
Fish 1A	10/9/10	19:10	3.34	0.00	9.17	12.51	3.34
Fish 1B	10/9/10	19:10	3.88	0.16	5.64	9.68	5.79
Fish 2A	10/9/10	18:55	3.15	0.00	7.41	10.56	4.54
Fish 2B	10/9/10	18:55	2.53	0.74	5.27	8.54	5.12
Lab Blank	10/9/10		ND	ND	ND	ND	ND
Fish 2B Dup	10/9/10						
Mean			**3.1**	**2.1**	**8.0**	**13.2**	**5.7**
SD			**0.5**	**5.5**	**4.2**	**9.3**	**1.4**

1. Chlorophyll units are mg/m^3

Mean phytoplankton levels from 8 sample sites at Diversion Reservoir in September 2005 to 2010.

	September 8, 2005			September 14, 2006			September 16, 2007			September 13, 2008			September 9, 2009			September 10, 2010		
	Mean (mg/m^3)	SD	N	Mean (mg/m^3)	SD	N	Mean (mg/m^3)	SD	N	Mean (mg/m^3)	SD	N	Mean (mg/m^3)	SD	N	Mean (mg/m^3)	SD	N
Chlorophyll a	2.33	0.77	8	2.98	0.55	8	2.13	0.67	8	12.80	3.47	8	11.68	4.50	8	3.08	0.59	8
Chlorophyll b	1.65	0.73	8	1.36	0.65	8	1.05	0.77	8	1.80	0.84	8	9.17	7.85	8	2.39	5.92	8
Chlorophyll c	1.98	2.01	8	6.84	1.81	8	0.19	0.53	8	5.90	5.57	8	17.94	14.10	8	8.42	4.37	8
Total Chlorophyll	6.69	3.72	8	11.17	2.48	8	3.37	1.13	8	18.80	7.53	8	38.81	25.82	8	13.88	9.83	8
Phaeophyton	1.17	2.00	8	4.76	0.96	8	0.29	0.54	8	8.00	4.29	8	1.82	2.54	8	5.53	1.5	8

Appendix 4 Diversion Reservoir Field Data – Individual Fish Data 2010

Site	Date	Method	Species	Length (mm)	Weight (g)	Sex	Maturity	Structure	Sample #	Age	Photo
1	2010/09/09	MT 4	RB	108	12.5			SC	1	1	9481
1	2010/09/09	MT 4	RB	157	37.5			SC	2	2	9482
1	2010/09/09	MT 1	TR	62	2.9				3		9484
1	2010/09/09	MT 1	RB	113	17			SC	4	1	9485
1	2010/09/09	MT 1	CT	135	24.8			SC	5	1	
1	2010/09/09	MT 5	RB	129	21.3				6		9486
1	2010/09/09	MT 5	RB	126	21.1				7		
1	2010/09/09	MT 5	RB	119	18.2				8		
1	2010/09/09	FGN 1	RB	230	125			SC	9	3	9488
1	2010/09/09	FGN 1	CT	288	211			SC	10	4	9489
1	2010/09/09	FGN 1	CT	284	201			SC	11	4	9490
1	2010/09/09	SGN 1	RB	194	88	f		SC/OT	12	2	
1	2010/09/09	SGN 1	CT	250	147	f		SC	13	3	9492
1	2010/09/09	SGN 1	RB	208	97			SC	14	3	9493
1	2010/09/09	SGN 1	RB	168	52			SC	15	2	9494
1	2010/09/09	SGN 1	RB	210	97	m		SC/OT	16	2	9495
1	2010/09/09	SGN 1	RB	245	156			SC	17	4	9496
1	2010/09/09	SGN 1	RB	277	175			SC	18	5	9497
1	2010/09/09	SGN 1	CT	250	150			SC	19	3	9498
1	2010/09/09	SGN 1	RB	181	64			SC	20	2	
1	2010/09/09	SGN 1	CT	238	112	f	mt	SC/OT	21	3	9499
1	2010/09/09	SGN 1	RB	235	132	f	mt	SC/OT	22	3	9500
1	2010/09/09	SGN 1	RB	240	152			SC	23	3	9501
1	2010/09/09	SGN 1	RB	174	64			SC	24	2	9502
1	2010/09/09	SGN 1	RB	132	26			SC	25	1	9503
1	2010/09/09	SGN 1	RB	125	22	f	mt	SC	26	1	9504
1	2010/09/09	SGN 1	RB	212	94	m	im	SC/OT	27	2	9505
1	2010/09/09	SGN 1	RB	210	93	f	mt	SC/OT	28	2	9506
2	2010/09/09	MT 8	RB	158	41.6			SC	29	1	9507
2	2010/09/09	MT 6	RB	98	10.8			SC	30	1	9508
2	2010/09/09	MT 6	RB	128	20	f		SC/OT	31	1	9509
2	2010/09/09	MT 6	RB	110	14.6			SC	32	1	9510
2	2010/09/09	SGN 2	RB	235	136			SC	33	3	
2	2010/09/09	SGN 2	RB	172	63			SC	34	2	
2	2010/09/09	FGN 2	RB	254	158			SC	35	3	
2	2010/09/09	FGN 2	RB	220	125			SC	36	3	
2	2010/09/09	FGN 2	RB	233	127	m	mt	SC/OT	37	3	
2	2010/09/09	FGN 2	RB	244	148			SC	38	4	
2	2010/09/09	FGN 2	RB	193	80	f	mt	SC/OT	39	2	
2	2010/09/09	FGN 2	RB	197	78		mt	SC	40	2	
2	2010/09/09	FGN 2	CT	243	134			SC	41	3	
2	2010/09/09	FGN 2	RB	232	115	f	mt	SC/OT	42	3	
2	2010/09/09	FGN 2	RB	180	72			SC	43	2	
2	2010/09/09	FGN 2	RB	188	78			SC	44	2	
2	2010/09/09	FGN 2	CT	235	127			SC	45	3	
2	2010/09/09	FGN 2	RB	150	38	m	im	SC/OT	46	2	

Appendix 5 Photo Documentation 2010

2010 Photodoc

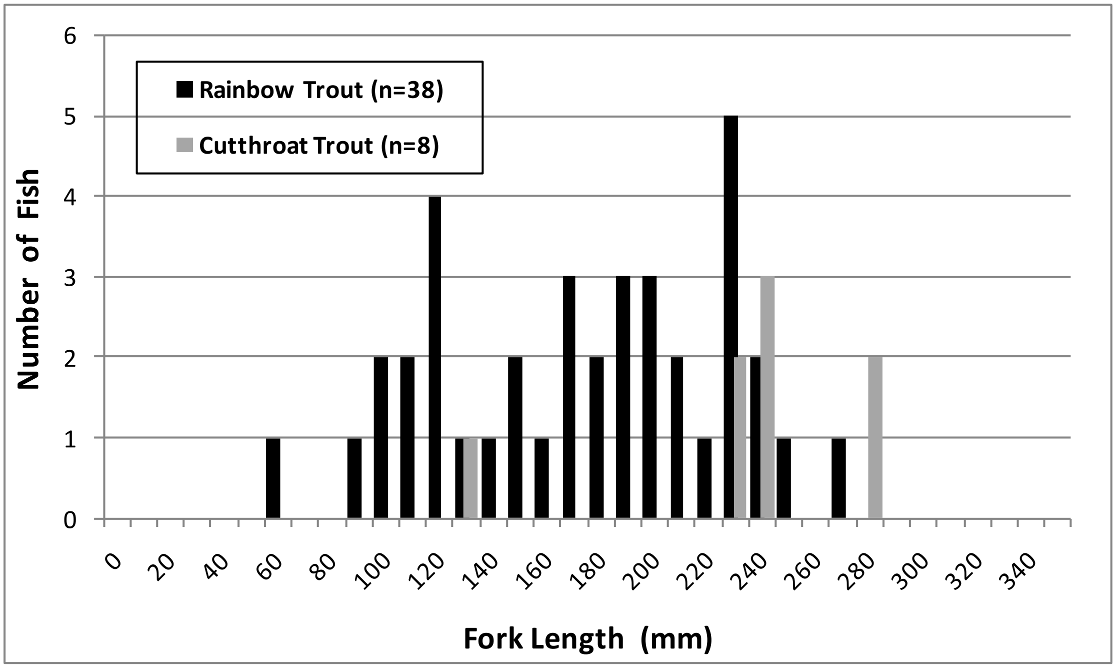
Photo #	Date	Details
9480	Sep 9, 2010	Drawdown zone, Diversion Reservoir
9481	Sep 9, 2010	Fish sample 1
9482	Sep 9, 2010	Fish sample 2
9483	Sep 9, 2010	Fisheries technician
9484	Sep 9, 2010	Fish sample 3
9485	Sep 9, 2010	Fish sample 4
9486	Sep 9, 2010	Fish sample 6
9487	Sep 9, 2010	Floating gillnet, Site 1
9488	Sep 9, 2010	Fish sample 9
9489	Sep 9, 2010	Fish sample 10
9490	Sep 9, 2010	Fish sample 11
9491	Sep 9, 2010	Sinking gillnet, Site 1
9492	Sep 9, 2010	Fish sample 13
9493	Sep 9, 2010	Fish sample 14
9494	Sep 9, 2010	Fish sample 15
9495	Sep 9, 2010	Fish sample 16
9496	Sep 9, 2010	Fish sample 17
9497	Sep 9, 2010	Fish sample 18
9498	Sep 9, 2010	Fish sample 19
9499	Sep 9, 2010	Fish sample 21
9500	Sep 9, 2010	Fish sample 22
9501	Sep 9, 2010	Fish sample 23
9502	Sep 9, 2010	Fish sample 24
9503	Sep 9, 2010	Fish sample 25
9504	Sep 9, 2010	Fish sample 26
9505	Sep 9, 2010	Fish sample 27
9506	Sep 9, 2010	Fish sample 28
9507	Sep 9, 2010	Fish sample 29
9508	Sep 9, 2010	Fish sample 30
9509	Sep 9, 2010	Fish sample 31
9510	Sep 9, 2010	Fish sample 32
9511	Sep 9, 2010	Sinking gillnet, Site 2

Appendix 6 Summary of 2005 to 2010 Gillnet Effort and Catch Data

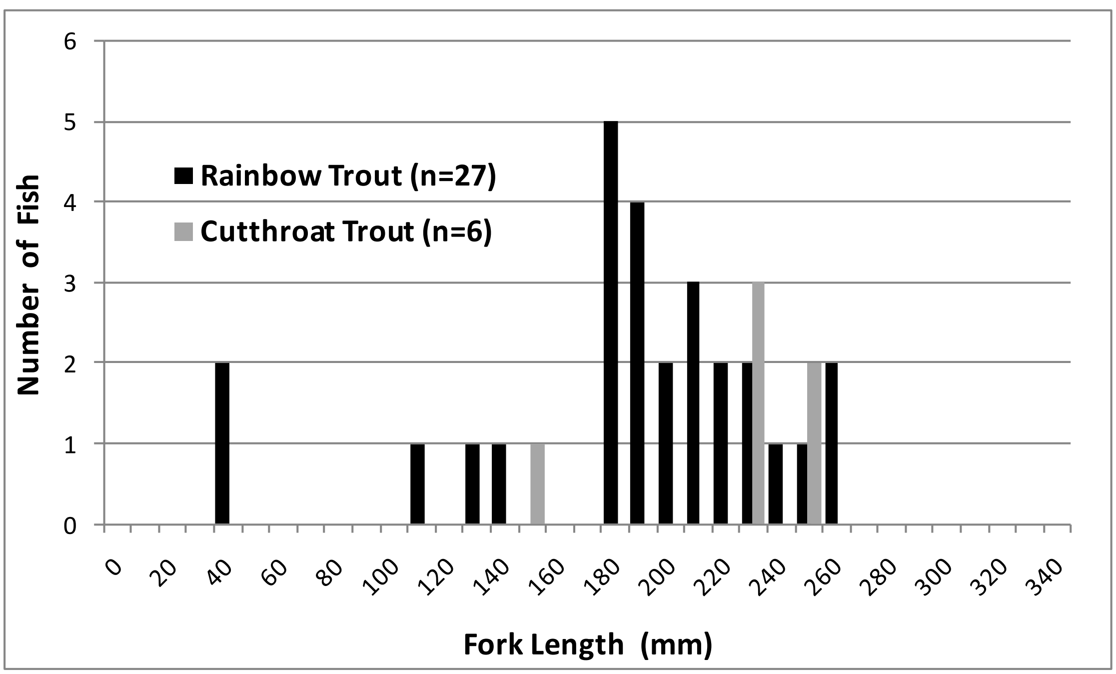
Catch, effort and CPUE (mean catch/hr) of lentic rainbow trout catch in 2 floating (FL) and 2 sinking (SN) variable-mesh gillnets (GN) in Diversion Reservoir, 2005 to 2010.

	FGN1	FGN2	SGN1	SGN2	COMBINED
2005					
Catch (rainbow trout)	7	23	6	19	55
Effort (net-hours)	1.60	2.50	1.25	2.50	7.85
CPUE (rainbow/hr)	4.4	9.2	4.8	7.6	6.5
2006					
Catch (rainbow trout)	7	39	22	13	81
Effort (net-hours)	1.50	4.40	2.75	2.10	10.75
CPUE (rainbow/hr)	4.7	8.9	8.0	6.2	7.0
2007					
Catch (rainbow trout)	6	5	24	3	38
Effort (net-hours)	0.33	0.25	1.00	0.25	1.83
CPUE (rainbow/hr)	18.2	20.0	24.0	12.0	18.6
2008					
Catch (rainbow trout)	3	10	19	14	46
Effort (net-hours)	0.42	0.25	0.50	0.64	1.81
CPUE (rainbow/hr)	7.1	40.0	38.0	21.9	26.8
2009					
Catch (rainbow trout)	4	8	8	5	25
Effort (net-hours)	0.25	0.5	0.25	0.25	1.25
CPUE (rainbow/hr)	28	22	32	20	25.5
2010					
Catch (rainbow trout)	1	10	14	2	27
Effort (net-hours)	0.1	0.2	0.4	0.2	0.9
CPUE (rainbow/hr)	10	50	35	10	26.3

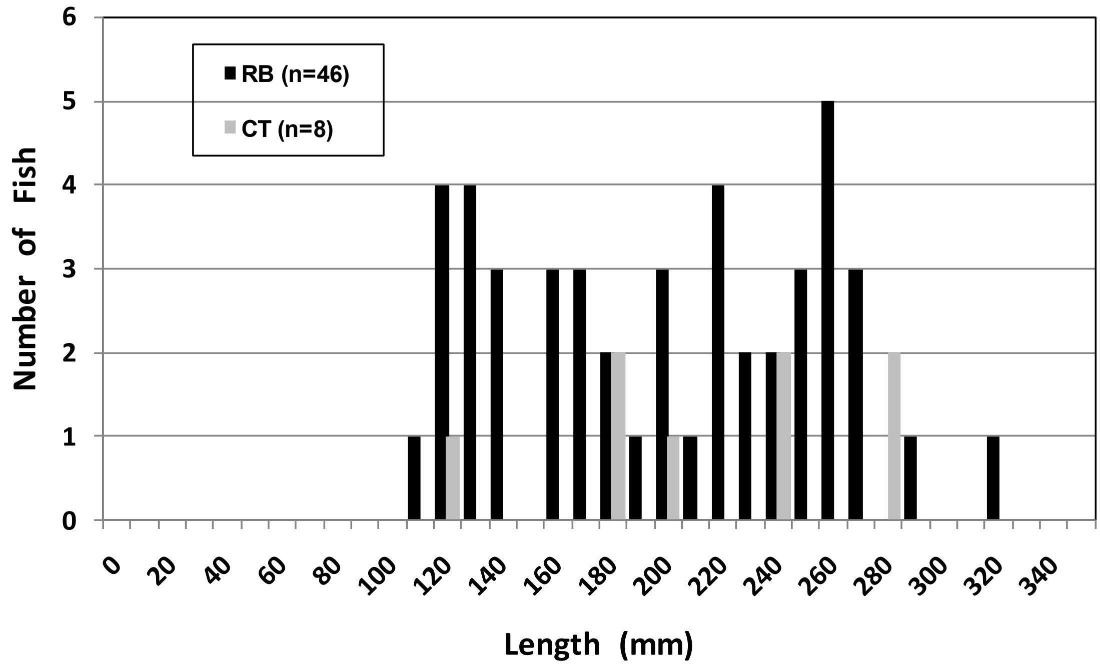
Appendix 7 Length Frequency Distribution, 2005-2010.



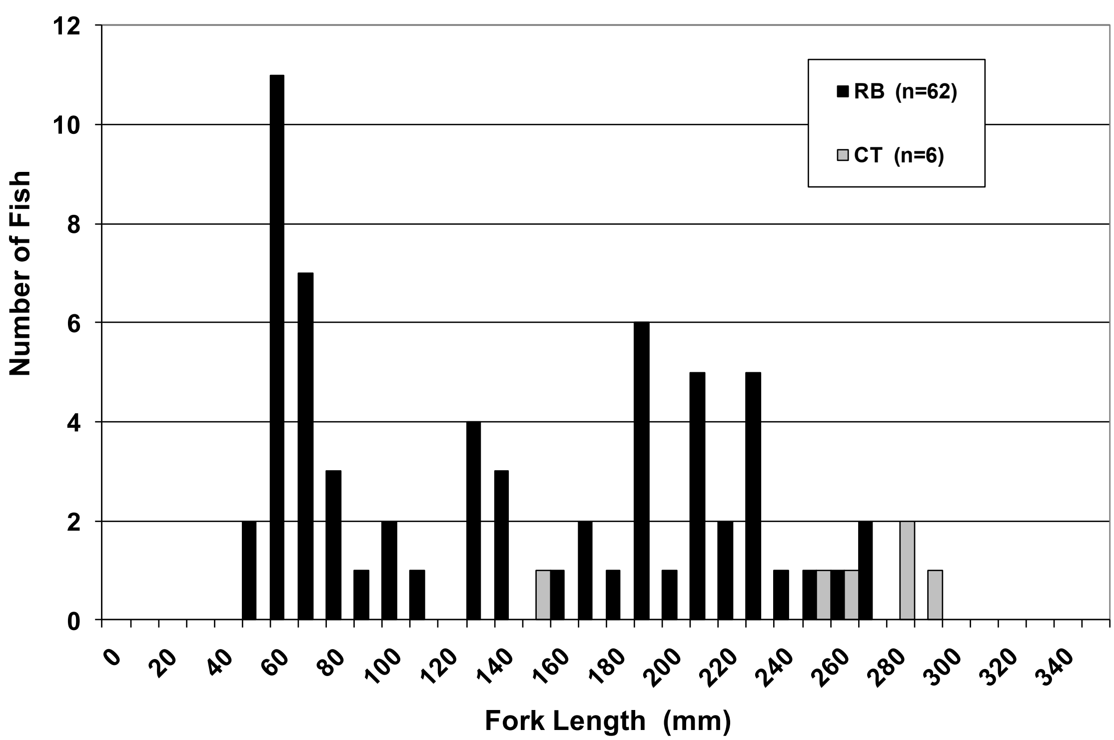
Length frequency distribution of fish sampled from Diversion Reservoir September 9, 2010.



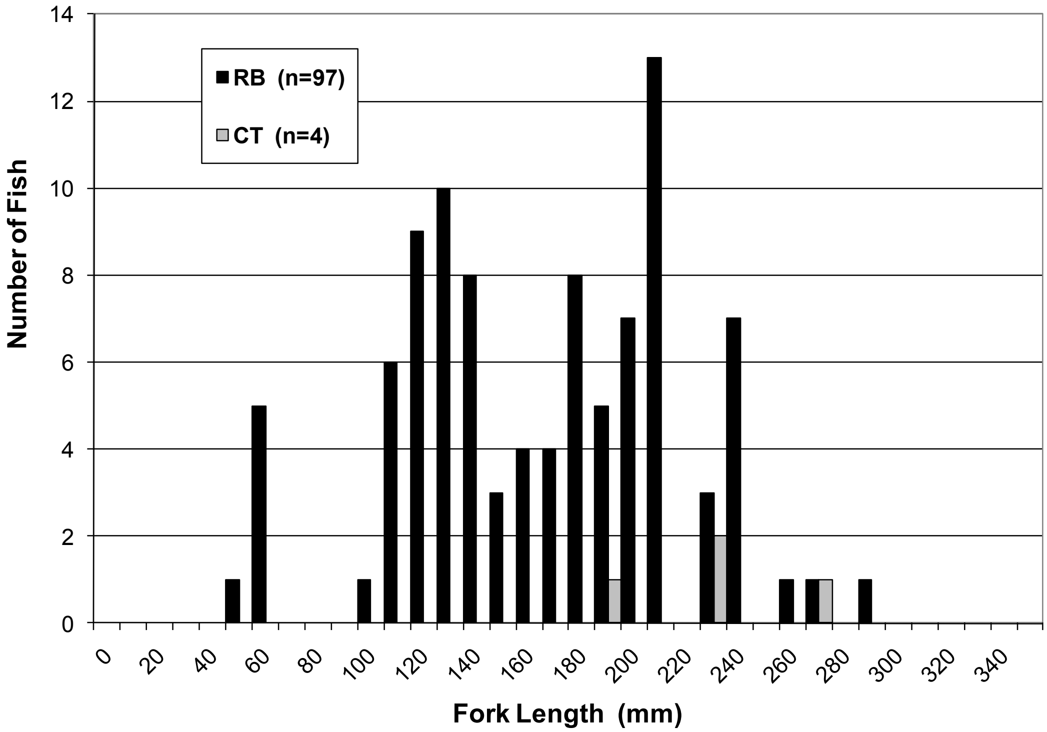
Length frequency distribution of fish sampled from Diversion Reservoir September 8-9, 2009.



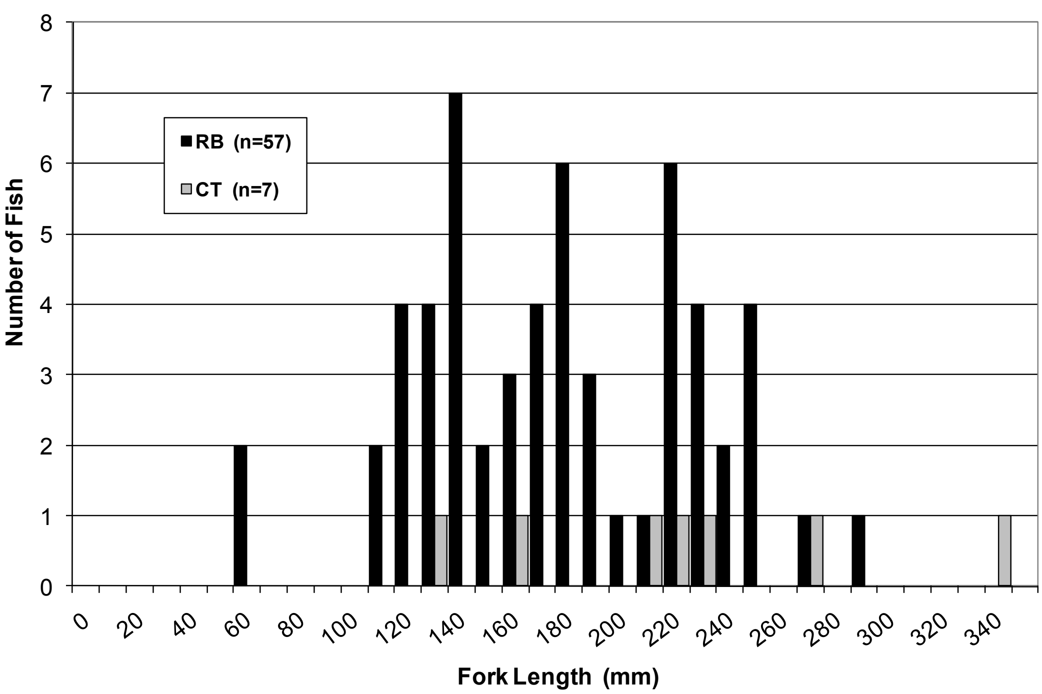
Length frequency distribution of fish sampled from Diversion Reservoir in 2008.



Length frequency distribution of fish sampled from Diversion Reservoir and lower Walker Creek, 2007.



Length frequency distribution of fish sampled from Diversion Reservoir and lower Walker Creek, 2006.



Length frequency distribution of fish sampled from Diversion Reservoir and lower Walker Creek, 2005.