Jordan River Project Water Use Plan

Diversion Reservoir Fish Indexing

Implementation Year 5

Reference: JORMON-4

Study Period: 2009

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Jordan River
Water Use Plan Monitoring Program

Diversion Reservoir
Fish Indexing - 2009

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Summary

- The Jordan River Water Use Plan included a 6-year monitoring period to assess the biological response to the required limits of reservoir drawdown. The objective is to collect baseline information on key indicators that will be used to assess aquatic productivity in Diversion Reservoir, then assess any changes during a treatment year. The indicators that will be monitored include chlorophyll, phosphorous, catch rates and fish condition.

- In September 2005, MJL Environmental Consultants (MJL) carried out the first year of field studies at Diversion Reservoir. In September 2006, 2007, 2008 and 2009 MJL repeated the field studies to augment the baseline information collected in 2005. The purpose of this document is to report on the findings from the 2009 field studies and compare this information to historical data.

- An intense wind and rain event occurred during the sampling period on September 8 and 9, 2009. Inflows from the rain event increased the water level of the reservoir by at least 1.2 m during the sampling period and the heavy winds appear to have caused the de-stratification (turn-over) of the reservoir during the sampling period. This may have affected the sampling conditions and therefore results for some of the limnology parameters such as nutrients but was unlikely to influence biological parameters sampled in 2009 such as fish abundance or condition factors.

- Water temperature and dissolved oxygen profiles in 2009 found that similar to previous years, the West Basin was clinograde, but stratification appeared to be breaking down during sampling, probably due to the heavy wind and rain event at the time of sampling. The shallower East Basin was not clinograde since the basin was not deep enough for the stratification. The anoxic hypolimnion in the West Basin prevented trout from inhabiting waters deeper than approximately 20 m in the West Basin. However, trout were able to inhabit the full water column in the shallower East Basin.

- The mean Secchi depth (turbidity) of Diversion Reservoir in 2009 was 3.1 m, which was not significantly different from the previous 4 years of study. In terms of productivity, Secchi depth is often related to algal biomass which, in this case suggests that the primary production in 2009 was not significantly different from previous study years.

- The 2009 mean total phosphorous was 3.24, which was the lowest in the 5 years of study and significantly lower than 2005, 2007 and 2008. The mean dissolved phosphorous level was 8.84 which was the highest in the 5 years of study and significantly higher than the previous 4 years of sampling. The marked difference between these parameters could be related to the turnover of the reservoir and the inflows from the heavy rain event.

- Chlorophyll a levels in 2009 were similar to the high levels observed in 2008 and significantly greater than 2005, 2006 and 2007. This elevated level of primary production may be linked to the increased availability of reactive phosphorous in 2009.

- The catch rates (catch per unit effort) of rainbow trout in gillnets during 2009 were not significantly different from the 4 previous years of study. This indicates that rainbow trout abundance was not different from the previous years of study.

- Age analysis found that despite major fluctuations in the proportion of 0+ fry and 1+ parr between the years, the main reproductive portion of the population; the 2+ and 3+ fish, remain relatively stable. The 2+ component has ranged from 25%-41% and the 3+ component has ranged from 10% to 30% over the 5 study years.
Rainbow trout sampled from Diversion Reservoir in 2009 had a Fulton’s condition factor value of 1.03, the lowest value observed in the 5 years of sampling. Nevertheless, this was still within the expected normal range of 1.00 to 1.15 for rainbow trout from lakes on Vancouver Island. Despite the apparent variation between years and an apparently declining trend for both species, the differences between most years were not significantly different. The exception is that the mean annual K-value for both species in 2009 was significantly less than 2006.

Recommendations identify precautions to reduce the potentially negative effects of reservoir drawdown during the summer and the need for advanced planning for the year of treatment as part of the study design.
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 rainbow trout condition factors. 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.

In September 2006, 2007, 2008 and 2009 MJL repeated the field studies to augment the baseline information collected in 2005. The purpose of this document is to report on the findings from the 2009 field studies and compare this information to data collected in previous years.

2.0 Methods

Field studies took place at Diversion Reservoir during September 8 to 9, 2009. The water level of Diversion Reservoir was El. 379.0 m at the start of the field sampling on September 8, 2009 at 0700 h, similar to previous sampling periods. However, the reservoir elevation gradually increased over that evening and the following day due to inflows from the heavy rainfall. The reservoir elevation on September 9, 2009 was El 379.1 m at 0800 h (Table 2.1).

<table>
<thead>
<tr>
<th>Reservoir Water Level During Sampling</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max Elevation</td>
<td>Min Elevation</td>
</tr>
<tr>
<td>2005</td>
<td>378.1 m</td>
</tr>
<tr>
<td>2006</td>
<td>378.3 m</td>
</tr>
<tr>
<td>2007</td>
<td>377.1 m</td>
</tr>
<tr>
<td>2008</td>
<td>378.0 m</td>
</tr>
<tr>
<td>2009</td>
<td>380.3 m</td>
</tr>
</tbody>
</table>
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 9, 2009.](image)

A 5 m aluminum skiff equipped with a Lowrance X-16 depth sounder and GPS were used to relocate 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 (Temp/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 2006, 2007, 2008 and 2009 (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 one of the isolated pools 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 2007, 2008 and 2009 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 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 8, 2009.

Figure 2.3 Location of baited minnow trap sites at Diversion Reservoir, September 8-9, 2009.
3.0 Results and Discussion

3.1 Limnology

3.1.1 Reservoir Levels
Reservoir operations vary between years according to factors such as operational requirements and weather. The surface elevation levels for Diversion Reservoir in 2005 to 2009 are summarized in Figure 3.1.

A subjective comparison of the reservoir levels in 2005 to 2007 shows that the reservoir conditions during the summer growth period of 2008 were generally higher than those in 2005-2007. Nevertheless, the reservoir appears to have been operated within the operational limits of the WUP since 2005.

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 5 years has ranged from El 376.2 m to 380.3 m. At the start of this year’s field sampling window in 2009, the reservoir levels were at 379.1 but heavy rains started soon after, and continued through September 8 and 9, resulting in significant inflows and an increase in the reservoir elevation during the remainder of the sampling period. Walker Creek, a major tributary to Diversion Reservoir was at flood stage for the entire sampling period on September 9. The mean daily level of diversion reservoir on Sept. 9 was 380.3 but the peak hourly level would have been somewhat higher. The result was that field samples have collected at similar reservoir levels over the study period, although the conditions may vary between years. For example, sampling was done during rising reservoir levels in 2009, as compared to falling reservoir levels in 2008.

![Figure 3.1](image-url)

**Figure 3.1** Surface elevations of Diversion Reservoir in 2005 to 2009 (Source: BC Hydro).
3.1.2 Temperature and Dissolved Oxygen

Limnology sampling was carried out as reservoir elevations gradually increased as a result of heavy rains and inflows on September 9, 2009. Sampling continued to a point where reservoir elevations were 2 m more than on previous years.

In 2009, the reservoir was clinorad at the time of sampling, but the thermocline was poorly defined and showed signs of mixing between the depths of 4 m and 20 m (Figures 3.2 and 3.3). The less pronounced thermocline and indications of mixing were likely the result of the cooling air temperature, significant inflows and high winds that were encountered as a storm event occurred during the sampling period. High winds resulted in a mixing of the surface waters and the inflows from the heavy rain event further de-stabilize the stratified reservoir. The temperature and dissolved oxygen profile suggest that the reservoir was actually de-stratifying or “turning over” during the sampling period.

Water temperatures in the deeper West Basin at the time of sampling decreased gradually from a maximum of 17.6 °C at the surface to 13.2 °C at the thermocline depth of 20 m. Temperatures below the thermocline ranged from 12.7 to 9.4 °C. This condition of a less pronounced thermocline is typical of the early stages of loss of stratification as the thermocline progressively erodes due to heat loss and circulation caused by surface winds (Wetzel 2001). The depth of the thermocline at 20 m was the deepest observed since 2005 (Table 3.1), perhaps due to the increased solar heat input during the warm dry summer of 2009 which may have resulting in the increased magnitude of the epilimnion.

<table>
<thead>
<tr>
<th>Year</th>
<th>Thermocline Depth (m)</th>
<th>Hypolimnion Depth (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>15</td>
<td>16</td>
</tr>
<tr>
<td>2006</td>
<td>12</td>
<td>15</td>
</tr>
<tr>
<td>2007</td>
<td>16</td>
<td>16</td>
</tr>
<tr>
<td>2008</td>
<td>16</td>
<td>18</td>
</tr>
<tr>
<td>2009</td>
<td>20</td>
<td>20</td>
</tr>
</tbody>
</table>

The West Basin was found to have an anoxic hypolimnion in 2009, as it has consistently had in each year of study since 2005. In 2009 the DO levels in the epilimnion ranged sporadically from 7.4 to 2.4 mg/l then rapidly declined to 0 mg/l at 21 m. The sporadic DO levels observed in the epilimnion were not typical of previous years and may have been the result of the lake circulation and mixing caused by the storm event at the time of sampling. The hypolimnion between 20 m and 23 m was anoxic and therefore uninhabitable by fish.

In 2009 the Temp/DO profile at Limnology Station 2 in the shallower East Basin indicated that the East Basin was not thermally stratified, possibly because the basin was too shallow for stratification to occur during a warm year, and/or because of mixing from the storm event during sampling. Water temperatures ranged from 17.7 °C near the surface to 15.1 °C near the bottom (Figure 3.4). DO levels in the water column ranged from 7.5 mg/l near the surface to 0.7 mg/l near the bottom depth of 13 m, but similar to the West Basin the DO levels were somewhat sporadic. As with the West Basin, this may have been the result of lake circulation and mixing caused by the storm event at the time of sampling.
Figure 3.2 Water temperature and dissolved oxygen profiles at Limnology Station 1 (West Basin), Diversion Reservoir on September 9, 2009.

Figure 3.3 Water temperature and dissolved oxygen profiles at Limnology Station 2 (East Basin), Diversion Reservoir on September 9, 2009.
Rainbow trout can survive DO levels as low as 3 or 4 mg/l but even levels higher than this appear to have a negative effect on their feeding rate and hence growth rate. Some studies have indicated that rainbow trout will avoid oxygen concentrations lower than 5 mg/l and will move to find higher oxygen concentrations if available (Matthews and Berg 1996). This suggests that in 2009 trout were less likely to inhabit portions of the reservoir that were deeper than approximately 17 m in the West Basin, although the DO profile appeared to be eroding at the time of sampling.

The optimum water temperature for rainbow trout growth is approximately 12 °C (Bell, 1973). They can tolerate higher water temperatures, but cease growth at approximately 18 °C primarily because of increased metabolic rates. They avoid temperatures higher than 19 °C and cannot survive water temperatures of 25 °C (Bell 1973). In previous years the water temperature in Diversion Reservoir was approximately 17 °C to 18 °C from the surface down to the anoxic hypolimnion, but in 2009 the temperatures in the epilimnion ranged from 13.3 to 17.6 °C. Conditions were therefore slightly more favorable for trout than the previous years since at the time of sampling, the water column was suitable for habitation from the surface right down to the anoxic hypolimnion at 20 m.

During the summers from 2005-2009, trout in Diversion Reservoir have been sandwiched between the warm, stress-inducing temperatures near the surface and the uninhabitable anoxic layer near the bottom. In 2009, the water column was habitable by trout to a depth of 20 m which is approximately El 358 m. Since this is deeper than the upper portion of the hollow cone valve (HCV) intake at Diversion Reservoir Dam, a drawdown using the HCV would extract water from the depths that are inhabited by rainbow trout. Unlike previous years however, the trout population is not sandwiched into a narrow depth of suitable habitat as in previous years, but instead is dispersed throughout the upper 20 m of the water column.

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 3.2. In 2006, 2 additional sites (Gillnet Sites 1 and 2) were added to the 2005 protocol and replicate samples at each of the 4 sites taken to allow for more robust statistical comparisons between years and these 2 additional sites were sampled again in 2007, 2008 and 2009.

<table>
<thead>
<tr>
<th>Sample date</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Secchi depth (m)</td>
<td>3.3</td>
<td>3.5</td>
<td>3.4</td>
<td>3.0</td>
<td>3.1</td>
</tr>
<tr>
<td>SD</td>
<td>0.4</td>
<td>0.2</td>
<td>0.2</td>
<td>0.1</td>
<td>0.2</td>
</tr>
<tr>
<td>N</td>
<td>2</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Color</td>
<td>brown</td>
<td>brown</td>
<td>brown</td>
<td>brown</td>
<td>brown</td>
</tr>
</tbody>
</table>

ANOVA tests indicate that turbidity levels in 2009 were not significantly different than the previous 4 years. Since Secchi depth is a measure of turbidity, this means that the 2009 levels of turbidity were not significantly different than the previous 4 years. Secchi depth is often related to algal biomass which, in this case might suggest that the primary production of Diversion Reservoir in 2009 was not significantly different than previous years (Figure 3.4).
3.1.4 Nutrients

Total phosphorous and dissolved phosphorous levels at the 2 limnology stations and the 2 gillnet sites for the 5 study years are summarized in Tables 3.3 and 3.4 and in Figure 3.6. 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).

Table 3.3 Mean total phosphorous levels at 4 sites in Diversion Reservoir, 2005 to 2009.

<table>
<thead>
<tr>
<th>Sample date</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>9.4</td>
<td>6.5</td>
<td>7.3</td>
<td>10.4</td>
<td>3.2</td>
</tr>
<tr>
<td>Mean total phosphorous (µg/l)</td>
<td>2.3</td>
<td>2.6</td>
<td>1.8</td>
<td>4.3</td>
<td>2.4</td>
</tr>
<tr>
<td>Range</td>
<td>6.1 - 12.7</td>
<td>3.7 - 10.6</td>
<td>5.8 - 10.3</td>
<td>1.1 - 16.0</td>
<td>0.5 - 7.7</td>
</tr>
<tr>
<td>N</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
</tr>
</tbody>
</table>

Table 3.4 Mean dissolved phosphorous levels from 4 sites in Diversion Reservoir, 2005 to 2009.

<table>
<thead>
<tr>
<th>Sample date</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6.4</td>
<td>2.4</td>
<td>5.9</td>
<td>8.4</td>
<td>8.8</td>
</tr>
<tr>
<td>Mean dissolved phosphorous (µg/l)</td>
<td>2.3</td>
<td>1.0</td>
<td>1.1</td>
<td>2.8</td>
<td>0.65</td>
</tr>
<tr>
<td>Range</td>
<td>4.7 - 11.2</td>
<td>1.2 - 4.1</td>
<td>3.9 - 7.4</td>
<td>6.2 - 14.5</td>
<td>7.6 - 9.8</td>
</tr>
<tr>
<td>N</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
</tr>
</tbody>
</table>
Figure 3.5 Annual mean total phosphorous and dissolved phosphorous levels at Diversion Reservoir, 2005 to 2009.

The mean total phosphorous level in 2009 was 3.2 ug/l, the lowest value since 2005. ANOVA tests found that 2009 was significant lower than 2005, 2007 and 2008 (p=0.00, 0.17 and 0.17 respectively). The reason for this is not clear but may possibly be related to the fall turnover that was apparently occurring at Diversion Reservoir during the field sampling. Even though this was the lowest level in the 5 years of study, all of the 5 years are still relatively low in terms of lake productivity and all are typical of oligo-mesotrophic reservoirs such as Diversion Reservoir (Wetzel 2001).

Phosphorous is typically the least abundant nutrient and is commonly the first nutrient to limit biological production (Wetzel 2001). The mean total dissolved phosphorous (TDP) was 8.8 ug/l in 2009. TDP levels in the Reservoir during September have increased since 2006. ANOVA tests indicate that 2009 was significantly lower than 2005 (p=0.024), 2006 (p=0.00), 2007 (p=0.003 and 2008 (p=0.003). In addition, 2006 was significantly lower than 2005 (p=0.000), 2007 (p=0.000) and 2008 (p=0.000). The reason for the inconsistent TDP levels over the sample period is not clear. TDP is typically taken-up quickly during the process of primary production, hence the elevated TDP levels suggest either an increased input into the system (e.g. elevated inflows and nutrients) or a decrease in uptake (e.g. reduced primary production, as might be expected during this late phase of the summer growth period. However, since the reservoir was in the process of de-stratifying, the inconsistent nutrient levels sampled in 2009 could also have been the result of inconsistent sampling conditions during 2009.

3.1.5 Phytoplankton

Chlorophyll $a$ levels in the reservoir in September for the 5 years of the study are summarized in Table 3.5. Two replicate samples were taken at each of the 4 sites so that there were a total of 8 samples (Appendix 3). Similar to 2008, the observed chlorophyll $a$ levels in 2009 of 11.7 mg/m$^3$ were significantly higher than 2005, 2006 and 2007 (p=0.00 all years) (Figure 3.6). Since 2008 and 2009 were both years of elevated TDP levels, it seems possible that the elevated chlorophyll
could possibly be linked to the increased level of phosphorous, as described in numerous studies by Wetzel (2001). However, this association between chlorophyll and phosphorous was not observed in 2005 when phosphorous levels were elevated but chlorophyll levels were low. In a disturbed (regulated) system such as Diversion Reservoir, factors other than nutrient loading may also affect primary production, thereby masking the relationship between nutrients and chlorophyll.

Table 3.5 Mean chlorophyll a levels in Diversion Reservoir in September 2005 to 2009.

<table>
<thead>
<tr>
<th>Sample date</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean chlorophyll a (mg/m³)</td>
<td>2.3</td>
<td>3.0</td>
<td>2.1</td>
<td>12.8</td>
<td>11.7</td>
</tr>
<tr>
<td>SD</td>
<td>0.8</td>
<td>0.6</td>
<td>0.7</td>
<td>3.47</td>
<td>4.5</td>
</tr>
<tr>
<td>Range</td>
<td>1.4 - 3.1</td>
<td>2.3 - 3.9</td>
<td>1.1 - 3.0</td>
<td>4.7 – 15.5</td>
<td>6.3 – 17.8</td>
</tr>
<tr>
<td>n</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
</tr>
</tbody>
</table>

Figure 3.6 Annual mean chlorophyll a levels at Diversion Reservoir, 2005 to 2009.

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 jaw. 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.

Thresholds would have to be established in the hazy continuum between rainbow, hybrid and cutthroat trout, but defining such thresholds would still be subjective.

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 3.6. The individual fish data is included in Appendix 4. A total of 33 fish were sampled in 2009, 31 from Diversion Reservoir and 2 trout fry from Walker Creek. The trout fry were too small to accurately speciate, so they included in the rainbow trout sample since they were small (indicating late emergence) and because numerically, their parents were more likely to be rainbow trout. Twenty-five (81%) rainbow trout and 6 (19%) cutthroat trout were sampled from the reservoir using gillnets. Twenty-one fish that appeared to be in healthy condition after sampling were released live at the point of capture (Table 3.7).

#### Table 3.6 Summary of effort and catch during fish capture activities at Diversion Reservoir September 8 to 9, 2009.

<table>
<thead>
<tr>
<th>Date of Deployment</th>
<th>Gear Type</th>
<th>Effort (hours)</th>
<th>Catch</th>
<th>CPUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sept. 8, 2009</td>
<td>FLGN 1</td>
<td>0.25</td>
<td>3 CT, 4 RB</td>
<td>28 fish/hr</td>
</tr>
<tr>
<td>Sept. 8, 2009</td>
<td>SKGN 1</td>
<td>0.25</td>
<td>0 CT, 8 RB</td>
<td>32 fish/hr</td>
</tr>
<tr>
<td>Sept. 8, 2009</td>
<td>FLGN 2</td>
<td>0.5</td>
<td>3 CT, 8 RB</td>
<td>22 fish/hr</td>
</tr>
<tr>
<td>Sept. 8, 2009</td>
<td>SKGN 2</td>
<td>0.5</td>
<td>0 CT, 5 RB</td>
<td>20 fish/hr</td>
</tr>
<tr>
<td>Sept. 8, 2009</td>
<td>MT 1</td>
<td>3.1</td>
<td>2 RB</td>
<td>0.1 fish/hr</td>
</tr>
<tr>
<td>Sept. 8, 2009</td>
<td>MT 2</td>
<td>2.8</td>
<td>0</td>
<td>0 fish/hr</td>
</tr>
<tr>
<td>Sept. 8, 2008</td>
<td>MT 3</td>
<td>2.7</td>
<td>0</td>
<td>0 fish/hr</td>
</tr>
<tr>
<td>Sept. 8, 2008</td>
<td>MT 4</td>
<td>2.5</td>
<td>0</td>
<td>0 fish/hr</td>
</tr>
<tr>
<td>Sept. 8, 2008</td>
<td>MT 5</td>
<td>2.2</td>
<td>0</td>
<td>0 fish/hr</td>
</tr>
<tr>
<td>Sept. 8, 2008</td>
<td>MT 6</td>
<td>2.4</td>
<td>0</td>
<td>0 fish/hr</td>
</tr>
<tr>
<td>Sept. 8, 2008</td>
<td>MT 7</td>
<td>2.3</td>
<td>0</td>
<td>0 fish/hr</td>
</tr>
<tr>
<td>Sept. 8, 2008</td>
<td>MT 8</td>
<td>2.3</td>
<td>0</td>
<td>0 fish/hr</td>
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<tr>
<td>Sept. 8, 2008</td>
<td>MT 9</td>
<td>1.7</td>
<td>0</td>
<td>0 fish/hr</td>
</tr>
<tr>
<td>Sept. 8, 2008</td>
<td>MT 10</td>
<td>1.7</td>
<td>0</td>
<td>0 fish/hr</td>
</tr>
<tr>
<td>Sept. 8, 2008</td>
<td>MT 11</td>
<td>1.4</td>
<td>0</td>
<td>0 fish/hr</td>
</tr>
<tr>
<td>Sept. 8, 2008</td>
<td>MT 12</td>
<td>1.3</td>
<td>0</td>
<td>0 fish/hr</td>
</tr>
</tbody>
</table>

#### Table 3.7 Fate of fish sampled at Diversion Reservoir September 8 to 9, 2009.

<table>
<thead>
<tr>
<th>Species</th>
<th>Killed</th>
<th>Released</th>
<th>Total</th>
</tr>
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<tr>
<td>Rainbow trout</td>
<td>9</td>
<td>18</td>
<td>27</td>
</tr>
<tr>
<td>Cutthroat trout</td>
<td>3</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>12</strong></td>
<td><strong>21</strong></td>
<td><strong>33</strong></td>
</tr>
</tbody>
</table>
3.2.2 Catch Per Unit Effort

CPUE is often used as an indicator of fish abundance. We compared the mean CPUE for rainbow trout in the 4 variable-mesh gillnet sets (2 floating gillnets, 2 sinking gillnets) made each year to monitor trends in fish abundance. The CPUE data for rainbow trout sampled using gillnets in 2005 to 2009 are summarized in Table 3.8, Figure 3.7 and Appendix 6.

<table>
<thead>
<tr>
<th>Year</th>
<th>n</th>
<th>CPUE (fish/hr) Floating Gillnets</th>
<th>SD</th>
<th>CPUE (fish/hr) Sinking Gillnets</th>
<th>SD</th>
<th>CPUE (fish/hr) All Nets Combined</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>4</td>
<td>6.8</td>
<td>3.4</td>
<td>6.2</td>
<td>3.4</td>
<td>6.5</td>
<td>2.3</td>
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<tr>
<td>2006</td>
<td>4</td>
<td>6.8</td>
<td>3.0</td>
<td>7.1</td>
<td>3.0</td>
<td>6.9</td>
<td>1.9</td>
</tr>
<tr>
<td>2007</td>
<td>4</td>
<td>19.1</td>
<td>1.3</td>
<td>18.0</td>
<td>1.3</td>
<td>18.6</td>
<td>2.0</td>
</tr>
<tr>
<td>2008</td>
<td>4</td>
<td>23.6</td>
<td>23.3</td>
<td>29.9</td>
<td>23.3</td>
<td>26.7</td>
<td>15.4</td>
</tr>
<tr>
<td>2009</td>
<td>4</td>
<td>16.0</td>
<td>0.0</td>
<td>26.0</td>
<td>0.0</td>
<td>21.0</td>
<td>7.6</td>
</tr>
</tbody>
</table>

Figure 3.7 Mean CPUE of floating and sinking gillnets combined, for rainbow trout in Diversion Reservoir, 2005 to 2009.
An analysis of variance test found that there were no significant differences between the floating gillnet CPUE for the 5 years of sampling. The same result was found for the sinking gillnets, despite the fact that a difference between the years seemed evident in the plotted data. These results are attributed to the small sample size (n=2 nets) when the results are examined separately by floating or sinking gillnets. However, when the data from all 4 nets are combined, the strength of the test was increased and the difference in gillnet CPUE was found to be significant for some years. The 2008 CPUE was greater than the 2005 \((p=0.047)\) and 2006 \((p=0.054)\) CPUE. The 2009 catch was not found to be significantly different from any of the previous years. If it is accepted that CPUE is in fact an indication of fish abundance, this suggests that the abundance of rainbow trout in Diversion Reservoir has been fairly stable during the sample years with the exception of 2008, where the abundance was found to be higher than 2005 and 2006.

3.2.3 Length Frequency Distribution

The length frequency distributions of rainbow and cutthroat trout sampled in Diversion Reservoir and Walker Creek \((n=33)\) in 2009 are summarized in Figure 3.8. The numerically dominant size group in the 2009 sample were the 180 mm to 190 mm component. Juvenile trout (those smaller than 180 mm) made up only a small part of the total, which is quite different from the 2008 sample where the juveniles were the dominant size categories. This suggests that there could be poor recruitment to the larger, mature size categories in 2010 which could result in a reduced number of spawning adults in the 2010 spawning escapement.

![Figure 3.8](image-url)  

**Figure 3.8** Length frequency distribution of fish sampled from Diversion Reservoir September 8-9, 2009.
3.2.4 Age

A total of 31 trout were aged using scale analysis, of which 9 were also aged using otoliths. The age determinations from otolith samples validated the age determination from the corresponding scales. The two fry that were sampled from Walker Creek were aged using the length frequency distribution for rainbow trout sampled in 2009. The ages of rainbow and cutthroat trout sampled in 2009 are summarized in Table 3.9.

<table>
<thead>
<tr>
<th>Age Group</th>
<th>0+</th>
<th>1+</th>
<th>2+</th>
<th>3+</th>
<th>4+</th>
<th>5+</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainbow (n=27)</td>
<td>2 (7%)</td>
<td>4 (15%)</td>
<td>11 (41%)</td>
<td>8 (30%)</td>
<td>2 (7%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Cutthroat (n=6)</td>
<td>0 (0%)</td>
<td>1 (17%)</td>
<td>0 (38%)</td>
<td>3 (50%)</td>
<td>2 (33%)</td>
<td>0 (0%)</td>
</tr>
</tbody>
</table>

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 (82%) of the sample.

The dominant age groups in the 2009 rainbow trout sample were 2+ and 3+ fish that together accounted for 71% of the sample. This is likely a product of 1+ and 2+ fish that were dominant in the 2008 sample. The dominant 1+ age in 2008 may in turn be a result of the very strong 0+ component that dominated the 2007 sample (Figure 3.9).

A subjective evaluation indicates that despite major fluctuations in the proportion of 0+ fry and 1+ parr between the years, the main reproductive portion of the population; the 2+ and 3+ fish, remain relatively stable. The 2+ component has ranged from 25%–41% and the 3+ component has ranged from 10% to 30% over the 5 study years.

Figure 3.9 Comparison of age structure of the rainbow trout, Diversion Reservoir, 2005 to 2009.
3.2.5 Length-Weight Regressions

The slope of the length-weight regression curve can be used to describe the condition factor of the rainbow trout that were collected with gillnets at Diversion Reservoir. A comparison of length-weight regressions from fish sampled in 2005 to 2009 show similar slopes, suggesting that the condition of the rainbow trout appears to have varied little between the 5 years of sampling (Figure 3.10).

![Length-Weight Relationship 2005-2009](image)

**Figure 3.10** Comparison of the length-weight regressions for Diversion Reservoir rainbow trout lentic samples, 2005 to 2009.

3.2.6 Condition Factor

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

\[
K = \frac{w}{l^3}
\]

Equation 1

where:

- \( K \) = Fulton’s condition factor
- \( w \) = wet weight in grams \( \times 10^5 \)
- \( l \) = 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 reflect 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 2009 was 1.03, SD=0.11 which was the lowest value observed in the 5 years of sampling (Table 3.10). Nevertheless, this was still within the expected normal range of 1.00 to 1.15 for rainbow trout from lakes on Vancouver Island (Ptolemy, pers. comm). Despite the low value in 2009, ANOVA tests found that the only significant difference from previous years was that 2009 was less than the 2006 ($p=0.05$).

Table 3.10 Summary of Fulton’s condition factor values (K) for Diversion Reservoir rainbow trout sampled in 2005 to 2009.

<table>
<thead>
<tr>
<th>Sample Date</th>
<th>N</th>
<th>K</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diversion Reservoir 2005</td>
<td>55</td>
<td>1.10</td>
<td>0.11</td>
</tr>
<tr>
<td>Diversion Reservoir 2006</td>
<td>81</td>
<td>1.10</td>
<td>0.12</td>
</tr>
<tr>
<td>Diversion Reservoir 2007</td>
<td>38</td>
<td>1.07</td>
<td>0.14</td>
</tr>
<tr>
<td>Diversion Reservoir 2008</td>
<td>46</td>
<td>1.08</td>
<td>0.07</td>
</tr>
<tr>
<td>Diversion Reservoir 2009</td>
<td>25</td>
<td>1.03</td>
<td>0.11</td>
</tr>
</tbody>
</table>

The mean K of Diversion Reservoir cutthroat trout sampled in 2009 was 0.93, SD=0.05 (Table 3.11). Similar to rainbow trout, this was lowest value observed in the 5 years of sampling. Unlike rainbow trout, this was slightly below the expected normal range of 0.95 to 1.05 for cutthroat trout from lakes on Vancouver Island (Ptolemy, pers. comm.). ANOVA tests found that despite the low value, the only statistically significant difference from previous years was that 2009 was less than 2006 ($p=0.03$). The distribution of K frequencies for rainbow and cutthroat trout is displayed in Figure 3.11.

Table 3.11 Summary of Fulton’s condition factor values (K) for Diversion Reservoir cutthroat trout sampled in 2005 to 2009.

<table>
<thead>
<tr>
<th>Sample Date</th>
<th>N</th>
<th>K</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diversion Reservoir 2005</td>
<td>7</td>
<td>1.03</td>
<td>0.08</td>
</tr>
<tr>
<td>Diversion Reservoir 2006</td>
<td>4</td>
<td>1.11</td>
<td>0.13</td>
</tr>
<tr>
<td>Diversion Reservoir 2007</td>
<td>10</td>
<td>1.00</td>
<td>0.05</td>
</tr>
<tr>
<td>Diversion Reservoir 2008</td>
<td>8</td>
<td>1.00</td>
<td>0.07</td>
</tr>
<tr>
<td>Diversion Reservoir 2009</td>
<td>6</td>
<td>0.93</td>
<td>0.05</td>
</tr>
</tbody>
</table>

The mean of all individual K-values for each sample year are plotted in Figure 3.12. Despite the apparent variation between years and a declining trend for both species, the differences between most years were not statistically significant. The exception for both species is that the mean annual K-value for 2009 was significantly less than 2006.
Figure 3.11 Frequency distribution of condition factor K-values for lentic rainbow and cutthroat trout sampled from Diversion Reservoir, September 8-9, 2009.

Figure 3.12 Mean Fulton’s Condition Factor of rainbow trout and cutthroat trout sampled at Diversion Reservoir during September 2005 to 2009.
4.0 Five-Year Data Trends

Graphic summaries of the key indicators used to assess aquatic productivity during the 5 years of study are presented in Figures 4.1 to 4.5.

**Figure 4.1** Annual mean Chlorophyll $\alpha$ levels

**Figure 4.2** Annual mean Secchi depth

**Figure 4.3** Annual mean phosphorous levels
5.0 Recommendations

- From 2005 to 2009 Diversion Reservoir was clinograde during September. Fish were to some degree, sandwiched between an anoxic hypolimnion and a stress-inducing epilimnion with high surface temperatures. Although the likelihood of a late-summer draw-down of the reservoir may be unlikely, recommendations to avoid potential stress and/or fish mortality have been made in the annual reports from this study if such an event was to take place. A limited draw-down event occurred in 2008, but was terminated prior to having a significant impact on fish and fish habitat. Establishing a temperature/dissolved oxygen profile at Limnology Stn. 1 prior to future draw-down events would provide a basis for assessing the potential impacts to fish during similar events in the future.

- Maintaining the reservoir level as close to 378.0 m as possible during the sampling window in mid-September 2009 will reduce sampling variability between years.

- The study design for this project calls for a “treatment” year during which the Diversion Reservoir is drawn down during the summer growth period below EL 376 m, thereby exceeding the lower limit of the present water license. However, the terms of reference for this study do not precisely identify the date, duration and target water level of this treatment event. Advanced identification of these details will assist the approvals and scheduling process that will be upcoming.
6.0 References


7.0 Personal Communications

Dodd I. Biologist. BC Hydro, Campbell River, BC.

Ptolemy R. Fish biologist, Aquatic Ecosystems Science Section, BC Ministry of Environment, Victoria, BC.
# Appendix 1  Diversion Reservoir Field Data - Temperature - Dissolved Oxygen Profile 2009

## Water Temperature and Dissolved Oxygen Profiles on September 9, 2009

<table>
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<th>Temp</th>
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Bottom
Appendix 2  Diversion Reservoir Field Data - Phosphorous 2009

Results of lab analysis of phosphorous levels at four sites in Diversion Reservoir on September 9, 2009. Replicate samples (A and B) were taken at each sampling location.

<table>
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<th>Site</th>
<th>TP (µg/l)</th>
<th>DTP (µg/l)</th>
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</tr>
<tr>
<td>Limnology Station 1B</td>
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<td>7.6</td>
</tr>
<tr>
<td>Limnology Station 2A</td>
<td>2.4</td>
<td>9.3</td>
</tr>
<tr>
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<tr>
<td>Gillnet Site 1B</td>
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</tr>
<tr>
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</tr>
<tr>
<td>Gillnet Site 2B</td>
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</table>
Appendix 3  Diversion Reservoir Field Data - Chlorophyll

2009 Chlorophyll

<table>
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<tr>
<th>Site</th>
<th>Date</th>
<th>Time</th>
<th>Chlorophyll A</th>
<th>Chlorophyll B</th>
<th>Chlorophyll C</th>
<th>Total Chlorophyll</th>
<th>Phaeophyton</th>
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<tr>
<td>Limno 1A</td>
<td>09/09/2009</td>
<td>14:45</td>
<td>17.8</td>
<td>26.8</td>
<td>42.5</td>
<td>87.1</td>
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1. Chlorophyll units are mg/m$^3$

Mean phytoplankton levels from 8 sample sites at Diversion Reservoir in September 2005 to 2009.

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<td>Diversion Reservoir shore near mouth of Walker Creek</td>
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<td>9377</td>
<td>09/09/09</td>
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<tr>
<td>9378</td>
<td>09/09/09</td>
<td>Site 1, MT 1, Fish #33, trout fry, 49mm, 1.0g</td>
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<td>9379</td>
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<td>Diversion Reservoir looking north from boat launch in W basin</td>
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## Appendix 6  Summary of 2005 to 2009 Gillnet Effort and Catch Data

Catch, effort and CPUE summary of rainbow trout catch in 4 variable-mesh gillnets in Diversion Reservoir, 2005 to 2009.

<table>
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<tr>
<th></th>
<th>FGN1</th>
<th>FGN2</th>
<th>SGN1</th>
<th>SGN2</th>
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<td>2005</td>
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<tr>
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<td>7</td>
<td>23</td>
<td>6</td>
<td>19</td>
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<tr>
<td>Effort (net-hours)</td>
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<td>2.50</td>
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<td>9.2</td>
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<td>7.6</td>
<td>6.5</td>
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<td>39</td>
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<td>Effort (net-hours)</td>
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<td>4.40</td>
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<tr>
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<td>8.9</td>
<td>8.0</td>
<td>6.2</td>
<td>6.9</td>
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<td></td>
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<td>5</td>
<td>24</td>
<td>3</td>
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<tr>
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<td>24.0</td>
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<td>Effort (net-hours)</td>
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<td>40.0</td>
<td>38.0</td>
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<td>5</td>
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<td>CPUE (rainbow/hr)</td>
<td>28</td>
<td>22</td>
<td>32</td>
<td>20</td>
<td>24.8</td>
</tr>
</tbody>
</table>

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.

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mjl  
page A-8
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.