Stave River Project Water Use Plan

Pelagic Monitor and Littoral Productivity Assessment

Implementation Year 7

Reference: SFLMON#1
Reference: SFLMON#2

Report on the 2011 Pelagic Monitor and Littoral Productivity Assessment

Study Period: 2011

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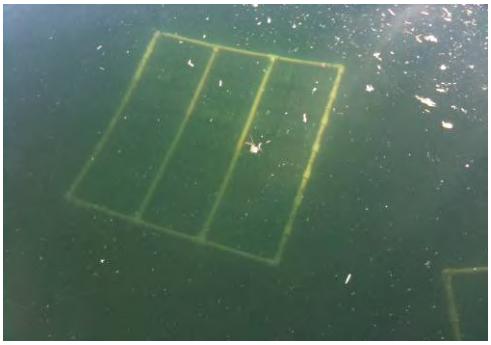
July 2012

STAVE RIVER WATER USE PLANNING

Report on the 2011 Pelagic Monitor and Littoral Primary Production Monitor

[StaveLimnoNess2009–2012; Amendment #4]



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1. Introduction

This report summarizes all components of a fresh water productivity monitoring and data collection program undertaken in 2011 on Stave and Hayward reservoirs as part of the Stave WUP Monitor. The 2011 monitoring program was the seventh year of the second phase of a comprehensive pelagic and littoral monitoring program resulting from BC Hydro's Stave River Water Use Planning process. Phase 2 monitoring is defined by BC Hydro as a ten-year base level sampling program (to 2014) or until the next Water Use Plan review process. The more intensive Phase 1 monitoring was conducted from 2000 to 2003 (Stockner and Beer, 2004; Beer 2004).

The objectives for both the littoral and pelagic components of the monitoring program are to collect the data necessary to test the impacts of reservoir operations on the productivity of Stave Reservoir (fluctuating water level) and Hayward Reservoir (comparatively stable water level). BC Hydro has identified four key management questions and several hypotheses to be tested against the collected data for each program. Each of the four pelagic and littoral monitoring questions is stated below and the null hypotheses for each program are provided in Appendix 1 (BC Hydro 2005).

Pelagic Management Questions:

1. **What is the current level of pelagic productivity in each reservoir, and how does it vary seasonally and annually as a result of climatic, physical and biological processes, including the effect of reservoir fluctuation?** This information is required to identify the key determinants that currently govern/constrain the level of productivity in each reservoir. Once these environmental factors have been identified, an assessment can be carried out to determine whether they are susceptible to change given alternative reservoir management strategies. Environmental factors that are susceptible to change are then monitored through time in conjunction with the productivity indicator variable (in this case primary productivity). This information sets up the foundation for the next management question.
2. **If changes in pelagic productivity are detected through time, can they be attributed to changes in reservoir operations as stipulated in the WUP, or are they the result of change to some other environmental factor?** This information allows one to clearly determine whether a causal link between reservoir operations and reservoir pelagic productivity exists, and if so, to describe its nature for use in future WUP processes.
3. **To what extent would reservoir operations have to change to 1) illicit a pelagic productivity response; and 2) improve or worsen the current state of pelagic productivity?**
4. **Given the answers to the management questions above, to what extent does Combo 6 operating alternative improve reservoir productivity in pelagic waters, and what can be done to make improvements, whether they be operations based or not?**

Littoral Management Questions:

1. **What is the current level of littoral productivity in each reservoir, and how does it vary seasonally and annually as a result of climatic, physical and biological processes, including the effect of reservoir fluctuation?** This information is required to identify the key determinants that currently govern/constrain the littoral productivity in each reservoir. Once these environmental factors have been identified, an assessment can be carried out to determine whether they are susceptible to change given alternative reservoir management strategies. Environmental factors that are susceptible to change are then monitored through time in conjunction with the productivity indicator variable (in this case primary productivity). This information sets up the foundation for the next management question.
2. **If changes in littoral productivity are detected through time, can they be attributed to changes in reservoir operations as stipulated in the WUP, or are they the result of change to some other environmental factor?** This information allows one to determine whether there is a significant, causal link between reservoir operations and reservoir littoral productivity, and if so, describe its nature for use in future WUP processes, particularly in the context of the ELZ performance measure (see next question). Implicit in this question is that gains or losses in primary productivity reflect gains or losses in overall fish production.
3. A performance measure was created during the WUP process so as to predict potential changes in littoral productivity based on a simple conceptual model. The Effective Littoral Zone (ELZ) performance measure was used extensively in the WUP decision making process, but its validity is unknown. **Is the ELZ performance measure accurate and precise, and if not, what other environmental factors should be included (if any) to improve its reliability?** The ELZ performance measure is purely a conceptual construct at this stage. Because decisions were made based on the values of this performance measure, it is imperative that it be validated in terms of its accuracy, precision, and reliability. Because littoral productivity is affected by reservoir operations elsewhere in the province, the ELZ tool may prove useful in other WUPs. Its transferability to other reservoirs should also be investigated.
4. **To what extent would reservoir operations have to change to 1) illicit a littoral productivity response, and 2) improve/worsen the current littoral and overall productivity levels?**

This report discusses both the littoral and the pelagic components of the Phase 2 data collection program, as defined by BC Hydro, and specifically addresses the activities conducted in 2011, including details of field sampling and laboratory programs, and summaries of both the littoral and pelagic components of the 2011 sampling season. Some relatively simple multiple-year summaries are also provided. While pelagic and littoral components of the monitoring program are considered separately in the terms of reference provided by BC Hydro, both components are presented together in this report.

Ness Environmental Sciences (Ness) is the project manager for Phase 2 of the monitoring and data collection program (BC Hydro contract StaveLimnoNess2009-2012; Amendment #4). Ness has experience in the practical application of both littoral and pelagic research components of the study, including study design, sampling, and laboratory and data analysis and reporting. Ness has over a decade of site-specific

expertise conducting littoral productivity assessments and nutrient sampling on Stave and Hayward reservoirs, as well as experience conducting ^{14}C incubations and estimates of pelagic productivity. Ness conducted all field components of Phase 1 with BC Hydro and contributed significantly to the preliminary data analysis as part of a Master's thesis at UBC (Beer, 2004). Development of the ELZ model by BC Hydro will rely on both Phase 1 and Phase 2 data. Data from phase 1 and phase 2 is currently under review by BC Hydro.

Ness has collaborated with Eco-logic Ltd. to act as senior scientific advisor on the monitoring program by providing the limnological expertise of Dr. John Stockner who has over 35 years of research experience. Eco-logic has extensive expertise in nutrient-poor ecosystems and in the methods of ^{14}C analysis. Dr. Stockner has acted as an advisor throughout the 2011 sampling season, conducted phytoplankton analyses and aided in the preparation of this report.

In 2011, Ness was able to use a BC Hydro boat to conduct all pelagic sampling, while much of the littoral program utilized a smaller vessel provided by Greenbank Environmental. Greenbank Environmental provided the boat operator and field assistance where needed.

2. Background

Stave Reservoir, created in the 1920s with the construction of Stave Falls dam, flooded nearly 2000 ha of adjacent lowland and raised the original lake level by 12 m to a maximum depth of 101 m above sea level (a.s.l.) (Jackson, 1994). The reservoir is 25 km long and covers a surface area of nearly 60 km^2. Approximately half of the upper basin of Stave Reservoir was originally Stave Lake, while the lower basin was formed when the existing river and surrounding riparian habitat was flooded. As a result Stave Reservoir is characterized by both lake and riverine characteristics of sedimentation, nutrient dynamics and water retention.

Operating as a hydroelectric storage facility, Stave Reservoir typically operates on a dual cycle of drawdown (i.e. partially drained twice per year). Traditionally this has meant water levels in Stave Reservoir are maintained near full pool (82.1 m a.s.l.) during the summer to accommodate recreational use and during the winter when energy demands are the highest (Figures 2.1 and 2.2). In the spring and fall, reservoir levels are drawn down by as much as 9 m (73.0 m a.s.l.) to prepare for inflows from fall and winter rainfall and spring snowmelt. Since 2000, the Stave Reservoir operating regime has been modified to follow guidelines set by the Stave River WUP Combo 6, which suggests that:

> "From 15 May to 7 September, the preferred elevation of Stave Lake Reservoir for recreational activities is between 80.0 and 81.5 m. During this period, the level of Stave Lake Reservoir will be targeted at 76 m or higher, and will be targeted between 80.0 and 81.5 m for a minimum of 53 days. In the case of conflict between recreational targets and flow management requirements for fish downstream of Ruskin, the flow management requirements for fish shall take precedence. In the event of high inflow into Stave Lake Reservoir with the lake level above 81.5 m, the Stave Falls generating plant will be run at maximum possible to draw the reservoir down below 81.5 m. Spilling at the Blind Slough Dam will be initiated when the level of Stave Lake Reservoir reaches 82.1 m. Recreational interests at Stave Lake Reservoir indicated that the preferred water levels in the reservoir for their needs were above 80 m. The recreational season was defined as occurring between Victoria Day and Labour Day" (BC Hydro, 2003).

Hayward Reservoir, situated approximately 5.5 km south of Stave Falls dam, lies in a relatively small watershed and is only 5 km long. Hayward Reservoir, built in the 1930s with the completion of Ruskin dam, is operated as a run-of-river facility whose main purpose is to control flow down stream. Consequently, little water is impounded by this system and water levels typically remain within a meter of mean surface water elevation. The normal operating range for Hayward Reservoir is between 41 m and 43 m a.s.l (Jackson, 1994) (Figure 2.3 and 2.4). In the last few years, Hayward reservoir has undergone drawdown during freshet of variable lengths in order for seismic upgrading, which has impacted data collection by altering the typical operating levels and in so measures of production, nutrients and plankton. A summary of the physical attributes of Stave and Hayward Reservoirs is provided in Table 2.1, below (Beer, 2004).

Figures 2.1 and 2.2: Stave Reservoir at full pool (left) and during drawdown (right)

Figures 2.3 and 2.4: Hayward Reservoir at full pool (left) and at drawdown (right)

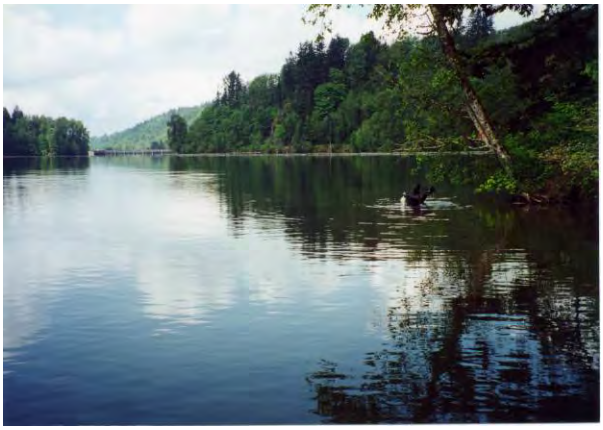


Table 2.1: Physical Attributes of Stave and Hayward Reservoirs

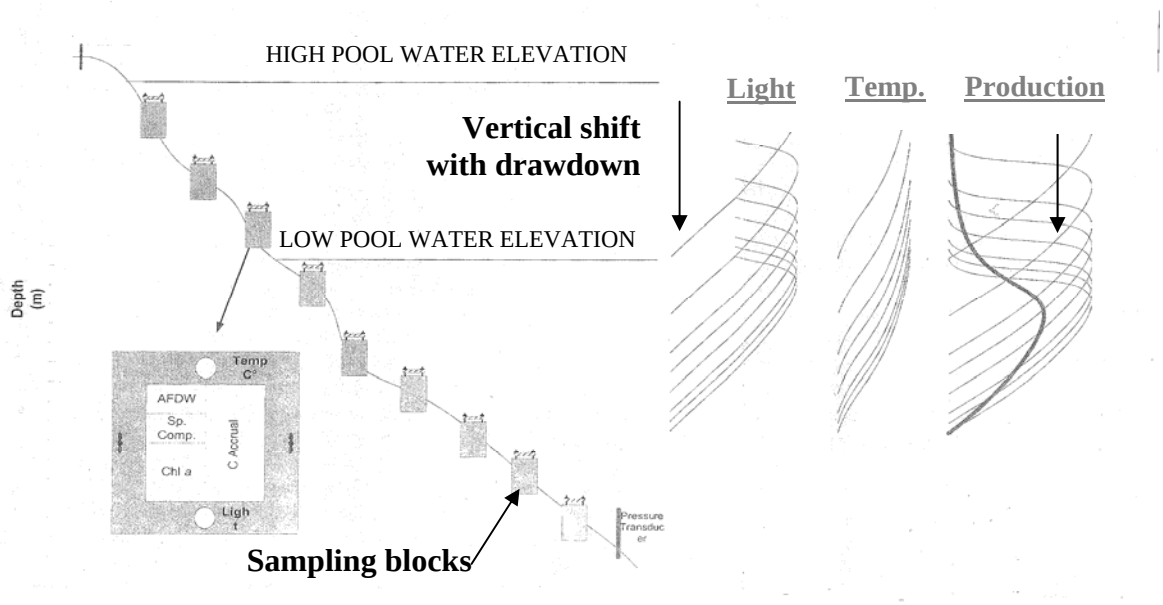
Variable	Stave Reservoir	Hayward Reservoir
Surface Area (km^2)	58	2.9
Volume (m^3x10^6)	2,040	42
Mean Depth (m)	35	14.5
Length (km)	25	5.6
Drainage Basin (km^2)	1,170	953
Max/Min water elevation (m a.s.l.)	82.1-73.0	42.9-33.0
Rainfall (cm)	230	230
Average Discharge (m^3/s)	130	145
Epilimnion Flush (years)	0.22	0.005

Water level fluctuation is the fundamental difference between natural lake and reservoir ecosystems. In large hydroelectric reservoirs, water level fluctuations are typically much more pronounced and frequently longer in duration than what is common in natural lakes (Gasith and Gafny, 1990) This study has been designed to assess concerns identified by

BC Hydro's Water Use Planning (WUP) process regarding the impact of water level fluctuation on reservoir function and in turn impacts to fish health.

In natural ecosystems, organisms are commonly adapted to tolerate moderate changes in water level; consequently wetlands, riparian areas and near-shore forests associated with littoral ecosystems are commonly thought of as rich, ecologically diverse communities that are critical components of fish and wildlife habitats (Carr and Moody, 2000). In reservoir ecosystems, littoral communities are frequently affected by exaggerated water level fluctuation and the impacts of these fluctuations are directly related to their amplitude, frequency, and duration (Thornton et al., 1990). The amplitude of the fluctuation determines the area that is affected, while the duration and frequency of occurrence determines the response time available to littoral organisms and biota. Godshalk and Barko (1985) reported that the impact of water level fluctuation may be beneficial or detrimental depending on the duration and the amplitude of the event. Generally it is established that brief periods of water level drawdown increases microhabitat complexity and species diversity (Gasith and Gafny, 1990). However, extreme, frequent fluctuations tend to stress aquatic organisms and plants, and in most cases result in a reduction in growth and productivity. Figure 2.5 illustrates how environmental variables, such as light and temperature, shift with fluctuating water levels and in turn may shift biological production.

Figure 2.5: Potential Impact of Water Level Fluctuation (Beer 2004)



The Phase 2 WUP pelagic and littoral monitoring programs commenced in 2005. As the Phase 1 monitoring program was completed in 2003, there was a need to re-establish the fixed monitoring locations for the littoral transects on both Stave and Hayward reservoirs. In July 2005 the same four littoral sampling transects from Phase 1 were re-established (three sites on Stave and one site on Hayward) using the concrete blocks that were left in place following the completion of the Phase 1 monitoring. Figure 2.6 indicates these transect locations along with their coordinates (Table 2.2).

The primary objective of the 3 transects on Stave and 1 transect on Hayward is to span the littoral zone and provide an estimate of the littoral zone productivity of each reservoir.

Thus it is the area under the productivity curve approximated by each transect's complement of stations that provides this estimate. In a statistical sense on Hayward this implies that each station is a separate and specific measurement (i.e. N=1). For Stave, where there are three transects, it is arguable that for each station N=3, but that is likely only valid if the variability in littoral zone productivity at different locations around the reservoir is low.

Figure 2.6: Transect Locations on Stave and Hayward Reservoirs (Beer 2004)

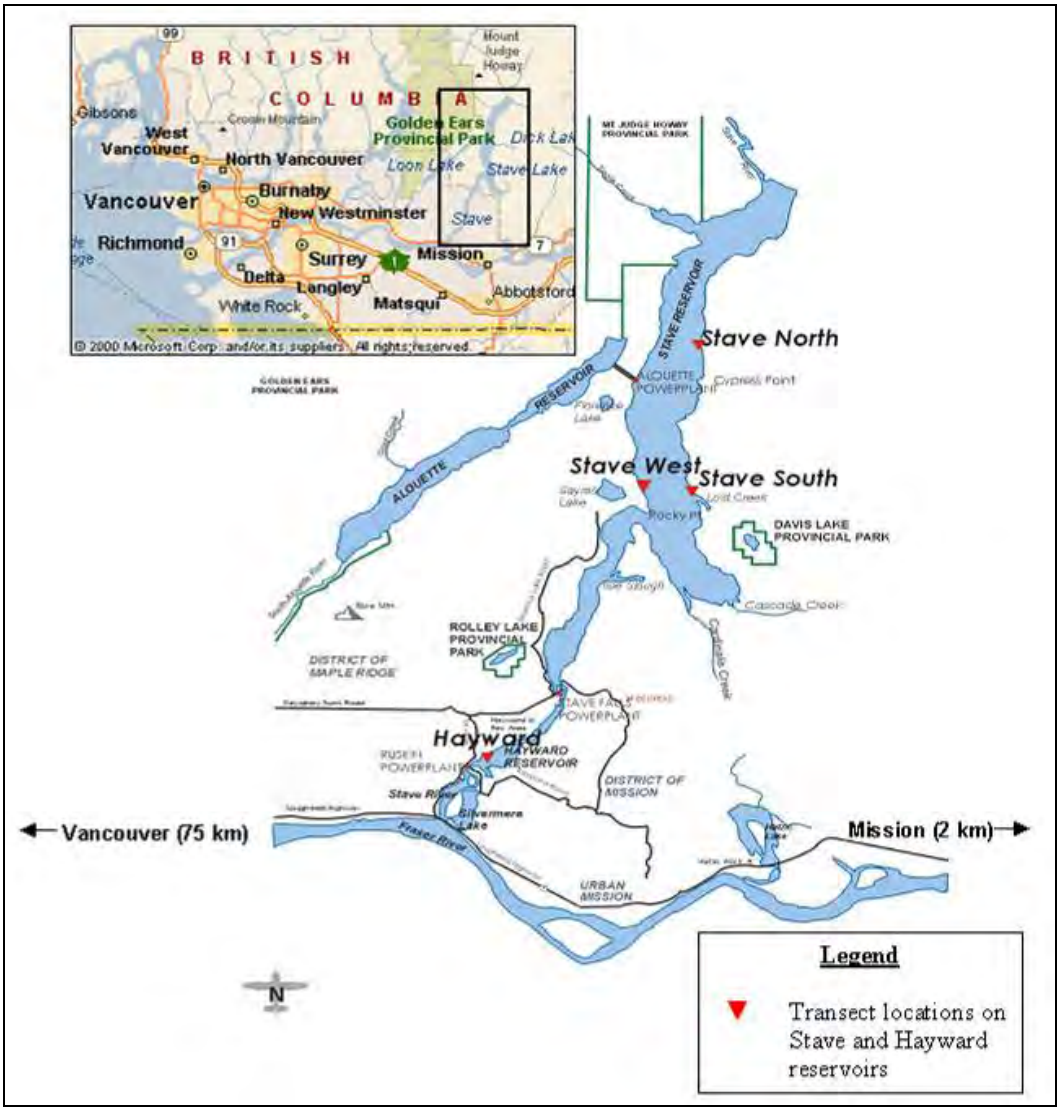


Table 2.2: GPS Coordinates of Transect Locations

Site	UTM Easting	UTM Northing
Stave North	552870	5469570
Stave West	549957	5464097
Stave South	552255	5465284
Hayward	544767	5450607

Each of the three sampling transects on Stave (Stave North, Stave West and Stave South) are comprised of 10 sampling stations, with approximately 2 metres elevation separating each station. Table 2.3 provides depths of each plate in meters above sea level (m a. s. l.) Hayward is comprised of 8 sampling stations. Each station includes a large concrete block (Figure 2.7) to act as an anchor for the sampling plate. The deepest 4 stations at each site have sampling plates suspended approximately 1 metre above the concrete block by buoyant sampling trays (Figure 2.8). This approach avoids having the sampling plates impacted by loose sediment at these depths. The upper stations at each site have the sampling plates attached directly to the concrete blocks by stainless steel studs (Figure 2.9). These sampling transects were used to conduct littoral sampling form 2005 through 2010, at which time it was assessed by BC Hydro and Ness that sufficient biomass data had been collected and the remaining years of the littoral monitor would focus on answering outstanding questions from the monitor.

Pelagic sampling in Stave reservoir is conducted mid-reservoir between the south and west transect. On Hayward, pelagic sampling is conducted mid-reservoir near to the sampling transect and the log booms at the south end of the reservoir.

Table 2.3 Plate Depths

Plate	Hayward (m a.s.l)	Stave (m a.s.l)		
		North	South	West
1	42.12	80.08	79.14	79.45
2	40.30	77.84	77.84	77.84
3	38.78	76.48	76.32	76.32
4	36.34	74.35	74.35	73.74
5	34.52	72.52	72.37	71.92
6	33.30	70.70	71.76	70.09
7	30.87	69.33	69.48	67.66
8	28.90	67.36	67.66	65.84
9		65.53	65.84	63.71
10		63.10	64.92	61.88

Figure 2.7 Concrete Littoral Sampling Block with Plate Attached (pre-2011)

Figure 2.8: Littoral Sampling Apparatus (Cement Block and Buoyant Tray) (Pre-2011)

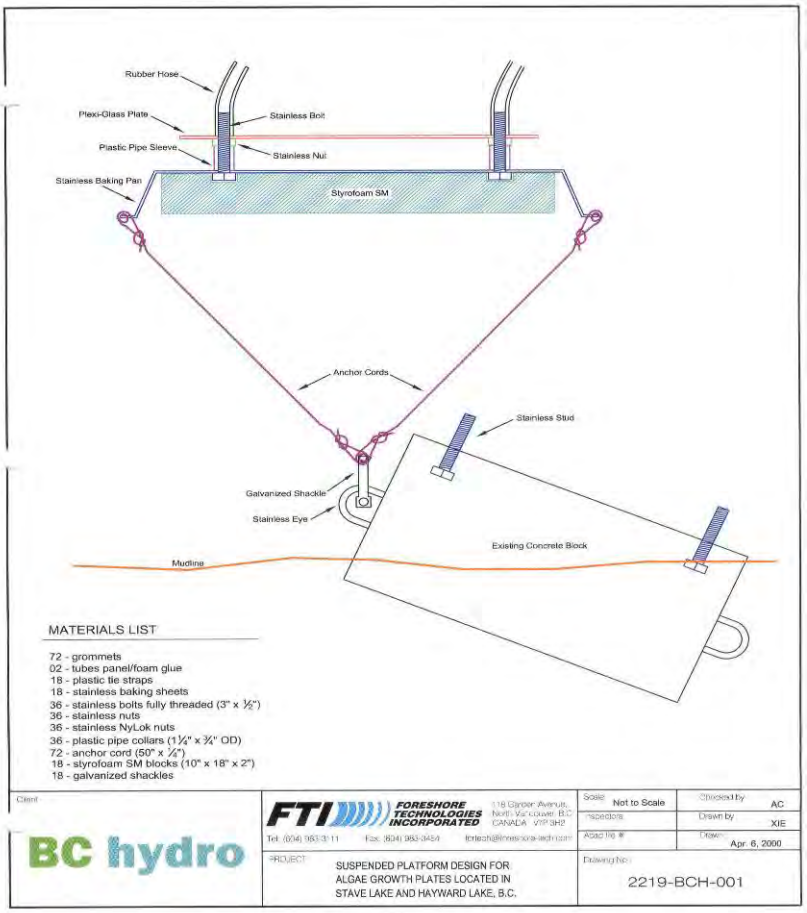
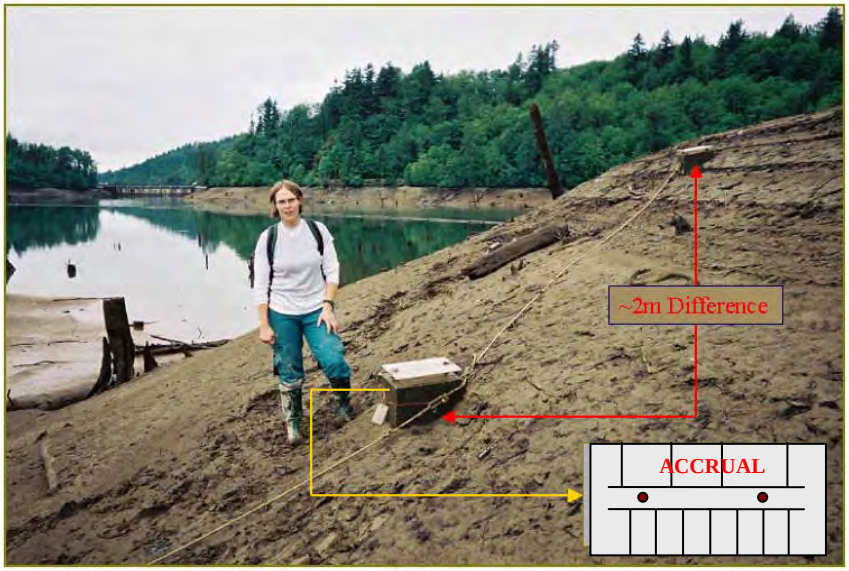


Figure 2.9: Littoral Sampling Design (Pre-2011)



3. Pelagic and Littoral Monitoring Programs for 2011

As part of the pelagic monitoring program, nutrient and plankton (pico, phyto and zooplankton) analyses are conducted in each year. As an indicator of overall productivity, pelagic primary productivity analyses using ^{14}C incubations were to be conducted every three years. In 2010 a decision was made to increase pelagic carbon estimates of primary production to every year, except for the final year in 2014. Four incubations were conducted in 2011 with runs scheduled for 2012, and 2013.

The littoral monitoring program measured periphyton biomass from artificial substrata from which primary productivity was estimated from 2001- 2003 (Phase 1) and from 2005 - 2010. As part of Phase 2, direct measures of littoral primary productivity using ^{14}C inoculation and incubation were conducted from 2006 to 2009. These direct estimates of primary production were found to be extremely variable and of limited value; therefore measurements were discontinued at the start of 2010. In 2011 the focus of the littoral program was shifted from estimating primary production from ash free dry weight measurements to assessing the impacts of dewatering in an intensive program where colonized plates were exposed for periods of zero days to 40 days.

3.1 Changes to the Littoral Productivity Monitor

Since 2001, the littoral monitoring program has measured periphyton biomass collected from artificial substrata from transects located in the near-shore areas of Stave and Hayward reservoirs as a surrogate from which to estimate primary productivity (Figures 2.7-2.9). The primary production data collected to date has been used in an attempt to validate an Effective Littoral Zone performance measure that was a conceptual model developed as part of the WUP to assess the consequence of various operating scenarios at Stave Reservoir. It was recommended at the time of the WUP that the ELZ model be validated through a monitoring program and refined as necessary for use in future trade-off analyses.

The conceptual ELZ model proved to be successful in mimicking the general pattern of periphyton growth as a function of water depth, regardless of whether water surface elevation was stable or highly variable. The model however, was not successful in characterizing the loss of periphyton biomass between scenarios, the intended use of the performance measure. This was most evident when comparing seasonal patterns of growth between stable and variable reservoir conditions, suggesting that the model is incomplete in its present form and requires some modification. Rather than continue with the ‘carbon layering’ approach adopted in the original form of the ELZ model, the ELZ model was reworked to explicitly incorporate a dewatering-based periphyton mortality component in addition to the growth parameter. The biomass data collected to date is sufficient to estimate growth (in terms of accumulated periphyton biomass) which includes the effects of light attenuation with water depth. However, there is no information on mortality, whether it is related to time dewatered or the effect of inadequate light levels to sustain growth. A literature review found few pertinent studies on either modes of mortality and its subsequent effects on periphyton production. As a result, a change to the monitor’s original terms was implemented in 2011, in order to

empirically collect the needed data to refine the ELZ model and improve its overall utility as a performance measure (BC Hydro, 2011 Draft).

A summary of the monitoring programs is provided in Table 3.1.

Table 3.1: Summary of 2011 Monitoring Programs

Pelagic Monitoring Program	Rationale	Littoral Monitoring Program	Rationale
• Sampling takes place on approximately 5-week intervals from March to November	• Coverage of photosynthetically active growth period	• As in Phase 1, sampling takes place on approximately 5-week intervals from March to November	• Coverage of photosynthetically active growth period • Discontinued spring of 2010
• 1 sample site on Stave, and 1 on Hayward, plus additional sampling at Alouette outfall when generating.		• 3 sample sites on Stave and 1 on Hayward (4 transects in total)	• Discontinued spring of 2010
• Nutrients including: total and dissolved phosphorous, total nitrate, and • chlorophyll-a concentrations	• characterizes nutrient dynamics of each reservoir using a composite water sample from 1,3, and 5 m. • index of photosynthesis of plankton >0.45 µm taken from a composite 1,3,5 m water sample	• Periphyton sampling from artificial substrata located at all 4 transects, to provide estimates of primary production (ash-free dry mass (AFDM) accrual)	• AFDM - measures accrual of organic biomass for periphyton fractions above 0.45 µm • Discontinued spring of 2010
• phytoplankton analyses	• estimates changes in density and biovolume of phytoplankton [pico, nano and micro size range (0.2-200 µm)] using a composite 1,3, 5 m sample	• ^{14}C incubation estimates of primary production are conducted each sampling trip from one plate at both Hayward and Stave North. The plate to be sampled is determined randomly.	• Discontinued at start of 2010 sampling season
• zooplankton analyses	• characterizes species and estimates abundance and biomass in the 200 µm- 2 mm size range	• Periphyton colonized on artificial substarata were removed from the water and left in a dewatered state on log booms for a range of time from no days to 40 days.	• Quantify the impact of dewatering on periphytic growth in a reservoir environment. • Completed on Stave reservoir at the log booms near the boat launch

• ^{14}C incubation estimates of primary production annually since 2010	• measures active photosynthesis of plankton in the 0.2-2.0 µm (pico), 2-20 µm (nano) and > 20 µm size range by estimating the difference in carbon uptake under light (photosynthesis) and dark conditions.		
• light intensity and temperature profiles	• a record of the physical conditions of the system on the day of sampling • may be extrapolated as an indicator of sampling period conditions using other sources of data.		
• other data: solar irradiance (Metro Vancouver air monitoring network); temperature (BC Hydro, Environment Canada, Metro Vancouver); reservoir levels (BC Hydro)			

Hard copies of all data are kept in field and laboratory notebooks. Excel spreadsheets are used to electronically store all data collected, along with some of the other data noted in Table 3.1.

The 2011 pelagic monitoring program began in March 2011 and continued in a similar manner and schedule (approximately 5 week interval) as previous years. The littoral program started in June of 2011 and continued through to October 2011 with sampling occurring at various times on a more intensive schedule than the previous sampling program. Field sampling dates for the pelagic sampling program and associated reservoir levels for 2011 are shown in Table 3.2.

Table 3.2: 2011 Pelagic Field Sampling Schedule and Reservoir Levels

Date	**Hayward Reservoir Level** (at noon, PST)	**Stave Reservoir Level** (at noon, PST)
March 26, 2011	41.14	77.14
April 29, 2011	41.0	77.0
June 6, 2011	34.6	79.2
July 9, 2011	41.16	81.0
August 18 2011	41.25	80.45
September 17, 2011	41.25	79.03
October 21, 2011	40.95	77.96
November 21, 2011	41.15	76.58

3.2 Littoral Monitoring Program Methods and Study Design

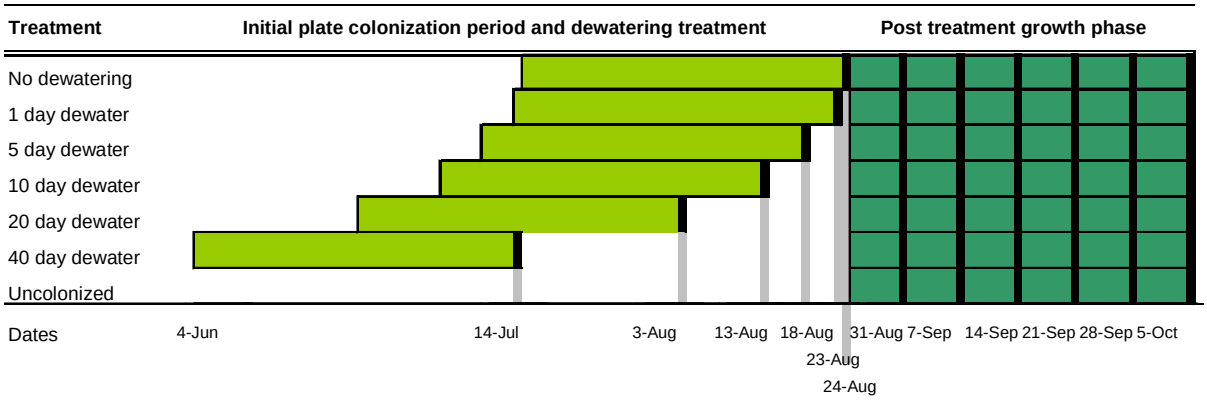
The intensive littoral dewatering study tracked changes in periphyton biomass (AFDW) over time to estimate growth rate over a 40 day period after undergoing dewatering treatments of various durations. Seven dewatering treatments were examined in the study:

a) Uninterrupted growth (no dewatering)
b) 1 day dewatering
c) 5 days dewatering
d) 10 days dewatering
e) 20 days dewatering
f) 40 days dewatering
g) Colonization of a new plate (indefinite dewatering)

Prior to each growth trial, the plates were submerged to a depth of 2 m and allowed to colonize and saturate the growing surface for a period of 40 days. Six grids with 7 sampling plates on each were suspended from log booms near to Stave dam, south east of the Stave Lake boat launch. After the colonization period, the growth plates were brought to the surface to mimic conditions of drawdown and dewatering. Growth plates were transported by boat and secured to log booms near the sampling area where they were left exposed to the prevailing environmental conditions of the site, but near to the surface of the water. Prior to the start of each dewatering treatment, biomass was measured to determine how similar growth was during the initial phase of growth and to serve as a base line to estimate the portion of biomass that survived the dewatering treatment. At the completion of the dewatering phase, all growth plates were returned to the initial colonization site and re-submerged to start a second phase of growth. To track the rate of growth during the second phase of growth, biomass was measured every 7 days over another 40 day period (six weeks).

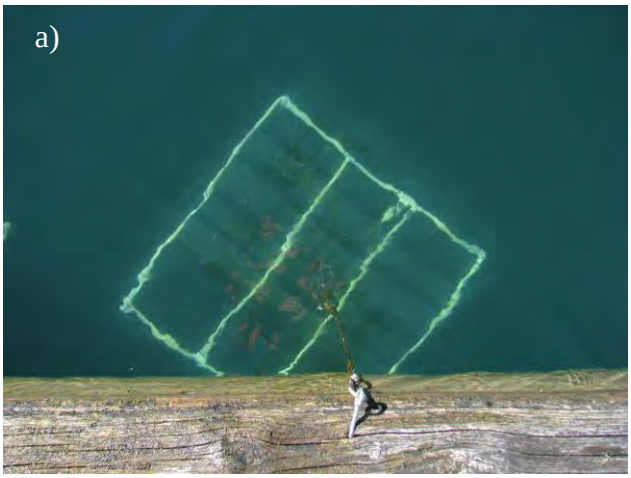
Figure 3.1 shows a schematic diagram where light green bars indicate the colonization period of 40 days and the dark green bars indicate the second growth phase. White areas between bars indicate the various dewatering treatments. The grey vertical lines indicate the timing of the study and the dark green bars and black vertical lines indicate when biomass measurements were taken (phase 2).

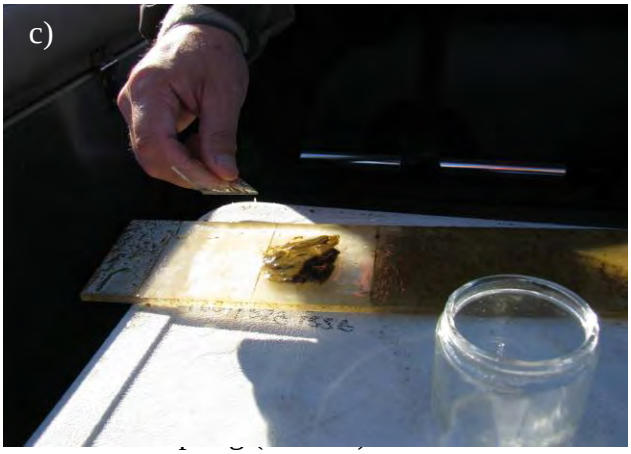
Figure 3.1 Schematic and Schedule of Intensive Littoral Dewatering Study



For this study, it was assumed that after 40 days periphyton biomass stabilizes as growth and mortality become similar to one another (pers. Comm. J. Stockner). Starting dates for the 40 day colonization period were staggered so that all growth plates finished the treatment phase at the same time. It is hypothesized by BC Hydro that by overlapping the growth curves and comparing the starting biomass between various dewatering periods to the uninterrupted growth treatment, that it is possible to infer the proportion of live biomass that survived each dewatering treatment, thus avoiding the need for expensive laboratory analysis. From these estimates, a relationship between periphyton survival and duration of a dewatering event can be obtained, which in turn can be used to estimate survival half-life through regression analysis (BC Hydro, 2011 Draft). Figure 3.2 shows images of the submerged growth plate grids, dewatering and biomass sampling.

Figure 3.2: Littoral Sampling Photos





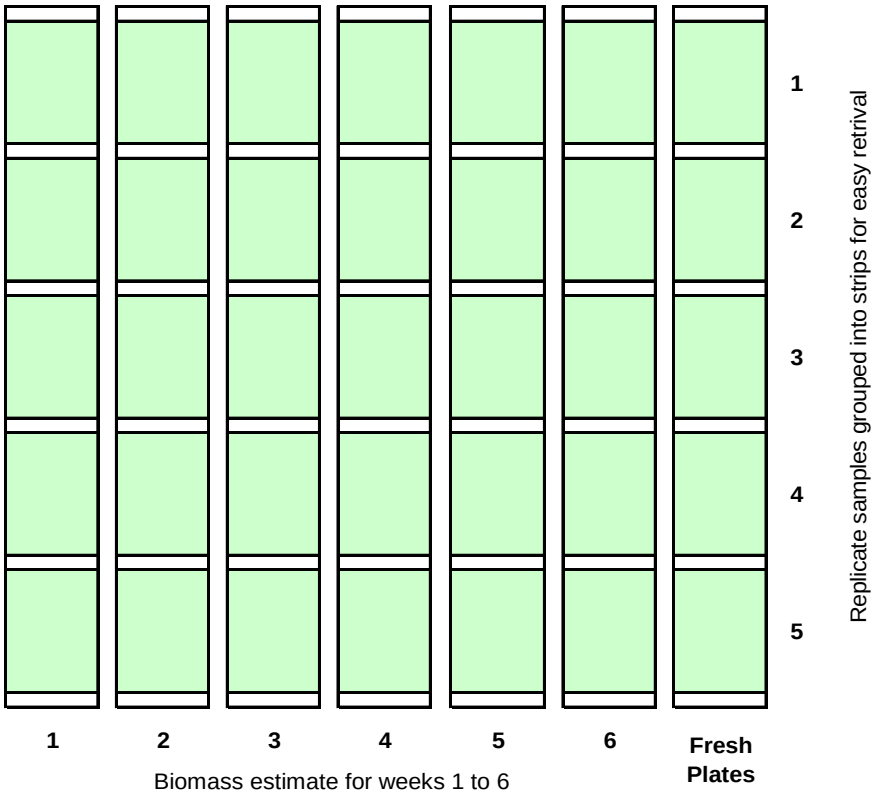
a) Sampling grid submerged below log boom; b) Growth plates being secured to log boom for dewatering; c) Phase 2 biomass sampling.

Biomass Sampling (AFDW methods)

Periphyton biomass was measured in terms of Ash Free Dry Weight (AFDW) using the same procedure as in the 2001-2010 littoral sampling program. To improve accuracy and detection limits of the sampling procedure, the surface area of growth substrate scraped clean (via glass slide) to remove the periphyton sample was increased from 100 cm^2 to 150 cm^2. In addition, five sample replicates were collected in order to assess sample

variation and to account for sampling error in all analyses. To simplify plate removal, replicate samples were grouped in to strips, as shown in Figure 3.3.

Figure 3.3 Sampling Grid Design



Each grid represents a different dewatering treatment. In total, 6 grids were suspended from log booms in Stave reservoir in order to measure growth for all treatments. Each grid was fitted with 7 acrylic growth plates that were scored into five 10 cm x 15 cm areas and roughened. Once all colonization periods and respective dewatering treatments were completed, the grids were re-suspended from the log booms 2 m below surface water elevation. Once per week, one plate was removed from each treatment grid and 5 replicate samples were collected. Each week, one "fresh plate" from one sample grid was collected and sampled to serve as a comparison of growth from an uncolonized condition.

Periphyton samples were collected using a glass microscope slide to scrape the periphyton from the acrylic plates and conveyed into a labeled jar using a stream of lake water taken from the immediate sampling location. Samples were labeled, stored in a cooler and taken to the laboratory for processing immediately following the sampling session. A total of 35 periphyton samples were collected during each sampling session.

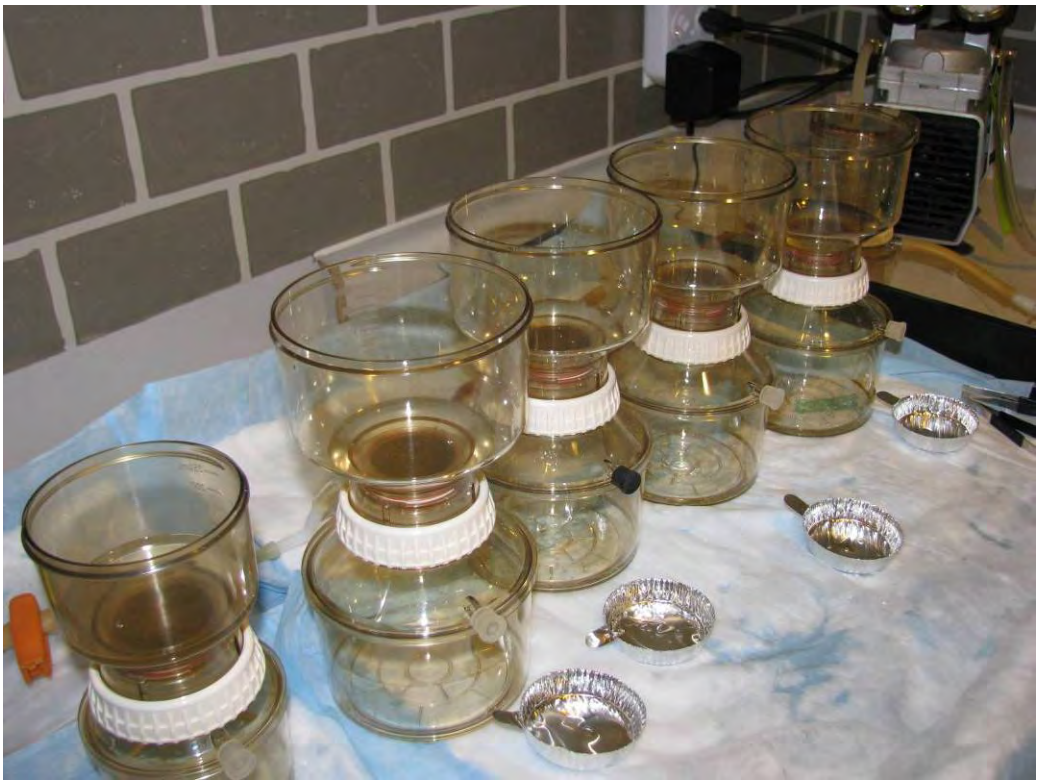
In the laboratory, each periphyton growth sample was treated similarly as follows (Figure 3.4):

- filtered at low vacuum pressure onto a pre-weighed, pre-ashed, 0.45 µm, 47 mm glass fibre filter (GFF).

- filter sample is placed in an aluminium weigh boat and dried in an oven at 100ºC for 12 hours to ensure all moisture is eliminated from the filter sample.
- oven-dried filter sample weight was recorded as dry-weight (DW_{oven}).
- oven-dried filter samples were ashed at 500ºC in a muffle furnace 5 hours and then re-weighed (DW_{muf}).
- ash free dry weight (AFDW) was calculated as the difference between the DW_{oven} and DW_{muf}.

AFDW (or periphyton accrual) is expressed in mass of organic content per unit area per day ($mg/cm^2/day$). The carbon (C) component of periphyton accrual is calculated as 45% of the organic content (AFDW) of the sample (Stockner and Armstrong, 1971). The carbon component of periphyton accrual is used as an estimate of littoral primary production.

Figure 3.4: AFDW Filtrations



3.3 Pelagic Monitoring Program Methods

Pelagic sampling consisted of a variety of environmental, biological and chemical parameters in both Stave and Hayward reservoirs, including:

- estimates of primary production using carbon 14 incubations
- water chemistry
- chlorophyll
- phytoplankton
- zooplankton
- water temperature, and
- light

Pelagic sampling and data collection was conducted mid-reservoir on both Stave and Hayward once per sampling trip. ^{14}C estimates of pelagic primary production were conducted for the first time in phase 2 in 2008. A program review in the spring of 2010 resulted in a change to the pelagic program allowing for estimates of primary production using the ^{14}C incubation technique to be conducted annually from 2010 through 2013 rather than on a three year cycle.

^{14}C estimates of primary production have been collected by taking a discrete water sample at 1, 3, 5, 7, and 10 meter depths. For each depth, 2 clear glass 300 ml Biological Oxygen Demand (BOD) bottles and one dark glass BOD bottle are filled and prepared for incubation with an inoculation of 2 µCu of carbon. More recently it has been determined that it would be of benefit to use a higher concentration of carbon stock and the concentration on future runs (i.e. 2010 and later) will use a minimum of 5 µCu (pers. comm. J. Stockner). Each of the BOD bottles and samples collected from Stave and Hayward were then attached to acrylic plates designed to hold the bottles in a horizontal plane at right angles to each other and then re-suspended to their original depths at Stave South. Samples were incubated *in-situ* for 2-4 hours, generally between 11 AM and 3 PM on the sampling day. Light penetration in the two clear bottles allowed photosynthesis to occur, while the dark bottle excluded light and measured dark uptake or respiration. After incubation, samples were retrieved and placed into light-tight boxes for transport back to the laboratory (Figure 3.5).

The incubations were terminated in the laboratory on the same day in the following process:

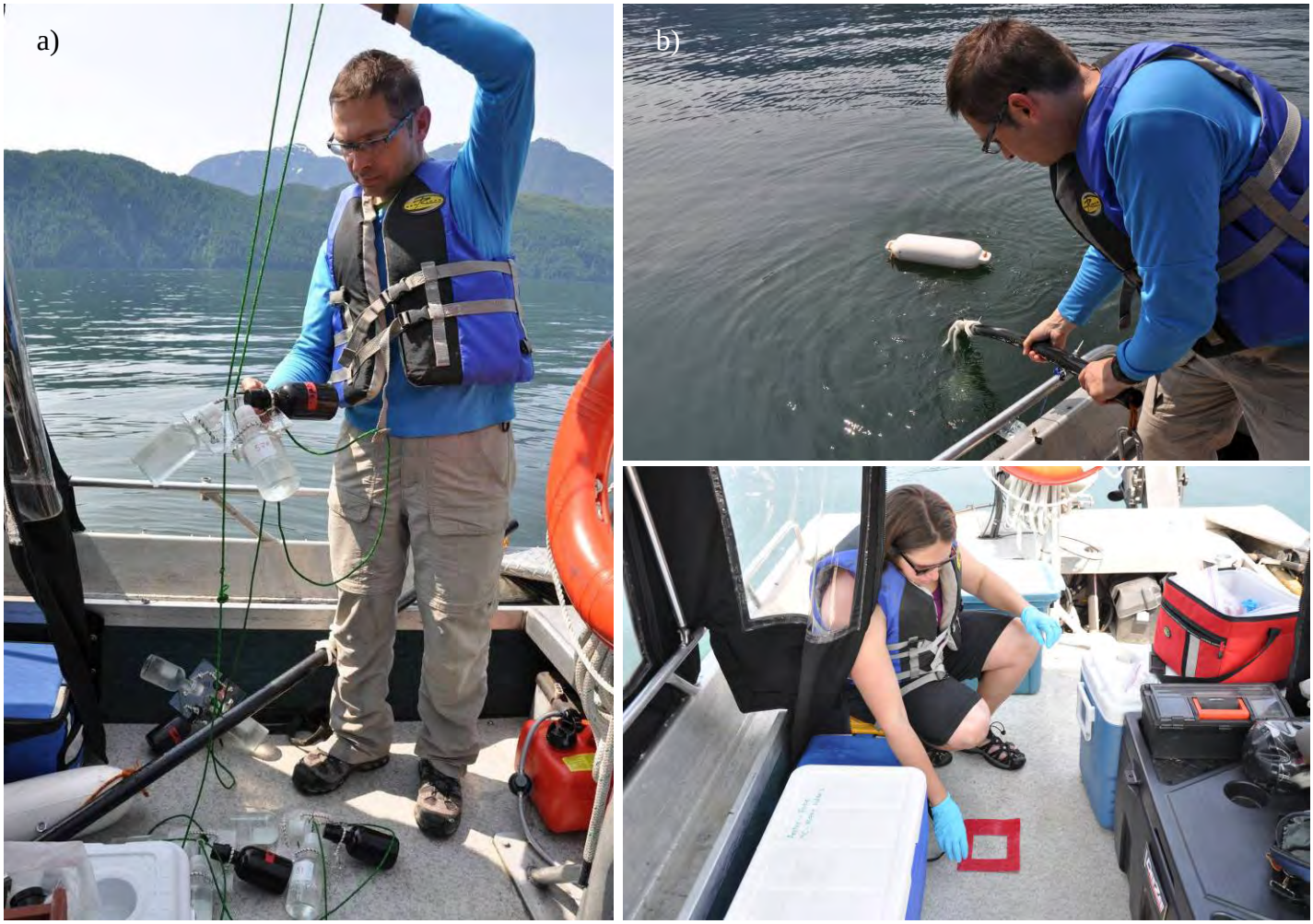
- 100 ml samples were filtered through a 0.2 µm 47 mm polycarbonate filter using <10 cm Hg vacuum differential (Joint and Pomroy, 1983);
- each filter was placed into a 7 ml scintillation vial;
- 200 µL of 0.5 N HCl was added to each vial to eliminate the unincorporated inorganic $NaH^{14}CO_3$ and the vials left uncapped in a darkened fumehood to dry for approximately 48 hours;
- when dry, 5 ml of Ecolite scintillation fluor was added to each filter and stored in the dark for at least 24 hours;
- samples were analyzed at the UBC Radiation Safety Office Laboratory in a Beckman LS6500 scintillation counter operated in an external standard mode to correct for quenching (Pieters et al. 2000). Three carbon assays were also included in the

analyses for each trip, as well as a series of swipe tests to test for contamination from both the boat and the lab areas.

Daily production values and assimilation rates were calculated using the incubation times in the water and did not include the time to transport to the lab and conduct the filtrations, as samples were kept in the dark at these times.

Figure 3.5: Carbon Incubations

a) setting the incubation apparatus
b) removing the apparatus from the floats after incubation
c) wipe test of the boat area



Water chemistry and chlorophyll samples were collected as part of the pelagic monitoring program. A mid-lake composite sample (1, 3, 5 m) was collected from Stave and Hayward using a Van Dorn non-metallic water sampler. Samples were processed in accordance with the appropriate methodology provided by SPA Chemtest (DFO Laboratory, Cultus Lake, BC) for total phosphorus, total dissolved phosphorus, nitrate, and chlorophyll *a*. A copy of this methodology is included as Appendix 2. Samples were processed immediately after the water samples were collected, and then stored according to the protocol, either cooled or frozen, until they could be transported to the laboratory for analysis.

Phytoplankton samples were collected from the same composite sample collected for water chemistry analyses. In the monitoring program Terms of Reference, BC Hydro identified that phytoplankton sampling in the Phase 2 monitoring program would be reduced to one late-summer sample from each reservoir. Senior scientific staff on this project pointed out that phytoplankton are the best early indicators of change in oligotrophic pelagic environments and that the sampling frequency should be increased. As a result, phytoplankton were collected once each sampling trip. In 2011, all samples were enumerated using the Utermohl (1958) method for micro-phytoplankton to the nearest species taxon level.

Each phytoplankton sample was preserved in acid Lugol's iodine preservative (iodine + 10% acetic acid) and stored in a cool location until analysis. Prior to quantitative enumeration by the Utermohl (1958) method, samples were gently shaken for 60 seconds, carefully poured into 25 mL settling chambers and allowed to settle for a minimum of 24 hours. Counts were done using a Carl Zeiss inverted phase-contrast plankton microscope. Counting followed a 2-step process:

- random fields (5 -10) were examined at 250X magnification (16X objective) and large micro-phytoplankton (20-200μm), e.g. diatoms, dinoflagellates, filamentous blue-greens, were enumerated, and
- all cells within a random transect (ranging from 10 to 15mm) were counted at 1560X magnification (100X objective). This high magnification permitted quantitative enumeration of many, but not all, minute (<2μm) autotrophic picoplankton cells (0.2-2.0μm) [Class Cyanophyceae], and also of small auto-, mixo- and heterotrophic nano-flagellates (2.0-20.0μm) [Classes Chrysophyceae and Cryptophyceae].

In total, random transects are repeated until between 250-300 cells are enumerated in each sample to assure statistical accuracy (Lund et al. 1958). The compendium of Canter-Lund & Lund (1995) was used as the taxonomic reference. Counts are reported as abundance (cell/ml) and estimates of biovolume (mm^3/L).

Zooplankton were sampled as a vertical tow at 20 metres depth in Stave and at 15 metres in Hayward with a 30 cm diameter, 90 cm long, 80 μm mesh plankton net. During sampling, the net was raised at a rate of approximately 0.5 m/s (Figure 3.6). Samples are preserved immediately after arriving at the lab using a small aliquot of sugar prior to the addition of formalin (37% formaldehyde solution) for a final concentration of approximately 10% formalin. Techniques used to subsample, count, and measure zooplankton were adopted from Utah State University (Steinhart et al. 1994) using techniques and length–weight relationships developed by McCauley (1984) and Koenings et al. (1987).

Preserved samples are transported to AMA Group for counting and upon arrival samples are logged and placed in a cool location. Prior to enumeration, the samples are filtered through a 0.45 μm mesh net and rinsed with water that has been settled overnight. The sample is transferred into a beaker for re-suspension in settled tap water. The volume of water and sample is recorded onto a data sheet. The amount of water added to the sample is dependent upon the quantity of zooplankton within the sample. For samples collected

for this project, the samples were diluted with 60 to 100 ml of water. Once the samples had been re-suspended a 2 ml sub-sample is collected with a Hensen-Stempel pipette.

Figure 3.6: Zooplankton Sampling

a) net preparation
b) net being released into water
c) sampling jar on net removed to rinse out sample
d) sample jar with completed sample

The sample is agitated during sub-sample collection to ensure a representative sample. The sub-sample is placed into a circular counting disk. The entire sub-sample is counted under a Meiji dissecting microscope at 30X magnification. The macrozooplankton are identified to genus or species according to Thorpe and Covich (2001). A minimum of two sub-samples are counted from each sample. During the counting, effort is made to count a minimum of 200 individuals. In some instances this results in the counting of the entire sample. The sample information as well as the counts are entered into a spreadsheet that is used to calculate density per unit volume as described in McCauley 1984. A copy of the count sheet used is included as Appendix 3.

The Phase 2 monitoring program TOR outlined collection of zooplankton only once per season on each reservoir, to occur in late summer when reservoir levels tend to be held relatively constant to accommodate recreational uses on Stave. However in 2006 a decision was made to sample zooplankton during each sampling trip and provide

enumeration on an annual basis. In 2009, all collected samples were enumerated, however, lengths of species were not measured so biomass estimates could not be made. Average species lengths from 2010 data have been used to estimate biomass for earlier data. In March 2010 at a meeting with BC Hydro it was decided to increase the number of samples on each reservoir to 5 per sampling trip in order to provide replication.

Oxygen levels (O_2, mg/L) were identified in BC Hydro's Terms of Reference to be measured at 1-metre intervals to a depth just beyond the thermocline and then at 5-metre intervals to the maximum depth possible with the Oxy Guard Handy Beta meter. It was determined through communication with BC Hydro staff that oxygen levels have not been included in the compliment of environmental variables sampled as part of the monitoring program to date. As a result, these data have not been collected as part of the Phase 2 monitoring program. If these data are desired then sampling for oxygen could be undertaken in the future.

Water temperature (ºC) was measured at 1-metre intervals using an Oxyguard Handy Beta to the maximum depth of the probe, approximately 25 meters. The temperature sensor was kept vertical using a light weight and maintaining constant boat position under windy conditions. Temperature profiles were collected at the same locations on the reservoir that other physical variables and water chemistry samples were measured. Accuracy of the instrument, as reported by Oxyguard, is better than ±0.2ºC.

Light intensity (photosynthetically active radiation – PAR) was measured at 1-metre intervals to a depth at which PAR is diminished to less than 1% of surface levels (the compensation depth). BC Hydro's LiCor Li-250 light meter and Li-192SA submersible quantum sensor were used to maintain consistency with Phase 1 of the sampling program. A light weight was used to keep the sensor vertical while taking measurements, and care was taken to ensure that the boat did not cast a shadow over the sensor (Figure 3.7). Each measurement was taken as a 15 second average, with a typical accuracy of ±0.6% (LiCor, 2004). A single light profile was collected mid-reservoir from Stave and Hayward during each sampling trip. Vertical light profiles were also used to calculate extinction coefficients (see Section 4.1).

Secchi disk readings were also taken on each sampling trip by lowering the secchi disk on the shaded side of the boat to the point where it can no longer be seen, then slowly raising it to where the black and white markings on the disk can be distinguished. The depth recorded for the Secchi disk is taken as the average of these two measures. This data will be incorporated into the light analysis conducted as part of the monitoring program.

Although not collected by this monitoring program, there are other important data available, including:

- global solar radiation from measurements collected continuously by Metro Vancouver at Port Moody, Coquitlam and Abbotsford using a LI-COR pyranometer (LI-200SA). This data will provide a continuous record of solar radiation at a proximal site that is assumed representative of the solar radiation reaching the surface of both Stave and Hayward Reservoirs.
- air temperature (BC Hydro, Environment Canada, Metro Vancouver)
- reservoir levels (BC Hydro)

Figure 3.7 Light Intensity Profile Being Measured on Stave Reservoir

4. Monitoring Results for 2011

Results are presented for data collected in 2011.

4.1 Light

Light profiles for Stave and Hayward on each of the sampling days in 2011 starting with the March 26th sampling session are presented in Figures 4.1 and 4.2. The lower light levels measured at Hayward result from the fact that light measurements on Hayward were typically made about 9-10 AM, while those on Stave were typically made about 1-2 PM.

Figure 4.1: Stave Solar Irradiance

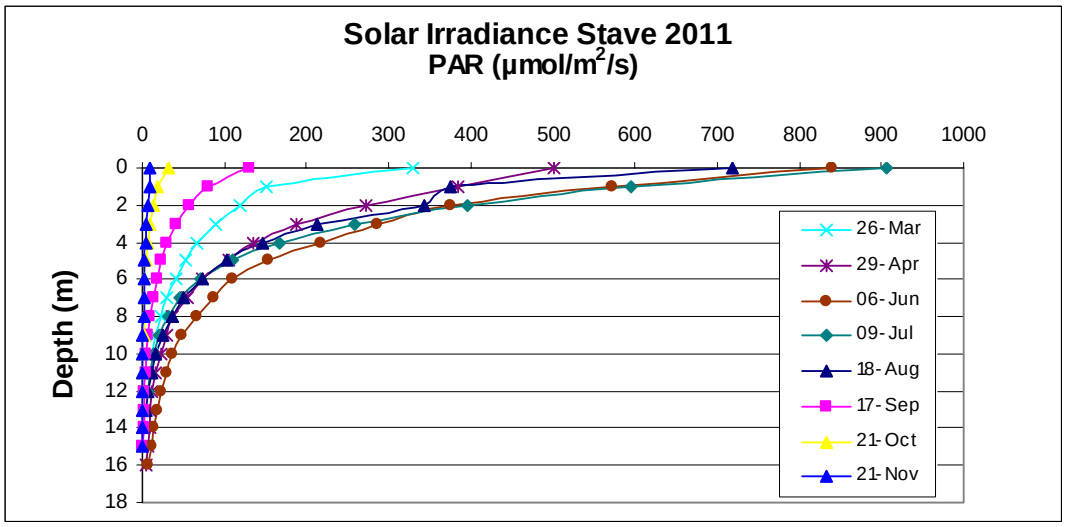
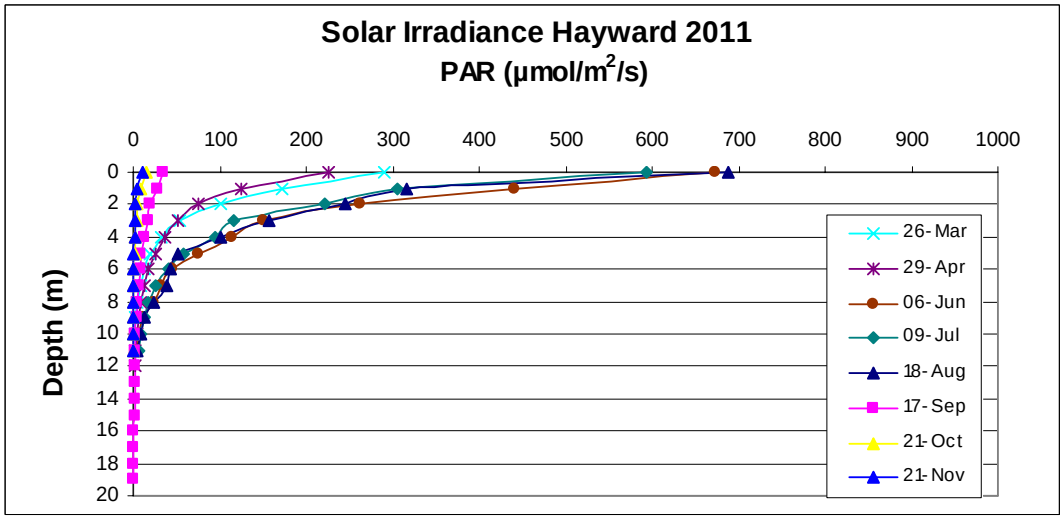
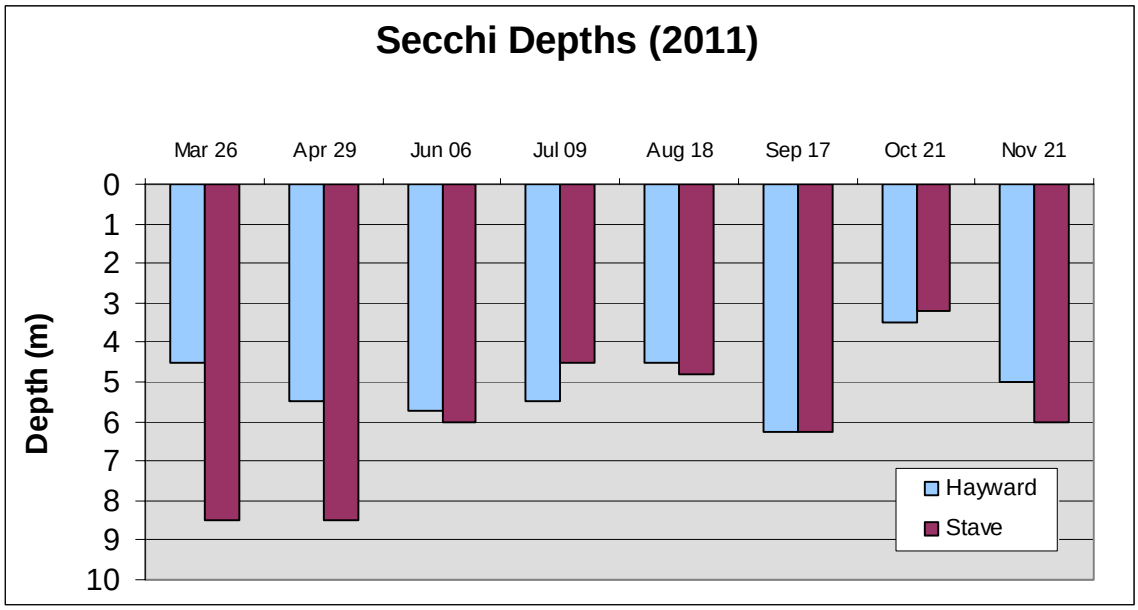


Figure 4.2: Hayward Solar Irradiance



Secchi depths for each sample day on Stave and Hayward are presented in Figure 4.3 below.

Figure 4.3: Secchi Depths for Stave and Hayward



As a reference, secchi depths measured in phase 1 (2002 and 2003) are presented in Figure 4.4 and secchi depths throughout phase 2 (2006-2011) are presented in Figure 4.5.

Figure 4.4: Phase 1 (2002-2003) Secchi Depths for Stave and Hayward

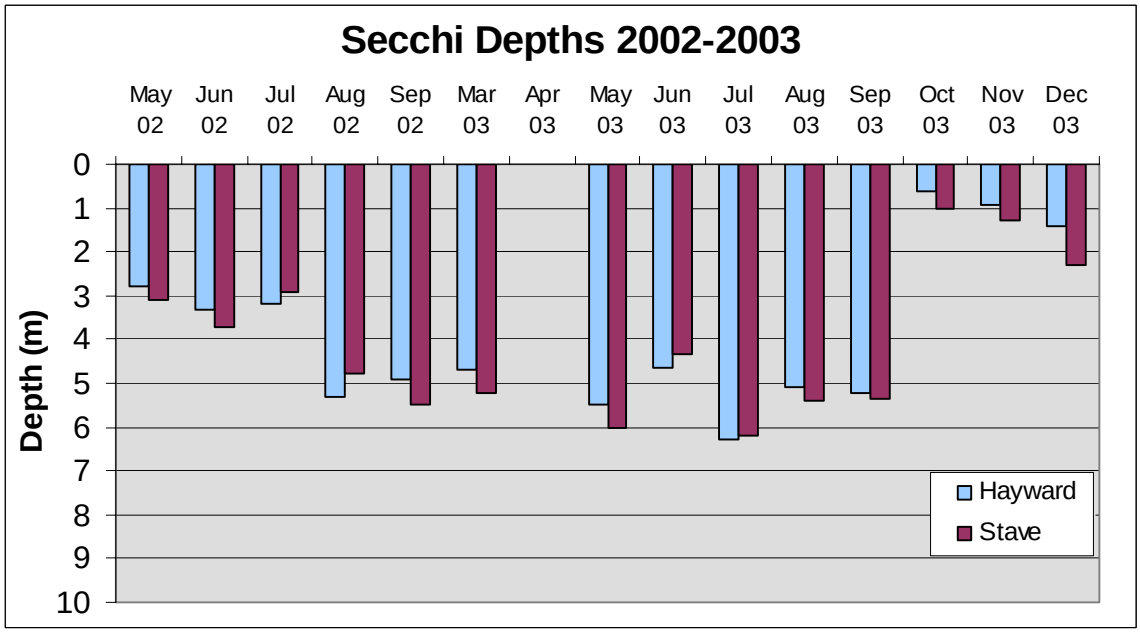
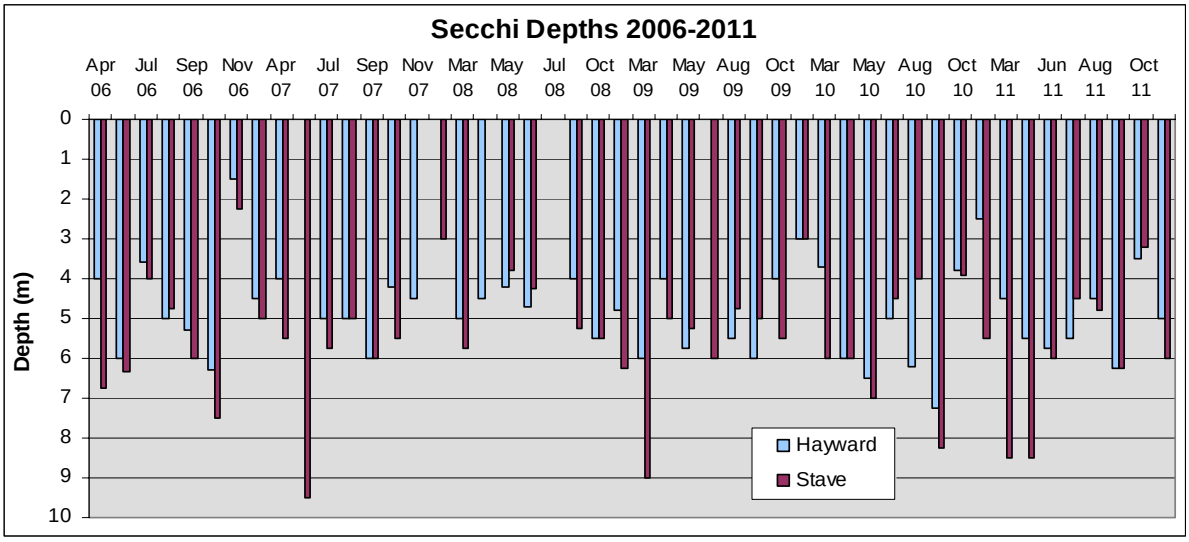


Figure 4.5: Phase 2 (2006-2011) Secchi Depths for Stave and Hayward



Light attenuation with depth typically follows an exponential decay in the water column, such that:

$$L = L_0(e^{-kZ})$$

or

$$\ln(L/L_0) = -kZ$$

where L is the light intensity at depth Z (m), L_0 is the surface light intensity, and k is the extinction coefficient (m^{-1}). The extinction coefficient describes the rate of this attenuation, with higher coefficients representing a greater attenuation rate.

Extinction coefficients calculated from each light sampling profile at Stave and Hayward during 2011 are presented in Table 4.1. The extinction coefficients in Table 4.1 are based on light levels measured between the surface and the compensation depth. Typically values are comparable between Stave and Hayward. Extinction coefficients typically range from 0.25 to 0.65 with higher values generally occurring later in the fall and into winter.

Table 4.1: Extinction Coefficients (2011)

Date	Hayward	Stave
Mar 26	0.50	0.28
Apr 29	0.38	0.30
Jun 6	0.45	0.29
Jul 9	0.41	0.42
Aug 18	0.43	0.37
Sep 17	0.24	0.31
Oct 21	0.42	0.36
Nov 21	0.42	0.32

Surface solar radiation throughout 2011 at Stave and Hayward reservoirs was estimated from hourly measurements of global radiation (sum of direct and diffuse solar radiation) collected by Metro Vancouver at Coquitlam and Abbotsford using a LI-COR pyranometer (LI-200SA). Solar radiation data collected in this manner includes

wavelengths from 400 – 1100 nm, a slightly wider range than is typically used in limnological studies (PAR, 400 – 700 nm).

Average daily global radiation estimated for Stave and Hayward are shown in figures 4.6 and 4.7. These data are the average of data collected at Coquitlam and Abbotsford and are expected to be representative of the conditions experienced at Stave and Hayward during the approximate 5-week intervals between sampling.

Figure 4.6: Global Solar Radiation (by day)

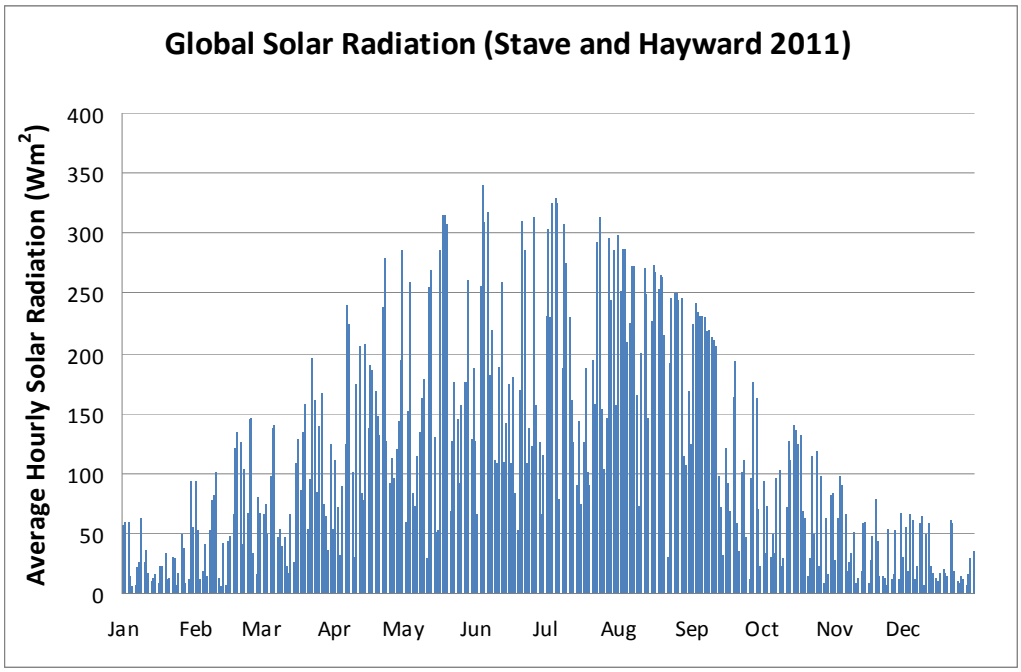
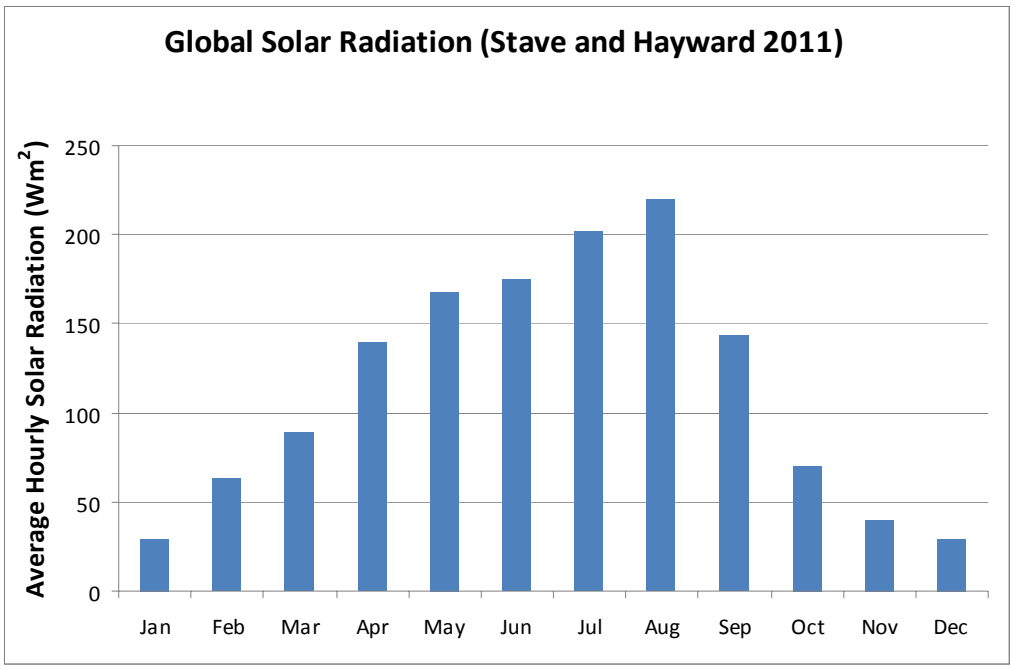


Figure 4.7: Global Solar Radiation (by month)



4.2 Water Temperature Profiles

Water temperature profiles for Hayward and Stave on each of the sampling days in 2011 are presented in figures 4.8 and 4.9, respectively. Temperatures between the two reservoirs were observed to be quite similar, with slightly warmer temperatures in Hayward. Temperature readings at Hayward were typically made about 9-10 AM, while those on Stave were typically made about 1-2 PM, which may account for the slightly higher summertime surface temperatures measured in Stave. Also notable is the summertime development of a warm surface layer and a thermocline in Stave that does not appear to develop in Hayward. Since Hayward is a run-of-the-river reservoir with a short residence time, typically about 2 days, it does not typically develop a thermocline. In Stave, the thermocline typically develops in summer (June - September) and is influenced by both fluctuations in water level and climatic conditions. In more recent years, under the Combo 6 operating regime the thermocline occurs at a depth of about 4 - 6 m early in the summer and deepens to as much as 16 m by September. By November the thermocline has eroded, likely a result of greater mixing caused by increased winds in the fall and reduced solar heating.

Figure 4.8: Hayward Temperature Profile

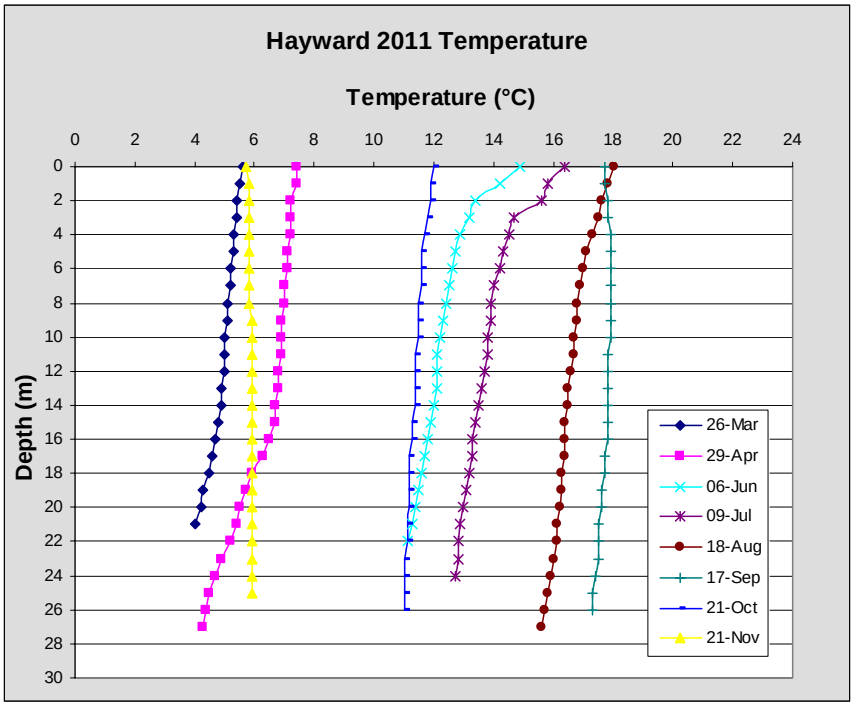
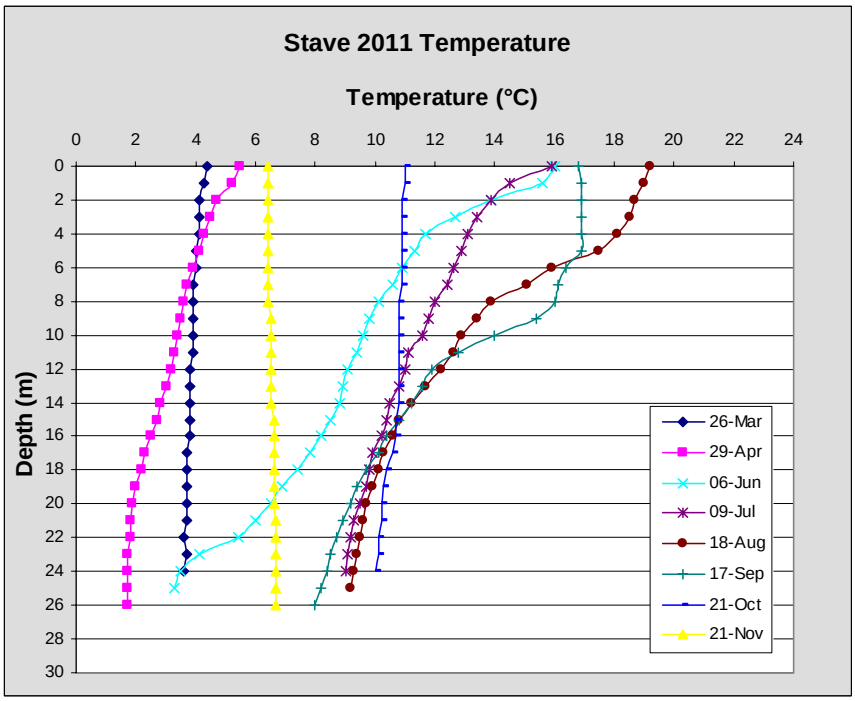


Figure 4.9: Stave Temperature Profile



4.3 Surface Water Elevation

Figure 4.10 shows daily averaged water levels in Hayward (pink, right axis) and Stave (blue, left axis) from 2000 to 2003 (phase 1) through 2010 (phase 2 – 2005 to 2011). It is notable that Hayward reservoir was generally managed at a slightly higher water level (by approximately 1 m) during the first phase of the monitor. Maximum water levels of 81-82 m a.s.l. in Stave Reservoir are consistent between phase 1 and phase 2. Water levels in Hayward reservoir remained relatively constant to the end of 2006, after which there is a period of variation that is attributed to BC Hydro managing Hayward for potential seismic hazard. In June 2009 Hayward was drawn down to 34.7 m a.s.l. In June 2010 and 2011 Hayward was drawn down to 34.6 m and 35.1 m respectively for approximately 2 weeks.

Stave water levels are typically lowered through the fall, reaching a winter and early spring low to accommodate spring melting, and recharging to maximum elevations during the summer months. In late winter 2006 and 2008 levels were drawn down significantly to 72 m a.s.l. The 2008 drawdown prevented sampling from occurring in April, as the Stave boat ramp does not allow for boats to be launched at such low water levels. In 2009 and 2010 the winter drawdown in Stave was not as pronounced as in previous years reaching only about 76 m a.s.l. Figure 4.11 shows the daily average water level in 2011 with sampling dates indicated.

Figure 4.10: Daily Average Water Elevation (2000 to 2011)

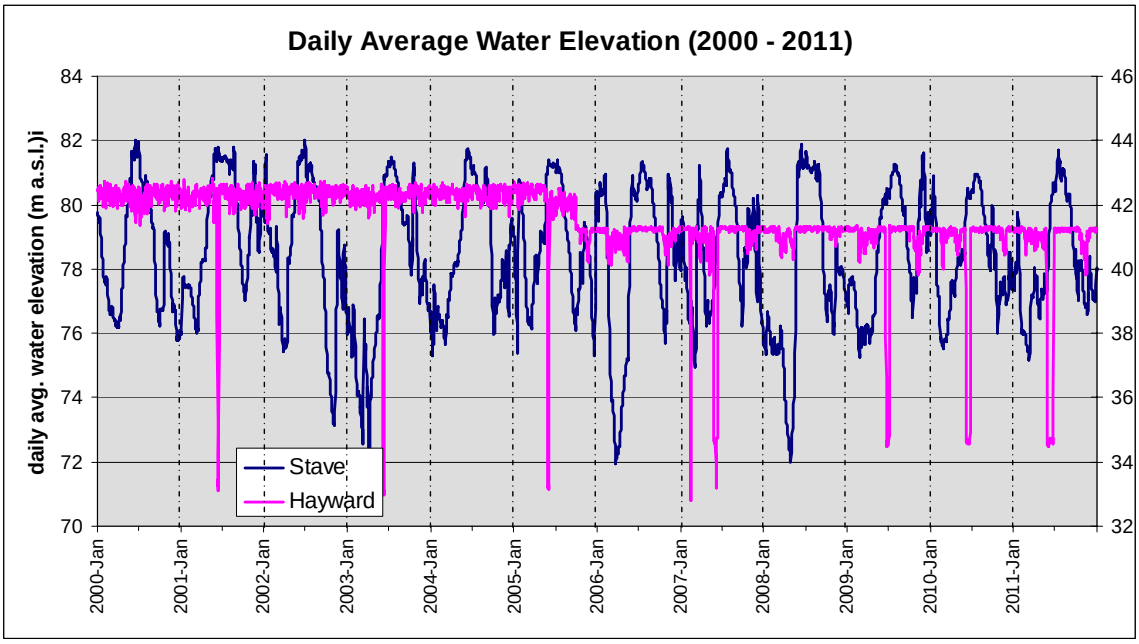
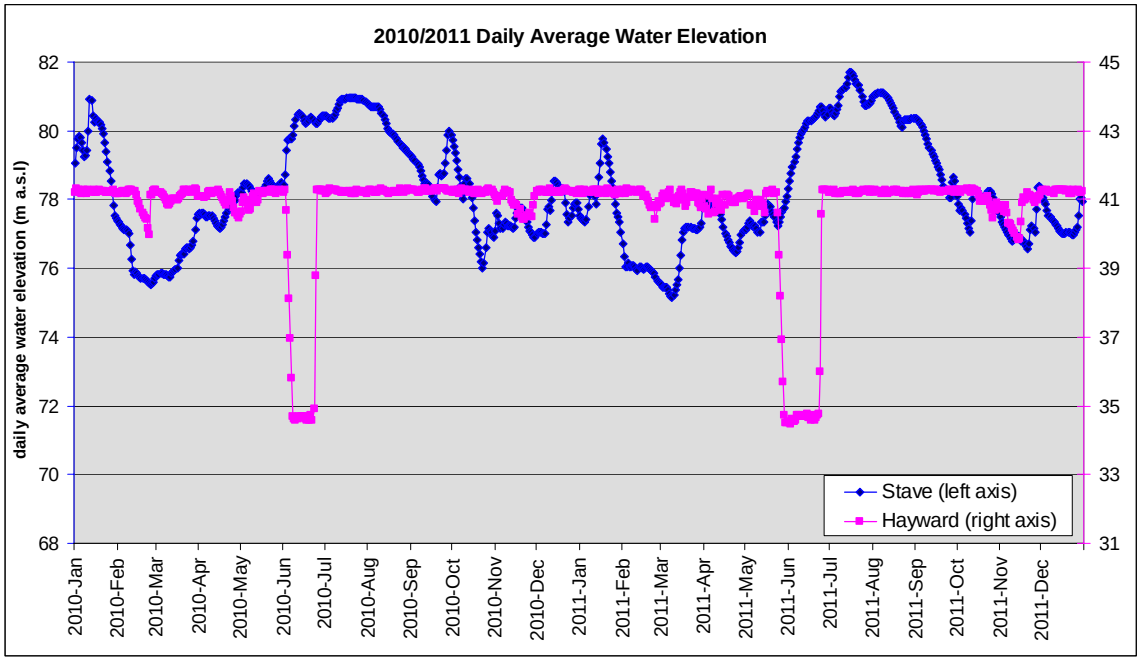


Figure 4.11: Daily Average Water Elevation (2011)



4.4 Water Chemistry

Water chemistry samples were analyzed at SPAChemtest (DFO Laboratory in Cultus Lake, BC) in order to maintain consistency with analyses from Phase 1. Figures 4.12-4.15 show graphically the total phosphorus (TP), total dissolved phosphorus (TDP), nitrates and chlorophyll-*a* values from 2005 through 2011, providing a record of the nutrient profiles in Stave and Hayward reservoirs. Tabular results from 2011 are presented in Appendix 5.

Similar to previous years, in 2011 nitrate concentrations in Stave and Hayward ranged from a high value of approximately 120 µg/L in spring to low values of approximately 35 µg/L in fall. Nitrate concentrations exhibit a seasonal trend with peak values occurring in the winter and early spring periods when the reservoirs are isothermal (mixing) and low values in stratified periods in summer and early fall. Stave and Hayward both exhibited low concentrations of phosphorus with TP ranging from 0.8-4.6 µg/L and TDP concentrations from <1.0-3.5 µg/L. Values of TDP in summer are very low, and in Stave they reach levels of as little as 0.1-0.2 µg/L. TDP values, which are the best approximation of bioavailable phosphorus, are generally 25- 40% lower than TP values, which is a typical pattern observed in reservoir systems (Stockner, 2003, pers. comm.). Chlorophyll-*a* estimates of biomass production from Hayward reservoir ranged from a summer high of 0.555 µg/L to a winter low of 0.105 µg/L. Stave reservoir ranged from 0.641 µg/L to 0.080 µg/L. Both reservoirs exhibited peaks in biomass production during the summer months, as expected.

Figure 4.12: Nitrate Concentrations

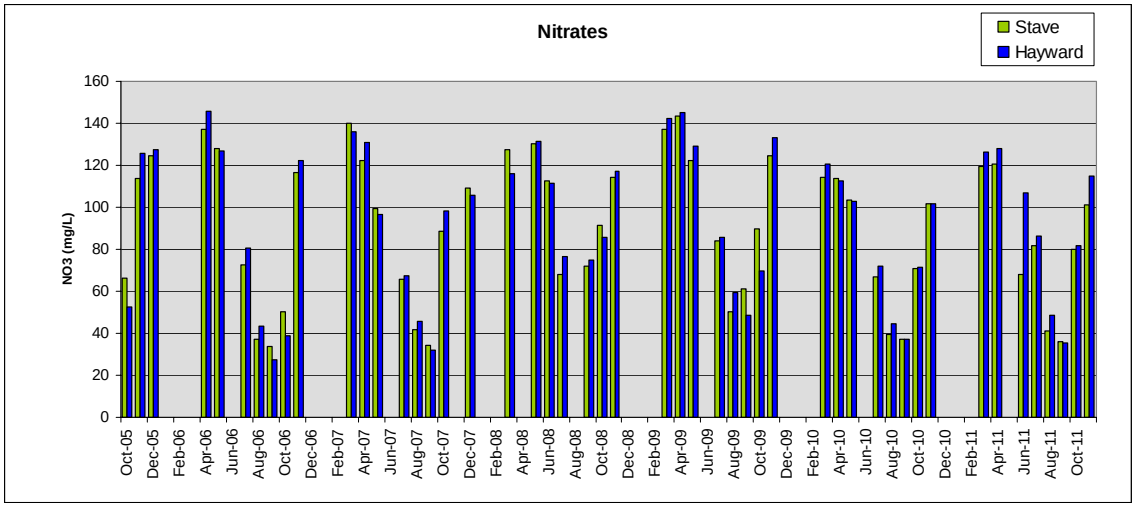


Figure 4.13: Total Phosphorus Concentrations

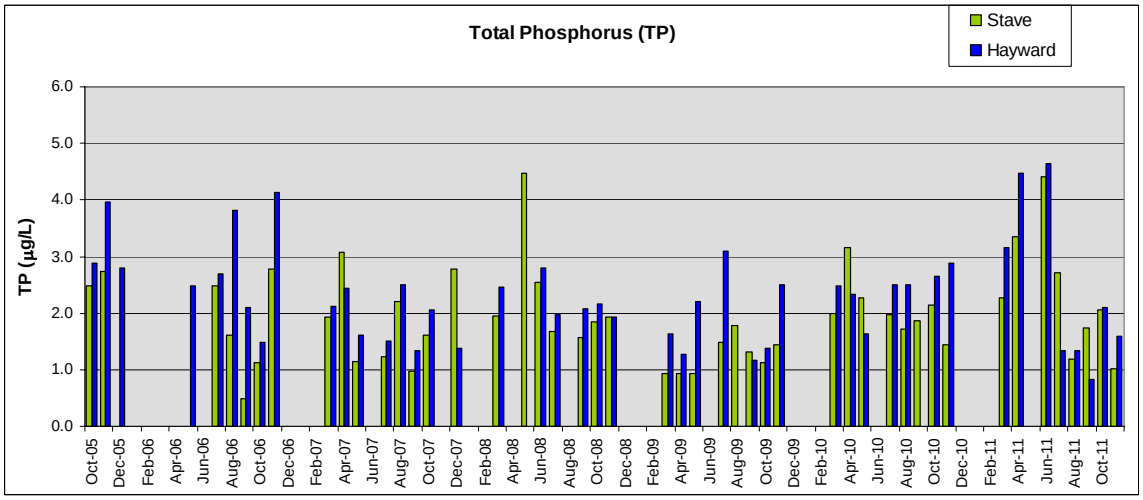


Figure 4.14: Total Dissolved Phosphorus Concentrations

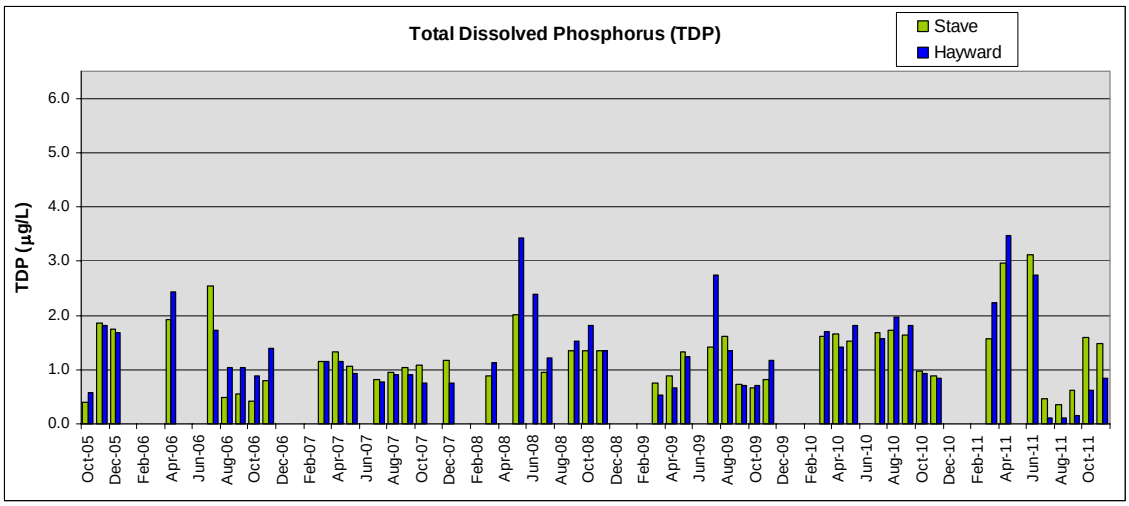
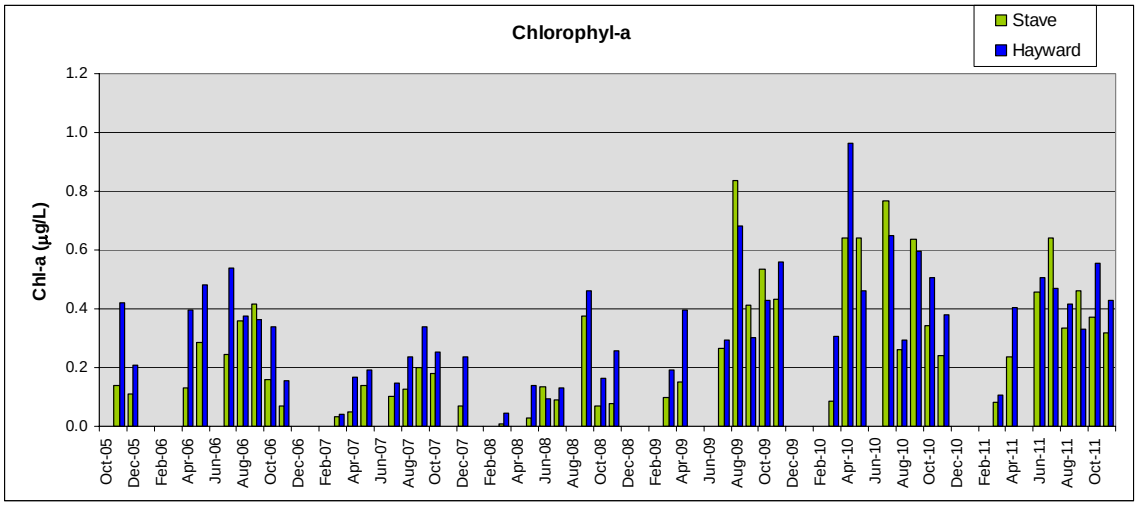


Figure 4.15: Chlorophyll-a Concentrations



4.5 Phytoplankton and Picoplankton

Owing to the ultra-oligotrophic status of Stave and Hayward reservoirs, changes in phytoplankton density and total biomass are important 'sentinels' of change in nutrient inputs or N/P imbalances (Stockner 1991). Small pico-phytoplankton and nano-flagellates currently dominate the phytoplankton assemblages in both reservoirs, and monitoring their population fluxes through the limnological seasons provides an essential record of key microbial and/or nutrient imbalances that often can occur in highly variable reservoir ecosystems.

The results of phytoplankton counts over the past seven years have been assessed in terms of total abundance for the duration of the Phase 2 condition (Figures 4.16), providing a general picture of the number of species present and how they vary seasonally. The average seasonal phytoplankton densities ranged between 1,000 and 2,000 cells/mL, close to densities found in neighboring Coquitlam Reservoir, which like Stave/Hayward is a very ultra-oligotrophic ecosystem (Stockner, unpublished data). The high abundance exhibited in fall 2007 and August-September 2009 are common in other Lower Mainland reservoirs, and likely occur in response to very stable summer stratification and warm epilimnetic temperatures, favoring small pico fractions with rapid uptake of recycled nutrients. With the commencement of deeper mixing in September and early October and associated nutrient entrainment, the secondary peak is sustained well into October (Stockner, 1987). The major components of these large peaks are small pico-cyanobacteria. Figure 4.17 shows total biovolume of phytoplankton from 2005-2011. Stave reservoir exhibits early summer peaks starting in June with maximum biovolume occurring in July with values reaching 0.43 mm^3/L. All other values appear to be similar to values measured in previous years.

Figures 4.18-4.21 show edible vs in-edible plankton biovolumes and densities in Stave and Hayward Reservoirs. In Stave reservoir, edible phytoplankton densities (cell/mL) show a clear dominance over inedible phytoplankton throughout the 2011 growing season, compared with previous years where phytoplankton that could be considered both edible or in-edible dependent on condition was more prevalent. Biovolume measurements

in Stave reservoir show a peak in edible phytoplankton in June, but by July in-edible phytoplankton prevail. In Hayward, phytoplankton densities in 2011 are dominated by edible fractions in the 1500 cells/mL range, whereas, in 2009/2010 phytoplankton that could be considered either edible or in-edible dominated and exhibited peaks in both years in July which were not apparent in 2011. Biovolumes in Hayward also show more edible phytoplankton than in previous years, although the measured volumes were similar at approximately 0.10 mm^3/L. In genereal, there was a variety of mostly edible plankton available to herbivorous zooplankton throughout the seasons in all years in both Stave and Hayward. A spike of inedible diatoms in July in Stave was the only exception; otherwise both reservoirs plankton were largely effectively contributing to carbon flows and not creating dead-end carbon 'sinks' that significantly reduce ecosystem efficiency and reduce fish production.

Picoplankton were collected and counted for the first time in 2010 from Stave and Hayward reservoirs and at the Alouette outfall when it was running. This data was added to the sampling regime for Stave and Hayward after a meeting held in March of 2010 identified that bacterial sized organisms are likely to be important drivers of production in oligotrophic systems like Stave. Figures 4.22 and 4.23 below show heterotrophic bacteria biovolume and density. Figures 4.24 and 4.25 show pico-cyano bacteria biovolume and density. Counts of heterotrophic bacteria at all three locations are similar to one another, with peak biovolumes occurring in late summer into fall. Generally values or heterotrophic bacteria sampled from the Alouette outfall area were similar to those of Stave and Hayward, while pico-cyano bacteria from Alouette tended to be higher in summer and fall which may be the result of fertilization in the Alouette system and what organisms are more easily entrained and transported. Bacteria counts from Stave and Hayward are still preliminary with only two years of data and a single sample from each sampling site. It is hoped that by adding data over the next few years more patterns will be discernable.

Figure 4.16: Total Abundance of Phytoplankton (2005-2011)

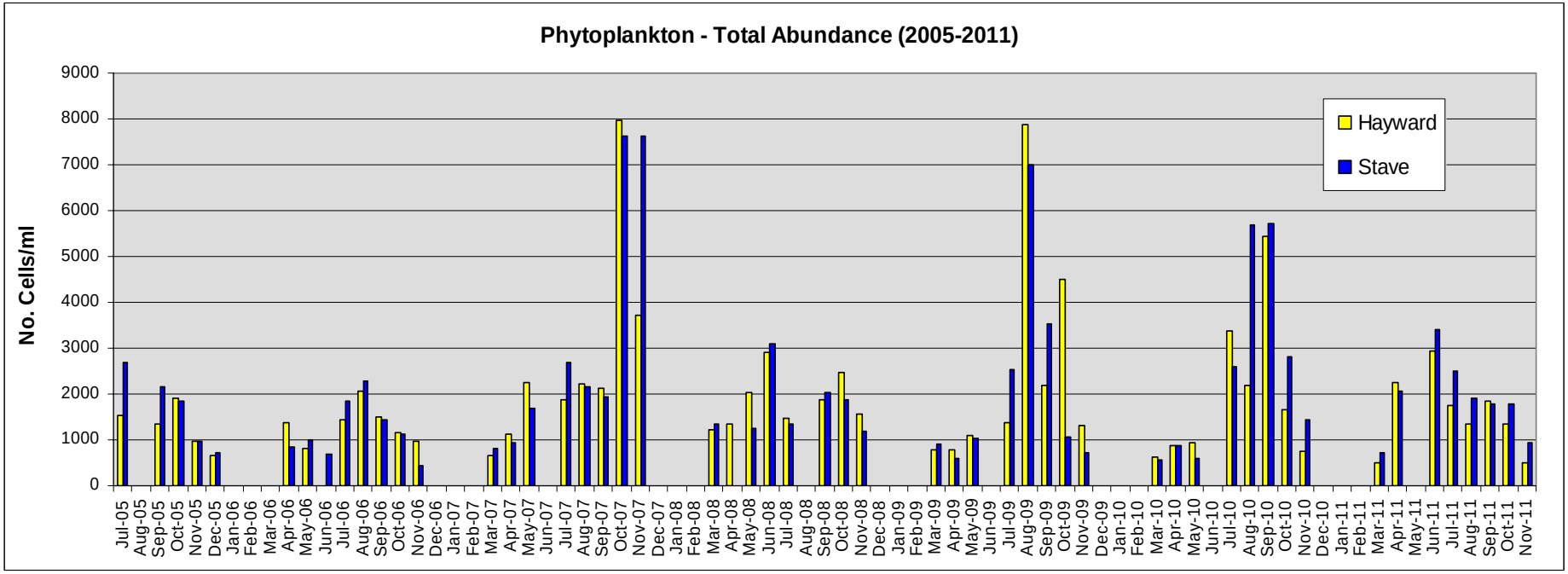


Figure 4.17: Total Biovolume of Phytoplankton (2005-2011)

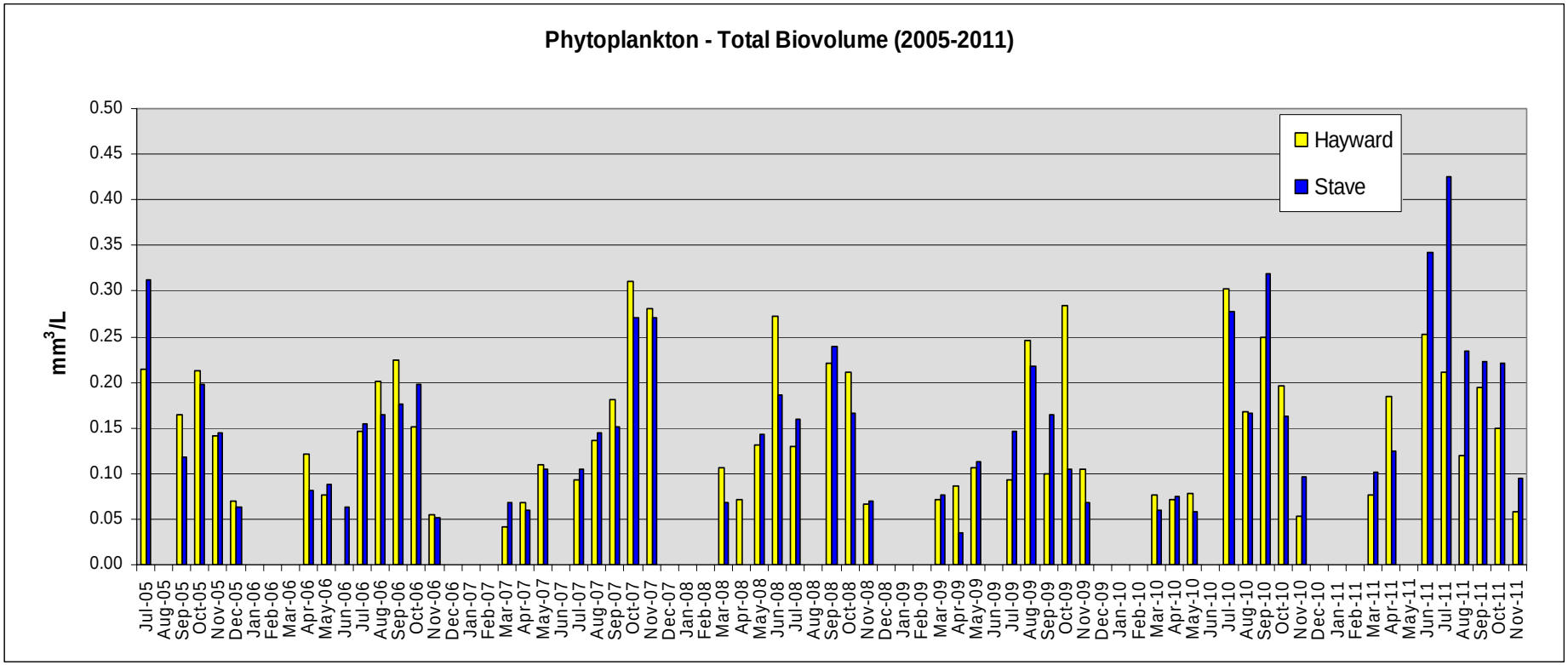


Figure 4.18: Stave Edible vs. In-Edible Phytoplankton Biovolume

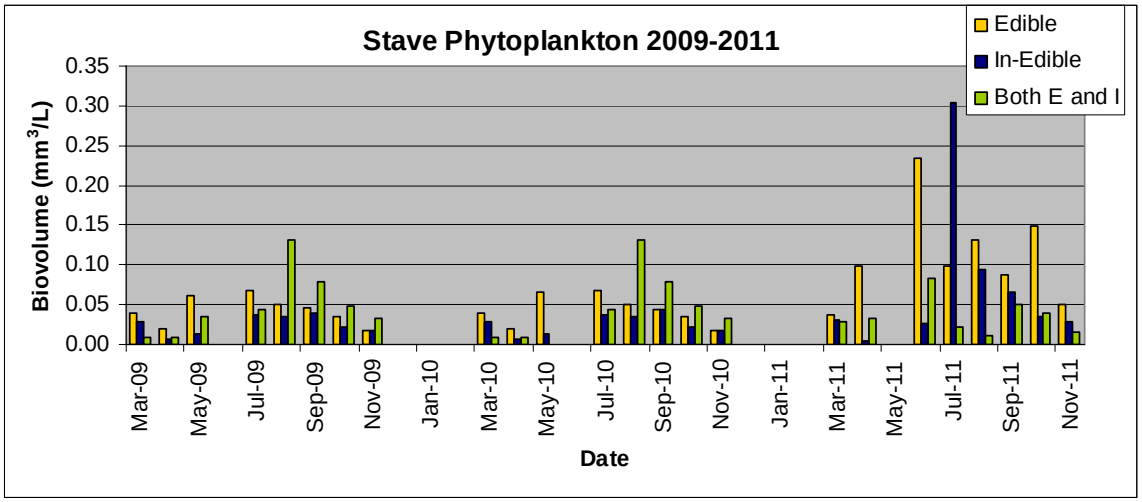


Figure 4.19: Stave Edible vs. In-Edible Phytoplankton Density

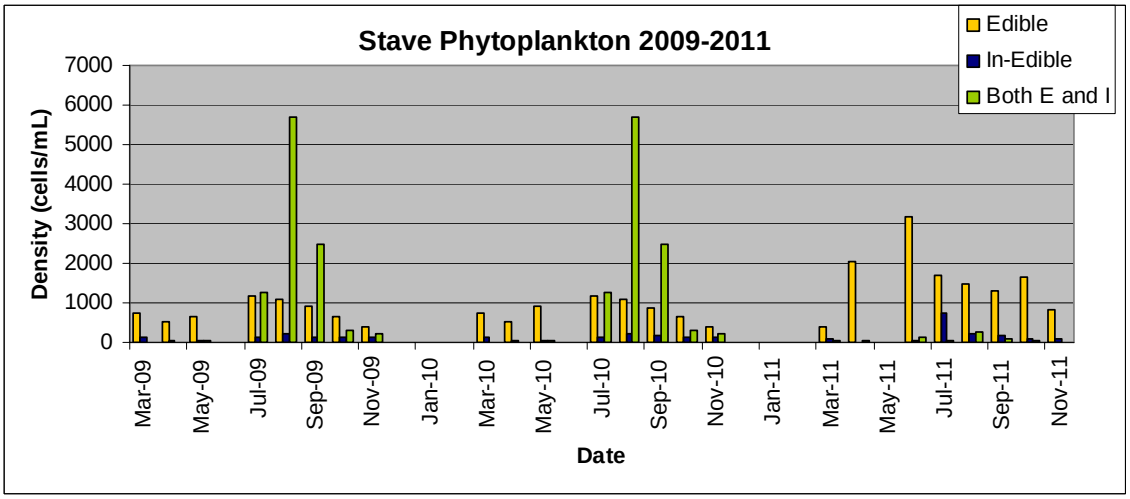


Figure 4.20: Hayward Edible vs. In-Edible Phytoplankton Biovolume

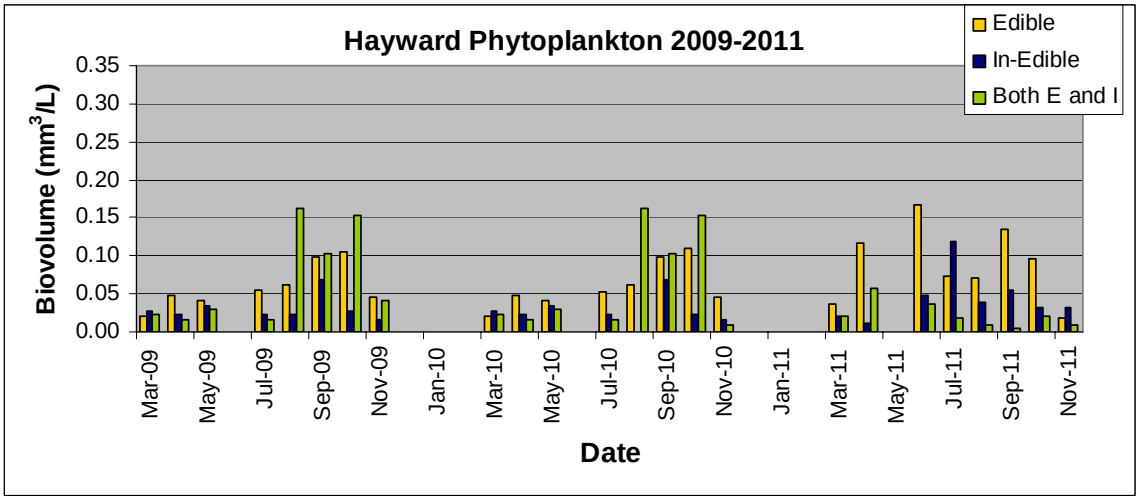


Figure 4.21: Hayward Edible vs. In-Edible Phytoplankton Density

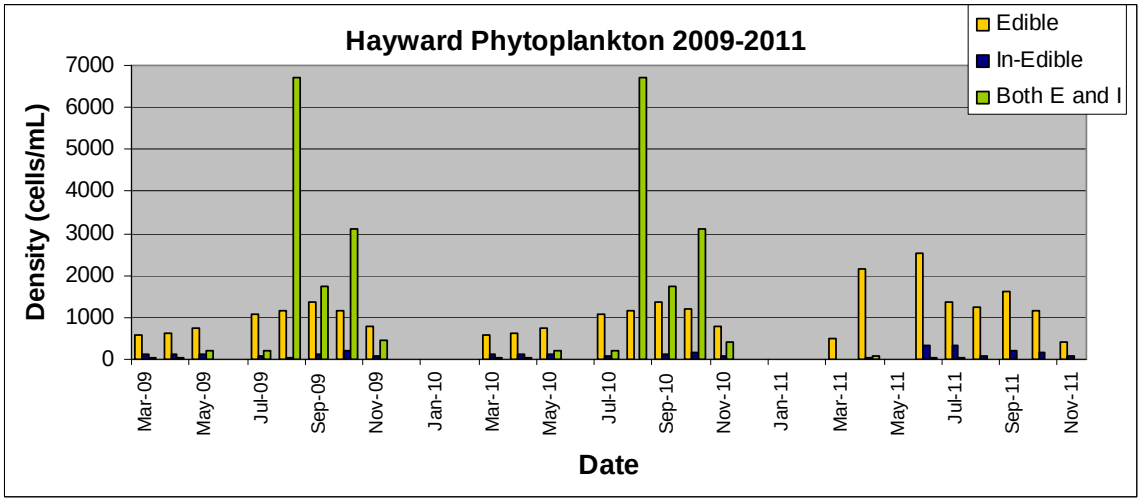


Figure 4.22: 2010/2011 Heterotrophic Bacteria - Biovolume

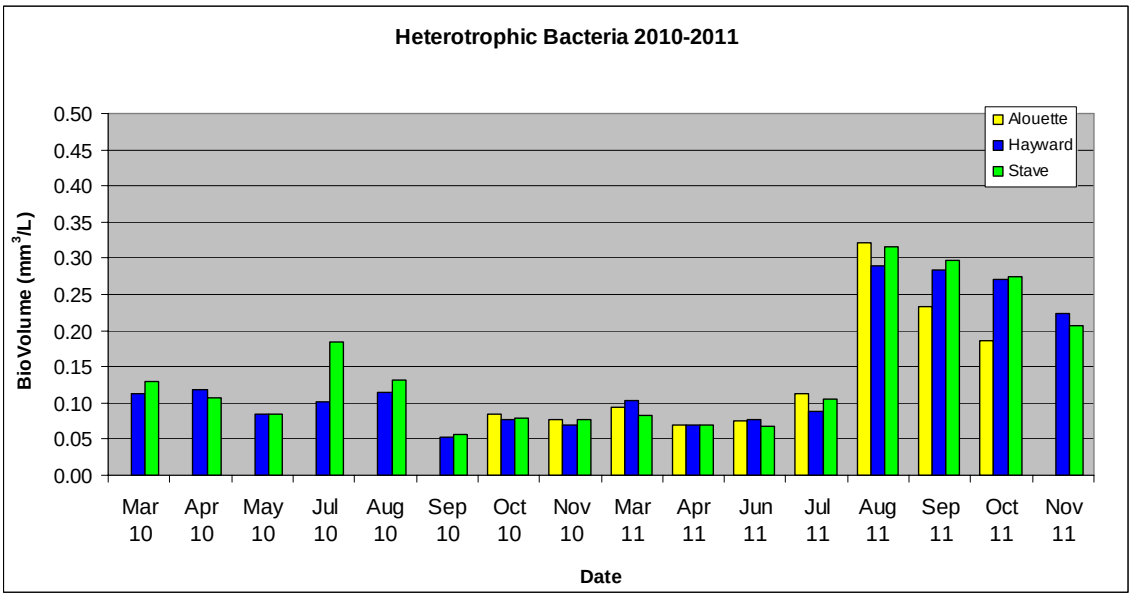


Figure 4.23: 2010/2011 Heterotrophic Bacteria - Density

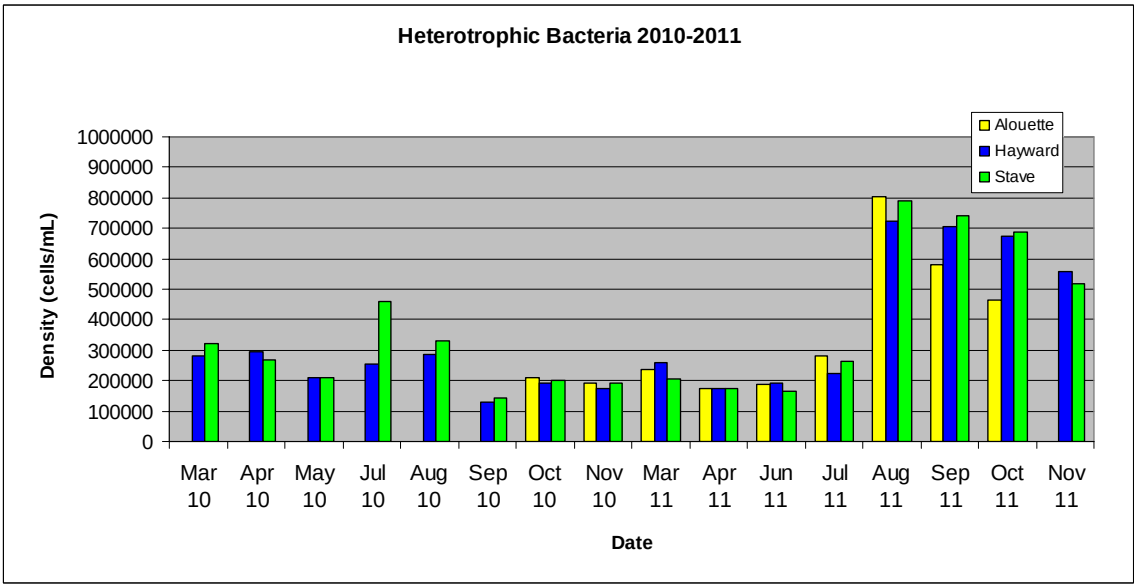


Figure 4.24: 2010/2011 Pico-Cyano Bacteria - Biovolume

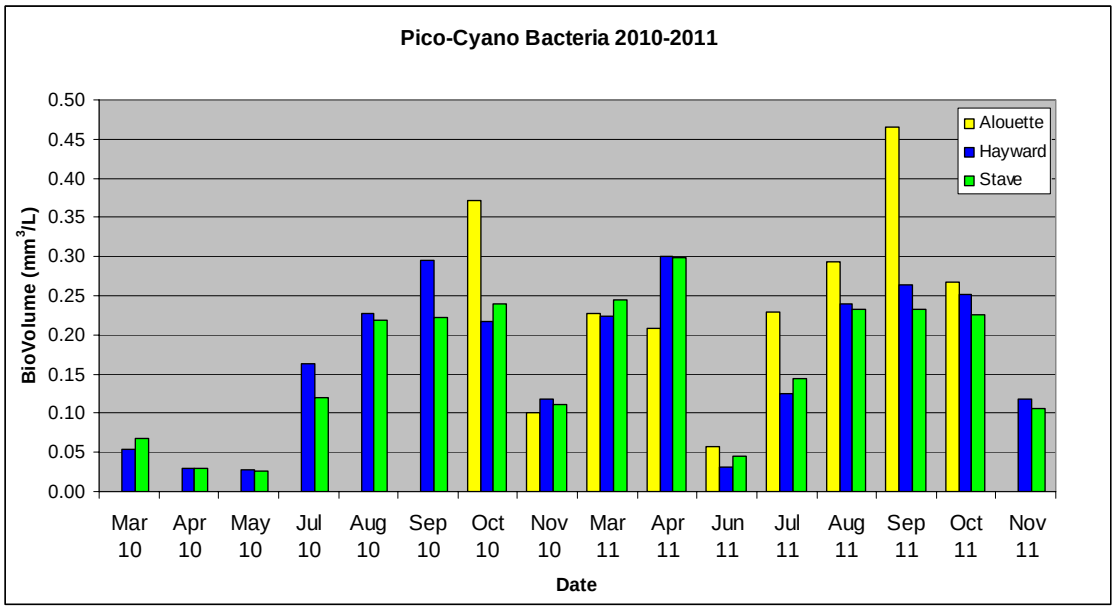
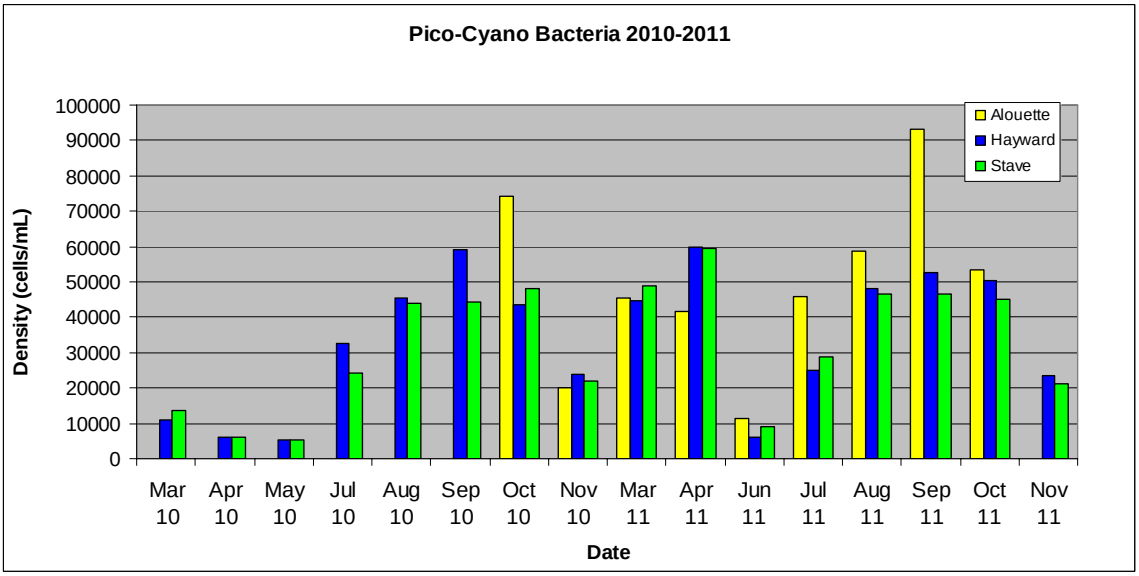


Figure 4.25: 2010/2011 Pico-Cyano Bacteria - Density



4.6 Zooplankton Analyses

Figures 4.26 and 4.27 show total zooplankton biomass and densities measured over the 2011 sampling season. Figures 4.28 and 4.29 show the total zooplankton biomass and densities measured from each sampling trip in Stave and Hayward from 2007 through 2011. Zooplankton sampling was increased in 2010, from one sample to five samples on each of Stave and Hayward Reservoirs due to the variability noted in the earlier data. For data from 2010 and 2011 an average of the 5 samples is graphed. Zooplankton exhibit a seasonal trend peaking in late summer/early fall at about 30 ug/L biomass and 10-15 individuals/L density. In 2010 and 2011 densities seem to be slightly higher than in other

years and the seasonal trend more evident which is likely a reflection of the 5 replicate samples adding more accuracy to values being reported.

Figure 4.30 shows zooplankton densities from surrounding BC reservoirs (Stockner 2012). By way of comparison, it is evident that Stave and Hayward reservoirs exhibit similar densities to Jones, Alouette and Upper Arrow, but are lower than Lower Arrow and Kootenay Lakes and somewhat higher than densities reported for Coquitlam reservoir.

Figure 4.31 shows average biomass data for individual species in both 2010 and 2011. While there is some seasonal variability in species composition and biomass, the trends between years appear to be similar with most species biomass less than 5 ug/L and occasional spikes of individuals > 5ug/L. Complete zooplankton counts from samples collected in 2011 are presented in Appendix 4.

Figure 4.26: Total Zooplankton Biomass 2011

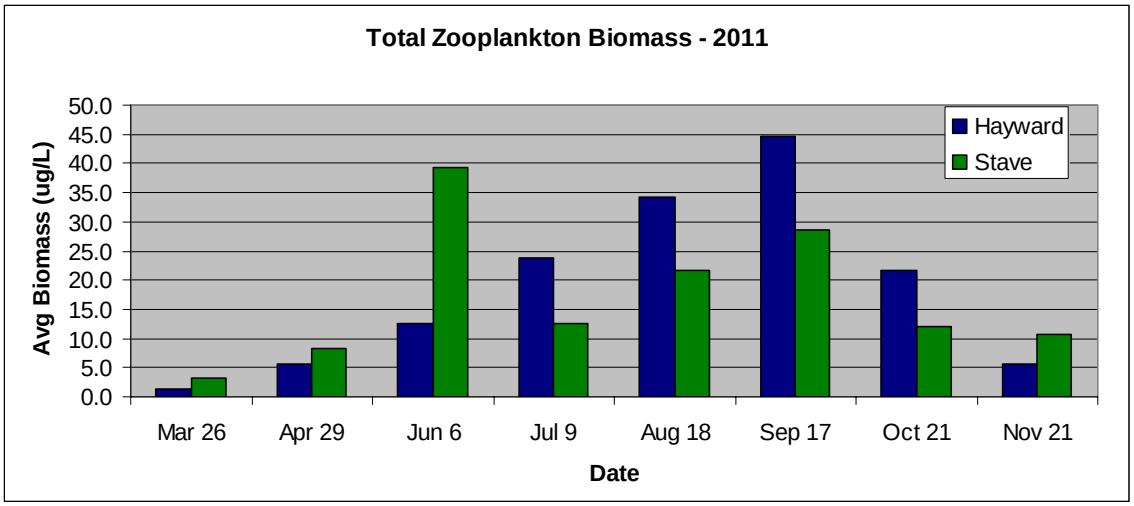


Figure 4.27: Total Zooplankton Density 2011

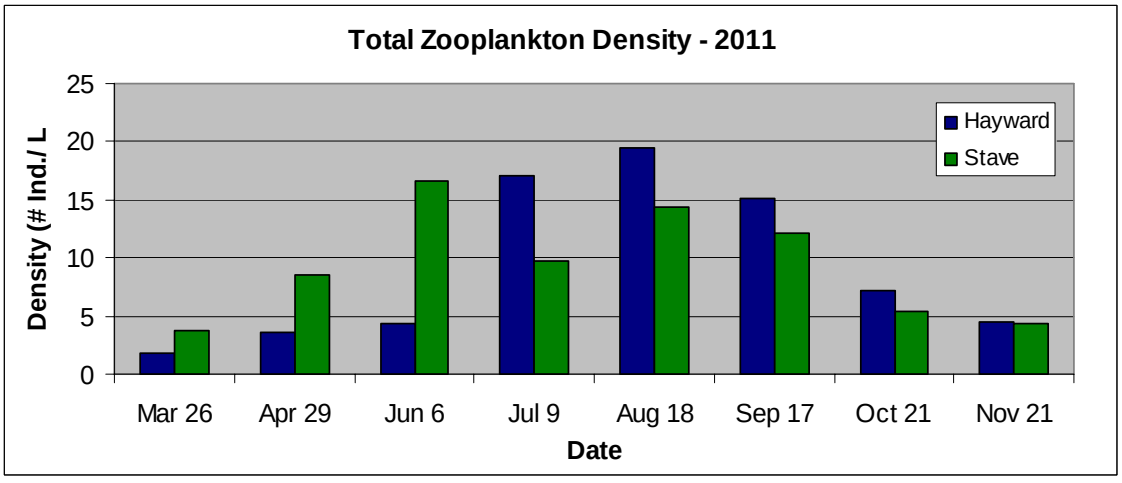


Figure 4.28: Total Zooplankton Biomass 2007-2011

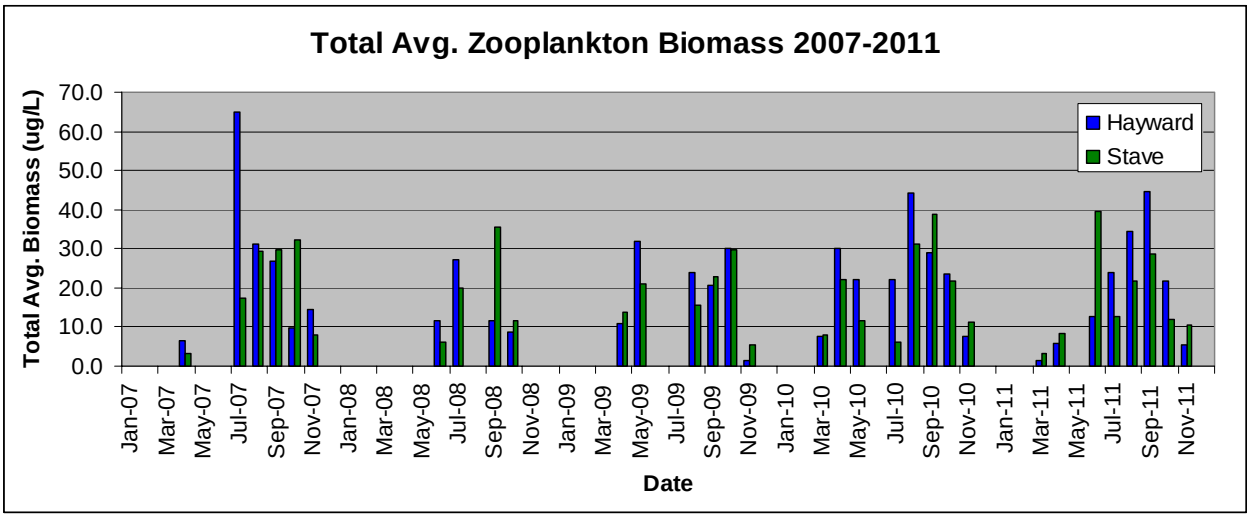


Figure 4.29: Total Zooplankton Density 2007-2011

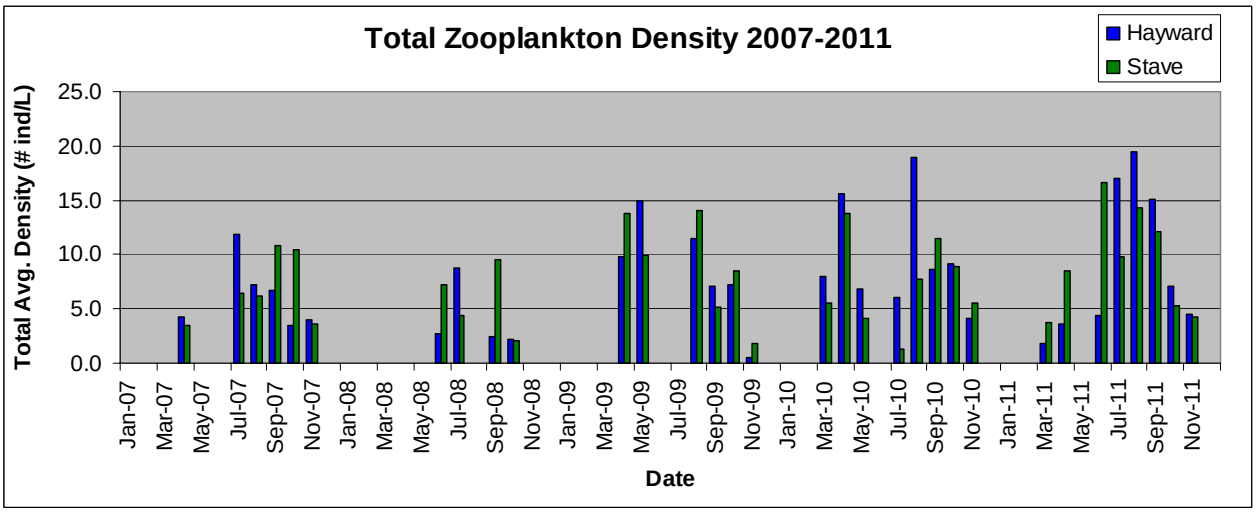


Figure 4.30: Zooplankton Densities from Other BC Reservoirs

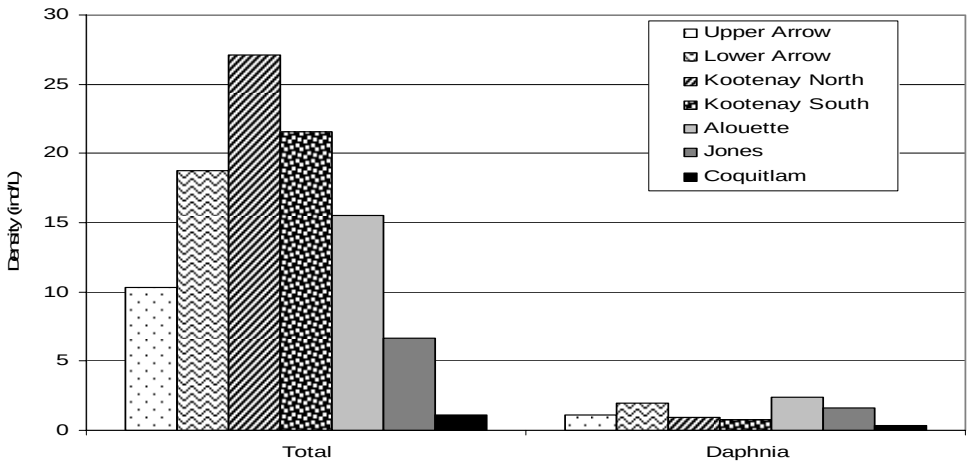
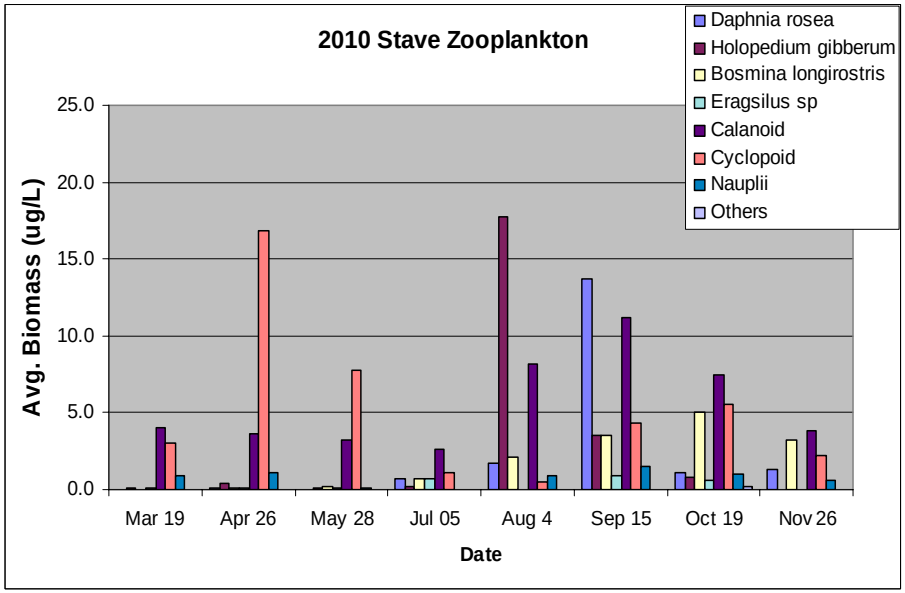
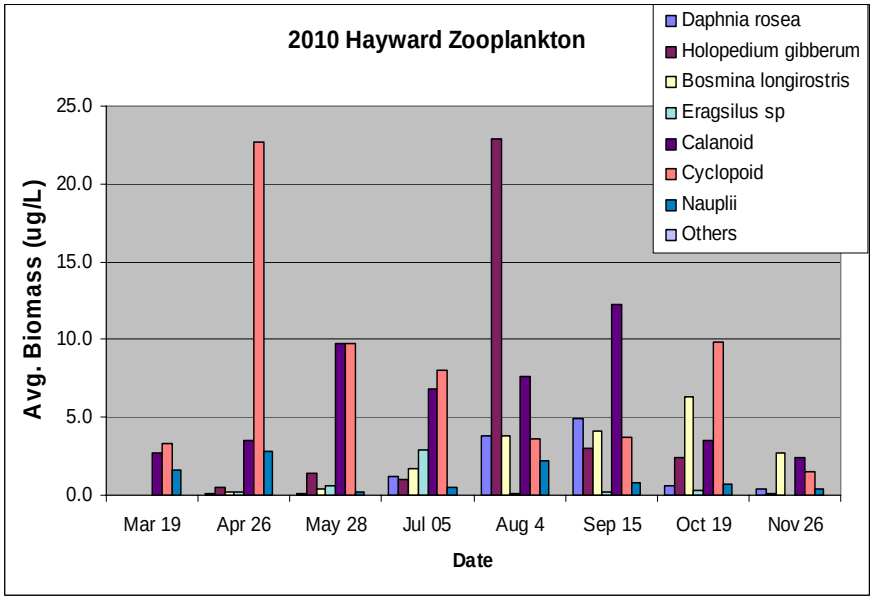
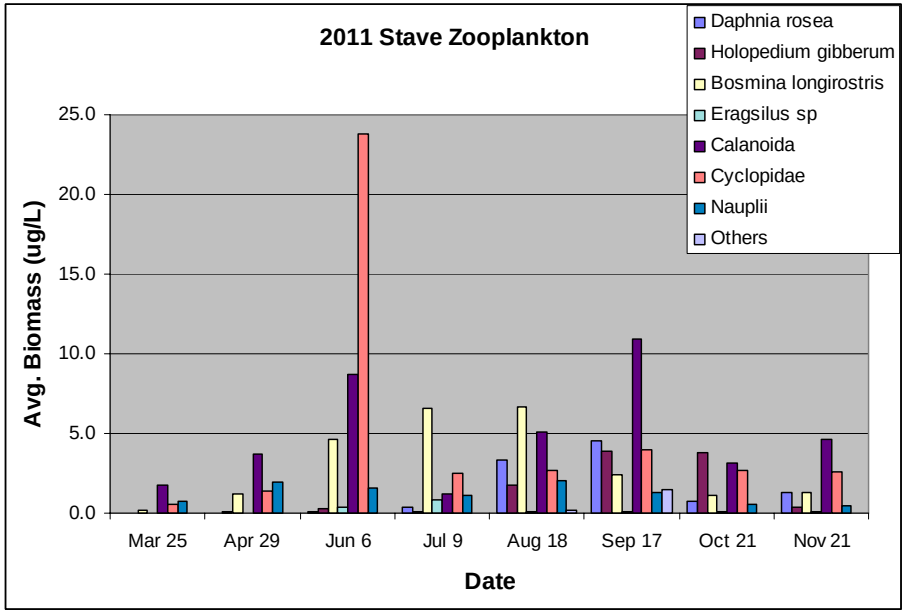
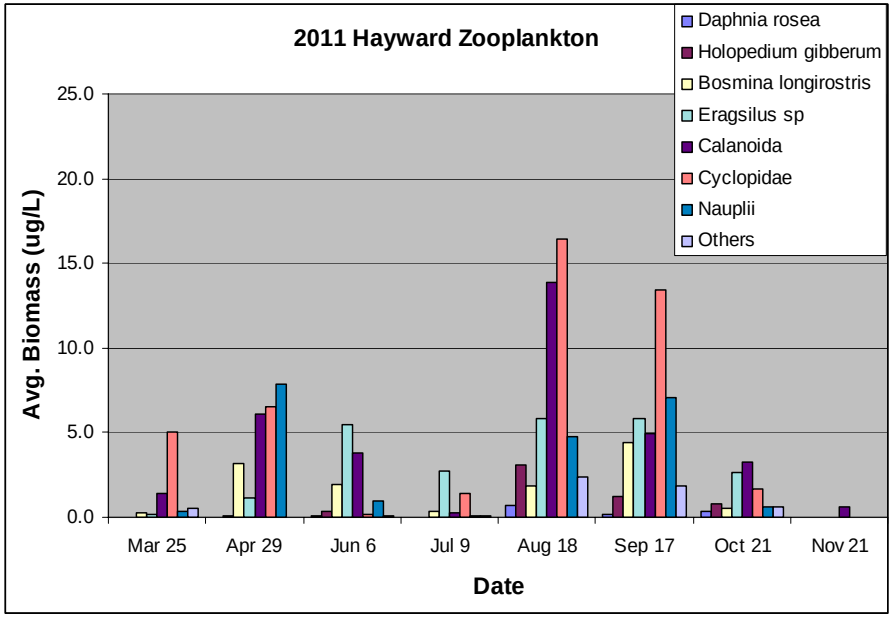


Figure 4.31: Stave and Hayward Zooplankton Species 2010 and 2011









4.7 Pelagic Primary Production – ^{14}C Incubation

Results from the pelagic primary production estimates from the ^{14}C incubations conducted in 2008 were unsuccessful due to contaminated carbon stock. In consultation with BC Hydro it was decided that additional pelagic primary production would be added to this study with incubations being conducted during the summer months (4 sampling trips each summer) in 2010 through 2013. In addition, production estimates are fractionated into picoplanton (0.22 – 2.0 µm), nanoplankton (2.0 – 20 µm) and microplankton (>20 µm) which will allow the production estimates to be categorized into the significant algal groups.

Data from the pelagic primary production incubations conducted in 2010 and 2011 are presented in Figures 4.32 and 4.33. Complete results of the primary production incubations are provided in Appendix 7. Estimates of daily carbon production at 1, 3, 5, 7, and 10 m depth intervals in Stave and Hayward (Figure 4.32 and 4.33) shows a general trend of peak production occurring near the surface and lessening with depth and decreased light penetration. In 2011, peak daily production in Hayward occurred in early summer with a peak of almost 20 mg C/m^3/day, while in Stave daily production peaked in fall at 15 mg C/m^3/day. Size fractionated production in Hayward indicates that pico and nano fractions are more prevalent, particularly in the summer months (June- August) (Figure 4.34). In 2011, Hayward exhibited a spike in micro-sized organisms occurring in September. There appears to be more variability in the break down of size classes in Stave with no clear trends being exhibited.

Based on the 2010 and 2011 data, it would appear that Hayward is more productive throughout the summer, while Stave is more productive in fall. This result is potentially explained by the short residence time of water in Hayward which prevents stratification of the water column from occurring in fall. With only two years of data, trends in production data can only be viewed as a preliminary result. More full analyses will be able to be provided with the additional carbon incubation that will be carried out in the remaining years.

Figure 4.32: Estimates of Daily Carbon Production

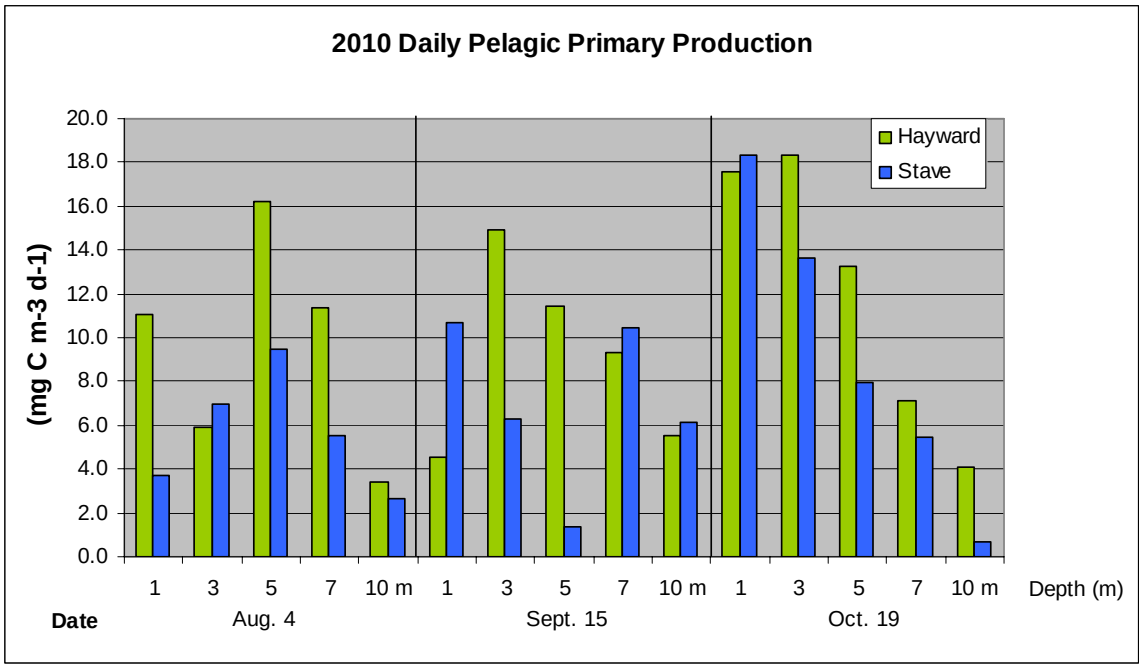


Figure 4.33: Estimates of Daily Carbon Production

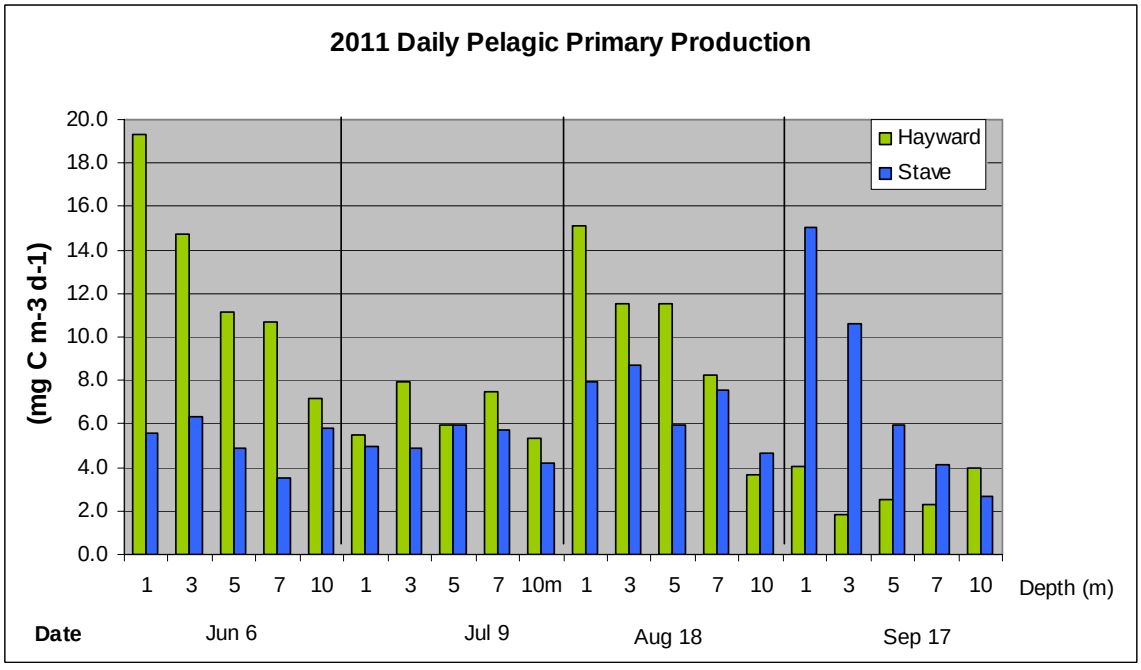
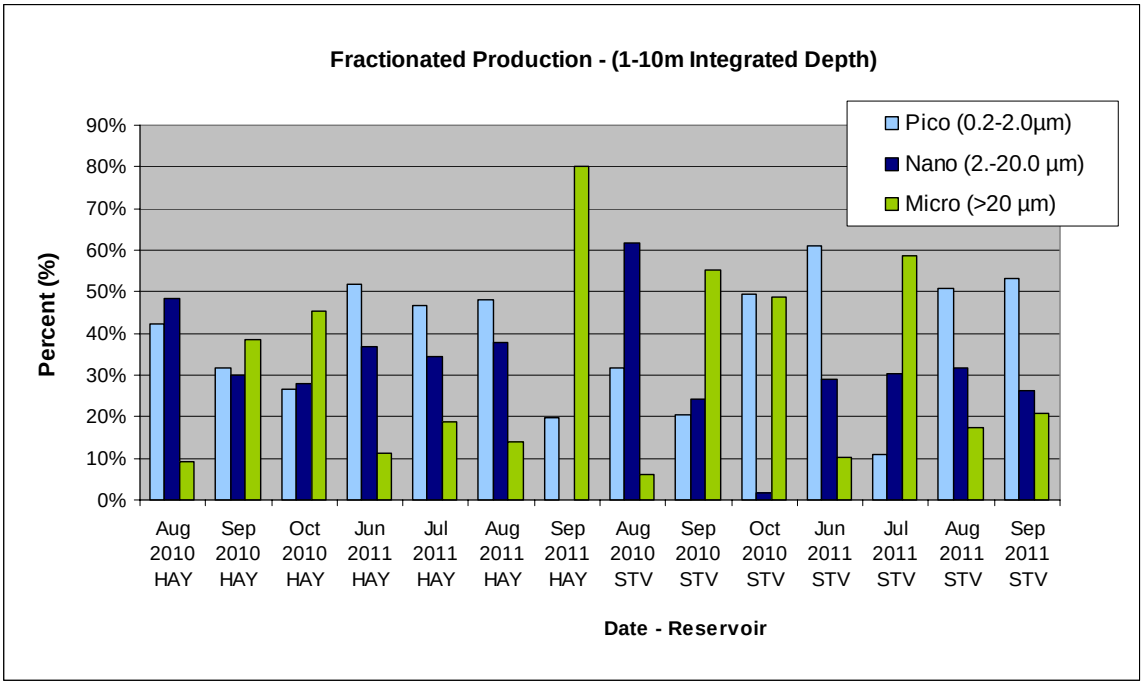


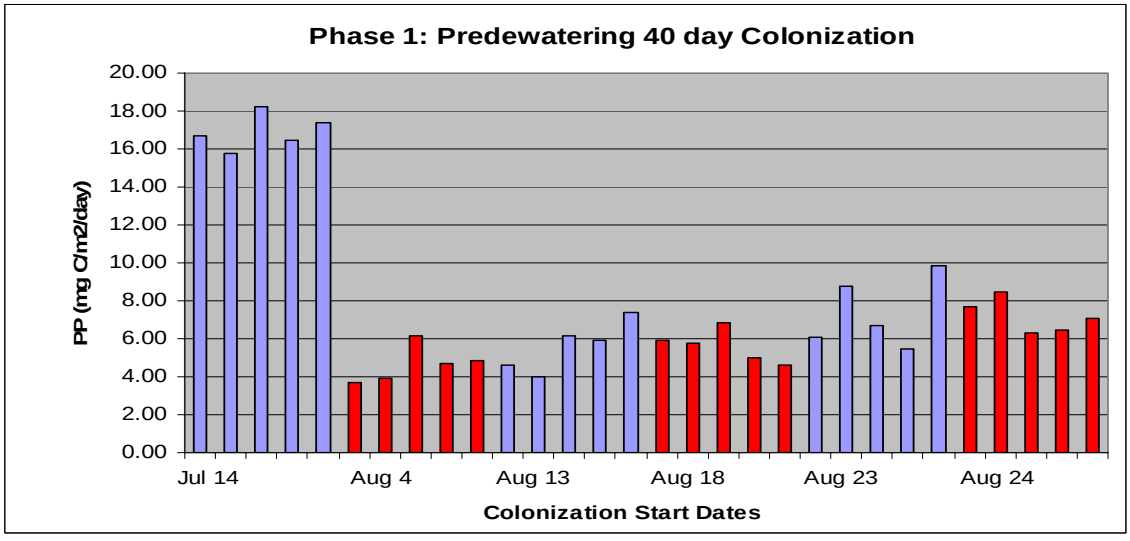
Figure 4.34: Fractionated Production (1-10m Integrated depth)



4.8 Intensive Littoral Dewatering and Growth Rate Study

Phase 1 of the intensive littoral dewatering and growth rate study examined a 40 day incubation period that had a staggered start day depending upon the length of the treatment (i.e. 40, 20, 10, 5, 1 or no days) of dewatering. Data from phase 1 samples were similar to one another with sample weights within 10-15% of one another, with the exception of the 40 day dewatering trial which was notably higher than all other treatments (Figure 4.35).

Figure 4.35: Phase 1 – 40 Day Colonization Period

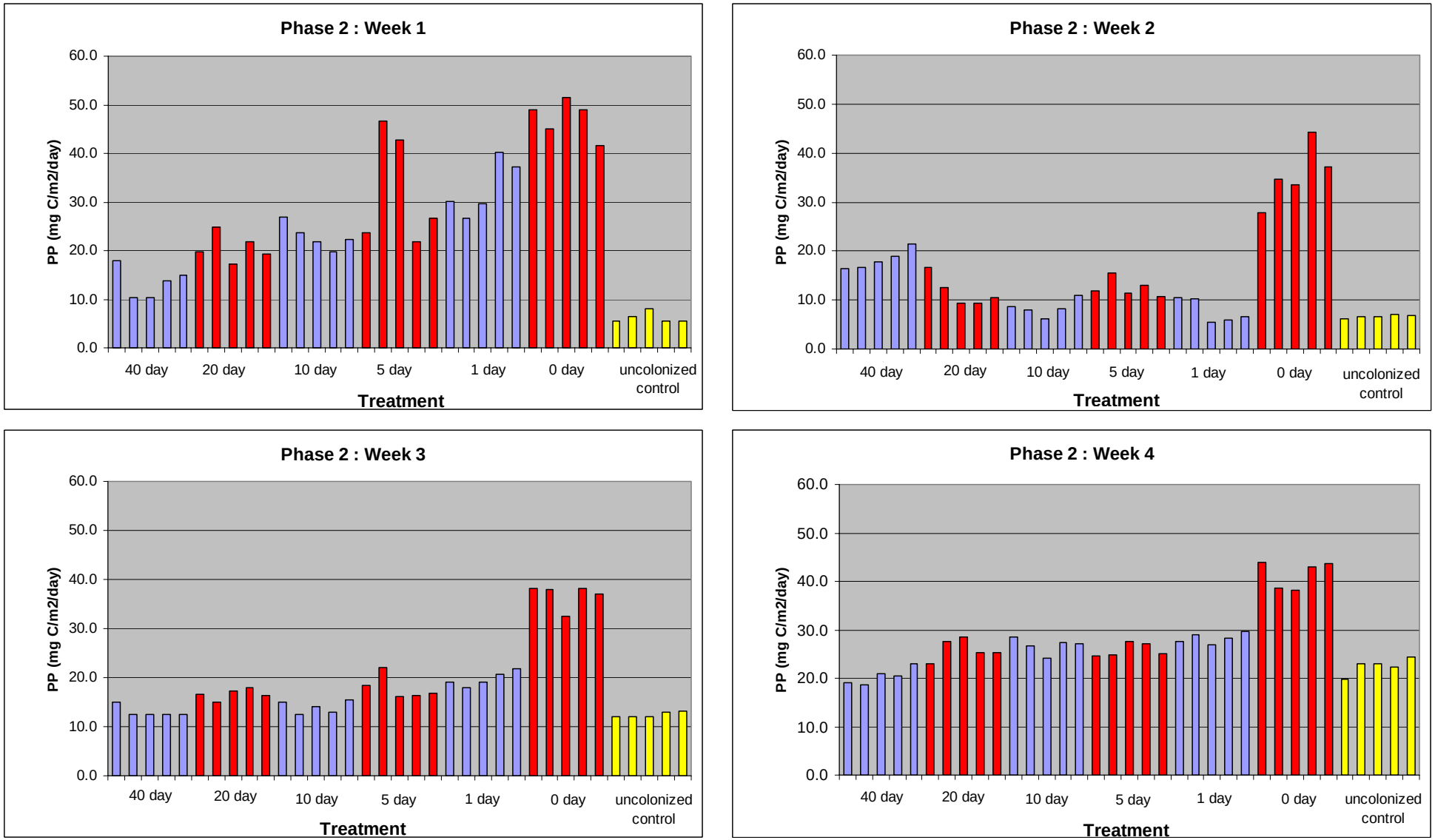


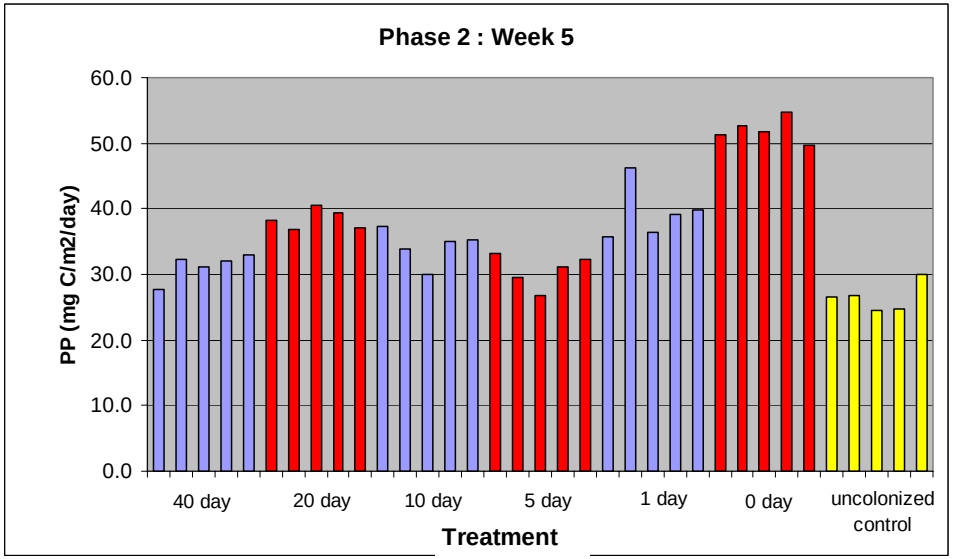
Some possible explanations for the higher growth that occurred during the incubation period of the 40 day dewatering trial may be that higher growth occurred due to the late onset of summer temperatures and in turn available nutrients or possible sampling error. The incubation period for the 40 day dewatering treatment had the least amount of overlap with incubation days for the other 5 treatments, thus it is possible that the conditions of growth varied more during the late summer. Further analyses conducted by BC Hydro (unpublished data) found that pre-treatment growth that started in July (40 day treatment) was generally twice that observed for all other treatment groups. The 20 day treatment was the lowest biomass in the pre-treatment phase and was found to be significantly different from the 1 day and the no dewatering treatments. All other groups were found to be similar to on another.

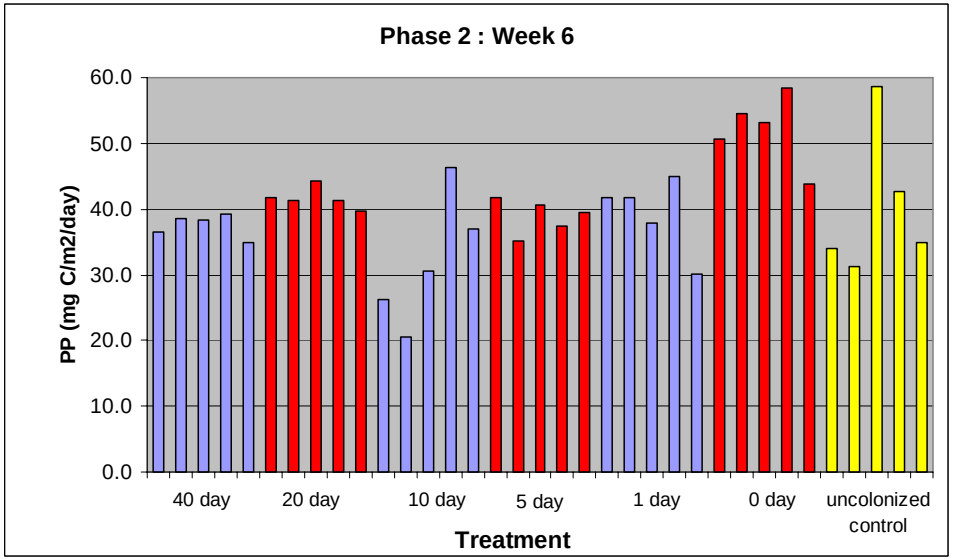
Data from phase 2 of the intensive littoral dewatering study found that although there is variability in the sample replicates, most replicates appear to be fairly consistent (Figure 4.36). Assuming uniform growth on the plate, this variability might be attributed to sampling loss or error in analytical analyses in the laboratory. The week 1 graph (indicating 1 week in the water after dewatering) appears to indicate that longer dewatering results in less growth. The uncolonized control plate exhibits lower growth than all treatments, but increases steadily over the 6 weeks of sampling such that it is comparable to all other treatments by the end of the study. Looking at weeks 2 through 6 it is notable that once resubmerged growth steadily increased for all treatments of 1 day or more out of water. By week 6 it appears that all treatments including those that were not dewatered and the uncolonized plates are comparable at approximately 40 mg $C/m^2/day$.

Further analyses conducted by BC Hydro (unpublished data) found that the majority of variance was explained by time alone which captured the effect of growth during the post treatment growth phase. The rates of growth between treatments were found to vary significantly. In general, periphyton growth was faster on colonized plates than uncolonized plates. Conversely plates that underwent no dewatering had the slowest rates of growth. All plates that experienced some dewatering were found to have similar rates of growth.

Figure 4.36: Phase 2 – Weekly Periphyton Primary Production for Six Dewatering Treatments




Phase 2 : Week 5
PP (mg C/m2/day)
60.0
50.0
40.0
30.0
20.0
10.0
0.0
40 day
20 day
10 day
5 day
1 day
0 day
uncolonized control
Treatment


Phase 2 : Week 6
PP (mg C/m2/day)
60.0
50.0
40.0
30.0
20.0
10.0
0.0
40 day
20 day
10 day
5 day
1 day
0 day
uncolonized control
Treatment

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Appendix 1: Pelagic and Littoral Null Hypotheses

As taken from the BC Hydro Monitoring Plan Terms of Reference (TOR)

Pelagic Null Hypotheses:
A total of 10 hypotheses were identified for the present monitor. Collectively, they form an impact hypothesis model that explores the interrelationship of various environmental factors on productivity, as well as inter-trophic interactions. The impact hypotheses, expressed here as null hypotheses (i.e., hypotheses of no difference or correlation), are tested separately for each reservoir and relate primarily to levels of primary productivity.

H01: Average reservoir concentration of Total Phosphorus (TP), an indicator of general phosphorus availability, does not limit pelagic primary productivity.
H02: Relative to the availability of phosphorus as measured by the level of total dissolved phosphorus (PO4), the average reservoir concentration of nitrate (NO3) does not limit pelagic primary productivity. Nitrate is the dominant form of nitrogen that is directly bio available to algae and is indicative of the general availability of nitrogen to pelagic organisms.
H03: Water retention time (τw) is not altered by reservoir operations such that it significantly affects the level of TP as described by Vollenweider's (1975) phosphorus loading equations (referred to here as TP(τw)).
H04: Water temperature, and hence the thermal profile of the reservoir, is not significantly altered by reservoir operations.
H05: Changes in TP as a result of inter annual differences in reservoir hydrology (i.e., TP(τw)) are not sufficient to create a detectable change in pelagic algae biomass as measured by levels of chlorophyll a (Chla). [This hypothesis can only be tested if H03 is rejected].
H06: Independent estimates of algae biomass based on TP(τw) and Secchi disk transparency (SD) prediction equations are statistically similar, suggesting that neither non-algal turbidity, nor intensive zooplankton grazing, are significant factors that influence standing crop of pelagic phytoplankton (Carlson 1980, cited in Wetzel 2001).
H07: The effect of non-algal turbidity on pelagic algae biomass, as indicated by the difference in independent predictions of Chla by TP(τw) and SD (Carlson 1980, cited in Wetzel (2001), does not change as a function of reservoir operation.
H08: The ratio of ultra-phytoplankton (< 20 µm in size) to micro-phytoplankton (20-200 µm in size) abundance is not altered by reservoir operations and hence, does not change through time with the implementation of the WUP Combo 6 operating strategy.
H09: The size distribution of the pelagic zooplankton population (an indicator of fish food bioavailability as larger organisms tend to be preferred over small ones) is not altered by reservoir operations and hence, does not change through time with the implementation of the WUP Combo 6 operating strategy.

H010: Primary production, as measured through C14 inoculation, is not altered by reservoir operations and hence, does not change through time with the implementation of the WUP Combo 6 operating strategy (BC Hydro, 2005).

Littoral Null Hypotheses:

H01: Average reservoir concentration of Total Phosphorus (TP), an indicator of general availability of phosphorus is not limiting to littoral primary productivity. [Relies on data collected during the pelagic monitor and assumes that nutrient concentrations are uniform through out each reservoir].

H02: Relative to the availability of phosphorus as indicated by level of total dissolved phosphorus (PO4), the average reservoir concentration of nitrate (NO3) is not limiting to littoral primary productivity. Nitrate is the dominant form of nitrogen that is directly bioavailable to algae and higher plants and is indicative of the general availability of nitrogen to littoral organisms. [Relies on data collected during the pelagic monitor and assumes that nutrient concentrations are uniform through out each reservoir].

H03: Water retention time (τw) is not altered by reservoir operations such that it significantly affects the level of TP as described by Vollenweider's (1975) phosphorus loading equations (referred to here as TP(τw)). [Relies on data collected during the pelagic monitor and assumes that nutrient concentrations are uniform through out each reservoir].

H04: Water temperature, and hence the thermal profile of the reservoir, is not significantly altered by reservoir operations. [Relies on data collected during the pelagic monitor and assumes that nutrient concentrations are uniform through out each reservoir].

H05: Changes in TP as a result of reservoir operations (through changes in τw) 1) are not sufficient to create a detectable change in littoral algae biomass as measured by littoral levels of chlorophyll a (CHL). [Relies on data collected during the pelagic monitor and assumes that nutrient concentrations are uniform through out each reservoir].

The next suite of hypotheses deals with the general premise that littoral productivity in clear, low nutrient lakes tends to be much greater than pelagic productivity, and hence defines the productivity of the system as a whole. Underlying this premise is the theory that in clear, low nutrient systems, incoming nutrients are quickly assimilated into the littoral zone before getting a chance to work their way to the pelagic zone via the littoral food web. Conversely, when turbid conditions exist, the low light levels inhibit littoral growth and thus allow pelagic productivity to prevail. Similarly, when eutrophic conditions exist, the ability for the littoral system to sequester nutrients is overwhelmed, also allowing the pelagic system to flourish. As pelagic productivity increases, the high biomass reduces light penetration and in turn begins to inhibit productivity in the littoral zone. This feedback mechanism allows the pelagic zone to eventually dominate overall lake productivity (Wetzel 1983, Dodds 2003, Liboriussen and Jeppensen, 2003).Included in this suite of hypotheses is a test of the premise that nutrient cycling processes in the littoral zone slows the overall loss of phosphorus (either by outflow or to hypolimnetic sediments), and therefore, increases overall lake productivity compared to similar

systems without a substantial littoral zone (Wetzel 1983). During the WUP, it was assumed that the two theories above applied to the Stave-Hayward system, and that the importance of the littoral zone to overall system productivity was deemed to be very high. The Stave–Hayward reservoir system however, is not a shallow water lake system. Also, the two reservoir systems tend to be very steep sided, so that the aerial extent of the littoral habitat may not be very large, even under ideal hydraulic conditions. Because of these two reasons, it is possible that the assumed theoretical importance of littoral zone productivity may be incorrect for these two reservoirs. Fortunately, the Stave-Hayward reservoir system does provide a unique opportunity to test this assumption. The Stave Lake reservoir, under present conditions, has limited littoral development because of the extensive drawdown events that it experiences. Hayward reservoir on the other hand, tends to be quite stable. If the assumption is indeed correct, then the following two hypotheses would hold true:

H06: Overall primary production (as measured by 14C inoculation and/or as inferred from ash free dry weight data) of Stave reservoir is less than that of Hayward Lake.

H07: Pelagic primary production dominates in Stave reservoir while littoral production dominates in Hayward reservoir. With the new WUP regime, the frequency and extent of drawdown in the Stave system is expected to decrease, while that of the Hayward system is likely to increase. Based on the assumptions that lead to the development of the ELZ performance measure (Appendix 2 of Failing 1999), these changes are expected to alter the quantity of littoral habitat suitable for primary production, and hence have an impact on overall system primary production. The extent with which this may occur, if indeed a response occurs at all, is uncertain. The test of this premise is the subject of the final set of hypotheses. It is important to note that in testing these hypotheses, one is also testing the validity of the ELZ measure. The null hypotheses are:

H08: Stable reservoir levels do not lead to maximum littoral development as measured by 14C inoculation and/or inferred from ash free dry weight data.

H09: Water level fluctuations that raise the euphotic zone (defined here as the depth at which photosythetically active radiation (PAR) is 1% that of the water surface) from lower elevations does not lead to a collapse of littoral primary production (as measured by 14C inoculation and/or inferred from ash free dry weight data) that occurred near the prior 1% PAR depth.

H010: Littoral zone productivity, as measured by 14C inoculation and/or inferred from ash free dry weight data, remains unchanged as reservoir water level stability increases.

H011: Changes in littoral productivity (as measured by 14C inoculation and/or inferred from ash free dry weight data) are expressed primarily in terms of changes in areal extent as defined by upper and lower boundary elevations. Within these boundaries, primary production does not vary in proportion to accumulated PAR exposure under wetted conditions [this is the premise that has lead to the development of the ELZ performance measure].

Appendix 2: Water Chemistry Methodology

Methods provided by SPA Chemtest - DFO Laboratory, Cultus Lake, BC

Nutrient Samples Collection Procedure

All methods can be found in K. Stephens and R. Brandstaetter 1983.

Sample Storage and Transport:

- TP and TDP samples are stored in reusable borosillicate glass culture test tubes with a screw cap that are PTFE-faced and rubber lined.
- Nitrates samples are stored in 130 ml high density polyethylene bottles.
- TP and TDP samples refrigerated and Nitrate/Nitrite samples are stored frozen until they are analysed. Samples are analysed shortly after delivery to the lab, therefore there is no long term storage of samples and limited holding times.
- Ensure that nutrient samples are kept frozen and test tubes cool during transport to Cultus Lake Lab. This is critically important, so use as much cubed ice in plastic bags as necessary.
- Prepare a field sample submission sheet and submit it along with the samples.

TP Sample Procedure:

1. Be sure not to touch the test tube mouth or inside of the cap as the Total Phosphorus analysis are extremely sensitive.
2. At each depth, fill a labeled test tube with unfiltered sample water then cap and shake tube to rinse, then discard sample water.
3. Refill test tube with unfiltered sample water.
4. Make sure that the bottom of the meniscus rests on the top of the shoulder of the test tube.
5. Put lids on tightly and
6. Ensure all labels are legible and state the lake, station, date, depth and test.
7. Once per field trip, prepare 2 labeled test tubes with unfiltered deionized distilled water (DDW) for TP blanks.
8. Do not freeze test tubes, but keep them cool by refrigerating.

Filter preparation for both TDP and Nitrate Samples:

- Using a 47-mm Swinnex holder with an ashed GFF filter and a clean 60-cc syringe, prepare the GFF filter by placing it in the Swinnex holder and rinsing it with 3 full syringes of DDW.
- If the water runs through with little or no resistance, the filter is either torn or not seated properly in holder. Readjust filter or replace it if readjustment does not rectify the problem.
- Use one ashed GFF filter for each station unless filtering efficiency becomes hampered (*i.e.* filter becomes plugged).

Total Dissolved Phosphorus (TDP) Sample Procedure:

1. For each depth, filter one full syringe of sample into the appropriate labeled test tube.
2. Put cap on test tube, shake and discard sample water. Refill test tube with filtered sample water.
3. Make sure that the bottom of the meniscus rests on the top of the shoulder of the test tube.
4. Put lids on tightly.
5. Ensure all labels are legible and state the lake, station, date, depth and test.
6. Once per field trip, prepare 2 labeled test tubes with filtered DDW for TDP blanks.
7. Do not freeze test tubes, but keep them cool.

TP/TDP methodology:

The sample is digested with a persulphate-sulphuric acid mixture. Polyphosphates and organically bound phosphorous are converted to orthophosphate. Orthophosphates are reacted with ammonium molybdate and stannous chloride and determined as the blue phospho-molybdenum complex. The range of method is 0.5 to 50 µg P/litre with the lower limit of detection being 0.5 µg P/litre.

Nitrate/Nitrite Sample Procedure:

1. For each depth (1.3, 5 m composite) filter one full syringe of sample water into a labeled high density polyethylene bottle.
2. Put cap on bottle, shake, and discard sample water.
3. Refill bottle to the shoulder with filtered sample water. Put lids on tightly.
4. Ensure all labels are legible and state the lake, station, date, depth, test (Ammonia/SRP or NO3)
5. Freeze bottles immediately after filtration.
6. Once per field trip, prepare 2 filtered DDW blanks for Ammonia/SRP and Nitrate tests.

Nitrate/Nitrite methodology:

Nitrates: The buffered sample is passed through a cadmium column which reduces nitrates to nitrites. The reduced samples is reacted with sulphanilamide and N-(1-Naphthyl)ethylenediamine Dihydrochloride (N.N.E.D) to form a coloured azodye. The intensity of the colour produced is measured. The range of method is 1 to 224 µg NO_3.N/litre.

Nitrites: The unreduced sample is reacted with sulphanilamide and N.N.E.D. to form a coloured dye which is measured. The range of method is 1 to 224 µg NO_2.N/litre.

The range of this method is: 1 to 224 µg $N0_3$.N/L and 1 to 224 µg $N0_2$.N/L.

Chlorophyll sampling procedure

1. Using clean blunt-nosed forceps designated to handle only chlorophyll filters and a 47 mm filter holder that has been taped with black electrical tape to limit light exposure, open the filter holder and insert the chlorophyll filter, making sure that the o-ring is seated properly in the filter holder.

2. Place the filter holder onto the top of the vacuum flask and attach to a pump that is regulated to 7 inches Hg.
3. Measure a suitable sized aliquot of lake water (usually between 250 - 500 ml is sufficient) using a clean graduated cylinder, pour into the filter holder and filter.
4. Preserve the filtered sample by placing the filter, folded in half in an aluminum weighing dish.
5. Ensure that the dish has been labelled with the lake, station, date, depth and filtered amount on the bottom of the dish with a nail or dry pen (do not use a pen with ink).
6. Aluminum dishes may be stacked (make sure that the top filter is covered with an empty dish) and tape all dishes together using masking tape.
7. Make sure that the tape is labelled for easy identification in the lab.
8. Place stack in a sealed ziploc bag and freeze immediately.
9. Chlorophyll samples must be kept in the dark and frozen at all times.

Chlorophyll samples are measured flurometrically using 0.45µm membrane filters which contain nitrocellulose. The flourometric method to measure chlorophyll is used because of it's sensitivity and simplicity. The limit of detection is dependent upon the volume of sample filtered and the sensitivity range of the fluorometer. With a 1L sample, the least detectable amount of chlorophyll a is 0.1 µg Chl a/L.

Appendix 3: Zooplankton Count Sheet

Lake_____ **Station**_____
Magnification_____ **Tow Depth**_____
Date Collected_____ **Flowmeter**_____
Date Counted_____ **Dilution**_____

Species	Sub 1	Sub 2	5	10	15	20
Daphnia						
Holepedium						
Bosmina						
Cyclopoid						
Calanoid						
Nauplii						

Lake_____ **Station**_____
Magnification_____ **Tow Depth**_____
Date Collected_____ **Flowmeter**_____
Date Counted_____ **Dilution**_____

Species	Sub 1	Sub 2	5	10	15	20
Daphnia						
Holepedium						
Bosmina						
Cyclopoid						
Calanoid						
Nauplii						

Appendix 4: 2010 Zooplankton Counts

Hayward

									Daphnia rosea				Holopedium gibberum				Bosmina longirostris				Ergasilus sp				Canthocamptidae: Diaptomus (oregonensis)				Cyclopidae: (Microcyclops rubellus)				Nauplii				Others			
Date	Sample Depth (m)	Tow Length (m)	Station	Dilution (mL)	Sub-sample Vol (mL)	Flow	Net Eff. (%)	Tot Vol (L)	Count	#/L	Dry Wt (ug)	Biomass (ug/L)	Count	#/L	Dry Wt (ug)	Biomass (ug/L)	Count	#/L	Dry Wt (ug)	Biomass (ug/L)	Count	#/L	Dry Wt (ug)	Biomass (ug/L)	Count	#/L	Dry Wt (ug)	Biomass (ug/L)	Count	#/L	Dry Wt (ug)	Biomass (ug/L)	Count	#/L	Dry Wt (ug)	Biomass (ug/L)	Count	#/L	Dry Wt (ug)	Biomass (ug/L)
25-Mar-11	0-15	15	1	60	60	NA	50.0	529.88	0	0.000	0.00	0.00	1	0.002	1.48	0.00	19	0.036	2.11	0.08	0	0.000	0.00	0.00	50	0.094	7.18	0.68	43	0.081	2.60	0.21	945	1.783	0.24	0.43	2	0.004	0.66	0.00
25-Mar-11	0-15	15	2	60	60	NA	50.0	529.88	0	0.000	0.00	0.00	3	0.006	1.32	0.01	26	0.049	1.95	0.10	1	0.002	2.69	0.01	46	0.087	7.74	0.67	38	0.072	2.88	0.21	900	1.699	0.20	0.34	5	0.009	0.78	0.01
25-Mar-11	0-15	15	3	60	60	NA	50.0	529.88	0	0.000	0.00	0.00	2	0.004	1.55	0.01	14	0.026	3.25	0.09	0	0.000	0.00	0.00	49	0.092	7.57	0.70	70	0.132	2.52	0.33	1020	1.925	0.26	0.50	5	0.009	1.14	0.01
25-Mar-11	0-15	15	4	60	60	NA	50.0	529.88	1	0.002	6.49	0.01	1	0.002	1.93	0.00	16	0.030	3.13	0.09	0	0.000	0.00	0.00	41	0.077	7.38	0.57	42	0.079	2.54	0.20	690	1.302	0.23	0.30	4	0.008	1.12	0.01
25-Mar-11	0-15	15	5	60	60	NA	50.0	529.88	0	0.000	0.00	0.00	0	0.000	0.00	0.00	14	0.026	3.24	0.09	0	0.000	0.00	0.00	51	0.096	7.68	0.74	34	0.064	2.16	0.14	480	0.906	0.24	0.22	1	0.002	6.75	0.01
29-Apr-11	0-15	15	1	60	16	NA	50.0	529.88	0	0.000	0.00	0.00	12	0.085	2.87	0.24	38	0.269	2.83	0.76	0	0.000	0.00	0.00	24	0.170	6.34	1.08	46	0.326	2.98	0.97	317	2.243	0.25	0.56	1	0.007	7.79	0.06
29-Apr-11	0-15	15	2	60	16	NA	50.0	529.88	0	0.000	0.00	0.00	17	0.120	1.80	0.22	31	0.219	1.67	0.37	0	0.000	0.00	0.00	40	0.283	6.65	1.88	63	0.446	2.53	1.13	403	2.852	0.38	1.08	3	0.021	0.39	0.01
29-Apr-11	0-15	15	3	60	16	NA	50.0	529.88	1	0.007	1.41	0.01	4	0.028	1.70	0.05	14	0.099	2.72	0.27	0	0.000	0.00	0.00	70	0.495	8.45	4.19	62	0.439	2.44	1.07	289	2.045	0.29	0.59	2	0.014	0.89	0.01
29-Apr-11	0-15	15	4	60	16	NA	50.0	529.88	0	0.000	0.00	0.00	7	0.050	2.06	0.10	9	0.064	2.99	0.19	0	0.000	0.00	0.00	77	0.545	8.28	4.51	78	0.552	2.16	1.19	384	2.718	0.30	0.82	0	0.000	0.00	0.00
29-Apr-11	0-15	15	5	60	16	NA	50.0	529.88	1	0.007	5.07	0.04	4	0.028	1.67	0.05	17	0.120	2.85	0.34	0	0.000	0.00	0.00	68	0.481	7.82	3.76	81	0.573	2.81	1.61	423	2.994	0.33	0.99	1	0.007	0.37	0.00
06-Jun-11	0-15	15	1	80	8	NA	50.0	529.88	0	0.000	0.00	0.00	1	0.019	7.67	0.14	47	0.887	1.96	1.74	5	0.094	4.94	0.47	54	1.019	2.39	2.44	55	1.038	3.52	3.65	79	1.491	0.42	0.63	0	0.000	0.00	0.00
06-Jun-11	0-15	15	2	60	4	NA	50.0	529.88	1	0.028	27.54	0.78	1	0.028	3.98	0.11	33	0.934	2.97	2.77	1	0.028	5.61	0.16	25	0.708	2.51	1.78	50	1.415	2.80	3.96	47	1.331	0.42	0.56	0	0.000	0.00	0.00
06-Jun-11	0-15	15	3	60	4	NA	50.0	529.88	0	0.000	0.00	0.00	1	0.028	3.28	0.09	24	0.679	2.01	1.37	3	0.085	4.77	0.41	21	0.594	2.48	1.47	60	1.699	3.27	5.55	38	1.076	0.36	0.39	0	0.000	0.00	0.00
09-Jul-11	0-15	15	1	60	4	NA	50.0	529.88	1	0.028	3.66	0.10	4	0.113	3.99	0.45	65	1.840	2.12	3.90	25	0.708	4.65	3.29	33	0.934	4.24	3.96	44	1.246	5.31	6.61	298	8.436	0.21	1.77	0	0.000	0.00	0.00
09-Jul-11	0-15	15	2	60	4	NA	50.0	529.88	3	0.085	3.86	0.33	9	0.255	3.86	0.98	65	1.840	3.52	6.48	29	0.821	4.66	3.83	57	1.614	4.97	8.02	40	1.132	5.70	6.45	412	11.663	0.23	2.68	0	0.000	0.00	0.00
09-Jul-11	0-15	15	3	60	4	NA	50.0	529.88	2	0.057	3.47	0.20	10	0.283	6.21	1.76	64	1.812	2.76	5.00	28	0.793	4.61	3.65	49	1.387	4.35	6.03	42	1.189	4.19	4.98	360	10.191	0.25	2.55	0	0.000	0.00	0.00
09-Jul-11	0-15	15	4	60	4	NA	50.0	529.88	4	0.113	3.79	0.43	12	0.340	4.47	1.52	60	1.699	2.98	5.06	13	0.368	4.37	1.61	71	2.010	3.03	6.09	46	1.302	5.12	6.67	435	12.314	0.21	2.59	0	0.000	0.00	0.00
09-Jul-11	0-15	15	5	60	4	NA	50.0	529.88	0	0.000	0.00	0.00	9	0.255	4.85	1.24	81	2.293	3.08	7.06	9	0.255	4.66	1.19	45	1.274	3.88	4.94	40	1.132	3.95	4.47	540	15.287	0.23	3.52	0	0.000	0.00	0.00
18-Aug-11	0-15	15	1	100	4	NA	50.0	529.88	8	0.377	3.61	1.36	30	1.415	4.51	6.38	20	0.944	2.03	1.92	0	0.000	0.00	0.00	107	5.048	3.39	17.11	42	1.982	2.28	4.52	203	9.578	0.36	3.45	1	0.047	29.51	1.39
18-Aug-11	0-15	15	2	100	4	NA	50.0	529.88	0	0.000	0.00	0.00	36	1.699	4.12	7.00	26	1.227	2.80	3.43	0	0.000	0.00	0.00	104	4.907	3.15	15.46	45	2.123	2.28	4.84	221	10.427	0.43	4.48	2	0.094	0.13	0.01
18-Aug-11	0-15	15	3	100	4	NA	50.0	529.88	5	0.236	7.06	1.67	23	1.085	4.08	4.43	33	1.557	4.01	6.24	2	0.094	4.98	0.47	79	3.727	3.39	12.64	47	2.218	2.47	5.48	218	10.285	0.27	2.78	1	0.047	32.30	1.52
18-Aug-11	0-15	15	4	100	4	NA	50.0	529.88	4	0.189	5.67	1.07	32	1.510	4.29	6.48	18	0.849	4.09	3.47	1	0.047	4.38	0.21	73	3.444	2.65	9.13	42	1.982	1.91	3.78	179	8.445	0.33	2.79	1	0.047	0.23	0.01
18-Aug-11	0-15	15	5	100	4	NA	50.0	529.88	11	0.519	5.63	2.92	29	1.368	4.51	6.17	27	1.274	2.93	3.73	3	0.142	4.39	0.62	97	4.577	3.32	15.19	71	3.350	1.88	6.30	223	10.521	0.29	3.05	0	0.000	0.00	0.00
																																						12.43	
17-Sep-11	0-15	15	1	150	4	NA	50.0	529.88	13	0.920	4.98	4.58	21	1.486	6.03	8.96	1	0.071	1.43	0.10	5	0.354	4.86	1.72	44	3.114	4.12	12.83	47	3.326	3.97	13.21	89	6.299	0.23	1.45	0	0.000	0.00	0.00
17-Sep-11	0-15	15	2	120	4	NA	50.0	529.88	8	0.453	4.63	2.10	18	1.019	6.03	6.15	1	0.057	1.43	0.08	4	0.226	4.48	1.01	58	3.284	5.00	16.42	64	3.623	3.30	11.96	105	5.945	0.37	2.20	0	0.000	0.00	0.00
17-Sep-11	0-15	15	3	120	4	NA	50.0	529.88	30	1.699	5.88	9.99	20	1.132	5.46	6.18	1	0.057	4.85	0.27	3	0.170	4.32	0.73	59	3.340	6.23	20.81	64	3.623	3.06	11.09	108	6.115	0.28	1.71	1	0.057	3.45	0.20
17-Sep-11	0-15	15	4	120	4	NA	50.0	529.88	17	0.962	6.08	5.85	17	0.962	5.57	5.36	2	0.113	2.51	0.28	10	0.566	4.56	2.58	50	2.831	5.89	16.67	68	3.850	3.80	14.63	95	5.379	0.26	1.40	0	0.000	0.00	0.00
17-Sep-11	0-15	15	5	120	4	NA	50.0	529.88	7	0.396	6.83	2.71	16	0.906	6.59	5.97	0	0.000	0.00	0.00	4	0.226	4.20	0.95	51	2.887	5.34	15.42	74	4.190	3.93	16.47	105	5.945	0.24	1.43	0	0.000	0.00	0.00
21-Oct-11	0-15	15	1	150	8	NA	50.0	529.88	2	0.071	6.39	0.45	36	1.274	6.95	8.85	14	0.495	3.64	1.80	0	0.000	0.00	0.00	51	1.805	2.27	4.10	67	2.371	4.59	10.88	74	2.619	0.28	0.73	0	0.000	0.00	0.00
21-Oct-11	0-15	15	2	80	4	NA	50.0	529.88	2	0.075	6.43	0.49	35	1.321	6.86	9.06	8	0.302	4.81	1.45	0	0.000	0.00	0.00	32	1.208	3.17	3.83	43	1.623	3.29	5.34	64	2.416	0.32	0.77	1	0.038	0.23	0.01
21-Oct-11	0-15	15	3	80	4	NA	50.0	529.88	3	0.113	5.87	0.66	37	1.397	6.64	9.27	5	0.189	3.60	0.68	1	0.038	4.38	0.17	28	1.057	4.29	4.53	51	1.925	4.15	7.99	57	2.151	0.18	0.39	0	0.000	0.00	0.00
21-Oct-11	0-15	15	4	80	4	NA	50.0	529.88	0	0.000	0.00	0.00	21	0.793	7.55	5.98	9	0.340	2.41	0.82	1	0.038	5.18	0.20	36	1.359	3.74	5.08	48	1.812	3.90	7.07	59	2.227	0.28	0.62	1	0.038	4.33	0.16
21-Oct-11	0-15	15	5	80	4	NA	50.0	529.88	0	0.000	0.00	0.00	28	1.057	5.78	6.11	4	0.151	1.95	0.29	1	0.038	4.38	0.17	44	1.661	3.70	6.14	32	1.208	3.26	3.94	63	2.378	0.28	0.67	0	0.000	0.00	0.00
21-Nov-11	0-15	15	1	60	16	NA	50.0	529.88	13	0.092	8.71	0.80	1	0.007	4.77	0.03	4	0.028	4.24	0.12	1	0.007	4.57	0.03	33	0.234	7.77	1.81	74	0.524	3.79	1.98	489	3.461	0.17	0.59	0	0.000	0.00	0.00
21-Nov-11	0-15	15	2	60	12	NA	50.0	529.88	10	0.094	4.79	0.45	0	0.000	0.00	0.00	2	0.019	4.11	0.08	1	0.009	6.05	0.06	31	0.293	7.48	2.19	54	0.510	3.10	1.58	469	4.426	0.17	0.75	0	0.000	0.00	0.00
21-Nov-11	0-15	15	3	60	12	NA	50.0	529.88	14	0.132	8.10	1.07	1	0.009	10.06	0.09	1	0.009	4.85	0.05	2	0.019	3.00	0.06	45	0.425	7.53	3.20	45	0.425	3.84	1.63	356	3.359	0.18	0.60	0	0.000	0.00	0.00
21-Nov-11	0-15	15	4	60	12	NA	50.0	529.88	7	0.066	3.38	0.22	1	0.009	1.35	0.01	2	0.019	0.72	0.01	1	0.009	6.51	0.06	30	0.283	7.30	2.07	79	0.745	3.34	2.49	362	3.416	0.17	0.58	0	0.000	0.00	0.00
21-Nov-11	0-15	15	5	60	12	NA	50.0	529.88	2	0.019	2.01	0.04	0	0.000	0.00	0.00	3	0.028	3.12	0.09	1	0.009	4.57	0.04	36	0.340	7.73	2.63	48	0.453	3.24	1.47	329	3.105	0.20	0.62	0	0.000	0.00	0.00

Stave

									Daphnia rosea				Holopedium gibberum				Bosmina longirostris				Epischura nevadensis				Calanoida: Diaptomus (Hesperodiaptomus) shoshone				Cyclopidae: (Microcyclops rubellus cf)				Nauplii				Others			
Date	Sample Depth (m)	Tow Length (m)	Station	Dilution (mL)	Sub-sample Vol (mL)	Flow	Net Eff. (%)	Tot Vol (L)	Count	#/L	Day Wt (ug)	Biomass (ug/L)	Count	#/L	Day Wt (ug)	Biomass (ug/L)	Count	#/L	Day Wt (ug)	Biomass (ug/L)	Count	#/L	Day Wt (ug)	Biomass (ug/L)	Count	#/L	Day Wt (ug)	Biomass (ug/L)	Count	#/L	Day Wt (ug)	Biomass (ug/L)	Count	#/L	Day Wt (ug)	Biomass (ug/L)	Count	#/L	Day Wt (ug)	Biomass (ug/L)
25-Mar-11	0-20	20	1	60	12	NA	50.0	706.50	0	0.000	0.00	0.00	1	0.007	1.93	0.01	4	0.028	3.55	0.10	0	0.000	0.00	0.00	50	0.354	7.23	2.56	37	0.262	2.60	0.68	499	3.531	0.26	0.92	0	0.000	0.00	0.00
25-Mar-11	0-20	20	2	60	16	NA	50.0	706.50	1	0.005	5.61	0.03	1	0.005	1.93	0.01	7	0.037	1.21	0.04	0	0.000	0.00	0.00	44	0.234	7.00	1.63	52	0.276	1.95	0.54	564	2.994	0.23	0.69	0	0.000	0.00	0.00
25-Mar-11	0-20	20	3	60	16	NA	50.0	706.50	0	0.000	0.00	0.00	1	0.005	1.62	0.01	16	0.085	2.24	0.19	0	0.000	0.00	0.00	39	0.207	7.01	1.45	45	0.239	3.51	0.84	482	2.558	0.21	0.54	1	0.005	0.27	0.00
25-Mar-11	0-20	20	4	60	16	NA	50.0	706.50	0	0.000	0.00	0.00	2	0.011	1.55	0.02	20	0.106	1.73	0.18	0	0.000	0.00	0.00	50	0.265	6.01	1.60	26	0.138	2.21	0.30	643	3.413	0.23	0.78	0	0.000	0.00	0.00
25-Mar-11	0-20	20	5	60	16	NA	50.0	706.50	0	0.000	0.00	0.00	3	0.016	1.38	0.02	18	0.096	2.84	0.27	1	0.005	5.18	0.03	50	0.265	6.56	1.74	48	0.255	2.44	0.62	612	3.248	0.24	0.78	0	0.000	0.00	0.00
29-Apr-11	0-20	20	1	60	8	NA	50.0	706.50	0	0.000	0.00	0.00	5	0.053	1.63	0.09	92	0.977	2.27	2.22	0	0.000	0.00	0.00	50	0.531	6.04	3.21	75	0.796	1.90	1.51	400	4.246	0.26	1.10	0	0.000	0.00	0.00
29-Apr-11	0-20	20	2	60	8	NA	50.0	706.50	1	0.011	2.36	0.03	4	0.042	1.32	0.06	34	0.361	2.68	0.97	0	0.000	0.00	0.00	24	0.255	6.82	1.74	48	0.510	2.98	1.52	800	8.493	0.25	2.12	0	0.000	0.00	0.00
29-Apr-11	0-20	20	3	60	8	NA	50.0	706.50	0	0.000	0.00	0.00	3	0.032	1.30	0.04	35	0.372	2.87	1.07	0	0.000	0.00	0.00	72	0.764	6.94	5.30	72	0.764	2.30	1.76	671	7.123	0.31	2.21	0	0.000	0.00	0.00
29-Apr-11	0-20	20	4	60	8	NA	50.0	706.50	0	0.000	0.00	0.00	2	0.021	1.22	0.03	34	0.361	2.17	0.78	0	0.000	0.00	0.00	55	0.584	7.44	4.34	55	0.584	1.81	1.06	637	6.762	0.30	2.03	0	0.000	0.00	0.00
29-Apr-11	0-20	20	5	60	8	NA	50.0	706.50	0	0.000	0.00	0.00	2	0.021	1.72	0.04	31	0.329	3.14	1.03	0	0.000	0.00	0.00	50	0.531	7.39	3.92	53	0.563	1.97	1.11	715	7.590	0.28	2.13	0	0.000	0.00	0.00
06-Jun-11	0-20	20	1	150	4	NA	50.0	706.50	1	0.053	3.87	0.21	1	0.053	8.04	0.43	33	1.752	3.23	5.66	2	0.106	4.21	0.45	63	3.344	3.75	12.54	178	9.448	2.17	20.50	75	3.981	0.41	1.63	0	0.000	0.00	0.00
06-Jun-11	0-20	20	2	125	4	NA	50.0	706.50	0	0.000	0.00	0.00	1	0.044	7.67	0.34	31	1.371	3.28	4.50	0	0.000	0.00	0.00	32	1.415	3.59	5.08	152	6.723	2.50	16.81	73	3.229	0.40	1.29	0	0.000	0.00	0.00
06-Jun-11	0-20	20	3	125	4	NA	50.0	706.50	0	0.000	0.00	0.00	4	0.177	2.67	0.47	61	2.698	2.96	7.99	6	0.265	3.96	1.05	63	2.787	2.63	7.33	275	12.164	3.36	40.87	99	4.379	0.42	1.84	0	0.000	0.00	0.00
06-Jun-11	0-20	20	4	100	4	NA	50.0	706.50	1	0.035	1.78	0.06	2	0.071	1.87	0.13	29	1.026	1.74	1.79	1	0.035	4.38	0.15	58	2.052	4.87	10.00	226	7.997	2.83	22.63	77	2.725	0.52	1.42	0	0.000	0.00	0.00
06-Jun-11	0-20	20	5	125	4	NA	50.0	706.50	0	0.000	0.00	0.00	0	0.000	0.00	0.00	40	1.769	1.85	3.27	2	0.088	4.59	0.41	56	2.477	3.41	8.45	165	7.298	2.47	18.03	75	3.317	0.50	1.66	0	0.000	0.00	0.00
09-Jul-11	0-20	20	1	60	4	NA	50.0	706.50	3	0.064	5.61	0.36	0	0.000	0.00	0.00	89	1.890	3.95	7.46	9	0.191	4.52	0.86	7	0.149	9.36	1.39	23	0.488	5.04	2.46	242	5.138	0.16	0.82	0	0.000	0.00	0.00
09-Jul-11	0-20	20	2	60	4	NA	50.0	706.50	3	0.064	2.44	0.16	2	0.042	4.36	0.19	98	2.081	4.05	8.43	13	0.276	4.66	1.29	13	0.276	7.23	2.00	30	0.637	4.49	2.86	354	7.516	0.14	1.05	0	0.000	0.00	0.00
09-Jul-11	0-20	20	3	60	4	NA	50.0	706.50	1	0.021	4.33	0.09	1	0.021	3.06	0.06	79	1.677	3.47	5.82	4	0.085	5.14	0.44	0	0.000	0.00	0.00	22	0.467	5.07	2.37	334	7.091	0.17	1.21	2	0.042	0.72	0.03
09-Jul-11	0-20	20	4	60	4	NA	50.0	706.50	8	0.170	3.90	0.66	2	0.042	2.02	0.09	73	1.550	3.84	5.95	8	0.170	4.46	0.76	6	0.127	2.65	0.34	29	0.616	4.39	2.70	327	6.943	0.15	1.04	1	0.021	0.85	0.02
09-Jul-11	0-20	20	5	60	4	NA	50.0	706.50	4	0.085	6.19	0.53	0	0.000	0.00	0.00	101	2.144	2.52	5.40	8	0.170	4.53	0.77	16	0.340	6.67	2.27	17	0.361	5.53	2.00	363	7.707	0.18	1.39	0	0.000	0.00	0.00
18-Aug-11	0-20	20	1	90	4	NA	50.0	706.50	25	0.796	6.34	5.05	9	0.287	5.63	1.61	86	2.739	2.99	8.19	3	0.096	4.13	0.39	42	1.338	5.28	7.06	40	1.274	2.54	3.24	278	8.854	0.23	2.04	0	0.000	0.00	0.00
18-Aug-11	0-20	20	2	100	4	NA	50.0	706.50	10	0.354	4.58	1.62	5	0.177	6.22	1.10	64	2.265	3.06	6.93	0	0.000	0.00	0.00	34	1.203	3.86	4.64	32	1.132	2.64	2.99	227	8.033	0.22	1.77	0	0.000	0.00	0.00
18-Aug-11	0-20	20	3	100	4	NA	50.0	706.50	27	0.955	4.64	4.43	19	0.672	5.83	3.92	64	2.265	2.75	6.23	0	0.000	0.00	0.00	49	1.734	3.75	6.50	24	0.849	2.11	1.79	316	11.182	0.25	2.80	0	0.000	0.00	0.00
18-Aug-11	0-20	20	4	100	4	NA	50.0	706.50	11	0.389	3.42	1.33	16	0.566	4.11	2.33	49	1.734	3.28	5.69	0	0.000	0.00	0.00	23	0.814	3.27	2.66	22	0.778	2.32	1.81	215	7.608	0.23	1.75	1	0.035	26.87	0.95
18-Aug-11	0-20	20	5	100	4	NA	50.0	706.50	21	0.743	5.39	4.01	0	0.000	0.00	0.00	60	2.123	2.94	6.24	0	0.000	0.00	0.00	34	1.203	3.67	4.42	33	1.168	2.94	3.43	229	8.103	0.22	1.78	2	0.071	0.68	0.05
17-Sep-11	0-20	20	1	120	4	NA	50.0	706.50	16	0.679	6.40	4.35	13	0.552	8.19	4.52	14	0.594	3.67	2.18	2	0.085	4.29	0.36	72	3.057	4.17	12.75	29	1.231	2.09	2.57	154	6.539	0.20	1.31	1	0.042	79.33	3.37
17-Sep-11	0-20	20	2	120	4	NA	50.0	706.50	16	0.679	5.84	3.97	10	0.425	7.50	3.18	21	0.892	3.61	3.22	0	0.000	0.00	0.00	42	1.783	6.22	11.09	31	1.316	2.99	3.94	142	6.030	0.18	1.09	0	0.000	0.00	0.00
17-Sep-11	0-20	20	3	100	4	NA	50.0	706.50	18	0.637	7.74	4.93	17	0.602	7.84	4.23	26	0.920	3.33	3.06	0	0.000	0.00	0.00	57	2.017	4.48	9.04	40	1.415	2.50	3.54	149	5.272	0.19	1.00	1	0.035	74.38	2.63
17-Sep-11	0-20	20	4	100	4	NA	50.0	706.50	24	0.849	7.36	6.25	13	0.460	5.67	2.61	15	0.531	3.06	1.62	1	0.035	4.38	0.15	73	2.583	4.85	10.46	52	1.840	3.06	5.63	198	7.006	0.24	1.68	1	0.035	41.67	1.47
17-Sep-11	0-20	20	5	100	4	NA	50.0	706.50	17	0.602	5.66	3.40	17	0.602	7.92	4.76	14	0.495	3.83	1.90	1	0.035	4.38	0.15	76	2.689	4.21	11.32	47	1.663	2.62	4.36	171	6.051	0.24	1.45	0	0.000	0.00	0.00
21-Oct-11	0-20	20	1	100	8	NA	50.0	706.50	8	0.142	5.97	0.85	19	0.336	9.85	3.31	19	0.336	5.09	1.71	2	0.035	4.87	0.17	31	0.548	6.36	3.49	52	0.920	2.80	2.58	175	3.096	0.17	0.53	2	0.035	0.66	0.02
21-Oct-11	0-20	20	2	100	8	NA	50.0	706.50	6	0.106	2.27	0.24	10	0.177	7.28	1.29	11	0.195	3.73	0.73	0	0.000	0.00	0.00	20	0.354	5.92	2.09	42	0.743	3.38	2.51	151	2.672	0.21	0.56	0	0.000	0.00	0.00
21-Oct-11	0-20	20	3	100	8	NA	50.0	706.50	5	0.088	4.47	0.40	8	0.142	8.27	1.17	9	0.159	4.24	0.68	3	0.053	4.57	0.24	22	0.389	6.65	2.59	40	0.708	2.65	1.88	192	3.397	0.17	0.58	0	0.000	0.00	0.00
21-Oct-11	0-20	20	4	100	8	NA	50.0	706.50	9	0.159	3.79	0.60	30	0.531	5.60	2.97	25	0.442	3.31	1.46	0	0.000	0.00	0.00	45	0.796	6.09	4.85	69	1.221	3.30	4.03	224	3.963	0.18	0.71	1	0.018	2.36	0.04
21-Oct-11	0-20	20	5	100	8	NA	50.0	706.50	8	0.142	11.12	1.57	14	0.248	5.23	1.30	15	0.265	3.15	0.84	0	0.000	0.00	0.00	31	0.548	5.06	2.78	46	0.814	2.90	2.36	163	2.884	0.21	0.61	0	0.000	0.00	0.00
21-Nov-11	0-20	20	1	80	8	NA	50.0	706.50	8	0.113	5.90	0.67	5	0.071	6.48	0.46	20	0.283	3.25	0.92	0	0.000	0.00	0.00	45	0.637	6.55	4.17	59	0.835	2.73	2.28	179	2.534	0.19	0.48	0	0.000	0.00	0.00
21-Nov-11	0-20	20	2	80	8	NA	50.0	706.50	10	0.142	5.12	0.72	0	0.000	0.00	0.00	14	0.198	5.91	1.17	2	0.028	5.61	0.16	48	0.679	6.87	4.67	51	0.722	3.61	2.61	144	2.038	0.22	0.45	0	0.000	0.00	0.00
21-Nov-11	0-20	20	3	80	8	NA	50.0	706.50	19	0.269	7.34	1.97	2	0.028	12.71	0.36	20	0.283	3.28	0.93	0	0.000	0.00	0.00	57	0.807	7.26	5.86	76	1.076	3.62	3.89	173	2.449	0.21	0.51	0	0.000	0.00	0.00
21-Nov-11	0-20	20	4	80	8	NA	50.0	706.50	16	0.226	5.79	1.31	3	0.042	13.28	0.56	26	0.368	5.40	1.99	1	0.014	5.61	0.08	23	0.326	6.25	2.03	55	0.778	3.34	2.60	136	1.925	0.16	0.31	0	0.000	0.00	0.00
21-Nov-11	0-20	20	5	80	8	NA	50.0	706.50	20	0.283	6.36	1.80	1	0.014	17.79	0.25	25	0.354	3.91	1.38	1	0.014	5.83	0.08	56	0.793	8.11	6.43	45	0.637	2.37	1.51	183	2.590	0.16	0.41	0	0.000	0.00	0.00

Appendix 5: Water Chemistry Results (2011)

Station	Date	NO3	TP	Turb	TDP	Chl.45	0.45	Chl.45
		ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
Stave	11/03/25	119.6	2.3	<0.1	1.6	0.143	0.128	0.080
Hayward	11/03/25	126.3	3.2	<0.1	2.2	0.204	0.201	0.105
Alouette	11/03/25	130.9	1.9	<0.1	1.9	0.170	0.145	0.098
Stave	11/04/29	120.4	3.4	<0.1	3.0	0.343	0.213	0.238
Hayward	11/04/29	127.9	4.5	<0.1	3.5	0.587	0.374	0.403
Alouette	11/04/29	124.8	3.1	<0.1	2.8	0.558	0.315	0.403
Stave	11/06/01	67.8	4.4	<0.1	3.1	0.652	0.396	0.456
Hayward	11/06/01	106.6	4.6	<0.1	2.7	0.704	0.402	0.505
Alouette	11/06/01	104.7	3.6	<0.1	2.7	1.080	0.591	0.789
Stave	11/07/09	81.8	2.7	0.4	0.5	0.887	0.498	0.641
Hayward	11/07/09	86.0	1.3	0.3	0.1	0.677	0.422	0.468
Alouette	11/07/09	76.1	1.2	0.3	0.3	1.097	0.850	0.678
Stave	11/08/18	41.0	1.2	0.2	0.4	0.554	0.448	0.333
Hayward	11/08/18	48.5	1.3	0.3	0.1	0.677	0.530	0.415
Stave	11/09/17	35.9	1.7	0.3	0.6	0.701	0.489	0.460
Hayward	11/09/17	35.5	0.8	0.2	0.2	0.531	0.410	0.329
Alouette	11/09/17	33.2	1.5	0.3	0.3	0.610	0.362	0.431
Stave	11/10/21	79.9	2.1	0.3	1.6	0.575	0.415	0.370
Hayward	11/10/21	81.9	2.1	0.4	0.6	0.783	0.462	0.555
Alouette	11/10/21	70.6	1.4	0.3	0.2	0.672	0.397	0.477
Stave	11/11/21	101.4	1.0	0.3	1.5	0.396	0.160	0.316
Hayward	11/11/22	115.0	1.6	0.2	0.8	0.554	0.256	0.427
Alouette	11/11/22	101.4	1.4	0.4	0.9	0.654	0.342	0.485

Appendix 6: Phytoplankton

2011 Hayward Phytoplankton Results

Class	Species	25-Mar-11 No. Cells/mL	29-Apr-11 No. Cells/mL	06-Jun-11 No. Cells/mL	09-Jul-11 No. Cells/mL	18-Aug-11 No. Cells/mL	17-Sep-11 No. Cells/mL	21-Oct-11 No. Cells/mL	21-Nov-11 No. Cells/mL	25-Mar-11 BioV. mm3/L	29-Apr-11 BioV. mm3/L	06-Jun-11 BioV. mm3/L	09-Jul-11 BioV. mm3/L	18-Aug-11 BioV. mm3/L	17-Sep-11 BioV. mm3/L	21-Oct-11 BioV. mm3/L	21-Nov-11 BioV. mm3/L
Bacillariophyceae (diatoms)	*Achnanthidium spp.*	10.14	20.27				30.41	20.27	10.14	0.0008	0.0016				0.0024	0.0016	0.0008
Bacillariophyceae (diatoms)	*Fragilaria construens*					10.14	40.55		10.14					0.0008	0.0041		0.0008
Bacillariophyceae (diatoms)	*Cyclotella stelligera*			10.14								0.0015					
Bacillariophyceae (diatoms)	*Cyclotella glomerata*		314.24	70.96				10.14			0.0157	0.0035				0.0005	
Chlorophyceae (coccoid greens, desmids, etc.)	*Ankistrodesmus sp.*		10.14	30.41	10.14	20.27	40.55	10.14			0.0008	0.0024	0.0008	0.0016	0.0032	0.0008	
Chlorophyceae (coccoid greens, desmids, etc.)	*Elakatothrix sp.*																
Chlorophyceae (coccoid greens, desmids, etc.)	*Chlorella sp.*	30.41	40.55	60.82	40.55	30.41	50.68	40.55	20.27	0.0006	0.0008	0.0012	0.0008	0.0006	0.0010	0.0008	0.0004
Chlorophyceae (coccoid greens, desmids, etc.)	*Tetraedron sp.*			10.14			91.23					0.0005			0.0456		
Chlorophyceae (coccoid greens, desmids, etc.)	*Monoraphidium sp.*						10.14								0.0023		
Chlorophyceae (coccoid greens, desmids, etc.)	*Clamydocapsa sp.*						10.14								0.0007		
Chlorophyceae (coccoid greens, desmids, etc.)	*Oocystis sp.*	10.14				10.14				0.0051				0.0051			
Chlorophyceae (coccoid greens, desmids, etc.)	*Gleotila sp.*																
Chlorophyceae (coccoid greens, desmids, etc.)	*Stichococcus minutissimus*	20.27	40.55							0.0001	0.0003						
Chlorophyceae (coccoid greens, desmids, etc.)	*Coelastrum sp.*	10.14	10.14	50.68	10.14			10.14		0.0051	0.0051	0.0253	0.0051			0.0051	
Chlorophyceae (coccoid greens, desmids, etc.)	*Planctosphaeria sp.*																
Chlorophyceae (coccoid greens, desmids, etc.)	*Gyromitus sp.*		30.41	50.68	20.27	10.14		10.14			0.0068	0.0114	0.0046	0.0023		0.0023	
Chlorophyceae (coccoid greens, desmids, etc.)	*Monomastic sp.*		10.14								0.0030						
Chlorophyceae (coccoid greens, desmids, etc.)	*Nephroselmis sp.*			10.14								0.0013					
Chlorophyceae (coccoid greens, desmids, etc.)	*Scourfieldia sp.*							10.14								0.0007	
Chryso- & Cryptophyceae (flagellates)	*Chromulina sp.*		20.27	10.14	10.14	10.14	20.27	10.14	10.14		0.0004	0.0002	0.0002	0.0002	0.0004	0.0002	0.0002
Chryso- & Cryptophyceae (flagellates)	*Chrysochromulina sp.*	20.27	60.82	253.42	50.68	111.51	60.82	30.41	10.14	0.0015	0.0046	0.0190	0.0038	0.0084	0.0046	0.0023	0.0008
Chryso- & Cryptophyceae (flagellates)	*Chryptomonas spp.*	20.27	30.41	20.27	10.14	10.14	30.41	10.14	10.14	0.0101	0.0152	0.0101	0.0051	0.0051	0.0152	0.0051	0.0051
Chryso- & Cryptophyceae (flagellates)	*Boda spp.*	10.14	10.14	20.27		30.41				0.0010	0.0010	0.0020		0.0023			
Chryso- & Cryptophyceae (flagellates)	*Ochromonas sp.*	20.27	81.09	182.46	101.37	121.64	131.78	30.41	10.14	0.0051	0.0203	0.0456	0.0253	0.0304	0.0329	0.0076	0.0025
Chryso- & Cryptophyceae (flagellates)	*Mallomonas sp.*					10.14		20.27						0.0005		0.0142	
Chryso- & Cryptophyceae (flagellates)	*Kephyrion sp.*	10.14	10.14	10.14	20.27	30.41		10.14		0.0005	0.0005	0.0005	0.0010	0.0030		0.0005	
Chryso- & Cryptophyceae (flagellates)	*Dinobryon sp.*		70.96	81.09	10.14	324.38		182.46	10.14		0.0142	0.0162	0.0020	0.0049		0.0365	0.0020
Chryso- & Cryptophyceae (flagellates)	*Small microflagellates*	131.78	395.34	618.35	415.61		395.34	253.42	40.55	0.0020	0.0059	0.0093	0.0062		0.0059	0.0038	0.0006
Chryso- & Cryptophyceae (flagellates)	*Chroomonas acuta*	10.14	30.41	40.55	70.96		30.41	50.68	20.27	0.0008	0.0023	0.0030	0.0053		0.0023	0.0038	0.0015
Chryso- & Cryptophyceae (flagellates)	*Chrysococcus sp.*	10.14	40.55	20.27	50.68		60.82	20.27	10.14	0.0010	0.0041	0.0020	0.0051		0.0061	0.0020	0.0010
Chryso- & Cryptophyceae (flagellates)	*Uroglena sp.*		20.27		10.14						0.0035		0.0018				
Chryso- & Cryptophyceae (flagellates)	*Komma spp.*						10.14	30.41							0.0010	0.0030	
Cyanophyceae (blue-greens)	*Synechococcus sp. (coccoid)*	50.68	425.75	476.43	223.01	192.60	243.28	152.05	152.05	0.0003	0.0021	0.0024	0.0011	0.0010	0.0012	0.0008	0.0008
Cyanophyceae (blue-greens)	*Synechococcus sp (rod)*	91.23	395.34	466.30	283.83	273.70	304.11	233.15	60.82	0.0018	0.0079	0.0093	0.0057	0.0055	0.0061	0.0047	0.0012
Cyanophyceae (blue-greens)	*Synechocystis sp.*	20.27	70.96	40.55	40.55	30.41	40.55	20.27	20.27	0.0002	0.0007	0.0004	0.0004	0.0003	0.0004	0.0002	0.0002
		476.43	2138.88	2534.22	1378.61	1226.56	1601.63	1165.74	395.34	0.04	0.12	0.17	0.07	0.07	0.14	0.10	0.02
Bacillariophyceae (diatoms)	*Asterionella formosa*			70.96								0.0071					
Bacillariophyceae (diatoms)	*Fragilaria capucina*				20.27	20.27		40.55	10.14				0.0020	0.0020		0.0041	0.0010
Bacillariophyceae (diatoms)	*Fragilaria crotonensis*			60.82	30.41							0.0073	0.0024				
Bacillariophyceae (diatoms)	*Synedra nana*			131.78	40.55		91.23	60.82	10.14			0.0099	0.0030		0.0068	0.0046	0.0008
Bacillariophyceae (diatoms)	*Synedra acus*				10.14	10.14	50.68	10.14					0.0010	0.0010	0.0051	0.0010	
Bacillariophyceae (diatoms)	*Navicula sp.*		10.14		10.14	20.27	40.55	10.14	10.14		0.0051		0.0051	0.0101	0.0203	0.0051	0.0051
Bacillariophyceae (diatoms)	*Frustrulia spp.*																
Bacillariophyceae (diatoms)	*Pinnularia sp.*	10.14								0.0203							
Bacillariophyceae (diatoms)	*Rhizosolenia sp.*		10.14								0.0005						
Bacillariophyceae (diatoms)	*Tabellaria fenestrata*		10.14	30.41	162.19	20.27		30.41	50.68		0.0051	0.0152	0.0811	0.0101		0.0152	0.0253
Bacillariophyceae (diatoms)	*Aulacoseira italica*			40.55								0.0081					
Bacillariophyceae (diatoms)	*Tabellaria flocculosa*				40.55	30.41							0.0203	0.0152			
Bacillariophyceae (diatoms)	*Gomphonema sp.*						20.27								0.0152		
Bacillariophyceae (diatoms)	*Aulacoseira distans*						20.27								0.0071		
Bacillariophyceae (diatoms)	*Diatoma sp.*							10.14								0.0015	
Bacillariophyceae (diatoms)	*Synedra acus var angustissima*							10.14								0.0015	
Cyanophyceae (blue-greens)	*Gomphosphaeria sp.*																
Cyanophyceae (blue-greens)	*Lyngbya sp.*				10.14								0.0051				
Cyanophyceae (blue-greens)	*Aphanothecae sp.*																
Cyanophyceae (blue-greens)	*Microcystis sp.*																
Cyanophyceae (blue-greens)	*Gomphosphaeria sp.*																
		10.136872	30.410617	334.51679	324.3799	101.3687	223.0112	172.3268	81.09498	0.020274	0.010644	0.047593	0.120021	0.03852	0.054486	0.032945	0.032185
Bacillariophyceae (diatoms)	*Cyclotella comta*		10.14	20.27	10.14				10.14		0.0035	0.0071	0.0035				0.0035
Bacillariophyceae (diatoms)	*Eunotia sp.*																
Bacillariophyceae (diatoms)	*Cymbella sp.*																
Cyanophyceae (blue-greens)	*Merismopedia sp.*																
Cyanophyceae (blue-greens)	*Chroococcus sp.*																
Dinophyceae (dinoflagellates)	*Peridinium spp.*		20.27		10.14	10.14					0.0071		0.0035	0.0035			
Dinophyceae (dinoflagellates)	*Gymnodinium sp. (large).*	10.14	20.27	10.14				10.14		0.0152	0.0304	0.0152				0.0152	
Dinophyceae (dinoflagellates)	*Gymnodinium sp. (small)*	10.14	30.41	30.41	20.27	10.14	10.14	10.14	10.14	0.0051	0.0152	0.0152	0.0101	0.0051	0.0051	0.0051	0.0051
		20.27	81.09	60.82	40.55	20.27	10.14	20.27	20.27	0.02	0.06	0.04	0.02	0.01	0.01	0.02	0.01

2011 Stave Phytoplankton Results

Class	Species	25-Mar-11 No. Cells/mL	29-Apr-11 No. Cells/mL	06-Jun-11 No. Cells/mL	09-Jul-11 No. Cells/mL	18-Aug-11 No. Cells/mL	17-Sep-11 No. Cells/mL	21-Oct-11 No. Cells/mL	21-Nov-11 No. Cells/mL		25-Mar-11 BioV. mm3/L	29-Apr-11 BioV. mm3/L	06-Jun-11 BioV. mm3/L	09-Jul-11 BioV. mm3/L	18-Aug-11 BioV. mm3/L	17-Sep-11 BioV. mm3/L	21-Oct-11 BioV. mm3/L	21-Nov-11 BioV. mm3/L
Bacillariophyceae (diatoms)	*Achnanthidium spp.*		20.27	10.14	10.14		10.14	10.14	10.14			0.0016	0.0008	0.0008		0.0008	0.0008	0.0008
Bacillariophyceae (diatoms)	*Fragilaria construens*				30.41	10.14	40.55	10.14	10.14					0.0024	0.0008	0.0032	0.0008	0.0008
Bacillariophyceae (diatoms)	*Cyclotella stelligera*			30.41									0.0046					
Bacillariophyceae (diatoms)	*Cyclotella glomerata*	70.96	364.93	233.15	60.82	10.14	10.14	10.14	20.27		0.0035	0.0182	0.0117	0.0030	0.0005	0.0005	0.0005	0.0010
Chlorophyceae (coccoid greens, desmids, etc.)	*Ankistrodesmus sp.*	10.14	10.14	20.27	10.14	10.14	20.27	10.14			0.0008	0.0008	0.0016	0.0008	0.0008	0.0016	0.0008	
Chlorophyceae (coccoid greens, desmids, etc.)	*Elakatothrix sp.*																	
Chlorophyceae (coccoid greens, desmids, etc.)	*Chlorella sp.*	30.41	50.68	101.37	81.09	30.41	60.82	70.96	30.41		0.0006	0.0010	0.0020	0.0016	0.0006	0.0012	0.0014	0.0006
Chlorophyceae (coccoid greens, desmids, etc.)	*Tetraedron sp.*			20.27			10.14						0.0010			0.0005		
Chlorophyceae (coccoid greens, desmids, etc.)	*Monoraphidium sp.*																	
Chlorophyceae (coccoid greens, desmids, etc.)	*Clamydocapsa sp.*		10.14			10.14						0.0013			0.0056			
Chlorophyceae (coccoid greens, desmids, etc.)	*Oocystis sp.*		30.41	20.27					10.14			0.0068	0.0101					0.0051
Chlorophyceae (coccoid greens, desmids, etc.)	*Gleotila sp.*		10.14									0.0030						
Chlorophyceae (coccoid greens, desmids, etc.)	*Stichococcus minutissimus*	20.27	50.68	60.82							0.0001	0.0004	0.0004					
Chlorophyceae (coccoid greens, desmids, etc.)	*Coelastrum sp.*		10.14	30.41		10.14		20.27				0.0051	0.0152		0.0051		0.0101	
Chlorophyceae (coccoid greens, desmids, etc.)	*Planctosphaeria sp.*																	
Chlorophyceae (coccoid greens, desmids, etc.)	*Sphaerocystis sp.*																	
Chlorophyceae (coccoid greens, desmids, etc.)	*Staurastrum sp.*	10.14		10.14							0.0101		0.0101					
Chlorophyceae (coccoid greens, desmids, etc.)	*Nephroselmis sp.*		10.14	10.14								0.0013	0.0013					
Chlorophyceae (coccoid greens, desmids, etc.)	*Gyromitus sp.*		30.41	50.68				10.14	10.14			0.0068	0.0114				0.0023	0.0023
Chlorophyceae (coccoid greens, desmids, etc.)	*Monomastic sp.*		10.14									0.0030						
Chlorophyceae (coccoid greens, desmids, etc.)	*Botryococcus sp.*			10.14									0.0066					
Chlorophyceae (coccoid greens, desmids, etc.)	*Gyromitus sp.*				30.41	10.14	20.27							0.0068	0.0023	0.0046		
Chlorophyceae (coccoid greens, desmids, etc.)	*Scourfieldia sp.*				20.27	10.14	20.27	10.14						0.0013	0.0007	0.0013	0.0007	
Chlorophyceae (coccoid greens, desmids, etc.)	*Pyramimonas sp.*					10.14									0.0012			
Chlorophyceae (coccoid greens, desmids, etc.)	*Carteria sp.*							10.14									0.0023	
Chryso- & Cryptophyceae (flagellates)	*Chromulina sp.*			10.14	10.14	20.27	81.09	40.55	10.14				0.0002	0.0002	0.0004	0.0016	0.0008	0.0002
Chryso- & Cryptophyceae (flagellates)	*Chrysochromulina sp.*	30.41	50.68	182.46	50.68	111.51	111.51	121.64	40.55		0.0023	0.0038	0.0137	0.0038	0.0084	0.0084	0.0091	0.0030
Chryso- & Cryptophyceae (flagellates)	*Chryptomonas spp.*	20.27	10.14	20.27	20.27	10.14	10.14	30.41			0.0101	0.0051	0.0101	0.0101	0.0051	0.0051	0.0152	
Chryso- & Cryptophyceae (flagellates)	*Boda spp.*		20.27	30.41								0.0020	0.0030					
Chryso- & Cryptophyceae (flagellates)	*Ochromonas sp.*	20.27	50.68	182.46	121.64	314.24	141.92	141.92	60.82		0.0051	0.0127	0.0456	0.0304	0.0786	0.0355	0.0355	0.0152
Chryso- & Cryptophyceae (flagellates)	*Mallomonas sp.*			10.14									0.0071					
Chryso- & Cryptophyceae (flagellates)	*Kephyrion sp.*		10.14	20.27	10.14		10.14	10.14				0.0005	0.0010	0.0005		0.0005	0.0005	
Chryso- & Cryptophyceae (flagellates)	*Dinobryon sp.*			212.87	20.27	10.14		212.87	20.27				0.0426	0.0041	0.0020		0.0426	0.0041
Chryso- & Cryptophyceae (flagellates)	*Small microflagellates*	162.19	344.65	679.17	425.75	354.79	405.47	405.47	131.78		0.0024	0.0052	0.0102	0.0064	0.0053	0.0061	0.0061	0.0020
Chryso- & Cryptophyceae (flagellates)	*Isthmochloron sp.*																	
Chryso- & Cryptophyceae (flagellates)	*Bitrichia sp.*																	
Chryso- & Cryptophyceae (flagellates)	*Chroomonas acuta*	10.14	40.55	60.82	60.82	40.55	60.82	30.41	40.55		0.0008	0.0030	0.0046	0.0046	0.0030	0.0046	0.0023	0.0030
Chryso- & Cryptophyceae (flagellates)	*Chrysococcus sp.*	10.14	30.41	40.55	111.51	60.82	81.09	111.51	50.68		0.0010	0.0030	0.0041	0.0112	0.0061	0.0081	0.0112	0.0051
Chryso- & Cryptophyceae (flagellates)	*Uroglena sp.*		10.14									0.0018						
Chryso- & Cryptophyceae (flagellates)	*Pseudokephrion sp.*			20.27				10.14					0.0020				0.0010	
Chryso- & Cryptophyceae (flagellates)	*Komma spp.*				20.27				20.27					0.0020				0.0020
Cyanophyceae (blue-greens)	*Synechococcus sp. (coccoid)*		364.93	608.21	223.01	182.46		212.87	141.92			0.0018	0.0030	0.0011	0.0009		0.0011	0.0007
Cyanophyceae (blue-greens)	*Synechococcus sp (rod)*		446.02	425.75	314.24	202.74	182.46	152.05	202.74			0.0089	0.0085	0.0063	0.0041	0.0036	0.0030	0.0041
Cyanophyceae (blue-greens)	*Synechocystis sp.*	10.14	50.68	70.96	60.82	40.55	40.55	20.27	20.27		0.0001	0.0005	0.0007	0.0006	0.0004	0.0004	0.0002	0.0002
		405.47	2037.51	3182.98	1692.86	1459.71	1317.79	1662.45	831.22		0.04	0.10	0.23	0.10	0.13	0.09	0.15	0.05
Bacillariophyceae (diatoms)	*Asterionella formosa*								20.27									0.0020
Bacillariophyceae (diatoms)	*Fragilaria capucina*	10.14			81.09	20.27			10.14		0.0010			0.0081	0.0020			0.0010
Bacillariophyceae (diatoms)	*Fragilaria crotonensis*																	
Bacillariophyceae (diatoms)	*Synedra acus var angustissima*						10.14									0.0015		
Bacillariophyceae (diatoms)	*Synedra nana*				60.82		40.55	10.14	10.14					0.0046		0.0030	0.0008	0.0008
Bacillariophyceae (diatoms)	*Synedra acus*				30.41									0.0030				
Bacillariophyceae (diatoms)	*Navicula sp.*	10.14	10.14		30.41	10.14	20.27	10.14	10.14		0.0051	0.0051		0.0152	0.0051	0.0101	0.0051	0.0051
Bacillariophyceae (diatoms)	*Frustrulia spp.*																	
Bacillariophyceae (diatoms)	*Amphora sp.*																	
Bacillariophyceae (diatoms)	*Tabellaria fenestrata*	50.68		50.68	547.39	172.33	101.37	40.55	40.55		0.0253		0.0253	0.2737	0.0862	0.0507	0.0203	0.0203
Bacillariophyceae (diatoms)	*Rhizosolenia sp.*			10.14									0.0005					
Cyanophyceae (blue-greens)	*Gomphosphaeria sp.*																	
Cyanophyceae (blue-greens)	*Lyngbya sp.*							10.14									0.0051	
Cyanophyceae (blue-greens)	*Aphanothecae sp.*																	
Cyanophyceae (blue-greens)	*Microcystis sp.*																	
Cyanophyceae (blue-greens)	*Gomphosphaeria sp.*																	
Cyanophyceae (blue-greens)	*Anabaena spp.*																	
Cyanophyceae (blue-greens)	*Rhaphidiopsis sp.*																	
Cyanophyceae (blue-greens)	*Pseudoanabaena sp.*							10.14									0.0030	
		70.96	10.14	60.82	750.13	202.74	172.33	81.09	91.23		0.03	0.01	0.03	0.30	0.09	0.07	0.03	0.03
Bacillariophyceae (diatoms)	*Cyclotella comta*		10.14	70.96	10.14		10.14					0.0035	0.0248	0.0035		0.0035		
Bacillariophyceae (diatoms)	*Eunotia sp.*																	
Bacillariophyceae (diatoms)	*Cymbella sp.*																	
Cyanophyceae (blue-greens)	*Merismopedia sp.*					243.28									0.0049			
Cyanophyceae (blue-greens)	*Chroococcus sp.*																	
Dinophyceae (dinoflagellates)	*Peridinium spp.*	10.14	10.14	20.27	10.14		20.27	10.14			0.0035	0.0035	0.0071	0.0035		0.0071	0.0035	
Dinophyceae (dinoflagellates)	*Gymnodinium sp. (large).*	10.14	10.14	20.27			20.27	20.27	10.14		0.0152	0.0152	0.0304			0.0304	0.0304	0.0152
Dinophyceae (dinoflagellates)	*Gymnodinium sp. (small)*	20.27	20.27	40.55	30.41	10.14	20.27	10.14			0.0101	0.0101	0.0203	0.0152	0.0051	0.0101	0.0051	
		40.55	50.68	152.05	50.68	253.42	70.96	40.55	10.14		0.03	0.03	0.08	0.02	0.01	0.05	0.04	0.02

Appendix 7: Pelagic Primary Production Results

Date	Lake	Depth (m)	Hourly mg C m-3 hr-1	Daily mg C m-3 d-1	CHL A ug/L	AN		Size Fractionated Pico	Nano	Micro
06-Jun-11	Hayward	1	2.22	19.30	0.460	41.942		2.00	0.14	0.08
06-Jun-11	Hayward	3	1.70	14.73	0.538	27.360		0.84	0.76	0.09
06-Jun-11	Hayward	5	1.28	11.14	0.526	21.183		0.50	0.57	0.22
06-Jun-11	Hayward	7	1.24	10.72	0.571	18.778		0.49	0.52	0.23
06-Jun-11	Hayward	10 m	0.82	7.14	0.600	11.911		0.38	0.35	0.09
Integrated (1-10)			12.5	108.6	4.9	203.8		6.5	4.6	1.4
							%	52%	37%	11%
09-Jul-11	Hayward	1	0.86	5.51	0.411	13.413		0.480	0.315	0.067
09-Jul-11	Hayward	3	1.24	7.96	0.481	16.554		0.544	0.399	0.302
09-Jul-11	Hayward	5	0.93	5.96	0.497	11.991		0.203	0.430	0.300
09-Jul-11	Hayward	7	1.17	7.48	0.497	15.038		0.671	0.431	0.068
09-Jul-11	Hayward	10 m	0.84	5.37	0.501	10.716		0.499	0.122	0.218
Integrated (1-10)			9.4	60.1	4.4	124.2		4.4	3.2	1.8
							%	47%	34%	19%
18-Aug-11	Hayward	1	1.75	15.09	0.329	45.919		0.00	0.11	0.07
18-Aug-11	Hayward	3	1.34	11.52	0.399	28.896		0.66	0.60	0.07
18-Aug-11	Hayward	5	1.34	11.56	0.472	24.472		0.64	0.40	0.30
18-Aug-11	Hayward	7	0.96	8.26	0.555	14.899		0.49	0.31	0.15
18-Aug-11	Hayward	10 m	0.42	3.65	0.411	8.887		0.21	0.24	0.00
Integrated (1-10)			10.1	87.4	4.1	203.2		4.1	3.3	1.2
							%	48%	38%	14%
17-Sep-11	Hayward	1	0.47	4.03	0.329	12.266		0.000	0.000	0.424
17-Sep-11	Hayward	3	0.21	1.85	0.399	4.637		0.235	0.000	0.925
17-Sep-11	Hayward	5	0.29	2.50	0.472	5.284		0.176	0.000	1.011
17-Sep-11	Hayward	7	0.27	2.29	0.555	4.128		0.278	0.000	0.691
17-Sep-11	Hayward	10 m	0.46	3.99	0.411	9.719		0.190	0.000	0.872
Integrated (1-10)			2.8	24.4	4.1	57.0		1.8	0.0	7.3
							%	20%	0%	80%
06-Jun-11	Stave	1	0.65	5.60	0.399	14.053		0.25	0.37	0.03
06-Jun-11	Stave	3	0.73	6.33	0.452	13.998		0.17	0.32	0.24
06-Jun-11	Stave	5	0.56	4.87	0.452	10.777		0.03	0.39	0.14
06-Jun-11	Stave	7	0.40	3.50	0.690	5.073		1.56	0.51	0.15
06-Jun-11	Stave	10 m	0.67	5.79	0.842	6.880		1.88	0.30	0.04
Integrated (1-10)			5.2	45.4	5.2	86.6		7.4	3.5	1.2
							%	61%	29%	10%
09-Jul-11	Stave	1	0.78	5.00	0.559	8.940		0.19	0.34	0.25
09-Jul-11	Stave	3	0.77	4.91	0.818	6.001		0.00	0.15	0.69
09-Jul-11	Stave	5	0.93	5.95	0.719	8.275		0.00	0.50	0.60
09-Jul-11	Stave	7	0.90	5.73	0.764	7.498		0.13	0.31	0.45
09-Jul-11	Stave	10 m	0.65	4.18	0.551	7.594		0.22	0.00	0.47
Integrated (1-10)			7.4	47.3	6.4	67.6		0.9	2.4	4.7
							%	11%	30%	59%
18-Aug-11	Stave	1	0.92	7.97	0.296	26.951		0.64	0.18	0.11
18-Aug-11	Stave	3	1.01	8.72	0.230	37.882		0.75	0.28	0.00
18-Aug-11	Stave	5	0.69	5.96	0.304	19.605		0.23	0.19	0.27
18-Aug-11	Stave	7	0.87	7.52	0.362	20.802		0.43	0.33	0.11
18-Aug-11	Stave	10 m	0.54	4.67	0.657	7.106		0.04	0.27	0.23
Integrated (1-10)			7.3	63.1	3.3	204.6		3.7	2.3	1.3
							%	51%	32%	17%
17-Sep-11	Stave	1	1.73	15.02	0.551	27.286		1.3	0.3	0.1
17-Sep-11	Stave	3	1.22	10.62	0.546	19.443		0.6	0.4	0.2
17-Sep-11	Stave	5	0.68	5.94	0.514	11.570		0.3	0.3	0.1
17-Sep-11	Stave	7	0.47	4.13	0.464	8.904		0.3	0.1	0.2
17-Sep-11	Stave	10 m	0.30	2.65	0.588	4.508		0.2	0.0	0.3
Integrated (1-10)			7.2	62.5	4.7	118.3		4.2	2.1	1.6
							%	53%	26%	21%