Stave River Project Water Use Plan

Pelagic Monitor and Littoral Productivity Assessment

Implementation Year 8

Reference: SFLMON#1
Reference: SFLMON#2

Report on the 2012 Pelagic Monitor and Littoral Productivity Assessment

Study Period: 2012

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STAVE RIVER WATER USE PLANNING

Report on the 2012 Pelagic Monitor and Littoral Primary Production Monitor

[StaveLimnoNess2009-2012; Amend #:004]



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1. Introduction

This report summarizes all components of a fresh water productivity monitoring and data collection program undertaken in 2012 on Stave and Hayward reservoirs as part of the Stave WUP Monitor. The 2012 monitoring program was the eighth 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 2012, including details of field sampling and laboratory programs, and summaries of both the littoral and pelagic components of the 2012 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 StaveLimnoNess 2012-2014 PO# 17969 Amendment # 006). 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 2012 sampling season, conducted phytoplankton analyses and aided in the preparation of this report.

In 2012, 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 hectares 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)

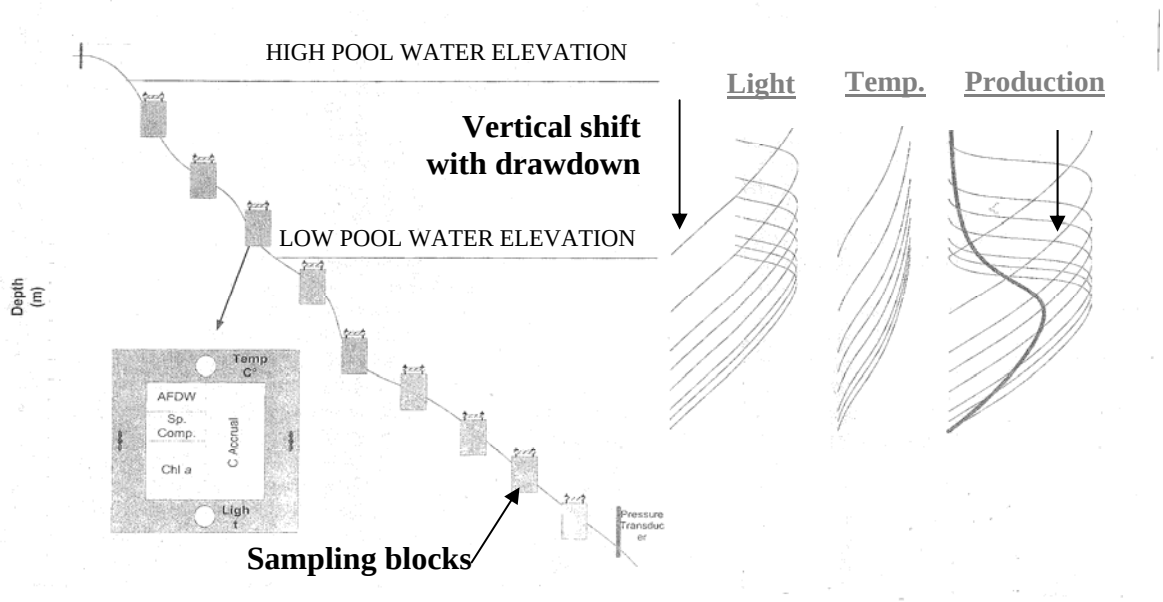
Table 2.1: Physical Attributes of Stave and Hayward Reservoirs

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)

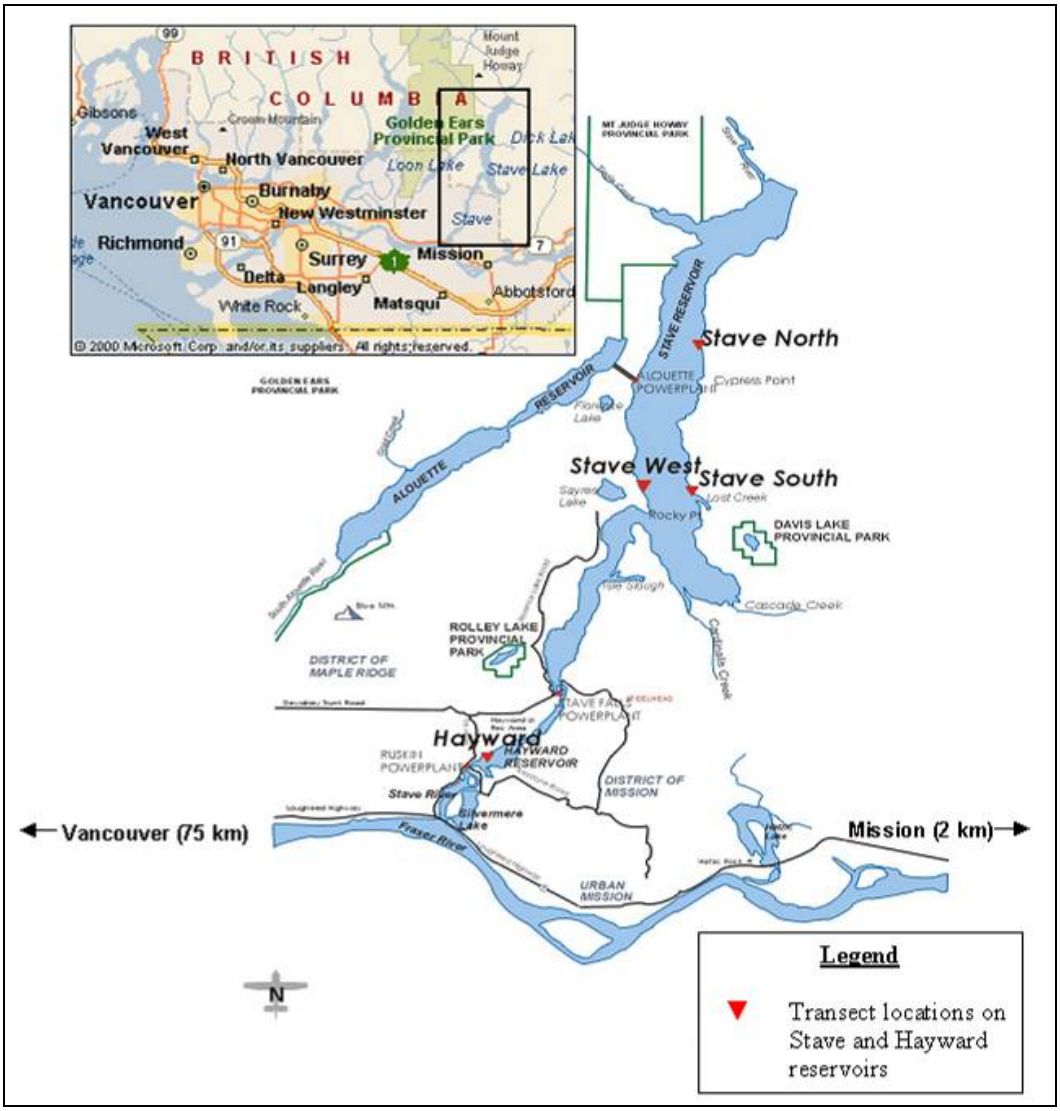


Table 2.2: GPS Coordinates of Transect Locations

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) were 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)

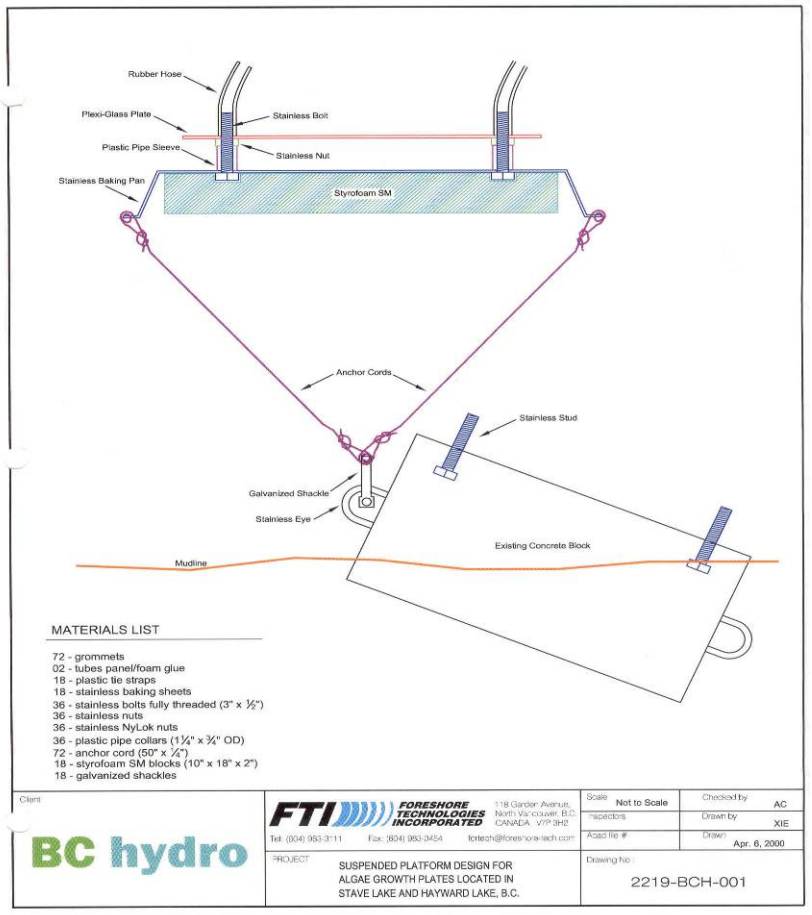
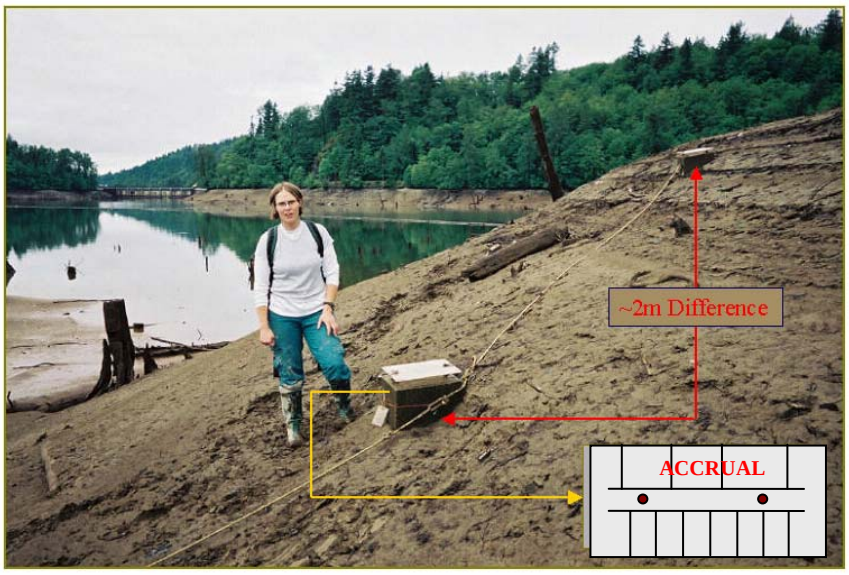


Figure 2.9: Littoral Sampling Design (Pre-2011)



3. Pelagic and Littoral Monitoring Programs for 2012

3.1 Overview

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. Four incubations were conducted in 2012.

The littoral monitoring program measured periphyton biomass from artificial substrata (AFDW) 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. At the end of the 2010 sampling season, the littoral monitoring program completed the collection of periphyton biomass data (AFDW) and moved forward with a study aimed at more closely defining periphyton growth under conditions of dewatering. In 2011 a study was conducted to assess the impacts of dewatering in an intensive program where colonized plates were exposed to the elements for periods of zero days to 40 days. In 2012, a study to look at the impact of varying levels of light on periphyton growth was developed for implementation in 2013. Details of the intended study are provided in section 3.2 of this report. 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	• characterizes nutrient dynamics of each reservoir using a composite water sample from 1, 3, and 5 m. • index of photosynthesis of	• Periphyton sampling from artificial substrata located at all 4 transects, to provide estimates of primary production (ash-free dry mass	• AFDM - measures accrual of organic biomass for periphyton fractions above 0.45 µm • Discontinued spring of 2010

concentrations	plankton >0.45 µm taken from a composite 1,3,5 m water sample	(AFDM) accrual)	
• 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 • 5 replicate samples collect on each of Stave and Hayward.	• (2011) Periphyton colonized on artificial substrata 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 • Study completed 2011
• ^{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.	• (2012/13) Rates of periphyton survival/mortality will be examined under conditions of varying light.	• Study to be completed starting late summer 2013 through to winter 2014
• 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 2012 pelagic monitoring program began in March and continued in a similar manner and schedule (approximately 5 week interval) as previous years. Field sampling dates for the pelagic sampling program and associated reservoir levels for 2012 are shown in Table 3.2.

Table 3.2: 2012 Pelagic Field Sampling Schedule and Reservoir Levels

Date	Hayward Reservoir Level (at noon, PST)	Stave Reservoir Level (at noon, PST)
2012-03-24	41.0	75.9
2012-04-28	41.2	78.9
2012-06-04	33.3	81.5
2012-07-06	35.6	81.0
2012-08-14	36.9	80.2
2012-09-14	41.2	78.3
2012-10-20	40.1	79.6
2012-11-23	41.0	78.7

3.2 Littoral Monitoring Program Methods and Study Design

In 2012 the focus of the littoral monitoring program was on the development of a study to examine survival and growth of periphyton during the winter months which is intended for implementation in 2013. To date the sampling strategy on Stave and Hayward has occurred between March and November focusing on the primary growing season of algae. As the monitors have advanced we are now in a phase of determining key information to more fully develop BC Hydro's ELZ model. In 2011, an experiment that looked at the effects of periodic dewatering clearly showed that the ELZ model assumption of mortality after only one day of dewatering was correct. In 2012 an experiment was proposed to determine the rate of mortality/survival when periphyton are subjected to extended periods of little or no light. This is another critical aspect of the ELZ model which is not well understood since data collection has been focused on the primary growing seasons. No sampling occurred when light levels are typically lower, while it is believed based on the growing season data that the clarity of water allowed significant photo-synthetically active light (PAR) to reach the deepest plates at the monitoring sites. This year, the study objective is to determine the rate of mortality/survival when periphyton are subjected to various degrees of light.

3.2.1 Study Design

This study is to be carried out in a sequence of phases, starting with an initial growth period to colonize a set of sampling strips. This will be followed by a treatment phase, during which the colonized strips will be subjected to varying degrees of sunlight. Light exposure will be controlled by installing light canopies that will sit above the sampling grid while still allowing in-situ flow of water. During the treatment phase, the Plexiglas growth strips will be sampled and analysed to track growth/survival using ^{14}C incubations and AFDM. The key metric of interest is the proportion of live individuals as indicated by radioactive carbon assimilation during a standardized regime of artificial light exposure

for periphyton grown under varying degrees of solar radiation. AFDM measures provide a useful comparison to data collected previously in the monitor. Details can be found in the sections that follow.

Table 3.3: Phases of Proposed Light Study

Phase 1	**Colonization**	
	42 day colonization of Plexiglas growth strips; in- situ- suspended from log booms in Stave Reservoir (as in the 2011 study); this allows for a full matt of periphyton to develop (REF)	
Phase 2	**Treatment**	Light canopy will be added to sampling grid to control exposure to solar radiation
	Full Light:	Clear Plexiglas cover; full light exposure
	High Light:	~75% light exposure
	Moderate Light:	~50% light
	Low Light:	~25% light exposure
	Darkness	Opaque cover; no light

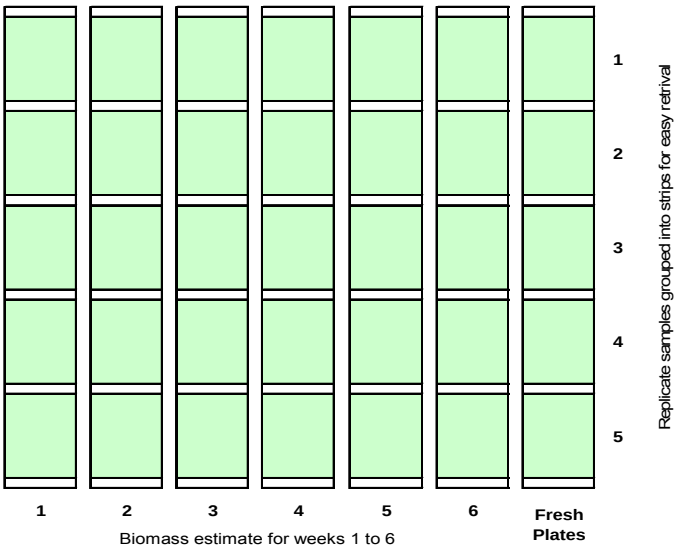
3.2.2 Experimental Design

3.2.2.1 Initial Growth Phase

Periphyton colonization will occur on artificial substrata consisting of ¼ inch thick Plexiglas strips sanded on one side with 180 grit sand paper to roughen the surface in order to create a growth medium. Each Plexiglas strip will have five etched quadrants (10cmx15cm) separated by a 5cm gap that will be the periphyton sampling areas. Seven strips will be mounted to a grid for a total of 35 sampling quadrants to create a replicate grouping strategy for ease of sampling (Figure 3.1). In this case, plates are grouped into strips that will be sampled on an interval that is yet to be determined. The strips are ordered, but retrieval is done randomly within each treatment. To ensure control over light exposure, the back side of the growth strips will be coated or painted black to prevent the passage of scattered light from below.

Prior to each treatment, the grids will be installed off the edge of a log boom in the fore bay of Stave Falls Dam (across from the boat launch). They will be set horizontally at a depth of 2 m for a five to six week colonization period to ensure that all quadrants are fully seeded with periphyton material before under going the various light treatments.

Figure 3.1: Sampling grid design



3.2.2.2 Treatment

Five grids will undergo pre-treatment colonization after which each grid will be fitted with a light canopy. The canopy will be constructed from Plexiglas in varying colour shades (i.e. clear - shades of grey - black) in order to achieve the desired light limitation. Transmissivity of the Plexiglas as well as light measurements will determine the exact light exposure for each grid. The canopy will be a lid that will sit above each sampling grid without enclosing it, such that water circulation will not be inhibited. Relative light will be measured at each grid sight using HOBO Pendant temperature/light data recorders. The following five light treatments will be used to monitor the survival response of periphyton under limited light conditions:

Grid 1: Full Light (UV filtered)
Grid 2: High Light
Grid 3: Moderate Light
Grid 4 Low light
Grid 5: No Light

3.2.2.3 Sampling

The study is proposed to be carried out twice in 2013. The first sampling run will take place in summer, with incubations starting in early-mid June and sampling from July through September. A second sampling run will take place in the fall, with incubations starting in September and sampling through winter, providing there is sufficient budget. Each sampling day, a single Plexiglas growth strip (i.e. 5 replicate samples) will be collected from each treatment grid. Each sampling area has a secondary line to divide the sample into AFDW and one for carbon incubation. Each area is 75cm^2.

In the field a total of 10 samples, five AFDM and five for carbon incubations, will be scraped from each growth strip into labeled sampling jars. The jars will be placed in a cooler and brought to the lab for further processing. The table below provides an approximate sampling schedule. The sampling schedule will be modified based on the data collected at the time of sampling.

Table 3.4: Projected Sampling Schedules

Summer Sampling								
Phase 1		Jun-07	Jun-17	Jun-24	Jul-01	Jul-08	Jul-15	Jul-21
Colonization		Incubation period - no sampling						
		SAMPLING						
	Treatment day		1	3	6	11	24	48
Phase 2	Date	Jul-21	Jul-22	Jul-24	Jul-27	Aug-01	Aug-14	Sep-07
treament	no light inhibition	**Install canopy**	1strip	1strip	1strip	1strip	1strip	1strip
	high light condition		1strip	1strip	1strip	1strip	1strip	1strip
	mod light condition		1strip	1strip	1strip	1strip	1strip	1strip
	low light condition		1strip	1strip	1strip	1strip	1strip	1strip
	dark		1strip	1strip	1strip	1strip	1strip	1strip

Fall Sampling								
Phase 1		Sep-10	Sep-17	Sep-24	Oct-01	Oct-08	Oct-15	Oct-22
Colonization		Incubation period - no sampling						
		SAMPLING						
	Treatment day		1	3	6	11	24	48
Phase 2	Date	Oct-22	Oct-23	Oct-25	Oct-28	Nov-03	Nov-15	Dec-09
treament	no light inhibition	**Install canopy**	1strip	1strip	1strip	1strip	1strip	1strip
	high light condition		1strip	1strip	1strip	1strip	1strip	1strip
	mod light condition		1strip	1strip	1strip	1strip	1strip	1strip
	low light condition		1strip	1strip	1strip	1strip	1strip	1strip
	dark		1strip	1strip	1strip	1strip	1strip	1strip

3.2.3 Laboratory Analyses

Once collected, periphyton samples are stored cold and dark for transport back to the laboratory. In the lab, one sample will be filtered to determine an estimate of AFDM according to the method provided below.
In the laboratory, AFDM samples scraped from a known area of the sampling plate are treated similarly as follows:

- 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 12-24 hours to ensure all moisture is eliminated from the filter sample.
- oven-dried filter sample weight is recorded as dry-weight (DMoven).
- oven-dried filter samples were ashed at 500ºC in a muffle furnace for a minimum of 5 hours and then re-weighed (DMmuf).
- ash free dry weight (AFDM) was calculated as the difference between the DMoven and DMmuf.

AFDM (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 (AFDM) of the sample (Stockner and Armstrong, 1971).

The second 75cm^2 sample will be topped up with distilled water up to a known volume (200 ml). The sample would then be agitated and immediately split into two equal volumes (100ml each) into a dark and a clear bottle and inoculated with 1ml of 5µCi ^{14}C. The inoculated bottles will be placed on a specifically designed shaker table and incubated for a fixed duration (3 hours) under artificial grow lights (Sunblaster T5 High Output Florescent). During the incubation period the samples will be gently agitated to prevent settling of the periphytic material to the bottom of the sample jar.
Immediately after the incubation period, samples would be filtered and acid added to stop further ^{14}C uptake. Once filtered, 5 ml of Ecolite+ scintillation cocktail would be added to each sample. After 24 hours, the samples would be analysed at UBC Radiation Safety Office Laboratory in a Beckman LS6500 scintillation counter. By standardizing all laboratory procedures, the level of ^{14}C uptake can be considered to be directly proportional to the abundance of live organisms.

3.2.4 Data Analysis

Analysis of covariance will be used to compare the growth and/or survival of organisms through time across the light exposure treatment regimes. Tukey HSD will be used to assess specific differences between treatment groups where the ANCOVA identifies significant differences in growth rate (slope) or starting abundance estimates (intercepts).

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 on Stave reservoir. 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 fume hood 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 3.2: 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 3.3: 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 macro zooplankton 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.

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 3.4: Light Intensity Profile Being Measured on Stave Reservoir

4. Monitoring Results for 2012

Results are presented for data collected in 2012.

4.1 Light

Light profiles for Stave and Hayward on each of the sampling days in 2012 starting with the March 24th sampling session are presented in Figures 4.1 and 4.2. Light measurements on Hayward were typically made about 9-10 AM, while those on Stave were typically made about 1-2 PM, which accounts for the lower light levels measured on Hayward.

Figure 4.1: Stave Solar Irradiance

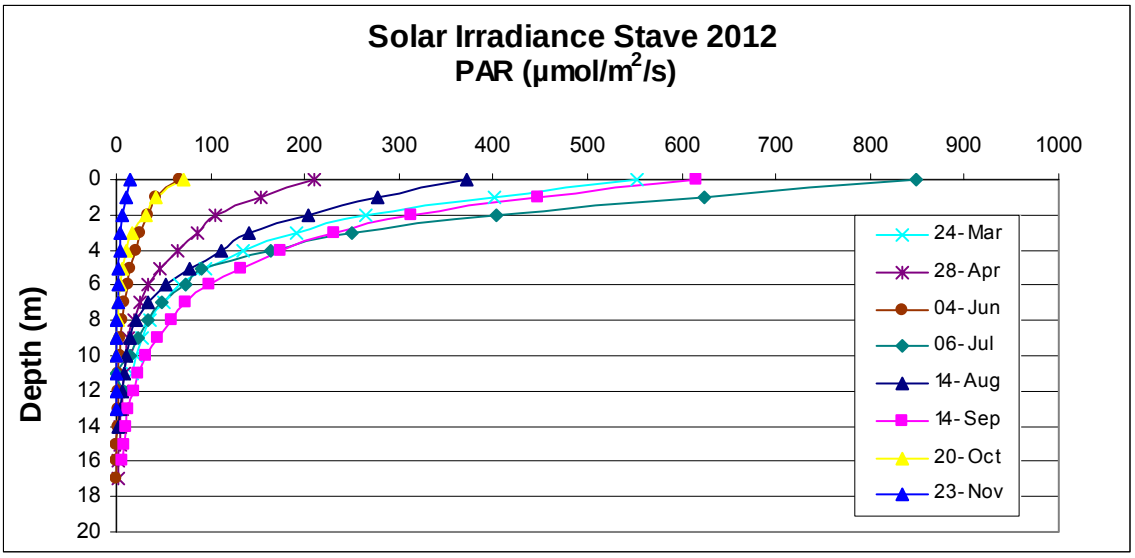
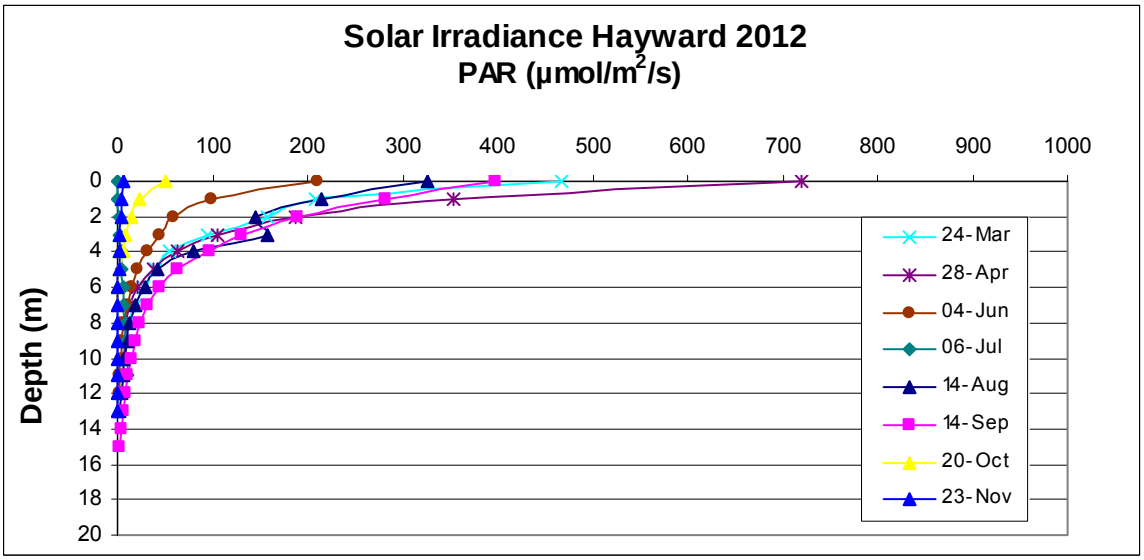
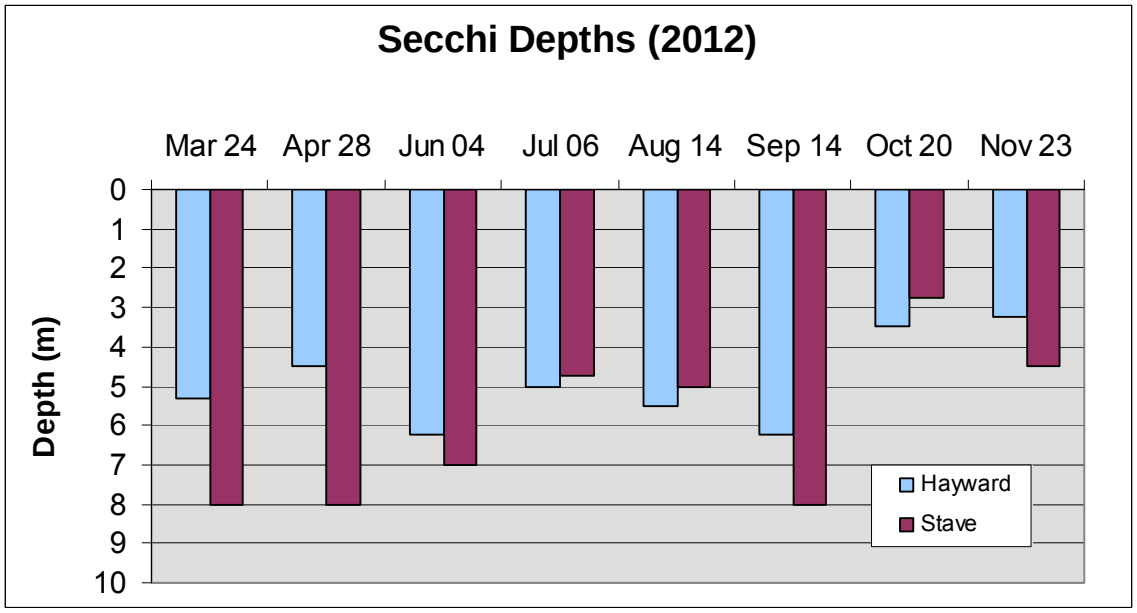


Figure 4.2: Hayward Solar Irradiance



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 (2006-2012) are presented in Figure 4.5.

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

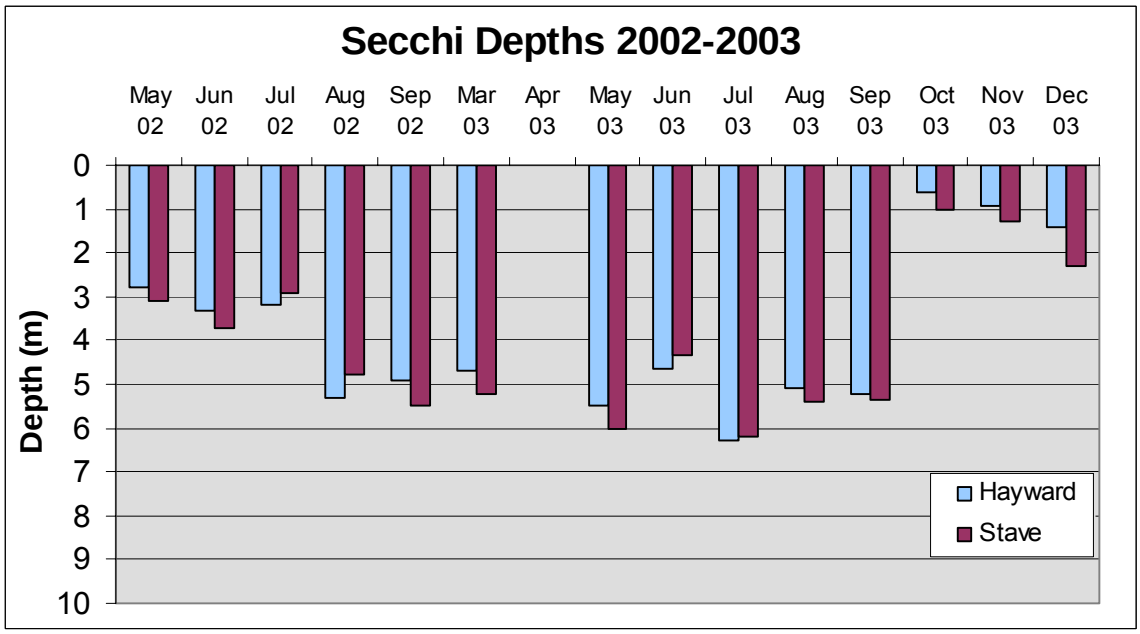
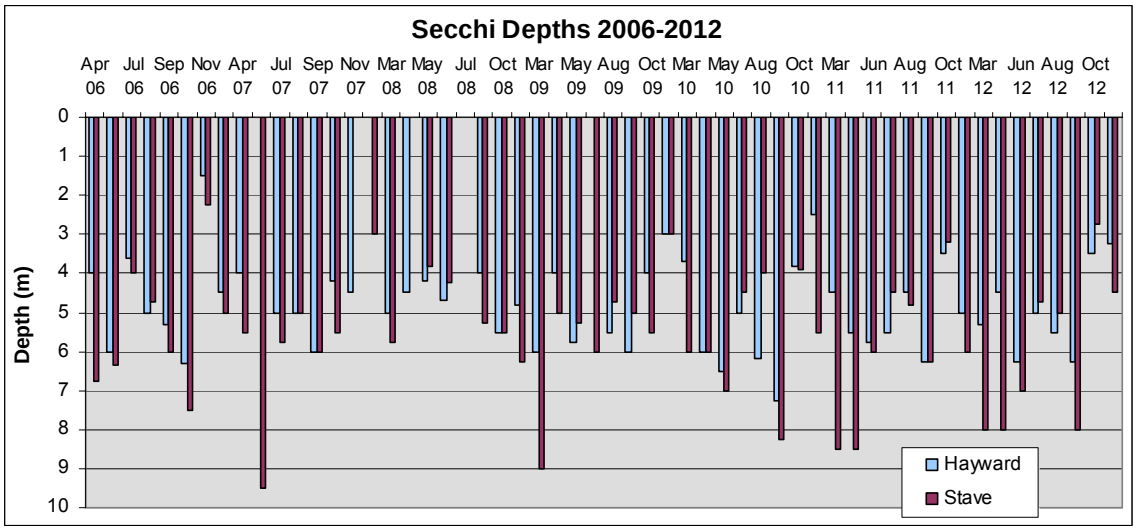


Figure 4.5: Phase 2 (2006-2012) Secchi Depths for Stave and Hayward



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 2012 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 (2012)

Date	Hayward	Stave
Mar 24	0.42	0.33
Apr 28	0.49	0.27
Jun 04	0.38	0.28
Jul 06	0.44	0.58
Aug 14	0.32	0.36
Sep 14	0.32	0.29
Oct 20	0.68	0.49
Nov 23	0.38	0.37

Surface solar radiation throughout 2012 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)

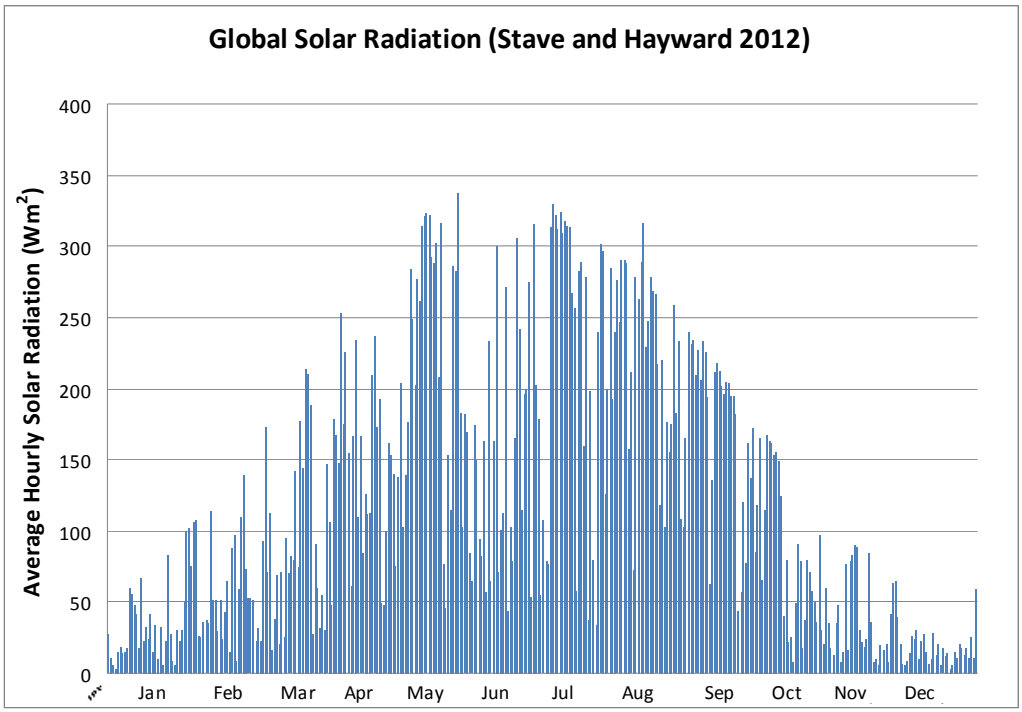
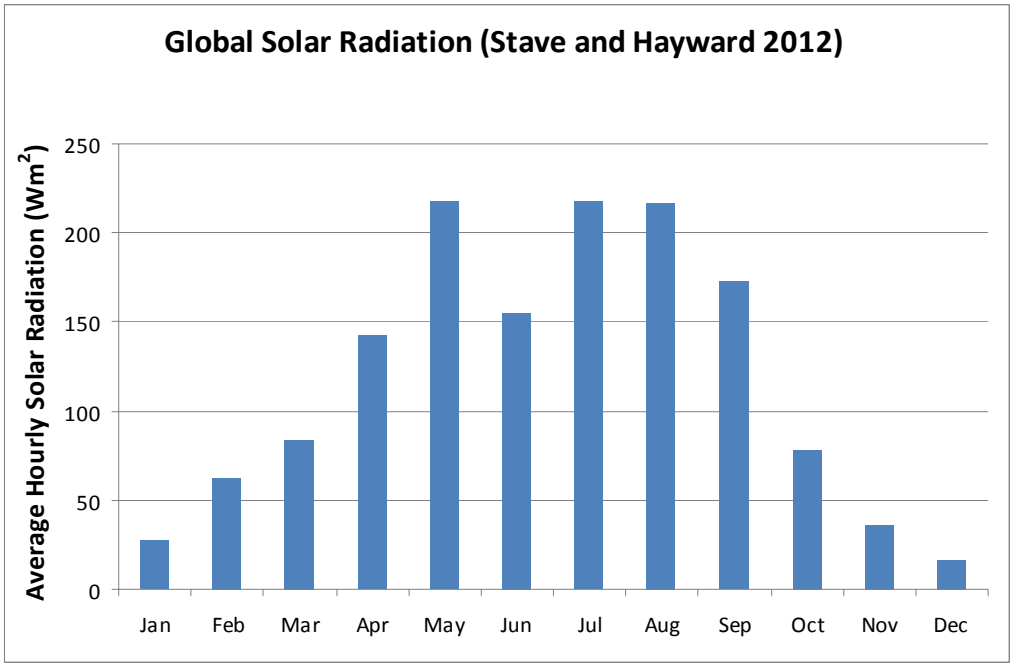


Figure 4.7: Global Solar Radiation (by month)



4.2 Water Temperature Profiles

Water temperature profiles for Hayward and Stave on each of the sampling days in 2012 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 late 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 (July- 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 in mid summer and deepens to as much as 14 m by September. By fall 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

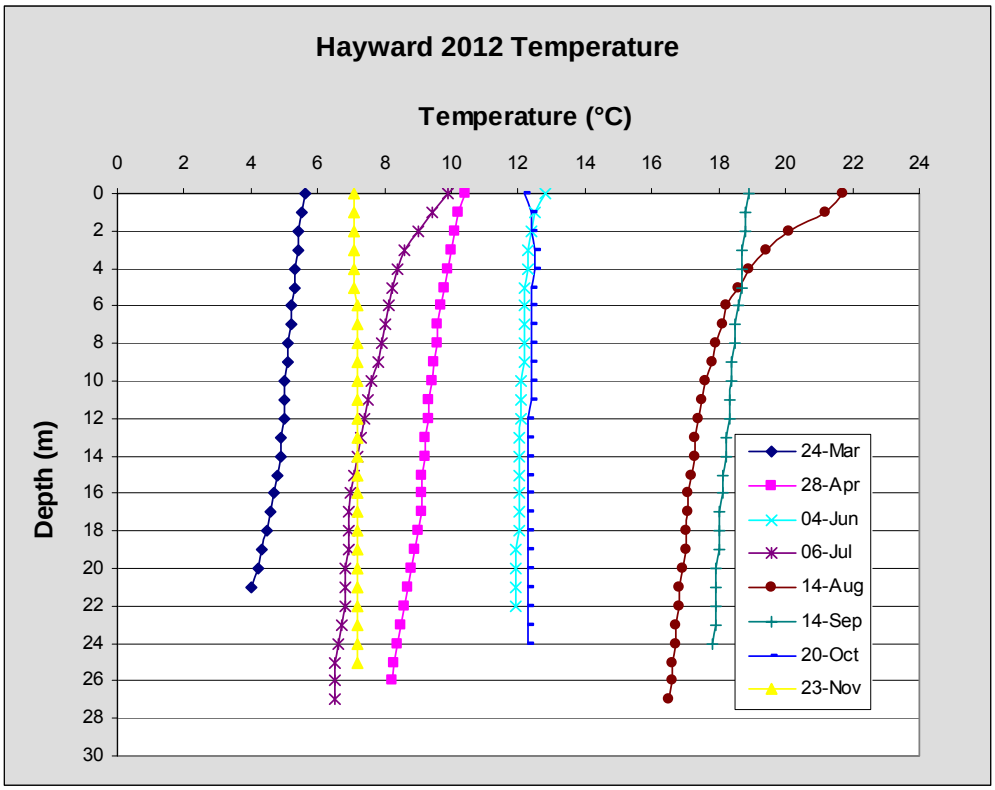
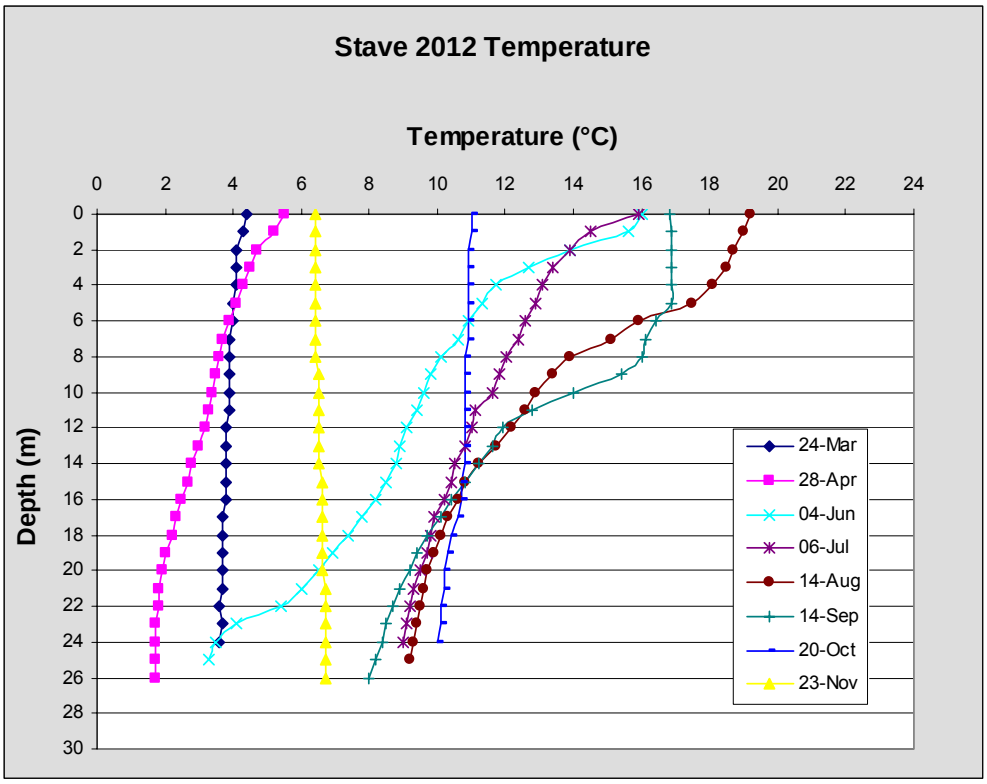


Figure 4.9: Stave Temperature Profile



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 2012 (phase 2 – 2005 to 2012). 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 and 2010 Hayward was drawn down to 34.7 m and 34.6 m a.s.l. respectively for a period of approximately 2 weeks. In subsequent years the drawdown in Hayward has been extended for a longer duration; in 2011 the drawdown took place for approximately 3 weeks with similar low levels as in previous years. In 2012 the drawdown took place from May 21 through the end of August, a period of over 3 months with notable lows held at 33, 35 and 37 m at various times in the drawdown period (Figure 4.11).

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 recent years operations in Stave have allowed water levels to follow a typical pattern with late fall/winter lows of approximately 75-76 m a.s.l. and summer time highs of approximately 80 m a.s.l. Figure 4.11 shows daily average water levels in 2010 and 2011, including the drawdown periods in Hayward. Figure 4.11 shows the daily average

water levels in 2012 with sampling dates indicated and highlighting the extended period of low in Hayward to allow work on seismic upgrades for the facility.

Figure 4.10: Daily Average Water Elevation (2000 to 2012)

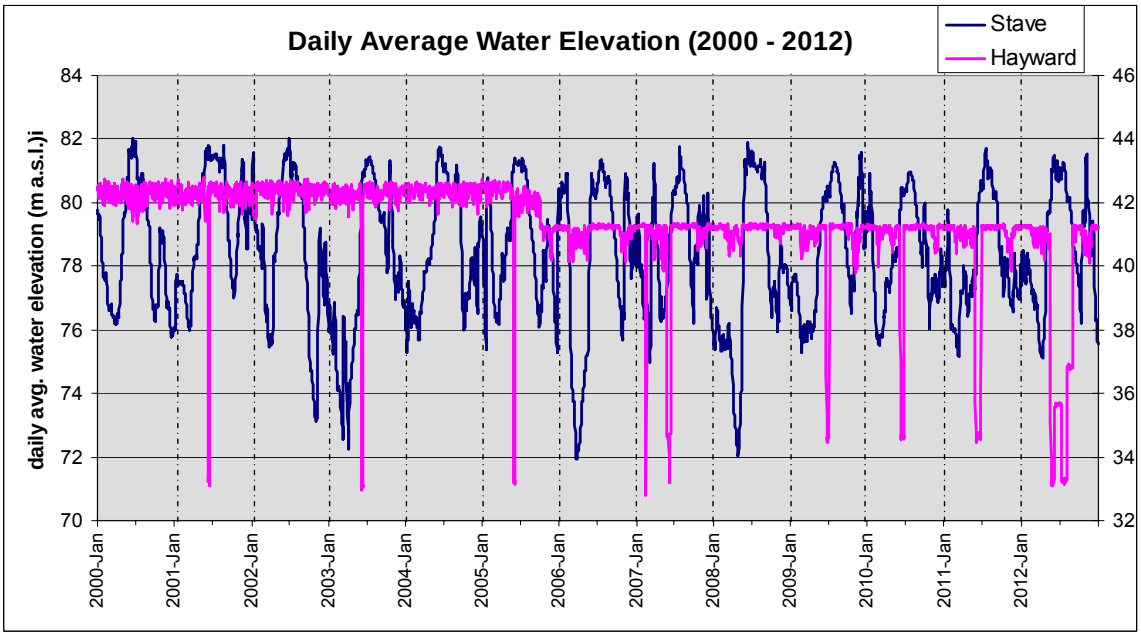
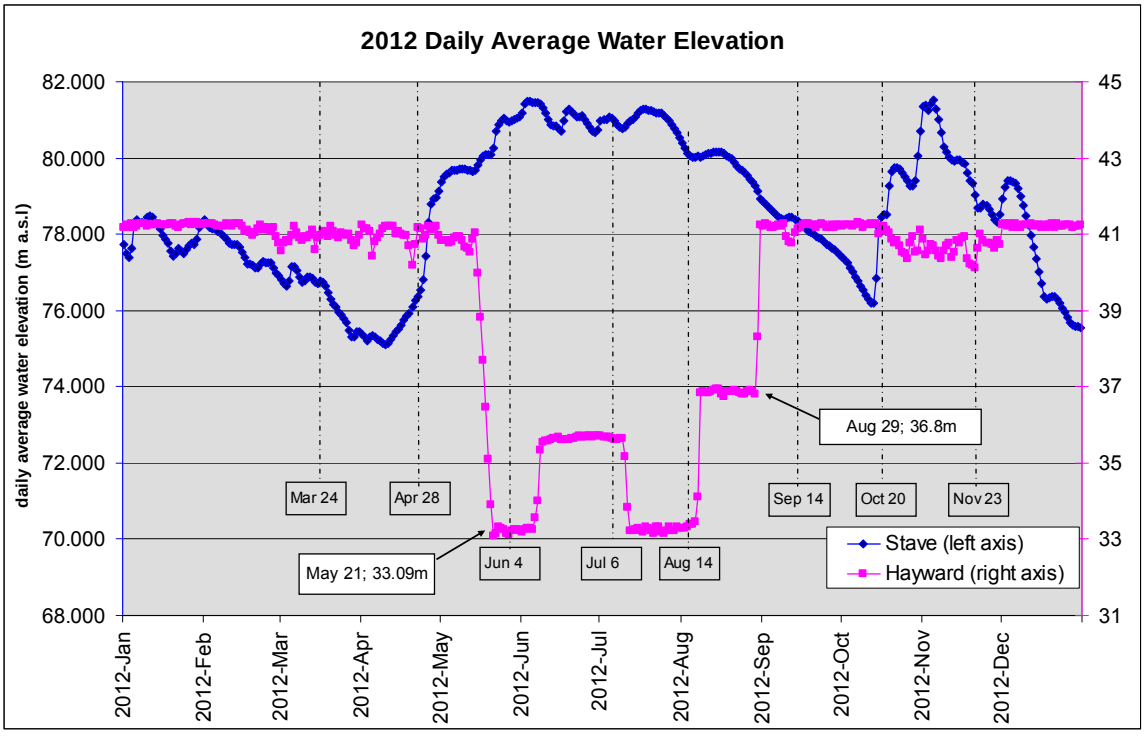


Figure 4.11: Daily Average Water Elevation (2012)



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 2012, providing a record of the nutrient profiles in Stave and Hayward reservoirs. Tabular results from 2012 are presented in Appendix 5.

Similar to previous years, in 2012 nitrate concentrations in Stave and Hayward ranged from a high value of approximately 120 µg/L in spring to low values of approximately 40 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 1.0-4.8 µg/L and TDP concentrations from <1.0-2.2 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 0.7 µg/L L to a winter low of 0.1 µg/L. Stave reservoir ranged from 0.4 µg/L to 0.09 µg/L. Both reservoirs exhibited peaks in biomass production during the summer months, as expected.

Figure 4.12: Nitrate Concentrations

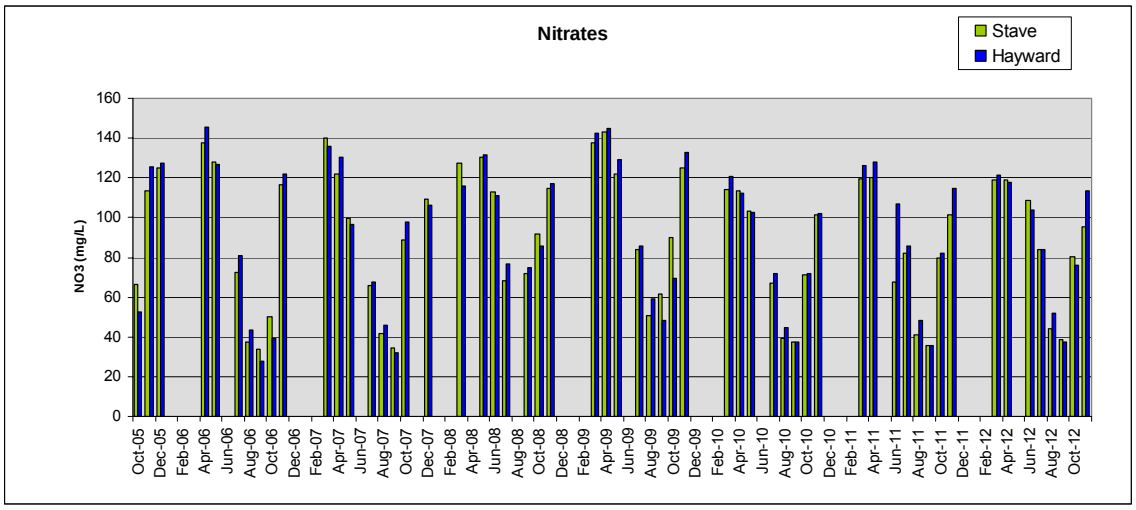


Figure 4.13: Total Phosphorus Concentrations

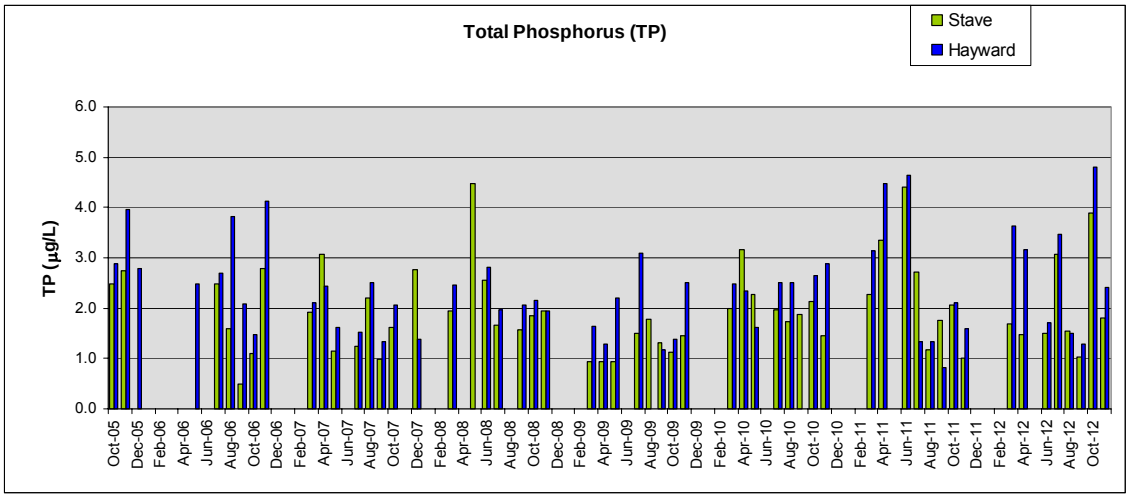


Figure 4.14: Total Dissolved Phosphorus Concentrations

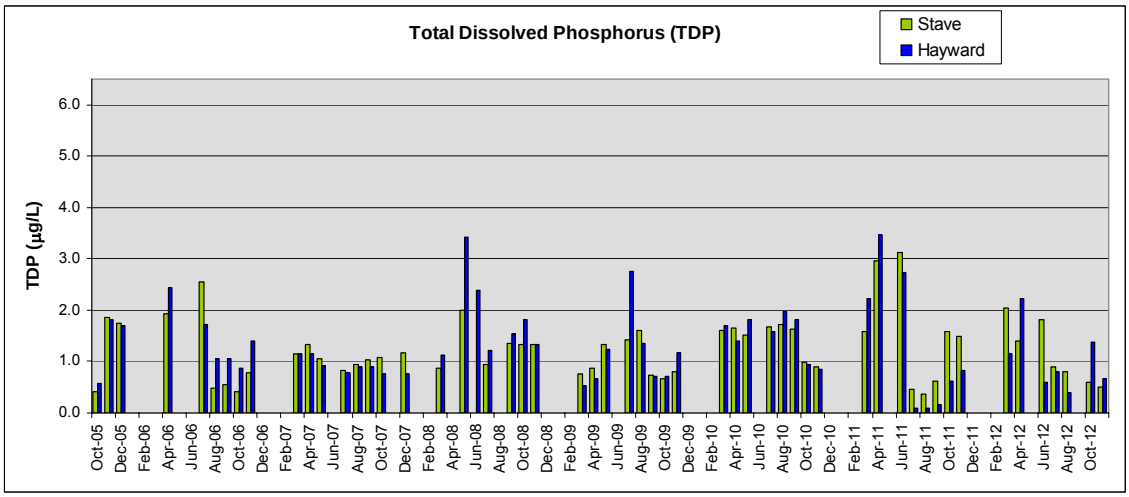
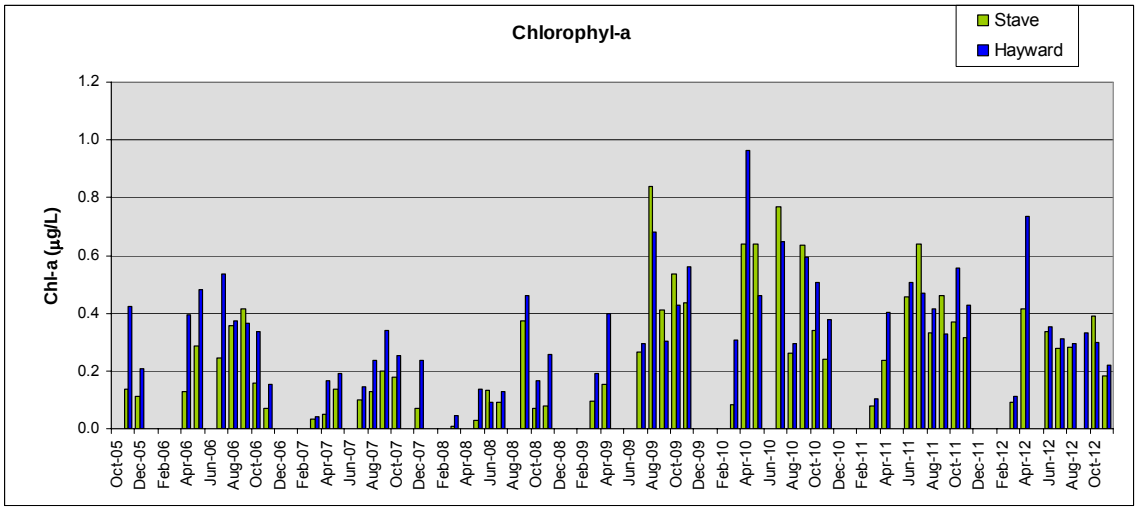


Figure 4.15: Chlorophyll-a Concentrations



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 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. Tabular result of counts conducted in 2012 are presented in Appendix 6. 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 2005-2012. Generally speaking, values exhibited in 2012 are similar to those in previous years. It is notable that in October 2012 we have the first significant appearance of Merismopedia species in both Stave and Hayward samples. Merismopedia sp., which is a microcystin toxin producer at densities greater than 500,000 cells/ml, exhibited a strong summer mini-bloom in Coquitlam reservoir (mean density of 100,000 cells/ml in September) and a lesser one in Alouette (J. Stockner, pers. Comm.). While Stave and Hayward are not yet approaching these kinds of densities, it is suggested that sampling for Merismopedia sp. be undertaken twice per month in September and October to see if it is increasing in the Stave/Hayward system.

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 2012 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 in 2012 were dominated by edible fractions at approximately 0.10 mm^3/L, whereas in 2011 there were some notable peaks in the summer months and in 2009/2010 fractions that could be either edible or in-edible were exhibited.

In Hayward, phytoplankton densities measured in 2012 are dominated by edible fractions in the 1500- 2000 cells/mL range in early summer but by mid-summer into fall in-edible fractions are prevalent. This result differs from 2011 where edible fractions were dominant through out the growing season and in 2009/2010 where phytoplankton that could be considered either edible or in-edible dominated. Similar to 2011, biovolumes measured in Hayward were dominated by edible fractions with maximums of approximately 0.15mm^3/L.

In general, there was a variety of mostly edible plankton available to herbivorous zooplankton throughout the seasons with both reservoirs showing that plankton were largely effective in contributing to carbon flows rather than 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. Tabular results of the 2012 counts are presented in Appendix 7. 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 (2005-2012)

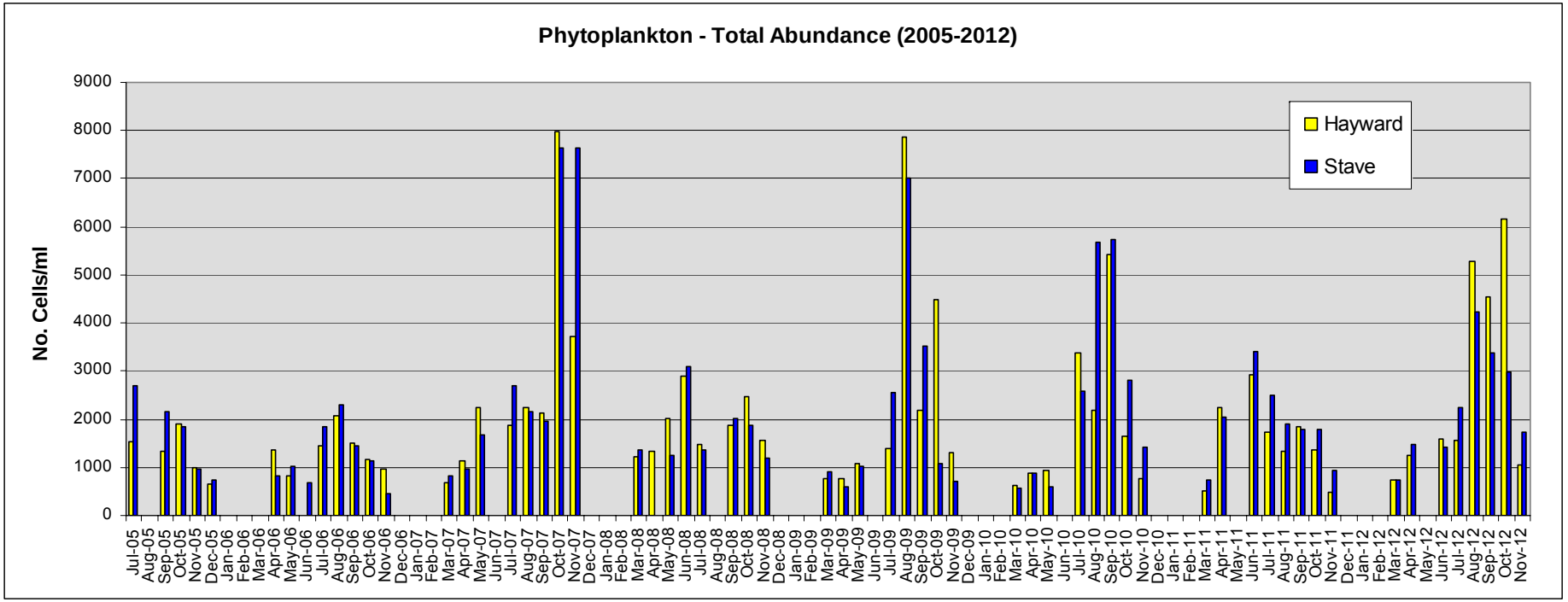


Figure 4.17: Total Biovolume of Phytoplankton (2005-2012)

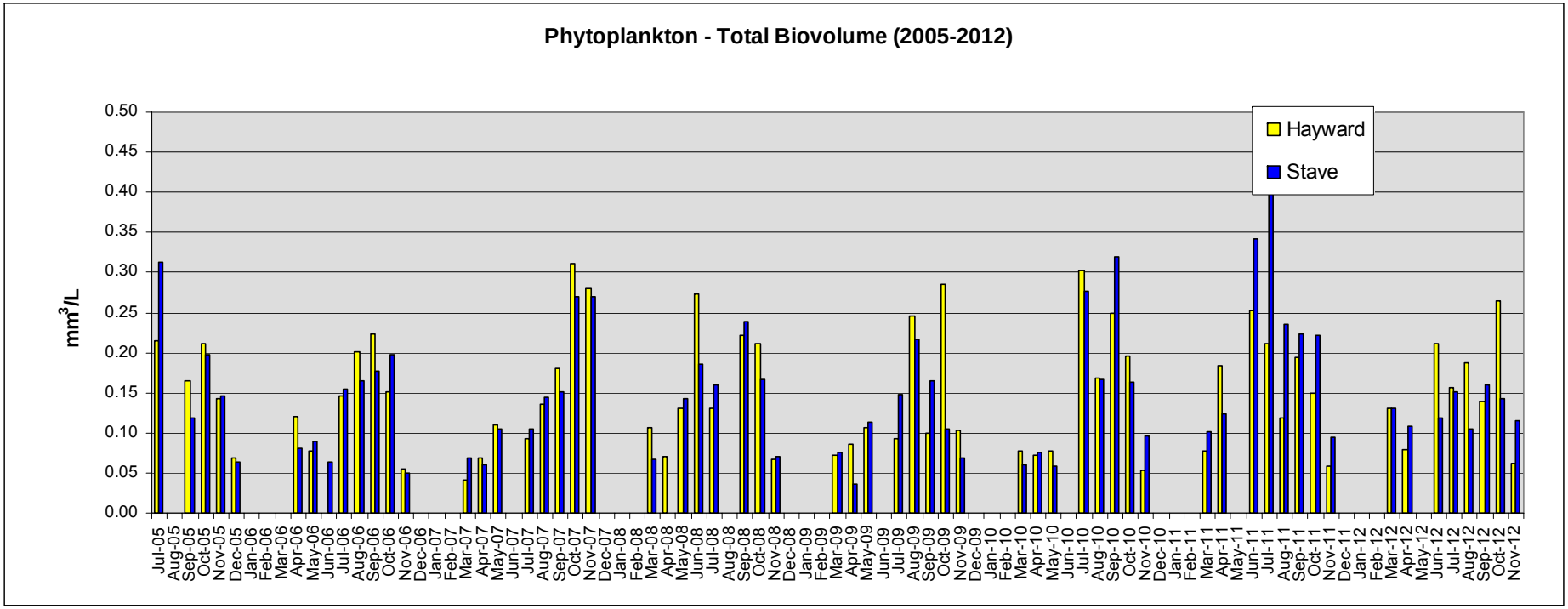


Figure 4.18: Stave Edible vs. In-Edible Phytoplankton Biovolume

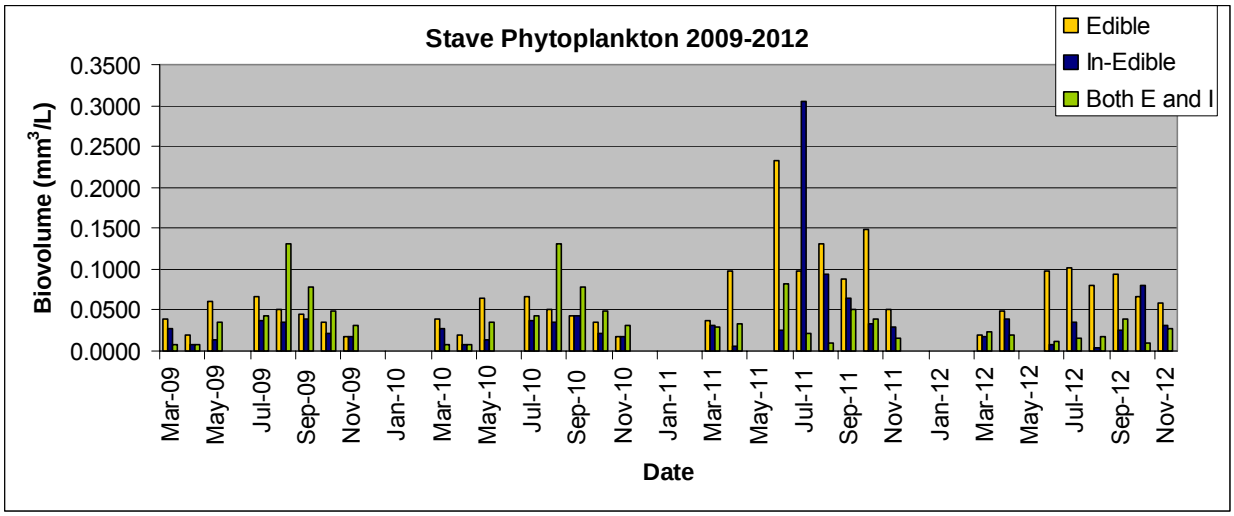


Figure 4.19: Stave Edible vs. In-Edible Phytoplankton Density

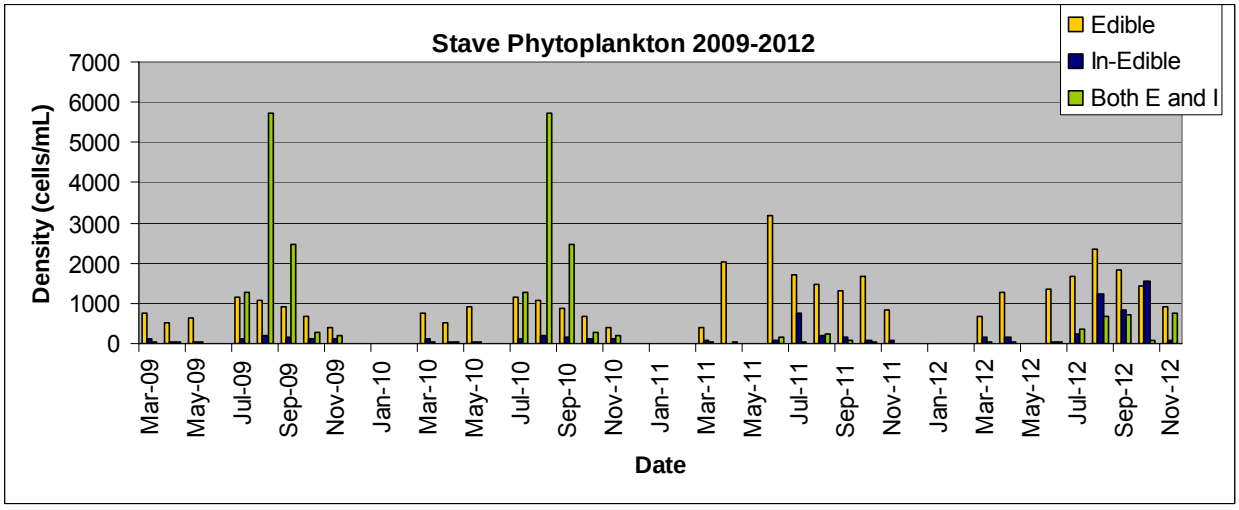


Figure 4.20: Hayward Edible vs. In-Edible Phytoplankton Biovolume

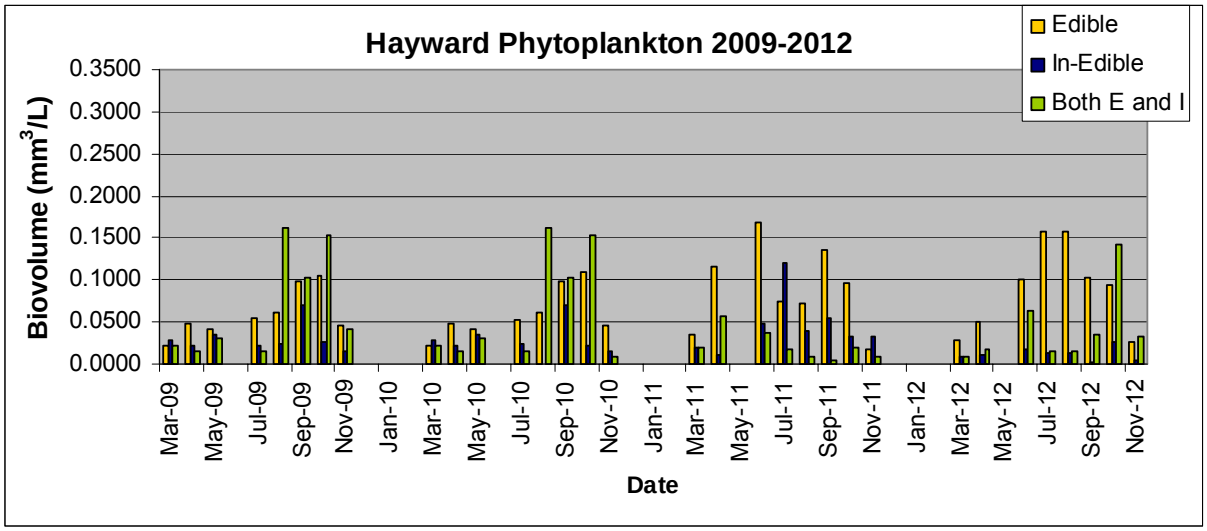


Figure 4.21: Hayward Edible vs. In-Edible Phytoplankton Density

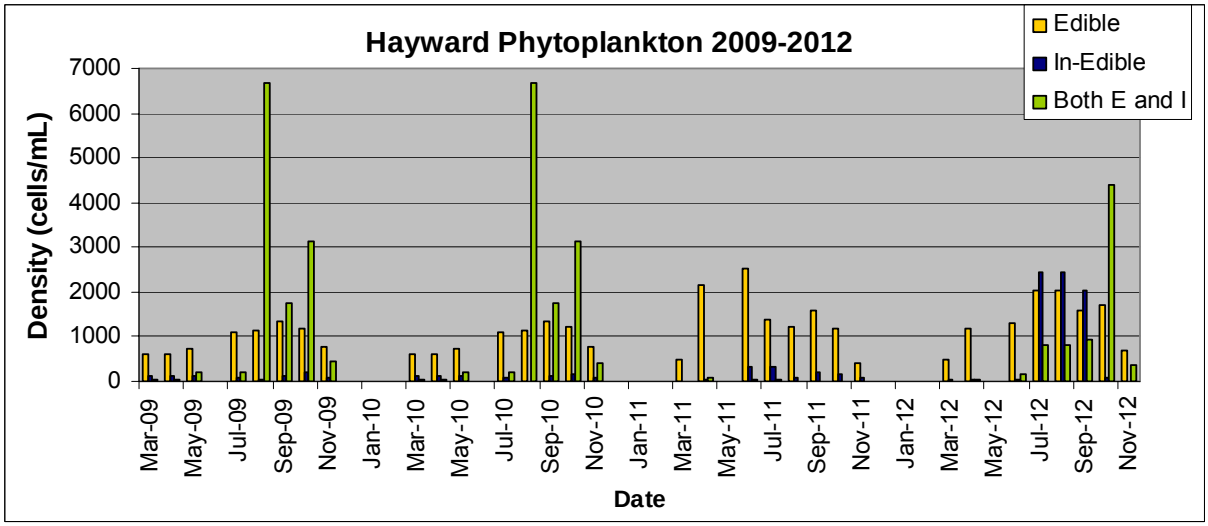


Figure 4.22: 2010/2011 Heterotrophic Bacteria - Biovolume

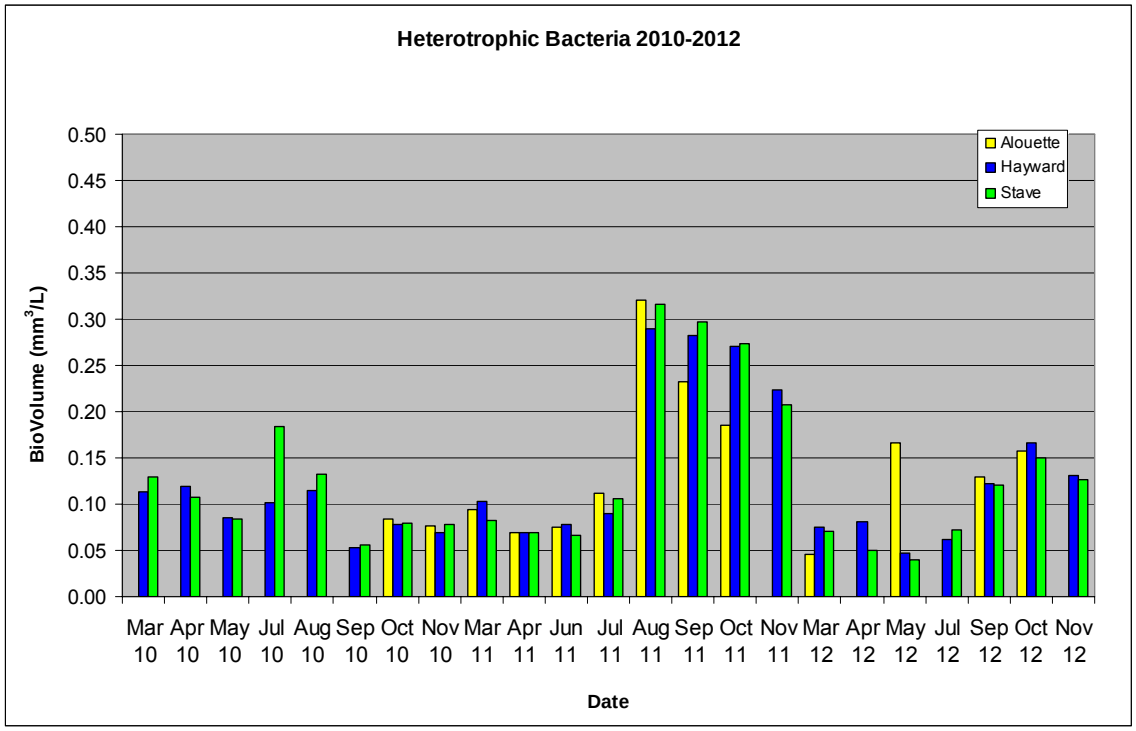


Figure 4.23: 2010/2011 Heterotrophic Bacteria - Density

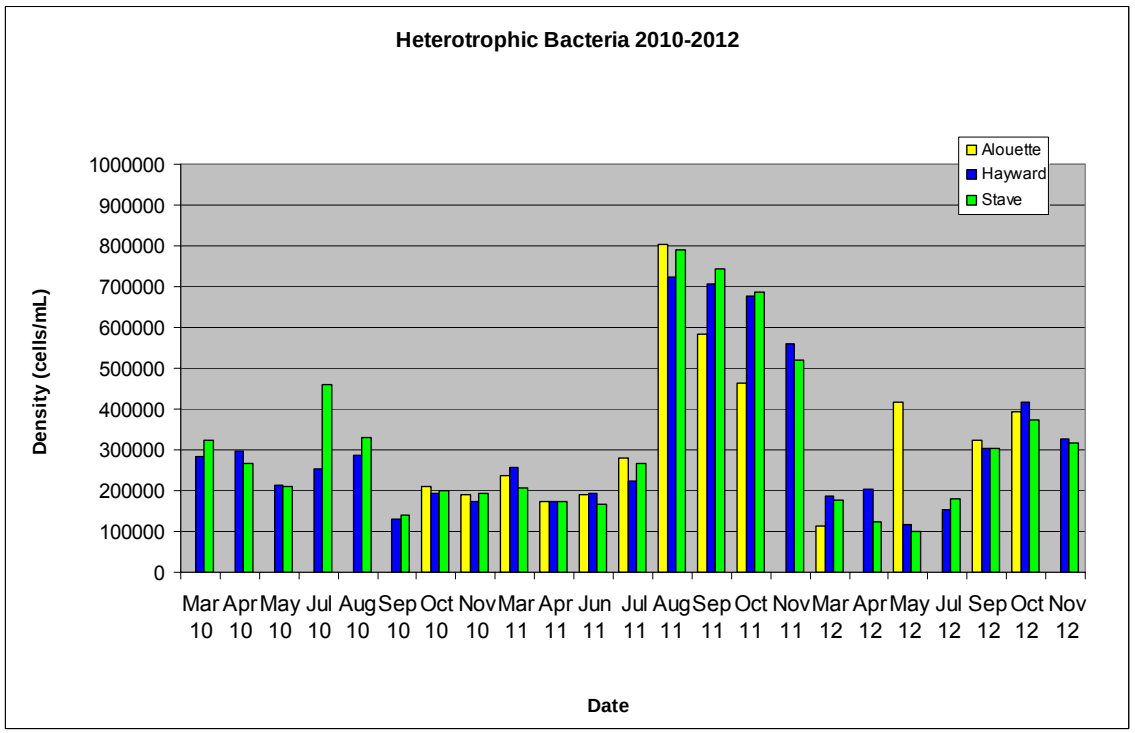


Figure 4.24: 2010/2011 Pico-Cyano Bacteria - Biovolume

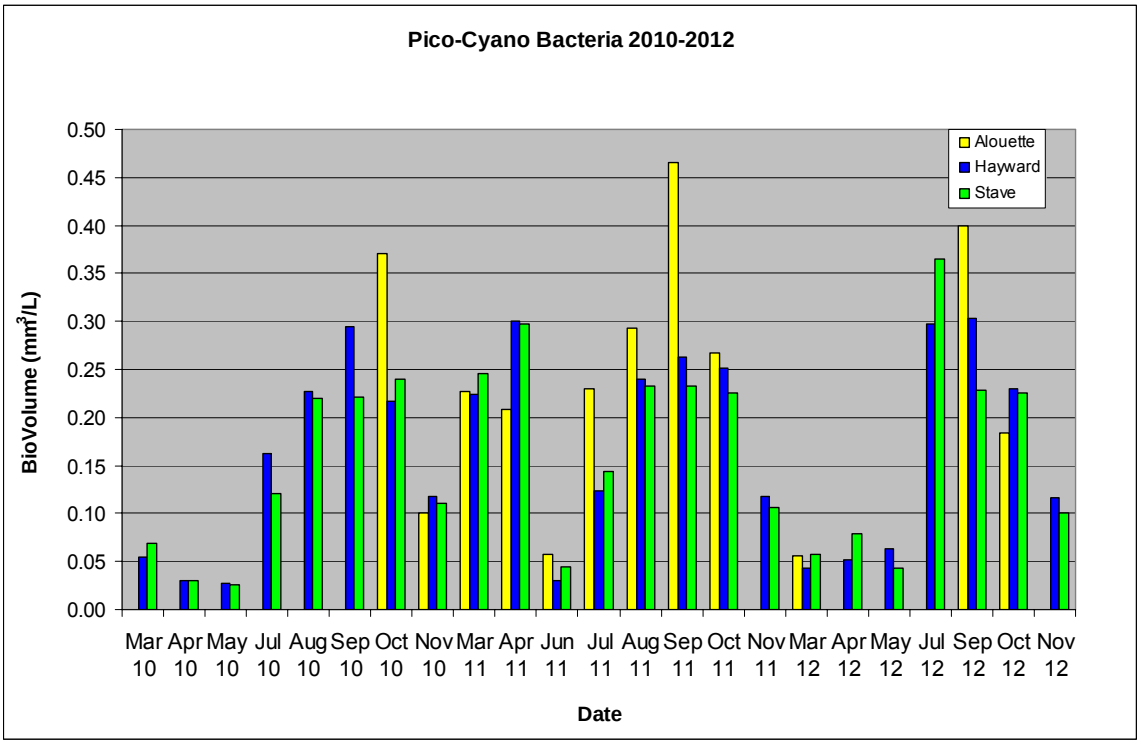
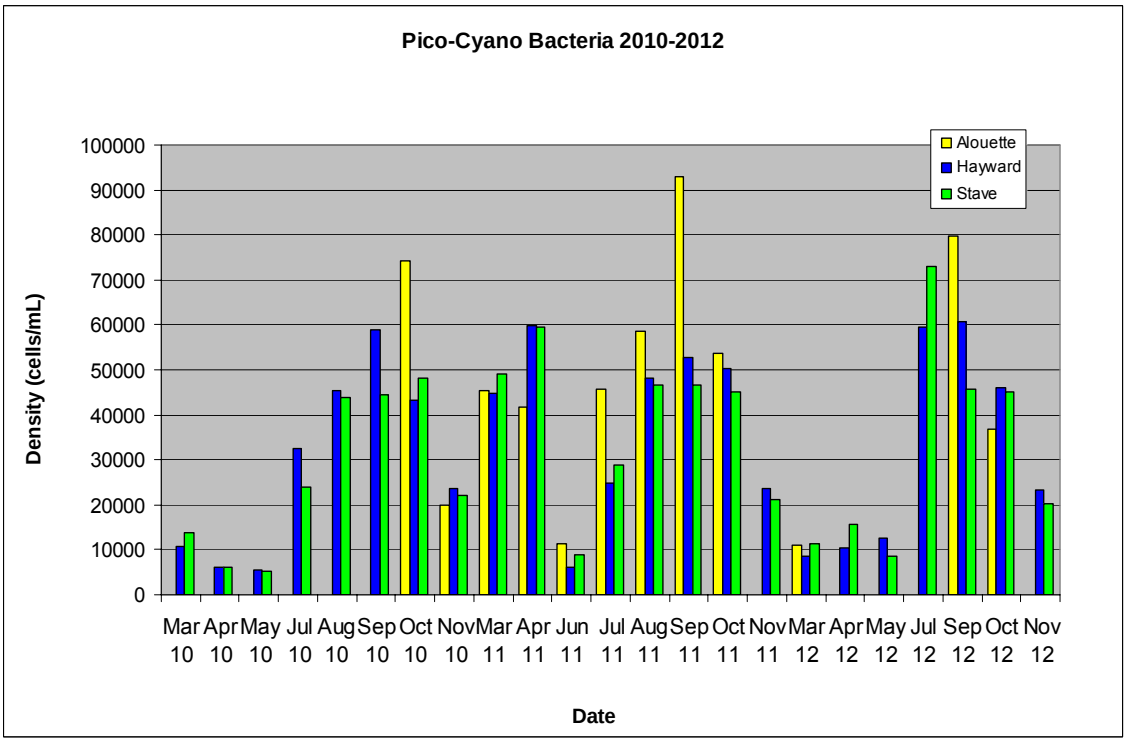


Figure 4.25: 2010/2011 Pico-Cyano Bacteria - Density



4.6 Zooplankton Analyses

Figures 4.26 and 4.27 show total zooplankton biomass and densities measured over the 2012 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 2012. 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 through 2012 an average of the 5 samples is graphed. Zooplankton exhibit a seasonal trend peaking in late summer/early fall at about 35-50 µg/L biomass and 15-25 individuals/L density. From 2010 through 2012 densities seem to be higher than in previous years of data which may be a reflection of the increased replicate sampling.

Figure 4.30 shows zooplankton densities from surrounding BC reservoirs (Stockner 2012) that has been amended to include mean densities from Stave and Hayward in 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 from 2010-2012. 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 2012

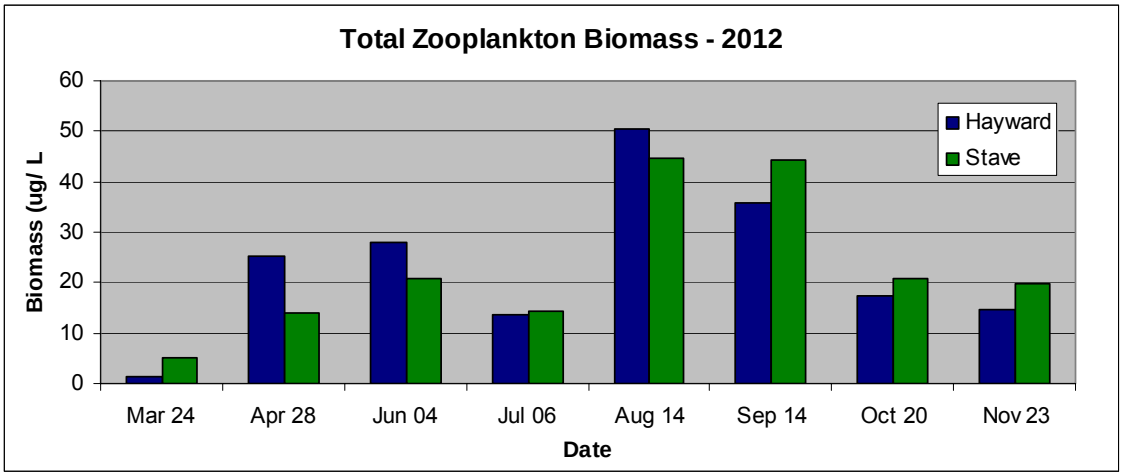


Figure 4.27: Total Zooplankton Density 2012

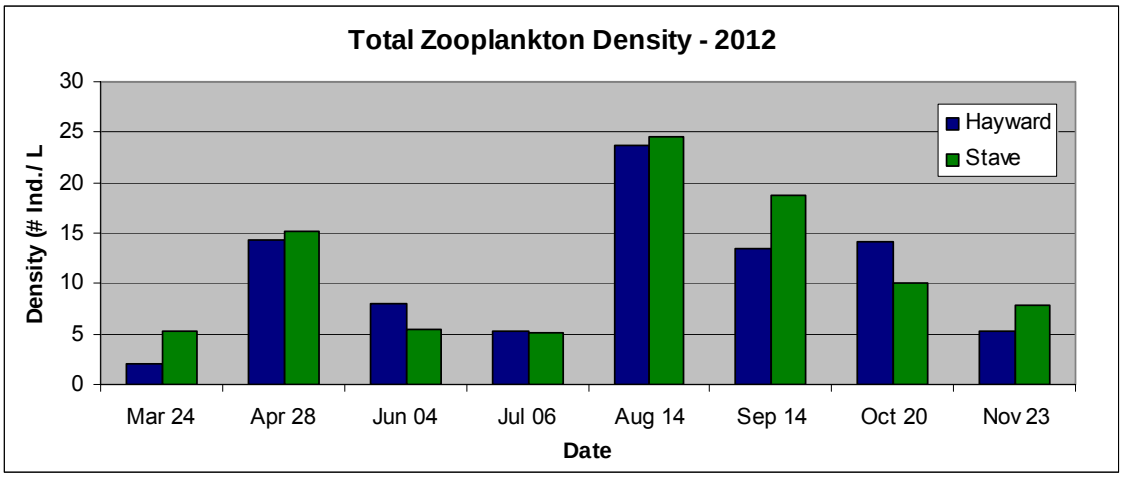


Figure 4.28: Total Zooplankton Biomass 2007-2012

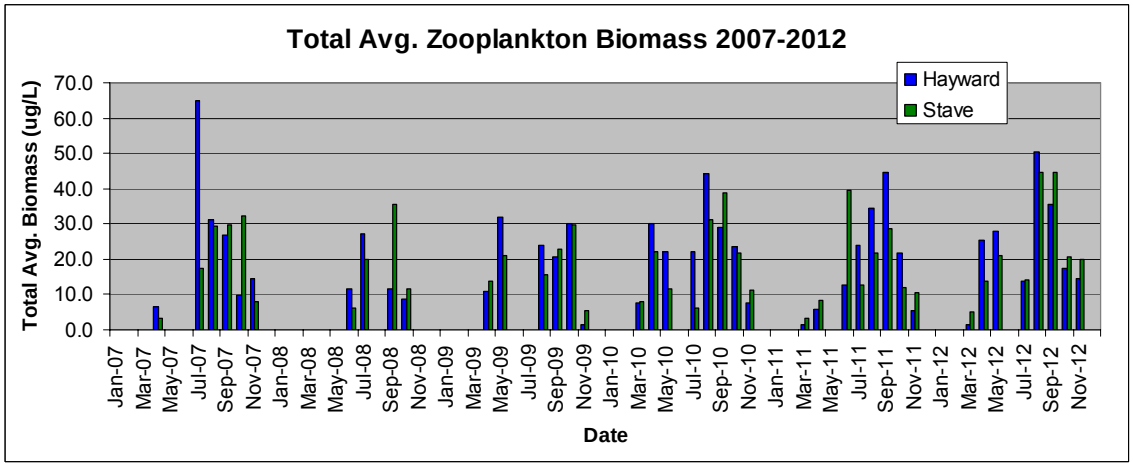


Figure 4.29: Total Zooplankton Density 2007-2012

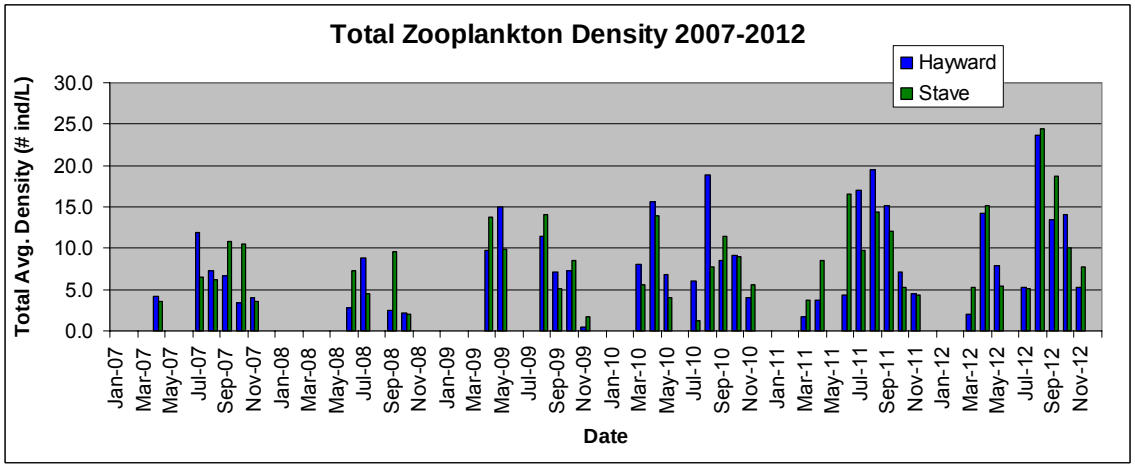


Figure 4.30: Zooplankton Densities from BC Reservoirs Including Stave and Hayward

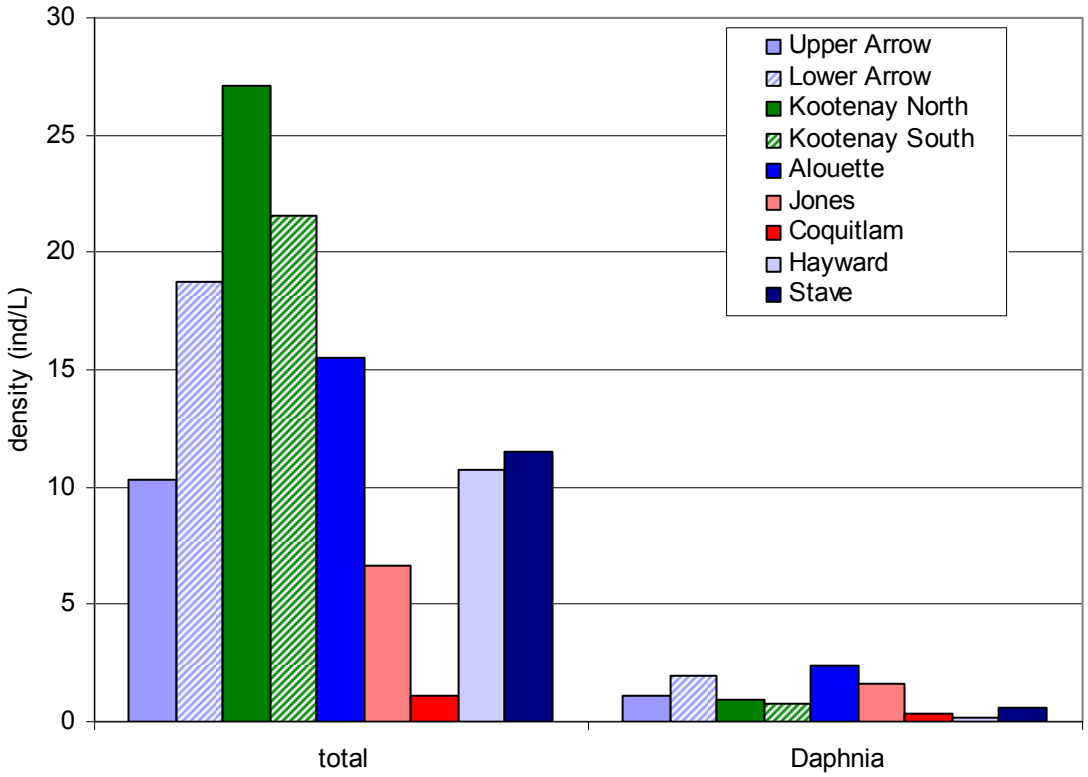
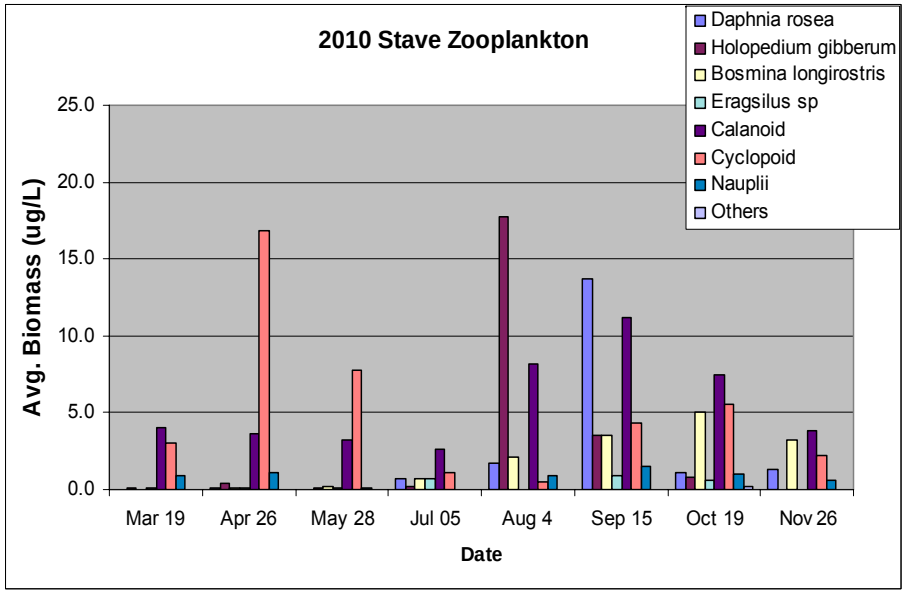
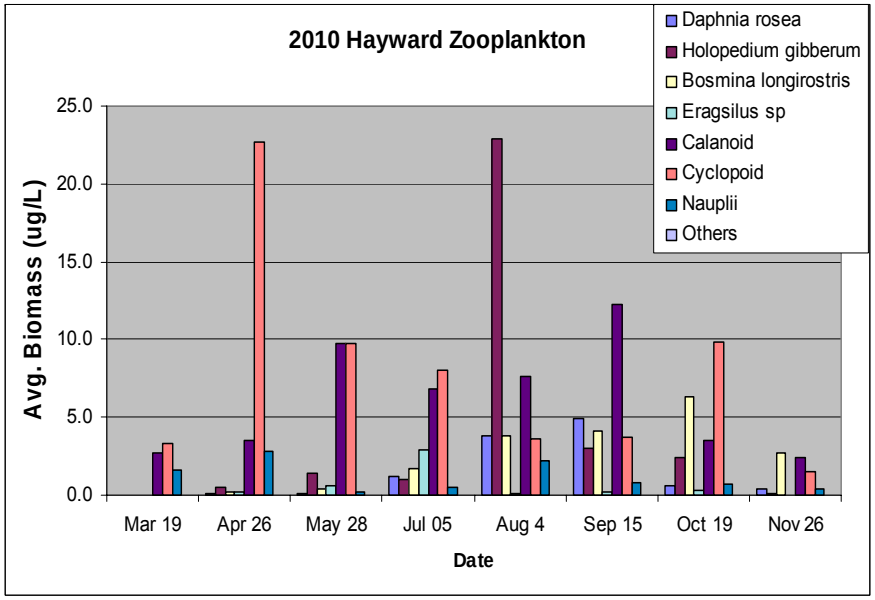
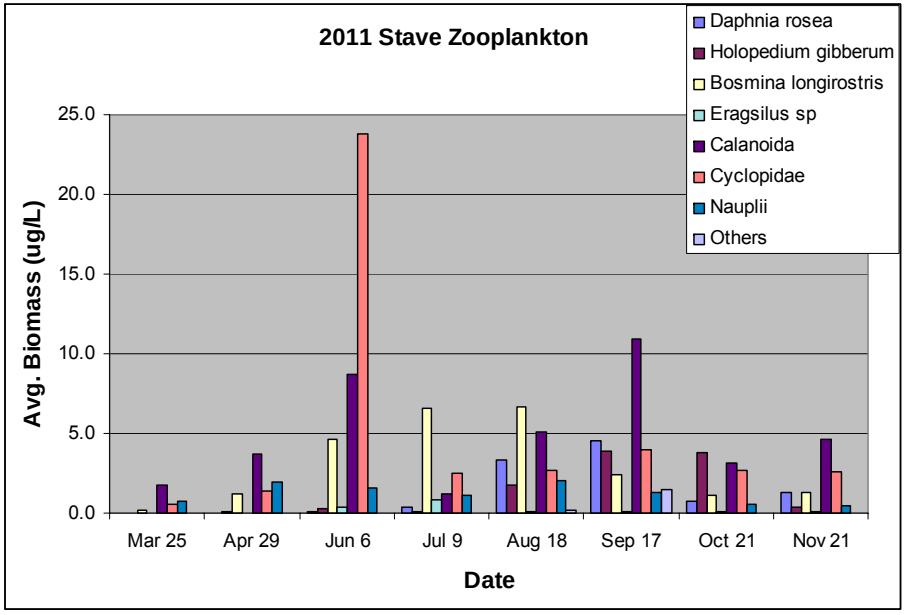
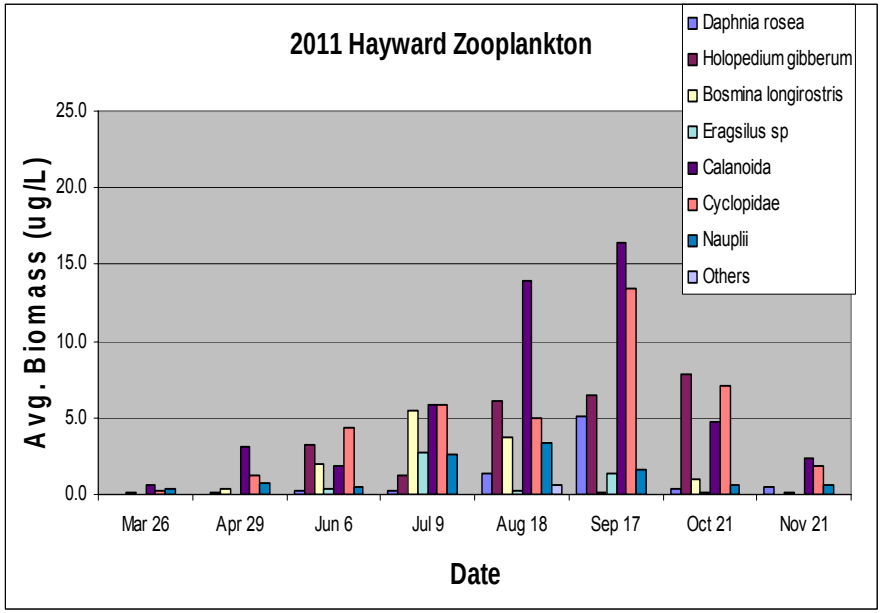


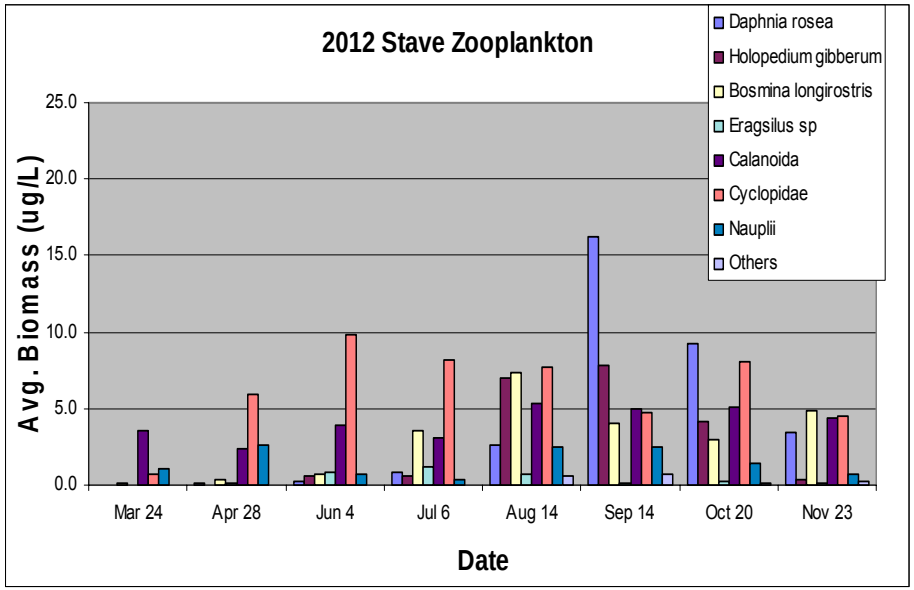
Figure 4.31: Stave and Hayward Zooplankton Species 2010, 2011 and 2012

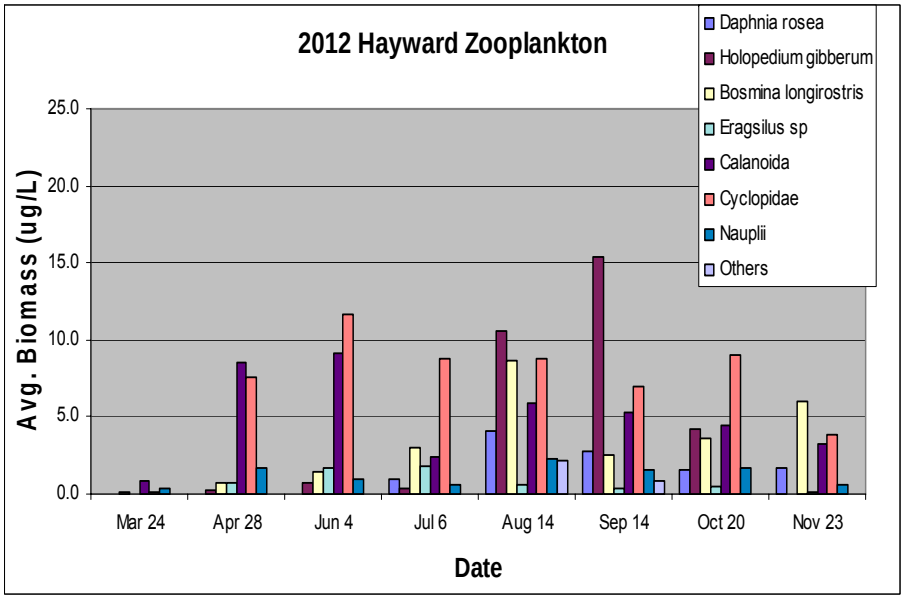









2012 Stave Zooplankton
Daphnia rosea
Holopedium gibberum
Bosmina longirostris
Eragsilus sp
Calanoida
Cyclopidae
Nauplii
Others
Avg. Biomass (ug/L)
25.0
20.0
15.0
10.0
5.0
0.0
Mar 24
Apr 28
Jun 4
Jul 6
Aug 14
Sep 14
Oct 20
Nov 23
Date


2012 Hayward Zooplankton
Daphnia rosea
Holopedium gibberum
Bosmina longirostris
Eragsilus sp
Calanoida
Cyclopidae
Nauplii
Others
Avg. Biomass (ug/L)
25.0
20.0
15.0
10.0
5.0
0.0
Mar 24
Apr 28
Jun 4
Jul 6
Aug 14
Sep 14
Oct 20
Nov 23
Date

4.7 Pelagic Primary Production – ^{14}C Incubation

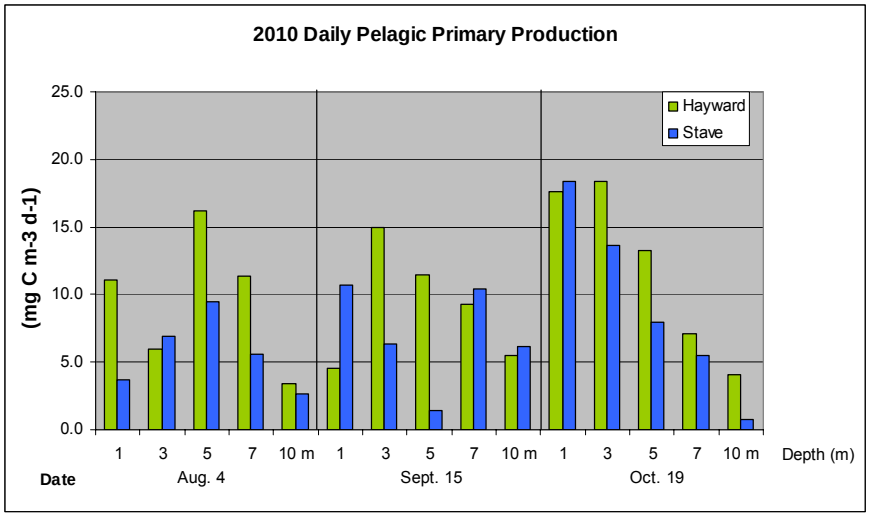
In consultation with BC Hydro it was decided that additional pelagic primary production would be added to this study with incubations being conducted during the summer months (4 sampling trips each summer) in 2010 through to the end of the monitors. In addition, production estimates are fractionated 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.

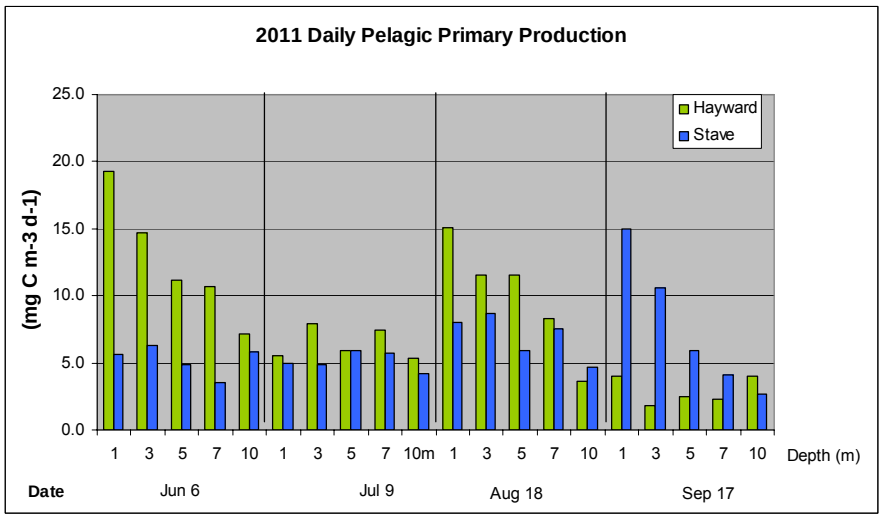
Data from the pelagic primary production incubations conducted in 2010 through 2012 are presented in Figures 4.32. Complete results of the 2012 primary production incubations are provided in Appendix 8. Estimates of daily carbon production at 1, 3, 5, 7, and 10 m depth intervals in Stave and Hayward (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 examining the graphs for the 2010 through 2012 sampling periods, it stands out that in 2011 and 2012 the impacts of an extended period of drawdown are evident in daily production exhibited in Hayward reservoir. Production in Hayward in 2011 in late summer was <5mgC/m^3/day and in 2012 was <10 mgC/m^3/day, whereas in 2010 daily production values in Hayward were much more similar to Stave ranging from about15-20 mgC/m3/day. It also appears that under conditions of drawdown, the trend in production with depth and decreased light is less prominent. It is also notable that in 2010 the sampling extended into October, due to a later start in sampling. In late-summer and early autumn (September & October) as the epilimnion deepens and begins to mix deeper bringing cooler and more nutrient enriched waters to the suface layers results in peaks in productivity. Most temperate BC lakes show this pattern of autumnal increases in production and a shift in density and biomass of phytoplankton (Stockner 1987). In 2010 the later sampling captured one such peak that would lend itself to the idea that it may be worthwhile to extend the carbon estimates into the fall.

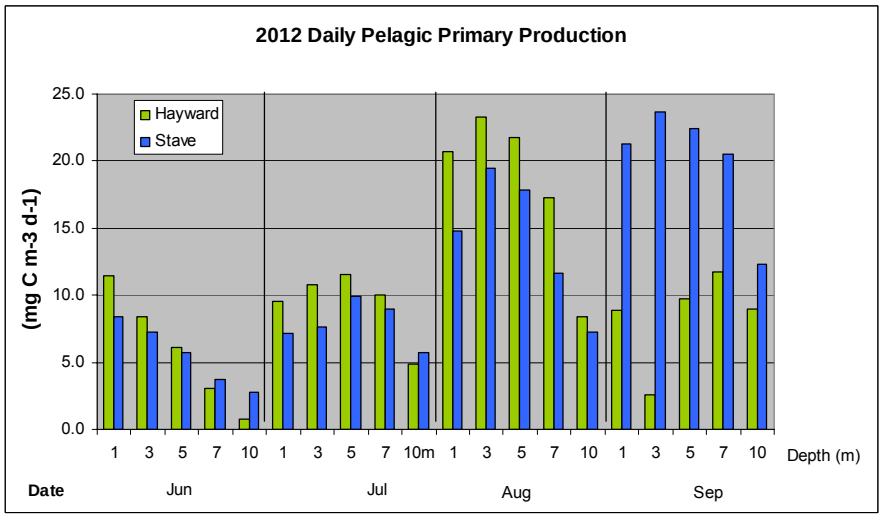
Size fractionated production in Hayward indicates that pico and nano fractions are more prevalent, particularly in the summer months (June- August) (Figure 4.34). In 2010 and 2011 there appears to be more variability in the break down of size classes in Stave, while in 2012 pico and nano fractions are more prevalent.

With three years of carbon analyses, trends in production data are beginning to be more evident. Unfortunately the data from Hayward is likely skewed by the impact of extended periods of drawdown. More full analyses will be able to be provided with the additional carbon incubation that will be carried out in the remaining years.

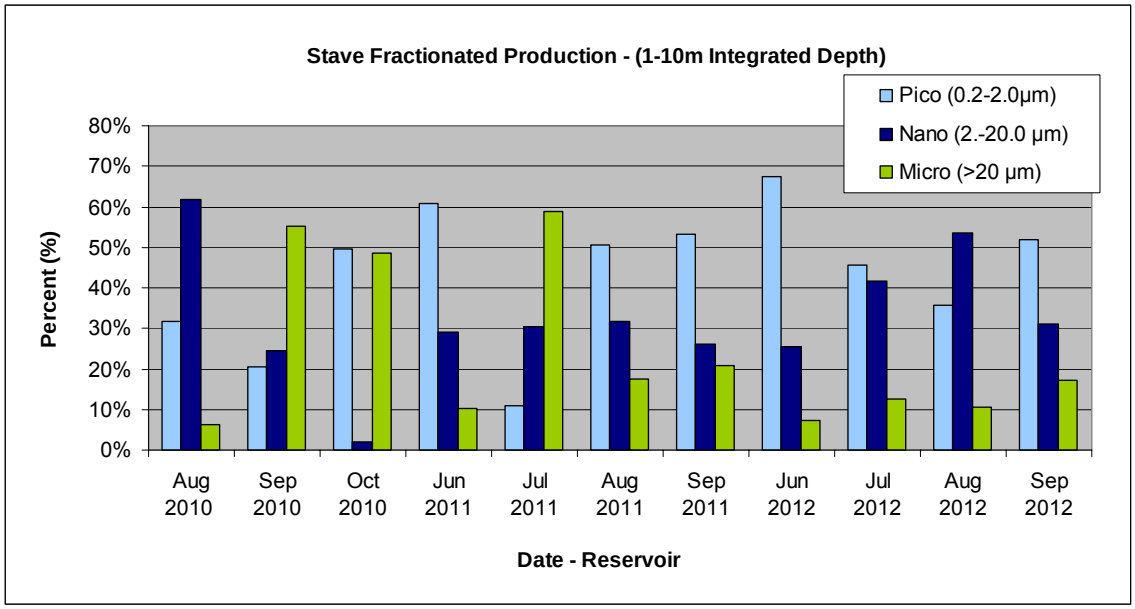
Figure 4.32: Estimates of Daily Carbon Production

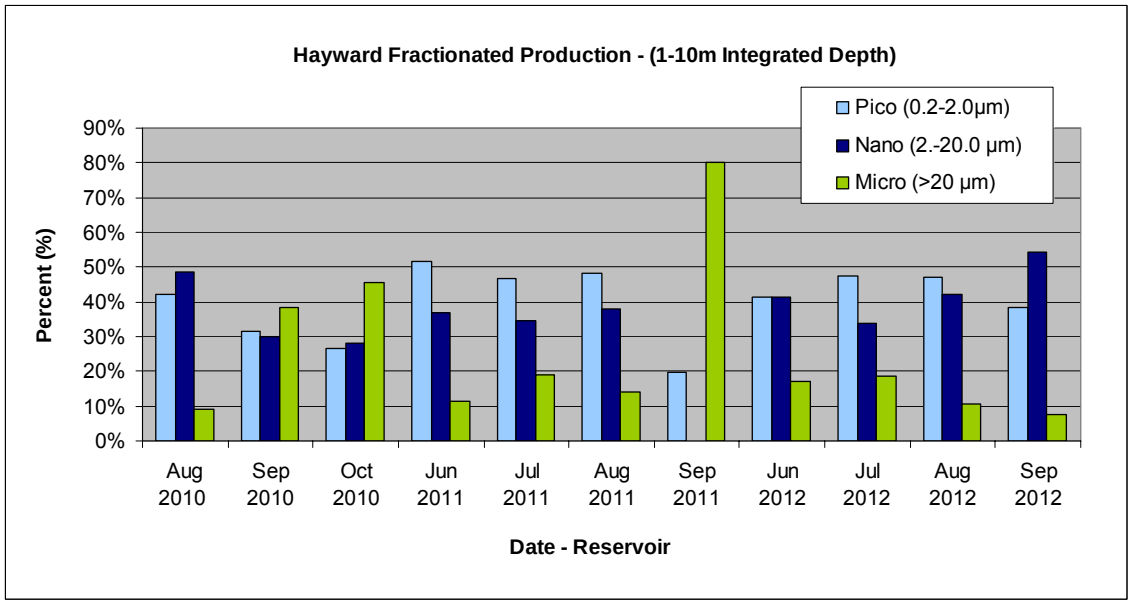






Figures 4.33 and 4.34: Fractionated Production (1-10m Integrated depth)





5. Summary and Conclusion

Stave and Hayward reservoirs are nutrient poor, ultra oligotrophic ecosystems. The WUP study undertaken by BC Hydro indicates that ambient concentrations of chlorophyll, dissolved phosphorus and plankton biomass are among the lowest measured in Coastal BC lakes and reservoirs. Contributing to this condition are high flushing and low residence times of water in the system that result in high export of carbon, nitrogen and phosphorus, already at extremely low levels. In addition, the productive capacity of Stave and Hayward is impacted further by hydroelectric operations that require the ecosystem to undergo high and atypical water level fluctuations. These fluctuations have been even more pronounced in recent years, since Hayward reservoir has undergone long periods of drawdown over the productive summer months.

Water levels in Stave reservoir are typically maintained within the operating regime set as part of the WUP planning process, which includes maintaining water levels in Stave between 80.0 and 81.5 m a.s.l. throughout the summer to allow for recreation. In fall and winter Stave reservoir levels are drawn down by up to 6 m to allow for the accumulation of spring melt water and runoff. Hayward reservoir is typically maintained at approximately 40.0 – 41.0 m a.s.l., traditionally with little fluctuation. In this study, Hayward was intended to provide a comparison of what production might be like if the system were not being maintained to generate power (i.e. consistent water level). During the course of this study, Hayward reservoir has undergone episodes of drawdown. Since the start of the second phase of monitoring, Ruskin dam has been undergoing seismic upgrades resulting in varying but extended periods of drawdown in Hayward over the summer months in 2005, 2007, 2009, 2010, 2011 and 2012. These periods of drawdown make comparisons between Stave and Hayward more complicated. In addition, Hayward is extremely fast flushing with water residing in the basin (residence time) for only about two days, which means that as a system, it functions more like a river than lake.

Light levels in this study are measured on the day of sampling. As expected, light values increase through spring reaching maximum values of about 800-900 $\mu mol/m^2/s$ in Stave and 700 $\mu mol/m^2/s$ in Hayward reservoir. Maximum values in Hayward are lower because Hayward measurements on are taken earlier in the day. Levels of light measured using a Secchi disk consistently show that light penetration in both Stave and Hayward is deeper in fall and spring than in summer months. Measured Secchi depths also indicate that light penetration in Stave generally 1-2 m deeper than in Hayward, and in some instances up to 4 m deeper than in Hayward. Minimum light values were consistently measured in late fall/winter and were commonly <100 $\mu mol/m^2/s$. It is of interest to consider that episodes of drawdown in both reservoirs result in the exposure and desiccation of the shoreline areas of these ecosystems which shift light curves to deeper depths so that organisms that normally receive low light receive intensive

light and organisms that may normally be in darkness are exposed to low light levels.

Springtime (March) surface water temperatures in Hayward are typically about 6 ºC, increasing to 22ºC by August. As a run of the river system, with short residence times and a continuous flow of water, it is notable that there is no development of a stratified layer in Hayward. In Stave, spring temperatures are usually 1-2 degrees cooler than in Hayward at 4-5 ºC. Surface water temperature in Stave increases through the summer months reaching a maximum that ranges from 18-24 ºC by August when a thermocline develops at 6-10 m and lasts through the fall until deep-mixing occurs in September or October.

Spring time inflows in Stave and Hayward result in nitrogen levels around 100µg/L dropping to <40µg/L as productivity increases in the summer. Total phosphorus values are generally less than 4µg/L and bioavailable TDP is typically <2µg/L. Chlorophyll-a concentrations are typically low (<0.4-0.6 µg/L). Peak values are generally seen at the onset of autumn mixing, particularly in Stave. Low overall nutrient levels combined with short residence times or high flushing (as is the case in Hayward) result in high export of both particulate and dissolved carbon, nitrogen and phosphorus from the ecosystem. The export of nutrients impacts the overall benthic-pelagic-littoral productivity of both reservoirs ensuring the persistence of very low biotic pelagic productivity.

Phytoplankton assemblages in both Stave and Hayward reservoirs are dominated by small pico-sized plankton and nano-flagellates. Average seasonal phytoplankton densities typically range between 1000-2000 cells/mL, close to densities found in neighbouring ultra-oligotrophic Coquitlam Reservoir (Stockner, unpublished data). Phytoplankton communities in both reservoirs are dominated by small opportunistic species that are adapted to living in low nutrient conditions (Stockner 1981, 1987). Phytoplankton carbon production is limited by a lack of dissolved phosphorus, which in Stave can occur at almost undetectable levels (<1ug/L) throughout the primary growing season. Periodically, Stave exhibits high abundance of small pico sized plankton (6000-8000 cells/mL), when conditions are stable and the reservoir develops a strong stratified layer and warm epilimnetic temperatures. Once established these peaks in the pico-sized fractions persist into the fall supported by nutrients entrained as part of fall mixing (Stockner, 1987). By autumn, nitrogen levels in Stave are also declining to low levels, and there is a notable lack of large-celled diatoms and blue-green algae.

Similar to phytoplankton, zooplankton densities measured in Stave and Hayward were typically low. Average biomass is generally 25 µg/L and densities of about 10 individuals/L. The measured densities are similar to densities measured in other surrounding BC reservoirs, such as Jones Lake, Coquitlam reservoir, and Upper Arrow reservoir.

Free-living bacteria densities in Stave and Hayward are generally in the 200-300,000 cells/mL range, with episodic events that result in higher abundances in the 500-800,000 cells/mL range. Pico-cyanobacteria counts in Stave system indicate that there are seasonal peaks in late summer/fall with densities reaching 60,000 cells/mL in Stave and Hayward and even higher near to Alouette outfall. These small phytoplankton can be considered opportunistic species that are capable of rapid growth and high turnover rates, even in extremely low nutrient habitats (Stockner and Beer, 2004). High in abundance, but low in average biomass, bacteria and pico-cyanobacteria are the populations that drive carbon through the food web in ecosystems like Stave. Transfer of carbon to higher levels is by micro-flagellates and ciliate grazers that are in turn gazed by rotifers, nauplii and micro-zooplankton.

Rates of pelagic production estimated by ^{14}C incubations indicate that Stave and Hayward reservoirs both have extremely low C-productive capacity. Peak production measured in Stave and Hayward is typically between 20-25 mgC/m2/day. These values are low, even when compared to other coastal BC lakes. For example Kitlope Lake was measured to have an average daily value of 35 mgC/m2, while Nimpkish Lake on the east coast of Vancouver Island was 67 mgC/m2 and Kennedy Lake on the west coast was 70 mgC/m^2 (Stockner 1987, Stockner et al. 1993). It is notable that production measured in Hayward in 2011 and 2012, appears to show a marked response the extended periods of drawdown over the summer period with production values plummeting to <10mgC/m3/day.

In Summary the WUP monitoring of Stave and Hayward has shown that both reservoirs are exceptionally nutrient deprived with the combined effect of low nutrient levels and high export has driven carbon production to the lowest levels observed in any coastal BC lake or reservoir. Hayward reservoir, which is generally considered to me more productive than Stave largely due to the continuous flow of low levels of nutrients through the system, has been impacted throughout the latter part of this study by extended periods of drawdown during the primary phytoplankton growth season. As part of an earlier WUP monitor, total aquatic carbon production was estimated based on the amount of littoral versus the pelagic habitats in the Stave/Hayward ecosystem. Littoral area in Stave was estimated to account for 5% of the total aquatic C-production, while littoral area in Hayward was estimated to account for approximately 50% of total aquatic C-production (Stockner and Beer, 2004). While these projections were at best an approximation, the riverine nature of Hayward has a significant effect of the overall production of the system, common in flowing water habitats (Allan, 1995). This observation serves to highlight the significant impact that water level fluctuation may be having on reservoir ecosystems similar to Stave/Hayward further affecting the overall C-production of these ecosystems.

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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 (Chl a). [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 Chl a 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: 2012 Zooplankton Counts

Hayward

									Daphnia rosea				Holopedium gibberum				Bosmina longirostris				Epischura sp				Calanoida: Diaptomus (Hesperodiaptomus) oregonensis cf)				Cyclopidae: Micrcyclops rubellus cf)				Nauplii				Others			
Date	Sample Depth (m)	Tow Length (m)	Station	Dilution (mL)	Sub-sample Vol (mL)	Flow	NetEff. (%)	TotVol (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)
24-Mar-12	0-15	15	1	60	60	NA	50.00	529.88	1	0.002	2.87	0.01	0	0.000	0.00	0.00	8	0.015	4.80	0.07	0	0.000	0.00	0.00	73	0.138	8.06	1.11	52	0.098	1.56	0.15	850	1.604	0.22	0.35	2	0.004	0.52	0.00
24-Mar-12	0-15	15	2	60	60	NA	50.00	529.88	0	0.000	0.00	0.00	3	0.006	1.34	0.01	10	0.019	4.60	0.09	1	0.002	4.57	0.01	54	0.102	7.30	0.74	39	0.074	1.77	0.13	810	1.529	0.17	0.26	1	0.002	0.37	0.00
24-Mar-12	0-15	15	3	60	60	NA	50.00	529.88	1	0.002	17.39	0.03	1	0.002	1.48	0.00	4	0.008	5.24	0.04	1	0.002	2.84	0.01	51	0.096	7.56	0.73	50	0.094	1.79	0.17	1020	1.925	0.19	0.37	0	0.000	0.00	0.00
24-Mar-12	0-15	15	4	60	60	NA	50.00	529.88	2	0.004	6.34	0.02	0	0.000	0.00	0.00	20	0.038	5.29	0.20	0	0.000	0.00	0.00	48	0.091	7.41	0.67	50	0.094	1.95	0.18	880	1.661	0.15	0.25	1	0.002	0.85	0.00
24-Mar-12	0-15	15	5	60	60	NA	50.00	529.88	4	0.008	7.30	0.06	5	0.009	1.39	0.01	17	0.032	5.18	0.17	0	0.000	0.00	0.00	71	0.134	6.90	0.92	56	0.106	2.02	0.21	1100	2.076	0.19	0.39	0	0.000	0.00	0.00
28-Apr-12	0-15	15	1	100	4	NA	50.00	529.88	0	0.000	0.00	0.00	4	0.189	3.50	0.66	2	0.094	4.98	0.47	6	0.283	4.81	1.36	24	1.132	7.40	8.38	109	5.143	2.28	11.73	149	7.030	0.35	2.46	0	0.000	0.00	0.00
28-Apr-12	0-15	15	2	90	4	NA	50.00	529.88	0	0.000	0.00	0.00	0	0.000	0.00	0.00	4	0.170	6.70	1.14	4	0.170	4.36	0.74	45	1.911	7.06	13.49	96	4.076	2.21	9.01	158	6.709	0.24	1.61	1	0.042	0.58	0.02
28-Apr-12	0-15	15	3	80	4	NA	50.00	529.88	0	0.000	0.00	0.00	1	0.038	2.65	0.10	5	0.189	6.45	1.22	5	0.189	4.62	0.87	40	1.510	7.40	11.17	105	3.963	2.32	9.19	227	8.568	0.28	2.40	1	0.038	0.23	0.01
28-Apr-12	0-15	15	4	90	4	NA	50.00	529.88	0	0.000	0.00	0.00	4	0.170	3.07	0.52	3	0.127	3.42	0.44	7	0.297	4.77	1.42	44	1.868	7.02	13.12	112	4.756	2.36	11.22	198	8.408	0.34	2.86	1	0.042	2.53	0.11
28-Apr-12	0-15	15	5	80	4	NA	50.00	529.88	1	0.038	3.25	0.12	2	0.075	1.36	0.10	6	0.226	4.38	0.99	2	0.075	4.57	0.34	32	1.208	7.24	8.74	112	4.227	1.91	8.07	221	8.342	0.31	2.59	0	0.000	0.00	0.00
30-May-12	0-15	15	1	80	4	NA	50.00	529.88	0	0.000	0.00	0.00	3	0.113	7.38	0.84	8	0.302	4.77	1.44	10	0.377	4.76	1.80	66	2.491	3.58	8.92	82	3.095	4.11	12.72	26	0.981	0.35	0.34	1	0.038	0.30	0.01
30-May-12	0-15	15	2	90	4	NA	50.00	529.88	0	0.000	0.00	0.00	5	0.212	3.20	0.68	9	0.382	2.76	1.05	11	0.467	4.79	2.24	45	1.911	4.07	7.78	74	3.142	4.08	12.82	30	1.274	0.37	0.47	0	0.000	0.00	0.00
30-May-12	0-15	15	3	90	4	NA	50.00	529.88	0	0.000	0.00	0.00	7	0.297	4.64	1.38	10	0.425	4.90	2.08	11	0.467	4.82	2.25	53	2.251	4.84	10.89	81	3.439	3.82	13.14	20	0.849	0.28	0.24	0	0.000	0.00	0.00
30-May-12	0-15	15	4	80	4	NA	50.00	529.88	0	0.000	0.00	0.00	5	0.189	7.12	1.34	13	0.491	2.86	1.40	15	0.566	4.76	2.69	41	1.548	4.52	6.99	108	4.076	3.90	15.90	42	1.585	0.32	0.51	0	0.000	0.00	0.00
30-May-12	0-15	15	5	90	4	NA	50.00	529.88	0	0.000	0.00	0.00	2	0.085	3.98	0.34	20	0.849	2.21	1.88	16	0.679	4.65	3.16	44	1.868	2.87	5.36	100	4.246	4.57	19.41	22	0.934	0.33	0.31	0	0.000	0.00	0.00
06-Jul-12	0-15	15	1	60	8	NA	50.00	529.88	8	0.113	7.94	0.90	4	0.057	3.88	0.22	63	0.892	4.11	3.66	12	0.170	4.83	0.82	17	0.241	5.53	1.33	48	0.679	5.58	3.79	198	2.803	0.22	0.62	0	0.000	0.00	0.00
06-Jul-12	0-15	15	2	60	8	NA	50.00	529.88	13	0.184	6.89	1.27	6	0.085	6.69	0.57	88	1.246	2.90	3.61	23	0.326	4.65	1.51	24	0.340	5.73	1.95	67	0.948	5.35	5.07	160	2.265	0.29	0.66	1	0.014	0.30	0.00
06-Jul-12	0-15	15	3	60	8	NA	50.00	529.88	16	0.226	7.13	1.61	3	0.042	4.98	0.21	65	0.920	3.17	2.92	27	0.382	4.72	1.80	14	0.198	4.77	0.95	82	1.161	5.72	6.64	159	2.251	0.33	0.74	0	0.000	0.00	0.00
06-Jul-12	0-15	15	4	60	8	NA	50.00	529.88	11	0.156	4.44	0.69	6	0.085	6.73	0.57	82	1.161	2.76	3.20	22	0.311	4.45	1.39	27	0.382	4.33	1.65	73	1.033	5.41	5.59	168	2.378	0.32	0.76	1	0.014	1.43	0.02
06-Jul-12	0-15	15	5	60	8	NA	50.00	529.88	7	0.099	5.54	0.55	9	0.127	7.00	0.89	61	0.863	3.15	2.72	8	0.113	4.11	0.47	25	0.354	4.81	1.70	97	1.373	5.08	6.97	182	2.576	0.24	0.62	1	0.014	0.21	0.00
14-Aug-12	0-15	15	1	100	4	NA	50.00	529.88	7	0.330	5.12	1.69	48	2.265	7.19	16.28	45	2.123	4.24	9.00	3	0.142	4.26	0.60	40	1.887	3.55	6.70	68	3.208	2.59	8.31	210	9.908	0.20	1.98	1	0.047	22.05	1.04
14-Aug-12	0-15	15	2	100	4	NA	50.00	529.88	3	0.142	10.15	1.44	33	1.557	6.54	10.18	47	2.218	5.56	12.33	2	0.094	4.57	0.43	33	1.557	3.28	5.11	71	3.350	2.23	7.47	272	12.833	0.18	2.31	0	0.000	0.00	0.00
14-Aug-12	0-15	15	3	100	4	NA	50.00	529.88	37	1.746	7.25	12.66	35	1.651	9.05	14.94	44	2.076	5.14	10.67	3	0.142	4.90	0.69	51	2.406	4.12	9.91	83	3.916	3.19	12.49	446	21.043	0.20	4.21	5	0.236	31.62	7.46
14-Aug-12	0-15	15	4	100	4	NA	50.00	529.88	5	0.236	7.34	1.73	62	2.925	6.75	19.75	68	3.208	5.37	17.23	4	0.189	4.14	0.78	40	1.887	4.21	7.95	60	2.831	1.84	5.21	221	10.427	0.22	2.29	0	0.000	0.00	0.00
14-Aug-12	0-15	15	5	100	4	NA	50.00	529.88	3	0.142	12.35	1.75	46	2.170	7.64	16.58	53	2.501	3.79	9.48	1	0.047	4.38	0.21	26	1.227	2.89	3.55	73	3.444	1.70	5.86	261	12.314	0.20	2.46	0	0.000	0.00	0.00
																																						10.73	
14-Sep-12	0-15	15	1	80	8	NA	50.00	529.88	24	0.453	6.41	2.90	68	1.283	7.24	9.29	5	0.094	7.14	0.67	2	0.038	4.57	0.17	101	1.906	4.06	7.74	138	2.604	3.13	8.15	288	5.435	0.21	1.14	3	0.057	22.17	1.26
14-Sep-12	0-15	15	2	90	4	NA	50.00	529.88	12	0.510	6.07	3.09	54	2.293	8.83	20.25	0	0.000	0.00	0.00	3	0.127	4.66	0.59	62	2.633	2.09	5.50	58	2.463	1.95	4.80	132	5.605	0.20	1.12	3	0.127	12.04	1.53
14-Sep-12	0-15	15	3	80	4	NA	50.00	529.88	14	0.528	5.88	3.11	49	1.849	8.31	15.37	0	0.000	0.00	0.00	2	0.075	4.38	0.33	51	1.925	2.32	4.47	88	3.322	2.79	9.27	153	5.775	0.23	1.33	1	0.038	9.74	0.37
14-Sep-12	0-15	15	4	90	4	NA	50.00	529.88	10	0.425	6.92	2.94	30	1.274	9.97	12.70	3	0.127	5.15	0.66	2	0.085	4.10	0.35	62	2.633	3.46	9.11	89	3.779	2.53	9.56	123	5.223	0.25	1.31	3	0.127	18.44	2.35
14-Sep-12	0-15	15	5	80	4	NA	50.00	529.88	11	0.415	6.52	2.71	55	2.076	7.15	14.84	4	0.151	3.07	0.46	2	0.075	4.78	0.36	59	2.227	3.15	7.01	109	4.114	2.47	10.16	150	5.662	0.23	1.30	0	0.000	0.00	0.00
20-Oct-12	0-15	15	1	90	4	NA	50.00	529.88	6	0.255	6.05	1.54	2	0.085	9.35	0.79	21	0.892	5.69	5.07	3	0.127	4.38	0.56	20	0.849	4.59	3.90	132	5.605	1.42	7.96	283	12.017	0.19	2.28	3	0.127	0.18	0.02
20-Oct-12	0-15	15	2	90	4	NA	50.00	529.88	7	0.297	4.76	1.41	3	0.127	6.21	0.79	20	0.849	4.33	3.68	5	0.212	4.35	0.92	17	0.722	4.94	3.57	125	5.308	1.67	8.86	233	9.894	0.20	1.98	1	0.042	0.23	0.01
20-Oct-12	0-15	15	3	90	4	NA	50.00	529.88	3	0.127	5.75	0.73	1	0.042	10.94	0.46	35	1.486	3.64	5.41	1	0.042	3.82	0.16	23	0.977	3.61	3.53	92	3.907	2.29	8.95	126	5.350	0.18	0.96	2	0.085	0.18	0.02
20-Oct-12	0-15	15	4	90	4	NA	50.00	529.88	1	0.042	5.07	0.22	2	0.085	3.28	0.28	14	0.594	5.86	3.48	0	0.000	0.00	0.00	6	0.255	3.78	0.96	86	3.652	1.37	5.00	147	6.242	0.20	1.25	1	0.042	0.13	0.01
20-Oct-12	0-15	15	5	70	4	NA	50.00	529.88	1	0.033	10.87	0.36	0	0.000	0.00	0.00	14	0.462	4.11	1.90	4	0.132	4.67	0.62	5	0.165	3.19	0.53	110	3.633	1.95	7.08	168	5.548	0.21	1.17	2	0.066	1.06	0.07
21-Nov-12	0-15	15	1	90	8	NA	50.00	529.88	11	0.234	8.79	2.05	0	0.000	0.00	0.00	34	0.722	5.61	4.05	0	0.000	0.00	0.00	21	0.446	5.98	2.67	65	1.380	2.39	3.30	74	1.571	0.22	0.35	1	0.021	0.13	0.00
21-Nov-12	0-15	15	2	80	8	NA	50.00	529.88	17	0.321	8.21	2.63	2	0.038	1.86	0.07	79	1.491	5.18	7.72	1	0.019	3.82	0.07	44	0.830	6.77	5.62	83	1.566	1.47	2.30	135	2.548	0.19	0.48	4	0.075	0.33	0.02
21-Nov-12	0-15	15	3	90	8	NA	50.00	529.88	12	0.255	6.83	1.74	0	0.000	0.00	0.00	84	1.783	5.87	10.47	0	0.000	0.00	0.00	33	0.701	5.76	4.04	61	1.295	1.96	2.54	92	1.953	0.18	0.35	2	0.042	0.23	0.01
21-Nov-12	0-15	15	4	80	8	NA	50.00	529.88	8	0.151	5.41	0.82	0	0.000	0.00	0.00	36	0.679	6.47	4.40	0	0.000	0.00	0.00	20	0.377	5.02	1.89	70	1.321	2.17	2.87	97	1.831	0.18	0.33	1	0.019	17.42	0.33
21-Nov-12	0-15	15	5	90	8	NA	50.00	529.88	10	0.212	6.79	1.44	0	0.000	0.00	0.00	41	0.870	5.06	4.40	1	0.021	4.00	0.08	11	0.234	6.28	1.47	65	1.380	2.59	3.57	98	2.081	0.16	0.33	3	0.064	0.24	0.02

Stave

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)
24-Mar-12	0-20	20	1	40	8	NA	50.00	706.50	1	0.007	1.53	0.01	0	0.000	0.00	0.00	12	0.085	2.72	0.23	0	0.000	0.00	0.00	42	0.297	7.20	2.14	42	0.297	1.80	0.54	574	4.062	0.25	1.02	0	0.000	0.00	0.00
24-Mar-12	0-20	20	2	60	8	NA	50.00	706.50	0	0.000	0.00	0.00	1	0.011	1.78	0.02	5	0.053	1.99	0.11	0	0.000	0.00	0.00	59	0.626	7.79	4.88	41	0.435	1.97	0.86	415	4.406	0.24	1.06	0	0.000	0.00	0.00
24-Mar-12	0-20	20	3	50	8	NA	50.00	706.50	1	0.009	1.30	0.01	0	0.000	0.00	0.00	4	0.035	2.70	0.10	0	0.000	0.00	0.00	57	0.504	7.54	3.80	42	0.372	1.73	0.64	557	4.927	0.21	1.03	0	0.000	0.00	0.00
24-Mar-12	0-20	20	4	50	8	NA	50.00	706.50	4	0.035	1.50	0.05	3	0.027	1.69	0.04	9	0.080	5.03	0.40	0	0.000	0.00	0.00	39	0.345	8.57	2.96	49	0.433	2.09	0.91	492	4.352	0.24	1.04	0	0.000	0.00	0.00
24-Mar-12	0-20	20	5	50	8	NA	50.00	706.50	0	0.000	0.00	0.00	2	0.018	1.28	0.02	9	0.080	3.37	0.27	0	0.000	0.00	0.00	29	0.257	7.58	1.94	43	0.380	2.24	0.85	447	3.954	0.21	0.83	0	0.000	0.00	0.00
28-Apr-12	0-20	20	1	90	4	NA	50.00	706.50	1	0.032	2.36	0.08	0	0.000	0.00	0.00	3	0.096	1.58	0.15	2	0.064	4.58	0.29	10	0.318	7.44	2.37	142	4.522	1.29	5.83	278	8.854	0.28	2.48	0	0.000	0.00	0.00
28-Apr-12	0-20	20	2	80	4	NA	50.00	706.50	2	0.057	3.49	0.20	0	0.000	0.00	0.00	1	0.028	10.07	0.29	1	0.028	4.57	0.13	6	0.170	6.13	1.04	169	4.784	1.36	6.51	342	9.682	0.33	3.19	0	0.000	0.00	0.00
28-Apr-12	0-20	20	3	90	4	NA	50.00	706.50	1	0.032	7.45	0.24	0	0.000	0.00	0.00	4	0.127	3.94	0.50	2	0.064	4.47	0.28	19	0.605	6.55	3.96	187	5.955	1.79	10.66	355	11.306	0.36	4.07	0	0.000	0.00	0.00
28-Apr-12	0-20	20	4	90	4	NA	50.00	706.50	2	0.064	4.51	0.29	0	0.000	0.00	0.00	3	0.096	3.47	0.33	0	0.000	0.00	0.00	19	0.605	6.02	3.64	134	4.268	1.86	7.94	302	9.618	0.36	3.46	0	0.000	0.00	0.00
28-Apr-12	0-20	20	5	80	4	NA	50.00	706.50	4	0.113	3.51	0.40	0	0.000	0.00	0.00	2	0.057	3.21	0.18	1	0.028	4.97	0.14	10	0.283	7.67	2.17	182	5.152	1.19	6.13	312	8.832	0.30	2.65	0	0.000	0.00	0.00
30-May-12	0-20	20	1	90	4	NA	50.00	706.50	0	0.000	0.00	0.00	9	0.287	4.10	1.18	10	0.318	2.45	0.78	7	0.223	4.47	1.00	21	0.669	6.10	4.08	110	3.503	2.98	10.44	10	0.318	0.20	0.06	0	0.000	0.00	0.00
30-May-12	0-20	20	2	90	4	NA	50.00	706.50	2	0.064	5.38	0.34	7	0.223	4.74	1.06	9	0.287	5.42	1.55	13	0.414	4.58	1.90	18	0.573	6.94	3.98	112	3.567	3.17	11.31	8	0.255	0.36	0.09	0	0.000	0.00	0.00
30-May-12	0-20	20	3	80	4	NA	50.00	706.50	2	0.057	4.11	0.23	2	0.057	2.02	0.11	4	0.113	3.37	0.38	3	0.085	4.84	0.41	27	0.764	6.78	5.18	110	3.114	3.74	11.65	7	0.198	0.21	0.04	0	0.000	0.00	0.00
30-May-12	0-20	20	4	90	8	NA	50.00	706.50	6	0.096	6.98	0.67	10	0.159	3.45	0.55	28	0.446	3.62	1.61	13	0.207	4.69	0.97	59	0.939	5.46	5.13	237	3.774	3.89	14.68	20	0.318	0.41	0.13	0	0.000	0.00	0.00
30-May-12	0-20	20	5	90	8	NA	50.00	706.50	2	0.032	4.43	0.14	12	0.191	3.63	0.69	24	0.382	2.87	1.10	14	0.223	4.69	1.05	65	1.035	7.43	7.69	248	3.949	3.59	14.18	24	0.382	0.24	0.09	0	0.000	0.00	0.00
06-Jul-12	0-20	20	1	60	4	NA	50.00	706.50	3	0.064	1.83	0.12	2	0.042	7.31	0.31	50	1.062	3.06	3.25	8	0.170	4.34	0.74	14	0.297	5.97	1.77	52	1.104	4.49	4.96	85	1.805	0.29	0.52	0	0.000	0.00	0.00
06-Jul-12	0-20	20	2	60	4	NA	50.00	706.50	9	0.191	6.05	1.16	3	0.064	11.51	0.73	62	1.316	3.84	5.05	9	0.191	4.49	0.86	13	0.276	4.32	1.19	56	1.189	5.38	6.40	79	1.677	0.18	0.30	0	0.000	0.00	0.00
06-Jul-12	0-20	20	3	60	4	NA	50.00	706.50	16	0.340	5.28	1.79	3	0.064	8.38	0.53	68	1.444	3.21	4.63	20	0.425	4.63	1.97	17	0.361	4.12	1.49	60	1.274	5.53	7.04	83	1.762	0.22	0.39	0	0.000	0.00	0.00
06-Jul-12	0-20	20	4	60	4	NA	50.00	706.50	16	0.340	4.53	1.54	0	0.000	0.00	0.00	56	1.189	3.44	4.09	7	0.149	4.28	0.64	12	0.255	5.43	1.38	41	0.870	5.97	5.20	109	2.314	0.18	0.42	0	0.000	0.00	0.00
06-Jul-12	0-20	20	5	60	4	NA	50.00	706.50	10	0.212	6.11	1.30	3	0.064	5.39	0.34	58	1.231	2.37	2.92	14	0.297	4.46	1.33	15	0.318	2.94	0.94	47	0.998	5.30	5.29	98	2.081	0.22	0.46	0	0.000	0.00	0.00
14-Aug-12	0-20	20	1	80	4	NA	50.00	706.50	34	0.962	6.49	6.25	33	0.934	9.37	8.75	56	1.585	5.14	8.15	7	0.198	4.28	0.85	49	1.387	6.55	9.09	97	2.746	3.55	9.75	558	15.796	0.25	3.95	2	0.057	10.06	0.57
14-Aug-12	0-20	20	2	100	4	NA	50.00	706.50	14	0.495	5.56	2.75	30	1.062	9.39	9.97	56	1.982	4.03	7.99	2	0.071	4.29	0.30	47	1.663	4.23	7.04	80	2.831	3.05	8.63	495	17.516	0.19	3.33	3	0.106	15.55	1.65
14-Aug-12	0-20	20	3	100	4	NA	50.00	706.50	2	0.071	2.53	0.18	43	1.522	5.96	9.07	55	1.946	5.29	10.30	1	0.035	4.97	0.18	47	1.663	2.65	4.41	88	3.114	2.35	7.32	325	11.500	0.20	2.30	1	0.035	2.45	0.09
14-Aug-12	0-20	20	4	100	4	NA	50.00	706.50	31	1.097	8.05	8.83	46	1.628	13.66	22.23	43	1.522	5.23	7.96	6	0.212	4.51	0.96	55	1.946	5.32	10.35	79	2.795	2.66	7.44	496	17.551	0.19	3.33	0	0.000	0.00	0.00
14-Aug-12	0-20	20	5	100	4	NA	50.00	706.50	31	1.097	5.26	5.77	23	0.814	10.61	8.64	41	1.451	5.55	8.05	2	0.071	3.96	0.28	55	1.946	2.92	5.68	56	1.982	4.15	8.22	535	18.931	0.17	3.22	0	0.000	0.00	0.00
14-Sep-12	0-20	20	1	100	4	NA	50.00	706.50	51	1.805	10.95	19.76	11	0.389	9.99	3.89	17	0.602	5.69	3.42	0	0.000	0.00	0.00	32	1.132	4.58	5.19	44	1.557	2.69	4.19	250	8.846	0.19	1.68	1	0.035	74.38	2.63
14-Sep-12	0-20	20	2	100	4	NA	50.00	706.50	51	1.805	8.12	14.65	21	0.743	10.45	7.77	11	0.389	5.62	2.19	0	0.000	0.00	0.00	30	1.062	4.85	5.15	38	1.345	2.58	3.47	403	14.260	0.20	2.85	0	0.000	0.00	0.00
14-Sep-12	0-20	20	3	80	4	NA	50.00	706.50	92	2.604	9.41	24.51	33	0.934	11.90	11.12	15	0.425	5.82	2.47	1	0.028	3.65	0.10	35	0.991	3.74	3.71	44	1.246	2.55	3.18	432	12.229	0.18	2.20	0	0.000	0.00	0.00
14-Sep-12	0-20	20	4	90	4	NA	50.00	706.50	93	2.962	9.10	26.95	15	0.478	8.93	4.27	17	0.541	5.89	3.19	2	0.064	4.11	0.26	35	1.115	3.67	4.09	45	1.433	2.34	3.35	458	14.586	0.20	2.92	0	0.000	0.00	0.00
14-Sep-12	0-20	20	5	90	4	NA	50.00	706.50	84	2.675	8.79	23.51	31	0.987	13.30	13.13	9	0.287	5.65	1.62	0	0.000	0.00	0.00	33	1.051	4.46	4.69	78	2.484	3.07	7.63	395	12.580	0.21	2.64	0	0.000	0.00	0.00
20-Oct-12	0-20	20	1	150	4	NA	50.00	706.50	11	0.584	7.16	4.18	5	0.265	3.77	1.00	22	1.168	5.50	6.42	0	0.000	0.00	0.00	35	1.858	4.11	7.64	82	4.352	2.63	11.45	123	6.529	0.21	1.37	0	0.000	0.00	0.00
20-Oct-12	0-20	20	2	120	8	NA	50.00	706.50	28	0.594	8.56	5.09	11	0.234	5.37	1.25	31	0.658	2.85	1.88	5	0.106	4.42	0.47	53	1.125	3.64	4.10	135	2.866	2.31	6.62	222	4.713	0.21	0.99	0	0.000	0.00	0.00
20-Oct-12	0-20	20	3	100	8	NA	50.00	706.50	25	0.442	9.09	4.02	13	0.230	5.91	1.36	25	0.442	4.82	2.13	4	0.071	4.24	0.30	45	0.796	5.05	4.02	161	2.849	2.33	6.64	202	3.574	0.25	0.89	1	0.018	32.30	0.57
20-Oct-12	0-20	20	4	90	8	NA	50.00	706.50	34	0.541	7.32	3.96	11	0.175	4.93	0.86	38	0.605	5.37	3.25	4	0.064	4.19	0.27	38	0.605	4.55	2.75	153	2.436	2.14	5.21	229	3.646	0.20	0.73	0	0.000	0.00	0.00
20-Oct-12	0-20	20	5	100	8	NA	50.00	706.50	16	0.283	10.19	2.88	5	0.088	5.20	0.46	27	0.478	4.06	1.94	4	0.071	3.92	0.28	31	0.548	3.73	2.05	153	2.707	1.95	5.28	262	4.636	0.21	0.97	2	0.035	19.70	0.70
23-Nov-12	0-20	20	1	90	8	NA	50.00	706.50	26	0.414	7.00	2.90	4	0.064	3.03	0.19	91	1.449	3.42	4.96	0	0.000	0.00	0.00	43	0.685	6.74	4.61	102	1.624	1.93	3.13	219	3.487	0.19	0.66	0	0.000	0.00	0.00
23-Nov-12	0-20	20	2	90	8	NA	50.00	706.50	39	0.621	7.28	4.52	3	0.048	10.37	0.50	138	2.197	3.53	7.76	0	0.000	0.00	0.00	57	0.908	7.17	6.51	128	2.038	2.42	4.93	188	2.994	0.20	0.60	0	0.000	0.00	0.00
23-Nov-12	0-20	20	3	100	8	NA	50.00	706.50	26	0.460	7.68	3.53	6	0.106	4.92	0.52	97	1.716	3.91	6.71	0	0.000	0.00	0.00	36	0.637	6.08	3.87	92	1.628	2.44	3.97	157	2.778	0.18	0.50	1	0.018	0.13	0.00
23-Nov-12	0-20	20	4	100	8	NA	50.00	706.50	20	0.354	8.58	3.04	2	0.035	3.71	0.13	118	2.088	4.74	9.90	2	0.035	4.38	0.15	27	0.478	6.32	3.02	73	1.292	1.98	2.56	174	3.079	0.18	0.55	0	0.000	0.00	0.00

Appendix 5: Water Chemistry Results (2012)

Station	Date	Depth m	NO3 ug/L	TP ug/L	TP Turb ug/L	TDP ug/L	Chl a 0.45 um ug/L	Phaeo 0.45 um ug/L	Corr. Chl 0.45 um ug/L	Chl a 0.2 um ug/L	Phaeo 0.2 um ug/L	Corr. Chl a 0.2 um ug/L	Alkalinity mgCaCO3/L	pH
Hayward	12/03/24	.	121.4	3.6	<0.1	1.2	0.183	0.139	0.114	.	.	.	.	.
Stave	12/03/24	.	119.2	1.7	<0.1	2.0	0.146	0.112	0.090	.	.	.	.	.
Hayward	12/04/28	.	117.9	3.2	0.4	2.2	0.912	0.357	0.735	.	.	.	.	.
Stave	12/04/28	.	118.8	1.5	0.6	1.4	0.516	0.205	0.415	.	.	.	.	.
Allouette	12/05/30	.	107.4	1.5	<0.1	0.8	0.566	0.506	0.316	.	.	.	.	.
Hayward	12/05/30	.	103.9	1.7	<0.1	0.6	0.558	0.415	0.353	.	.	.	.	.
Hayward	12/06/04	1	.	.	.	.	.	.	.	0.638	0.424	0.429	6.9	6.53
Hayward	12/06/04	3	.	.	.	.	.	.	.	0.437	0.293	0.293	.	.
Hayward	12/06/04	5	.	.	.	.	.	.	.	0.456	0.366	0.275	.	.
Hayward	12/06/04	7	.	.	.	.	.	.	.	0.718	0.498	0.472	.	.
Hayward	12/06/04	10	.	.	.	.	.	.	.	0.408	0.211	0.304	6.7	6.49
Stave	12/05/30	.	108.9	1.5	<0.1	1.8	0.522	0.376	0.337	.	.	.	.	.
Stave	12/06/04	1	.	.	.	.	.	.	.	0.668	0.439	0.452	6.2	6.53
Stave	12/06/04	3	.	.	.	.	.	.	.	0.749	0.575	0.466	.	.
Stave	12/06/04	5	.	.	.	.	.	.	.	0.687	0.726	0.329	.	.
Stave	12/06/04	7	.	.	.	.	.	.	.	0.704	0.552	0.431	.	.
Stave	12/06/04	10	.	.	.	.	.	.	.	0.868	0.544	0.600	6.2	6.50
Allouette	12/07/06	.	77.0	2.3	<0.1	0.6	0.847	0.451	0.624	.	.	.	.	.
Hayward	12/07/06	.	83.9	3.5	<0.1	0.8	0.473	0.325	0.312	.	.	.	.	.
Hayward	12/07/06	1	.	.	.	.	.	.	.	0.485	0.375	0.300	6.6	6.51
Hayward	12/07/06	3	.	.	.	.	.	.	.	0.468	0.375	0.283	.	.
Hayward	12/07/06	5	.	.	.	.	.	.	.	0.531	0.368	0.349	.	.
Hayward	12/07/06	7	.	.	.	.	.	.	.	0.562	0.356	0.386	.	.
Hayward	12/07/06	10	.	.	.	.	.	.	.	0.602	0.345	0.431	6.3	6.52
Stave	12/07/06	.	83.8	3.1	<0.1	0.9	0.427	0.299	0.279	.	.	.	.	.
Stave	12/07/06	1	.	.	.	.	.	.	.	0.383	0.260	0.255	.	3.58
Stave	12/07/06	3	.	.	.	.	.	.	.	0.423	0.290	0.279	.	.
Stave	12/07/06	5	.	.	.	.	.	.	.	0.593	0.311	0.440	.	.
Stave	12/07/06	7	.	.	.	.	.	.	.	0.670	0.418	0.464	.	.
Stave	12/07/06	10	.	.	.	.	.	.	.	0.697	0.364	0.518	5.7	6.46
Allouette	12/08/14	.	.	.	.	.	.	.	.	.	.	.	.	.
Hayward	12/08/14	.	51.9	1.5	<0.1	0.4	0.473	0.358	0.296	.	.	.	.	.
Hayward	12/08/14	1	.	.	.	.	.	.	.	0.329	0.217	0.222	7.5	6.63
Hayward	12/08/14	3	.	.	.	.	.	.	.	0.502	0.351	0.329	.	.
Hayward	12/08/14	5	.	.	.	.	.	.	.	0.637	0.442	0.419	.	.
Hayward	12/08/14	7	.	.	.	.	.	.	.	0.587	0.374	0.403	.	.
Hayward	12/08/14	10	.	.	.	.	.	.	.	0.531	0.351	0.357	6.6	6.47
Stave	12/08/14	.	44.1	1.5	<0.1	0.8	0.418	0.273	0.283	.	.	.	.	.
Stave	12/08/14	1	.	.	.	.	.	.	.	0.406	0.215	0.300	6.4	6.60
Stave	12/08/14	3	.	.	.	.	.	.	.	0.396	0.269	0.263	.	.
Stave	12/08/14	5	.	.	.	.	.	.	.	0.327	0.213	0.222	.	.
Stave	12/08/14	7	.	.	.	.	.	.	.	0.606	0.420	0.399	.	.
Stave	12/08/14	10	.	.	.	.	.	.	.	0.737	0.469	0.505	5.8	6.46
Allouette	12/09/14	.	36.3	1.8	<0.1	0.1	1.089	0.658	0.764	.	.	.	.	.
Hayward	12/09/14	.	37.7	1.3	<0.1	<0.1	0.518	0.376	0.333	.	.	.	.	.
Hayward	12/09/14	1	.	.	.	.	.	.	.	0.560	0.369	0.378	7.2	6.62
Hayward	12/09/14	3	.	.	.	.	.	.	.	0.597	0.428	0.386	.	.
Hayward	12/09/14	5	.	.	.	.	.	.	.	0.581	0.478	0.345	.	.
Hayward	12/09/14	7	.	.	.	.	.	.	.	0.514	0.459	0.288	.	.
Hayward	12/09/14	10	.	.	.	.	.	.	.	0.439	0.349	0.267	7.0	6.55
Stave	12/09/14	.	38.8	1.0	<0.1	<0.1	0.468	.	.	.	.	.	.	.
Stave	12/09/14	1	.	.	.	.	.	.	.	0.410	0.265	0.279	6.4	6.60
Stave	12/09/14	3	.	.	.	.	.	.	.	0.408	0.319	0.251	.	.
Stave	12/09/14	5	.	.	.	.	.	.	.	0.416	0.336	0.251	.	.
Stave	12/09/14	7	.	.	.	.	.	.	.	0.556	0.352	0.382	.	.
Stave	12/09/14	10	.	.	.	.	.	.	.	0.568	0.486	0.329	6.1	6.50
Allouette	12/10/20	.	80.2	3.4	<0.1	1.7	1.072	0.707	0.723	.	.	.	.	.
Hayward	12/10/20	.	75.8	4.8	<0.1	1.4	0.535	0.476	0.300	.	.	.	.	.
Hayward	12/10/20	1	.	.	.	.	.	.	.	.	.	.	.	.
Hayward	12/10/20	3	.	.	.	.	.	.	.	.	.	.	.	.
Hayward	12/10/20	5	.	.	.	.	.	.	.	.	.	.	.	.
Hayward	12/10/20	7	.	.	.	.	.	.	.	.	.	.	.	.
Hayward	12/10/20	10	.	.	.	.	.	.	.	.	.	.	.	.
Stave	12/10/20	.	80.2	3.9	<0.1	0.6	0.629	0.483	0.390	.	.	.	.	.
Stave	12/10/20	1	.	.	.	.	.	.	.	.	.	.	.	.
Stave	12/10/20	3	.	.	.	.	.	.	.	.	.	.	.	.
Stave	12/10/20	5	.	.	.	.	.	.	.	.	.	.	.	.
Stave	12/10/20	7	.	.	.	.	.	.	.	.	.	.	.	.
Stave	12/10/20	10	.	.	.	.	.	.	.	.	.	.	.	.
Allouette	12/11/23	.	.	.	.	.	.	.	.	.	.	.	.	.
Hayward	12/11/23	.	113.7	2.4	0.7	0.7	0.368	0.297	0.222	.	.	.	.	.
Hayward	12/11/23	1	.	.	.	.	.	.	.	.	.	.	.	.
Hayward	12/11/23	3	.	.	.	.	.	.	.	.	.	.	.	.
Hayward	12/11/23	5	.	.	.	.	.	.	.	.	.	.	.	.
Hayward	12/11/23	7	.	.	.	.	.	.	.	.	.	.	.	.
Hayward	12/11/23	10	.	.	.	.	.	.	.	.	.	.	.	.
Stave	12/11/23	.	95.3	1.8	0.8	0.5	0.333	0.309	0.181	.	.	.	.	.
Stave	12/11/23	1	.	.	.	.	.	.	.	.	.	.	.	.
Stave	12/11/23	3	.	.	.	.	.	.	.	.	.	.	.	.
Stave	12/11/23	5	.	.	.	.	.	.	.	.	.	.	.	.
Stave	12/11/23	7	.	.	.	.	.	.	.	.	.	.	.	.
Stave	12/11/23	10	.	.	.	.	.	.	.	.	.	.	.	.

Appendix 7: Picoplankton Results

Heterotrophic Bacteria

Lake	Date	Sample Event	Depth	Station	cells/ml	Biovolume (mm3/L)
Stave	24/03/2012	0	NP	Stave	175852.3	0.0703
Hayward	24/03/2012	0	NP	Hayward	187774.5	0.0751
Stave	28/04/2012	0	NP	Stave	124189.5	0.0497
Hayward	28/04/2012	0	NP	Hayward	201683.7	0.0807
Stave	30/05/2012	0	NP	Stave	100345.1	0.0401
Hayward	30/05/2012	0	NP	Hayward	116241.3	0.0465
Hayward (spl)	30/05/2012	0	NP	Hayward (spl)	107299.7	0.0429
Aloutte	04/06/2012	0	NP	Aloutte	112267.3	0.0449
Stave	06/07/2012	0	NP	Stave	180819.8	0.0723
Hayward	06/07/2012	0	NP	Hayward	153001.4	0.0612
Aloutte	06/07/2012	0	NP	Aloutte	417276.6	0.1669
Blank	10/08/2012	0	0	Blank	496.8	0.0002
Aloutte	14/09/2012	0	NP	Aloutte	324879.6	0.1300
Hayward	14/09/2012	0	NP	Hayward	304015.8	0.1216
Stave	14/09/2012	0	NP	Stave	302028.8	0.1208
Aloutte	20/10/2012	0	NP	Aloutte	394425.7	0.1578
Hayward	20/10/2012	0	NP	Hayward	415289.5	0.1661
Stave	20/10/2012	0	NP	Stave	373561.9	0.1494
Hayward	23/11/2012	0	NP	Hayward	325873.1	0.1303
Stave	23/11/2012	0	NP	Stave	317925.0	0.1272
Blank	10/01/2013	0	0	Blank	2980.5	0.0012

Pico-cyanobacteria

Lake	Date	Sample Event	Depth	Station	cells/ml	Biovolume (mm3/L)
Stave	24/03/2012	0	NP	Stave	11480.6	0.0574
Hayward	24/03/2012	0	NP	Hayward	8720.9	0.0436
Stave	28/04/2012	0	NP	Stave	15675.5	0.0784
Hayward	28/04/2012	0	NP	Hayward	10487.1	0.0524
Stave	30/05/2012	0	NP	Stave	8610.5	0.0431
Hayward	30/05/2012	0	NP	Hayward	12584.5	0.0629
Hayward (spl)	30/05/2012	0	NP	Hayward (spl)	8776.1	0.0439
Aloutte	04/06/2012	0	NP	Aloutte	11094.3	0.0555
Stave	06/07/2012	0	NP	Stave	72857.8	0.3643
Hayward	06/07/2012	0	NP	Hayward	59610.9	0.2981
Aloutte	06/07/2012	0	NP	Aloutte	264937.5	1.3247
Blank	10/08/2012	0	0	Blank	0.0	0.0000
Aloutte	14/09/2012	0	NP	Aloutte	79812.4	0.3991
Hayward	14/09/2012	0	NP	Hayward	60604.5	0.3030
Stave	14/09/2012	0	NP	Stave	45701.7	0.2285
Aloutte	20/10/2012	0	NP	Aloutte	36870.5	0.1844
Hayward	20/10/2012	0	NP	Hayward	45922.5	0.2296
Stave	20/10/2012	0	NP	Stave	45039.4	0.2252
Hayward	23/11/2012	0	NP	Hayward	23182.0	0.1159
Stave	23/11/2012	0	NP	Stave	20201.5	0.1010
Blank	10/01/2013	0	0	Blank	0.0	0.0000

Appendix 6: Phytoplankton – 2012 Hayward Phytoplankton Results

Class	Species	Edible/In-edible	29-Mar-12 BioV. mm3/L	28-Apr-12 BioV. mm3/L	04-Jun-12 BioV. mm3/L	06-Jul-12 BioV. mm3/L	14-Aug-12 BioV. mm3/L	14-Sep-12 BioV. mm3/L	20-Oct-12 BioV. mm3/L	23-Nov-12 BioV. mm3/L	29-Mar-12 No. Cells/mL	28-Apr-12 No. Cells/mL	04-Jun-12 No. Cells/mL	06-Jul-12 No. Cells/mL	14-Aug-12 No. Cells/mL	14-Sep-12 No. Cells/mL	20-Oct-12 No. Cells/mL	23-Nov-12 No. Cells/mL
Bacillariophyceae (diatoms)	*Achnanthidium spp.*	e	0.0020	0.0008				0.0008	0.0081	0.0008	20.27	10.14				10.14	101.37	10.14
Bacillariophyceae (diatoms)	*Fragilaria construens*	e	0.0008		0.0008				0.0008		10.14		10.14				10.14	
Bacillariophyceae (diatoms)	*Cyclotella stelligera*	e			0.0015								10.14					
Bacillariophyceae (diatoms)	*Cyclotella glomerata*	e		0.0005	0.0025	0.0005	0.0005	0.0005	0.0005			10.14	50.68	10.14	10.14	10.14	10.14	
Chryso- & Cryptophyceae (flagellates)	*Pseudokephrion sp.*	e							0.0010								10.14	
Chryso- & Cryptophyceae (flagellates)	*Chromulina sp.*	e				0.0051	0.0051	0.0030	0.0004	0.0004				253.42	253.42	152.05	20.27	20.27
Chryso- & Cryptophyceae (flagellates)	*Chrysochromulina sp.*	e	0.0008	0.0008	0.0061	0.0053	0.0053	0.0053	0.0046	0.0015	10.14	10.14	81.09	70.96	70.96	70.96	60.82	20.27
Chryso- & Cryptophyceae (flagellates)	*Chryptomonas spp.*	e	0.0051	0.0051	0.0051	0.0051	0.0051	0.0101	0.0051	0.0051	10.14	10.14	10.14	10.14	10.14	20.27	10.14	10.14
Chryso- & Cryptophyceae (flagellates)	*Boda spp.*	e	0.0010	0.0010	0.0030						10.14	10.14	30.41					
Chryso- & Cryptophyceae (flagellates)	*Ochromonas sp.*	e	0.0101	0.0127	0.0456	0.0558	0.0558	0.0405	0.0405	0.0051	40.55	50.68	182.46	223.01	223.01	162.19	162.19	20.27
Chryso- & Cryptophyceae (flagellates)	*Mallomonas sp.*	e							0.0023								30.41	
Chryso- & Cryptophyceae (flagellates)	*Kephyrion sp.*	e	0.0015	0.0020	0.0015				0.0010		30.41	40.55	30.41				20.27	
Chryso- & Cryptophyceae (flagellates)	*Dinobryon sp.*	e			0.0061	0.0061	0.0061						30.41	30.41	30.41			
Chryso- & Cryptophyceae (flagellates)	*Small microflagellates*	e	0.0018	0.0044	0.0024	0.0067	0.0067	0.0058	0.0084	0.0035	121.64	293.97	162.19	446.02	446.02	385.20	557.53	233.15
Chryso- & Cryptophyceae (flagellates)	*Chroomonas acuta*	e	0.0015	0.0038	0.0038	0.0046	0.0046	0.0046		0.0008	20.27	50.68	50.68	60.82	60.82	60.82		10.14
Chryso- & Cryptophyceae (flagellates)	*Chrysococcus sp.*	e		0.0010	0.0020	0.0020	0.0020		0.0010			10.14	20.27	20.27	20.27		10.14	
Chryso- & Cryptophyceae (flagellates)	*Uroglena sp.*	e																
Chryso- & Cryptophyceae (flagellates)	*Komma spp.*	e				0.0010	0.0010	0.0010	0.0030	0.0020				10.14	10.14	10.14	30.41	20.27
Chlorophyceae (coccoid greens, desmids, etc.)	*Scenedesmus sp.*	e		0.0006		0.0006	0.0006					10.14		10.14	10.14			
Chlorophyceae (coccoid greens, desmids, etc.)	*Sphaerocystis sp.*	e				0.0030	0.0030							10.14	10.14			
Chlorophyceae (coccoid greens, desmids, etc.)	*Cosmarium sp.*	e				0.0051	0.0051	0.0051						10.14	10.14	10.14		
Chlorophyceae (coccoid greens, desmids, etc.)	*Coccomyxa sp.*	e							0.0046								30.41	
Chlorophyceae (coccoid greens, desmids, etc.)	*Ankistrodesmus sp.*	e	0.0008	0.0016		0.0016	0.0016	0.0008			10.14	20.27		20.27	20.27	10.14		
Chlorophyceae (coccoid greens, desmids, etc.)	*Elakatothrix sp.*	e		0.0025	0.0025	0.0051	0.0051					10.14	10.14	20.27	20.27			
Chlorophyceae (coccoid greens, desmids, etc.)	*Chlorella sp.*	e	0.0006	0.0016	0.0020		0.0355	0.0016	0.0012	0.0006	30.41	81.09	101.37		70.96	81.09	60.82	30.41
Chlorophyceae (coccoid greens, desmids, etc.)	*Tetraedron sp.*	e																
Chlorophyceae (coccoid greens, desmids, etc.)	*Monoraphidium sp.*	e																
Chlorophyceae (coccoid greens, desmids, etc.)	*Clamydocapsa sp.*	e																
Chlorophyceae (coccoid greens, desmids, etc.)	*Oocystis sp.*	e																
Chlorophyceae (coccoid greens, desmids, etc.)	*Gleotila sp.*	e							0.0008								10.14	
Chlorophyceae (coccoid greens, desmids, etc.)	*Stichococcus minutissimus*	e																
Chlorophyceae (coccoid greens, desmids, etc.)	*Coelastrum sp.*	e		0.0051	0.0051	0.0355		0.0051				10.14	10.14	70.96		10.14		
Chlorophyceae (coccoid greens, desmids, etc.)	*Planctosphaeria sp.*	e																
Chlorophyceae (coccoid greens, desmids, etc.)	*Gyromitus sp.*	e			0.0023	0.0046	0.0046	0.0091	0.0046	0.0023			10.14	20.27	20.27	40.55	20.27	10.14
Chlorophyceae (coccoid greens, desmids, etc.)	*Monomastic sp.*	e				0.0030	0.0030							10.14	10.14			
Chlorophyceae (coccoid greens, desmids, etc.)	*Nephroselmis sp.*	e						0.0013	0.0013							10.14	10.14	
Chlorophyceae (coccoid greens, desmids, etc.)	*Scourfieldia sp.*	e			0.0007	0.0007	0.0007	0.0020	0.0013	0.0013			10.14	10.14	10.14	30.41	20.27	20.27
Cyanophyceae (blue-greens)	*Synechococcus sp. (coccoid)*	e	0.0007	0.0011	0.0006	0.0016	0.0016	0.0010	0.0019	0.0010	141.92	212.87	111.51	324.38	324.38	202.74	385.20	202.74
Cyanophyceae (blue-greens)	*Synechococcus sp (rod)*	e	0.0006	0.0055	0.0069	0.0030	0.0030	0.0030	0.0020	0.0010	30.41	273.70	344.65	152.05	152.05	152.05	101.37	50.68
Cyanophyceae (blue-greens)	*Synechocystis sp.*	e		0.0005	0.0004	0.0022	0.0022	0.0015	0.0004	0.0003		50.68	40.55	223.01	223.01	152.05	40.55	30.41
		Edible Tota	0.0274	0.0506	0.1010	0.1581	0.1581	0.1022	0.0948	0.0257	486.57	1165.74	1307.66	2017.24	2017.24	1581.35	1713.13	689.31
Bacillariophyceae (diatoms)	*Asterionella formosa*	i	0.0016								20.27							
Bacillariophyceae (diatoms)	*Fragilaria capucina*	i	0.0010	0.0010	0.0010	0.0010	0.0010				10.14	10.14	10.14	10.14	10.14			
Bacillariophyceae (diatoms)	*Fragilaria crotonensis*	i	0.0005								10.14							
Bacillariophyceae (diatoms)	*Synedra nana*	i	0.0051						0.0015		10.14						20.27	
Bacillariophyceae (diatoms)	*Synedra acus*	i																
Bacillariophyceae (diatoms)	*Synedra acus var angustissima*	i																
	Synedra ulna	i				0.0101	0.0101							10.14	10.14			
Bacillariophyceae (diatoms)	*Navicula sp.*	i							0.0051								10.14	
Bacillariophyceae (diatoms)	*Frustrulia spp.*	i																
Bacillariophyceae (diatoms)	*Pinnularia sp.*	i																
Bacillariophyceae (diatoms)	*Rhizosolenia sp.*	i																
Bacillariophyceae (diatoms)	*Tabellaria fenestrata*	i		0.0101					0.0203	0.0051		20.27					40.55	10.14
Bacillariophyceae (diatoms)	*Aulacoseira italica*	i																
Bacillariophyceae (diatoms)	*Tabellaria flocculosa*	i																
Bacillariophyceae (diatoms)	*Gomphonema sp.*	i																
Bacillariophyceae (diatoms)	*Aulacoseira distans*	i																
Bacillariophyceae (diatoms)	*Diatoma sp.*	i																
	Limnothrix redekei	i			0.0071								20.27					
Cyanophyceae (blue-greens)	*Gomphosphaeria sp.*	i																
Cyanophyceae (blue-greens)	*Lyngbya sp.*	i			0.0101								20.27					
Cyanophyceae (blue-greens)	*Aphanothecae sp.*	i																
Cyanophyceae (blue-greens)	*Microcystis sp.*	i				0.0024	0.0024	0.0020						2432.85	2432.85	2027.37		
Cyanophyceae (blue-greens)	*Gomphosphaeria sp.*	i																
		In-Edible To	0.0082	0.0112	0.0182	0.0136	0.0136	0.0020	0.0269	0.0051	50.68	30.41	50.68	2453.12	2453.12	2027.37	70.96	10.14
Bacillariophyceae (diatoms)	*Cyclotella comta*	i/e			0.0639								182.46					
Bacillariophyceae (diatoms)	*Eunotia sp.*	i/e																
Bacillariophyceae (diatoms)	*Cymbella sp.*	i/e																
Dinophyceae (dinoflagellates)	*Peridinium spp.*	i/e	0.0035	0.0071				0.0071	0.0035		10.14	20.27				20.27	10.14	
Dinophyceae (dinoflagellates)	*Gymnodinium sp. (large).*	i/e							0.0152	0.0152							10.14	10.14
Dinophyceae (dinoflagellates)	*Gymnodinium sp. (small)*	i/e	0.0051	0.0101				0.0101	0.0152	0.0101	10.14	20.27				20.27	30.41	20.27
Cyanophyceae (blue-greens)	*Merismopedia sp.*	i/e				0.0162	0.0162	0.0178	0.0860	0.0065				810.95	810.95	892.04	4298.03	324.38
Cyanophyceae (blue-greens)	*Chroococcus sp.*	i/e							0.0228								30.41	
		Both Total	0.0086	0.0172	0.0639	0.0162	0.0162	0.0351	0.1427	0.0318	20.27	40.55	182.46	810.95	810.95	932.59	4379.13	354.79

2012 Stave Phytoplankton Results

Class	Species	Edible/In-edible	23-Mar-12 BioV. mm3/L	28-Apr-12 BioV. mm3/L	04-Jun-12 BioV. mm3/L	06-Jul-12 BioV. mm3/L	14-Aug-12 BioV. mm3/L	14-Sep-12 BioV. mm3/L	20-Oct-12 BioV. mm3/L	23-Nov-12 BioV. mm3/L	23-Mar-12 No. Cells/mL	28-Apr-12 No. Cells/mL	04-Jun-12 No. Cells/mL	06-Jul-12 No. Cells/mL	14-Aug-12 No. Cells/mL	14-Sep-12 No. Cells/mL	20-Oct-12 No. Cells/mL	23-Nov-12 No. Cells/mL
Bacillariophyceae (diatoms)	*Achnanthidium spp.*	e	0.0016	0.0024		0.0008	0.0008	0.0008	0.0020	0.0032	20.27	30.41		10.14	10.14	10.14	20.27	40.55
Bacillariophyceae (diatoms)	*Fragilaria construens*	e			0.0008	0.0091			0.0035				10.14	91.23			10.14	
Bacillariophyceae (diatoms)	*Cyclotella stelligera*	e			0.0030	0.0046							20.27	30.41				
Bacillariophyceae (diatoms)	*Cyclotella glomerata*	e	0.0005		0.0005	0.0051	0.0005	0.0010			10.14		10.14	101.37	10.14	20.27		
Chryso- & Cryptophyceae (flagellates)	*Chromulina sp.*	e				0.0004	0.0004	0.0018	0.0008	0.0004				20.27	20.27	91.23	40.55	20.27
Chryso- & Cryptophyceae (flagellates)	*Chrysochromulina sp.*	e	0.0008	0.0015	0.0030	0.0046	0.0015	0.0046	0.0038	0.0030	10.14	20.27	40.55	60.82	20.27	60.82	50.68	40.55
Chryso- & Cryptophyceae (flagellates)	*Chryptomonas spp.*	e	0.0051	0.0051	0.0051	0.0101	0.0051	0.0051	0.0051	0.0101	10.14	10.14	10.14	20.27	10.14	10.14	10.14	20.27
Chryso- & Cryptophyceae (flagellates)	*Boda spp.*	e	0.0015		0.0020	0.0010					20.27		20.27	10.14				
Chryso- & Cryptophyceae (flagellates)	*Ochromonas sp.*	e		0.0152	0.0304	0.0228		0.0304	0.0203	0.0177		60.82	121.64	91.23		121.64	81.09	70.96
Chryso- & Cryptophyceae (flagellates)	*Mallomonas sp.*	e					0.0152			0.0071					60.82			10.14
Chryso- & Cryptophyceae (flagellates)	*Kephyrion sp.*	e	0.0020	0.0005	0.0010	0.0005			0.0005	0.0005	40.55	10.14	20.27	10.14			10.14	10.14
Chryso- & Cryptophyceae (flagellates)	*Dinobryon sp.*	e				0.0020	0.0081							10.14	40.55			
Chryso- & Cryptophyceae (flagellates)	*Small microflagellates*	e	0.0020	0.0033	0.0033	0.0064	0.0087	0.0076	0.0053	0.0033	131.78	223.01	223.01	425.75	577.80	506.84	354.79	223.01
Chryso- & Cryptophyceae (flagellates)	*Isthmochloron sp.*	e																
Chryso- & Cryptophyceae (flagellates)	*Bitrichia sp.*	e																
Chryso- & Cryptophyceae (flagellates)	*Chroomonas acuta*	e		0.0030	0.0046	0.0061	0.0061	0.0068	0.0030	0.0030		40.55	60.82	81.09	81.09	91.23	40.55	40.55
Chryso- & Cryptophyceae (flagellates)	*Chrysococcus sp.*	e	0.0010	0.0041	0.0030	0.0101	0.0010	0.0020			10.14	40.55	30.41	101.37	10.14	20.27		
Chryso- & Cryptophyceae (flagellates)	*Uroglena sp.*	e																
Chryso- & Cryptophyceae (flagellates)	*Pseudokephrion sp.*	e	0.0010								10.14							
	Komma spp.	e					0.0020	0.0030	0.0010	0.0020					20.27	30.41	10.14	20.27
Chlorophyceae (coccoid greens, desmids, etc.)	*Ankistrodesmus sp.*	e	0.0008	0.0024	0.0008	0.0016	0.0016	0.0016	0.0016	0.0008	10.14	30.41	10.14	20.27	20.27	20.27	20.27	10.14
Chlorophyceae (coccoid greens, desmids, etc.)	*Elakatothrix sp.*	e			0.0025								10.14					
Chlorophyceae (coccoid greens, desmids, etc.)	*Chlorella sp.*	e	0.0006	0.0020	0.0004	0.0026	0.0016	0.0014	0.0008	0.0006	30.41	101.37	20.27	131.78	81.09	70.96	40.55	30.41
Chlorophyceae (coccoid greens, desmids, etc.)	*Tetraedron sp.*	e						0.0005								10.14		
Chlorophyceae (coccoid greens, desmids, etc.)	*Monoraphidium sp.*	e																
Chlorophyceae (coccoid greens, desmids, etc.)	*Clamydocapsa sp.*	e																
Chlorophyceae (coccoid greens, desmids, etc.)	*Oocystis sp.*	e																
Chlorophyceae (coccoid greens, desmids, etc.)	*Gleotila sp.*	e																
Chlorophyceae (coccoid greens, desmids, etc.)	*Stichococcus minutissimus*	e																
Chlorophyceae (coccoid greens, desmids, etc.)	*Coelastrum sp.*	e			0.0051								10.14					
Chlorophyceae (coccoid greens, desmids, etc.)	*Planctosphaeria sp.*	e																
Chlorophyceae (coccoid greens, desmids, etc.)	*Sphaerocystis sp.*	e					0.0061	0.0061							20.27	20.27		
Chlorophyceae (coccoid greens, desmids, etc.)	*Staurastrum sp.*	e																
Chlorophyceae (coccoid greens, desmids, etc.)	*Nephroselmis sp.*	e					0.0013								10.14			
Chlorophyceae (coccoid greens, desmids, etc.)	*Gyromitus sp.*	e			0.0205	0.0046	0.0046		0.0046				91.23	20.27	20.27		20.27	
Chlorophyceae (coccoid greens, desmids, etc.)	*Monomastic sp.*	e					0.0030	0.0030		0.0030					10.14	10.14		10.14
Chlorophyceae (coccoid greens, desmids, etc.)	*Botryococcus sp.*	e							0.0066								10.14	
Chlorophyceae (coccoid greens, desmids, etc.)	*Gyromitus sp.*	e						0.0091								40.55		
Chlorophyceae (coccoid greens, desmids, etc.)	*Scourfieldia sp.*	e			0.0007	0.0007	0.0007	0.0013	0.0013	0.0007			10.14	10.14	10.14	20.27	20.27	10.14
Chlorophyceae (coccoid greens, desmids, etc.)	*Pyramimonas sp.*	e					0.0012	0.0012							10.14	10.14		
	Carteria sp.	e			0.0023								10.14					
	Scenedesmus sp.	e				0.0024		0.0006	0.0006					40.55		10.14	10.14	
Cyanophyceae (blue-greens)	*Synechococcus sp. (coccoid)*	e	0.0011	0.0013	0.0010	0.0007	0.0030	0.0017		0.0015	223.01	263.56	202.74	131.78	608.21	334.52		304.11
Cyanophyceae (blue-greens)	*Synechococcus sp (rod)*	e	0.0020	0.0079	0.0079	0.0045	0.0026	0.0022	0.0030	0.0008	101.37	395.34	395.34	223.01	131.78	111.51	598.08	40.55
Cyanophyceae (blue-greens)	*Synechocystis sp.*	e	0.0003	0.0004	0.0003	0.0003	0.0055	0.0019	0.0018	0.0002	30.41	40.55	30.41	30.41	547.39	192.60	91.23	20.27
			0.0204	0.0493	0.0984	0.1010	0.0806	0.0940	0.0657	0.0582	658.90	1267.11	1358.34	1672.58	2331.48	1814.50	1439.44	922.46
Bacillariophyceae (diatoms)	*Asterionella formosa*	i							0.0032								40.55	
Bacillariophyceae (diatoms)	*Fragilaria capucina*	i	0.0081		0.0020	0.0008	0.0010		0.0051		81.09		20.27	10.14	10.14		10.14	
Bacillariophyceae (diatoms)	*Fragilaria crotonensis*	i							0.0139								81.09	
Bacillariophyceae (diatoms)	*Synedra acus var angustissima*	i																
Bacillariophyceae (diatoms)	*Synedra nana*	i	0.0038	0.0061	0.0015	0.0106	0.0008				50.68	81.09	20.27	141.92	10.14			
Bacillariophyceae (diatoms)	*Synedra ulna*	i						0.0101								10.14		
Bacillariophyceae (diatoms)	*Synedra acus*	i		0.0030		0.0041						30.41		40.55				
Bacillariophyceae (diatoms)	*Navicula sp.*	i	0.0051	0.0051		0.0051				0.0051	10.14	10.14		10.14				10.14
Bacillariophyceae (diatoms)	*Frustrulia spp.*	i																
Bacillariophyceae (diatoms)	*Amphora sp.*	i																
Bacillariophyceae (diatoms)	*Tabellaria fenestrata*	i						0.0152		0.0253						30.41		50.68
Bacillariophyceae (diatoms)	*Rhizosolenia sp.*	i																
Cyanophyceae (blue-greens)	*Gomphosphaeria sp.*	i							0.0276								1378.61	
Cyanophyceae (blue-greens)	*Lyngbya sp.*	i		0.0253	0.0051	0.0152			0.0304			50.68	10.14	30.41			40.55	
Cyanophyceae (blue-greens)	*Aphanothecae sp.*	i																
Cyanophyceae (blue-greens)	*Microcystis sp.*	i					0.0012	0.0008							1216.42	810.95		
Cyanophyceae (blue-greens)	*Gomphosphaeria sp.*	i																
Cyanophyceae (blue-greens)	*Anabaena spp.*	i																
Cyanophyceae (blue-greens)	*Rhaphidiopsis sp.*	i																
	Pseudoanabaena sp.	i																
			0.0170	0.0395	0.0086	0.0358	0.0030	0.0262	0.0802	0.0304	141.92	172.33	50.68	233.15	1236.70	851.50	1550.94	60.82
Bacillariophyceae (diatoms)	*Cyclotella comta*	i/e			0.0035	0.0035		0.0071					10.14	10.14		20.27		
Bacillariophyceae (diatoms)	*Eunotia sp.*	i/e																
Bacillariophyceae (diatoms)	*Cymbella sp.*	i/e		0.0051								20.27						
Dinophyceae (dinoflagellates)	*Peridinium spp.*	i/e	0.0035	0.0035				0.0035			10.14	10.14				10.14		
Dinophyceae (dinoflagellates)	*Gymnodinium sp. (large).*	i/e	0.0152								10.14							
Dinophyceae (dinoflagellates)	*Gymnodinium sp. (small)*	i/e	0.0051	0.0101		0.0051	0.0051	0.0152	0.0101	0.0051	10.14	20.27		10.14	10.14	30.41	20.27	10.14
Cyanophyceae (blue-greens)	*Merismopedia sp.*	i/e				0.0065	0.0130	0.0130	0.0005	0.0146				324.38	648.76	648.76	50.68	729.85
Cyanophyceae (blue-greens)	*Chroococcus sp.*	i/e			0.0076					0.0076			10.14					10.14
			0.02382	0.01875	0.01115	0.0151	0.01804	0.03882	0.01064	0.02727	30.41	50.68	20.27	344.65	658.90	709.58	70.96	750.13

Appendix 8: 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%