Stave River Project Water Use Plan

Pelagic Monitor and Littoral Productivity Assessment

Implementation Year 9

Reference: SFLMON#1
Reference: SFLMON#2

Report on the 2013 Pelagic Monitor and Littoral Productivity Assessment

Study Period: 2013

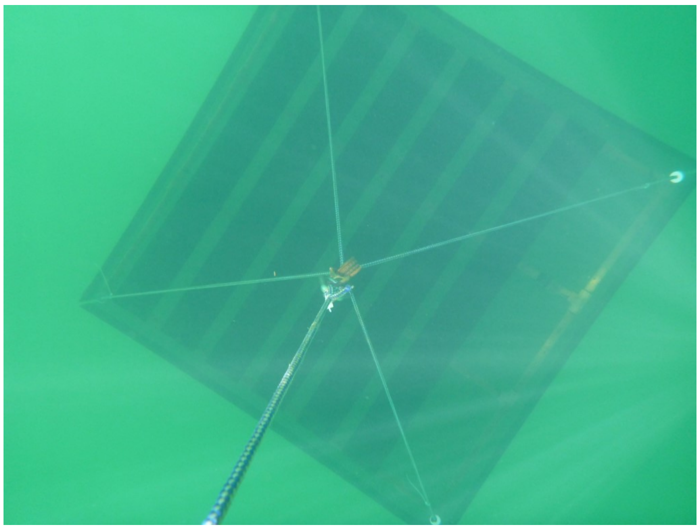
Julie Beer, Msc., PGeo.
Ness Environmental

April 2014

STAVE RIVER WATER USE PLANNING

Report on the 2013 Pelagic Monitor and Littoral Primary Production Monitor

[StaveLimnoNess2012-2014; Amend #:006]



Report to: **BC Hydro**
6911 Southpoint Drive
Burnaby, BC
Attention: Darin Nishi

Date: April 2014

Submitted by: **Ness Environmental Sciences**
2774 William Street
Vancouver, BC V5K 2Y8

Contact: **Julie Beer**, M.Sc., P.Geo.
Phone: 604.729.0925
Email: jabeer@shaw.ca

GST No. 837242676 RT000

Executive Summary

The Stave River littoral and pelagic monitoring programs were undertaken in 2004 as an outcome of the Stave Water Use Planning Process (WUP). The WUP identified a need for a monitoring and long term data collection program that would provide the necessary data to address long term management questions that were identified by the WUP. The objective of both the littoral and pelagic monitoring programs is to collect the necessary data to test the impacts of reservoir operations on primary productivity in Stave and Hayward reservoirs. The data collected in the monitor aims to examine if there is a link between reservoir operations, specifically the "Combo 6" operating regime, and primary production. It is hoped that the studies and data gathered in the monitor will be able to inform management decisions for the reservoirs.

BC Hydro identified four key management questions (section 1 of this report) and a series of hypotheses (Appendix 1) to be tested against the collected data for each of the littoral and pelagic monitors. The initial monitoring question focuses on measuring and defining primary production. If changes in primary production are found, the management questions examine if these changes are attributable to reservoir operations or other measured variables. The littoral monitor management questions also aims to validate the Effective Littoral Zone (ELZ) model that was conceptualized to predict potential changes in littoral productivity which may be applicable to other reservoir systems. The tables below outlines the monitoring questions and impact hypotheses identified as part of the WUP process and provides a monitoring status update.

Littoral Monitor Executive Summary Status Update

Objective	Management Question	Management Hypotheses	Status
Littoral Monitor			
To measure primary production and other environemtnal variables that are impacting primary production to provide the necessary data to answer the management questions regarding the impacts of reservoir operations on productivity of the Stave and Hayward Reservoir system.	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?	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].	The data to date suggests that both TP and TDP levels are very low, indicative of an ultra oligotrophic lake and is typical of coastal lake systems in the pacific northwest. TP reflects bio-available dissolved phosphorus, as well as phosphorus bound in organic matter. TP is a measure of bio- available phosphorus alone. Both sources of phosporus are limiting, leading to a rejection of of the TP and TDP null hypotheses.
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.	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?	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].	Nitrate levels varied oer the course of the season, being at its highest level in winter when producitivity is low, and being at it lowest in late summer fall when productivity is at its highest. Thus nitrate levels varied due to consumption. It would appear that nitrate levels are not as limiting as phoshorus, but generally limiting when compared ot other lake systems. This impat hypothesis can be rejected given the data colected to date.
To validate the ELZ performance measure in terms of its accuracy, precision, and reliability because the ELZ model was used extensivly to predict potential changes in littoral productivity in the WUP decision making process	Is the ELZ performance measure accurate and precise, and if not, what other environmental factors should be included (if any) to improve its reliability?	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].	Though reservoir inflow data are availble, test of the water retention hypothesis remains untested. It should be noted however, that despite the large difference in water retention rates between the Stave and Hayward systems, TDP and NO_3 levels were similar.
	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?	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].	This Hypoesis remains untested, though the neccessary data have been collected. Preliminary analysis suggests that the thermocline in Stave Lake is driven more by solar irradiance, and less by water inflow, especially given the fact the WUP calls for a stable summer time 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].	This Hypothesis has yet to be formally tested, though preliminary analysis suggests that between year variance in algae biomass is unrealted to between year variance in TP, despite that fact that TP includes a meaure of phosphorus bound to organic matter.

Pelagic Monitor Executive Summary Status Update

Objective	Management Question	Management Hypotheses	Status
Pelagic Monitor			
To measure or estimate primary production, environemtnal variable impacting production (light, temperature, nutirents) to provide the necessary data to answer the management questions regarding the impacts of reservoir operations on productivity of the Stave and Hayward Reservoirs as outlined in the WUP	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?	H01: Average reservoir concentration of Total Phosphorus (TP), an indicator of general phosphorus availability, does not limit pelagic primary productivity.	See $H_0$1 in the Littoral Monitor
To 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.	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?	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.	See $H_0$2 in the Littoral Monitor
	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?	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)).	See $H_0$3 in the Littoral Monitor
		H04: Water temperature, and hence the thermal profile of the reservoir, is not significantly altered by reservoir operations.	See $H_0$4 in the Littoral Monitor
	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?	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].	Remains untest for pelgic measure of productivity, though data have been collected to carry out the analysis
		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).	Remains untest for pelgic measures of productivity, though data have been collected to carry out the analysis. Requires a meta analysis of all data collected to date
		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.	Remains untest for pelgic measures of productivity, though data have been collected to carry out the analysis. Requires a meta analysis of all data collected to date
		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.	Remains untest for pelgic measures of productivity, though data have been collected to carry out the analysis. Requires a meta analysis of all data collected to date
		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.	Remains untest for pelgic measures of productivity, though data have been collected to carry out the analysis. Requires a meta analysis of all data collected to date
		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).	Remains untest for pelgic measures of productivity, though data have been collected to carry out the analysis. Requires a meta analysis of all data collected to date. ^{14}C data have been found to vary widely and not necessarily in relation to standing crop. a comprehensive review of the 14C data is required to ensure a robust test of $H_0$10

Table of Contents

1. Introduction

This report summarizes the components of a fresh water productivity monitoring program carried out in 2013 on the Stave and Hayward reservoirs as part of the Stave WUP Monitor. The 2013 monitoring program marked the ninth year of a comprehensive pelagic and littoral monitoring program stemming from BC Hydro's Stave River Water Use Planning process. The program consisted of two phases, the first of which was an intensive sampling program that was carried out in years 2000 to 2003 (Stockner and Beer, 2004; Beer 2004). The present work forms part of the second phase of monitoring that is less data intensive is scheduled to be completed in 2014/15) or when the next Water Use Plan review process.

The objectives for both the littoral and pelagic components of the monitoring program were to collect the data necessary to assess the impacts of reservoir operations on the productivity of Stave Reservoir (fluctuating water level) and Hayward Reservoir (comparatively stable water level). BC Hydro identified four key management questions and several impact hypotheses to be tested with the data collected in each of the programs. Four pelagic and littoral monitoring questions were identified during the WUP process and are stated below. Null hypotheses associated with each of these management questions 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 2013, including details of field sampling and laboratory programs, and summaries of both the littoral and pelagic components of the 2013 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.

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 downstream. 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

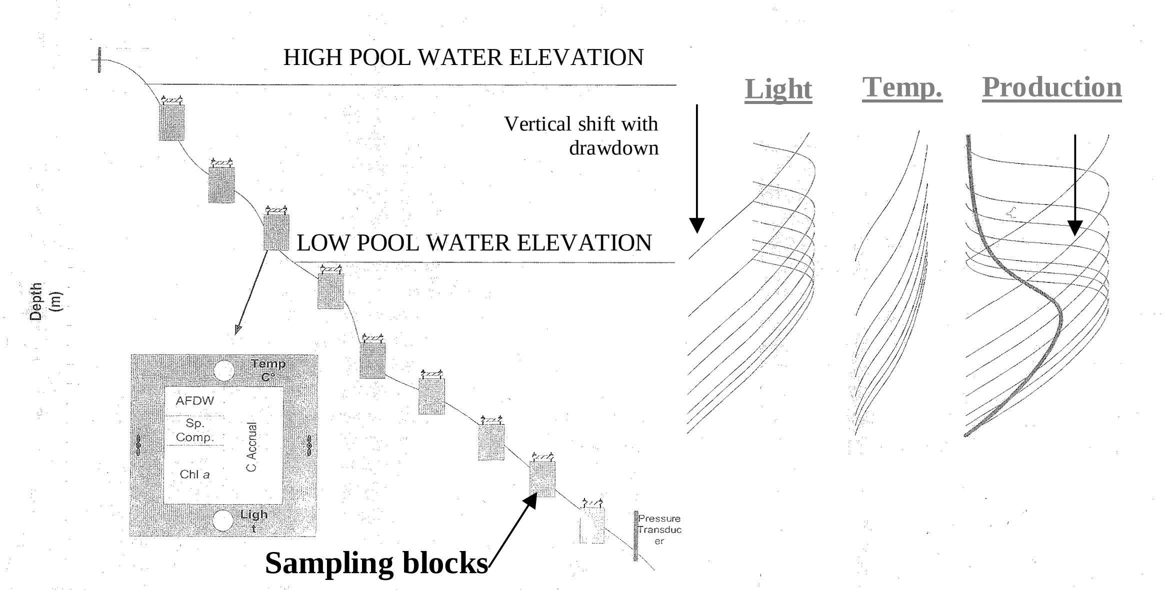
Variable	Stave Reservoir	Hayward Reservoir
Surface Area (km^2)	58	2.9
Volume ($m^3 x10^6$)	2,040	42
Mean Depth (m)	35	14.5
Length (km)	25	5.6
Drainage Basin (km^2)	1,170	953
Max/Min water elevation (m a.s.l.)	82.1-73.0	42.9-33.0
Rainfall (cm)	230	230
Average Discharge (m^3/s)	130	145
Epilimnion Flush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

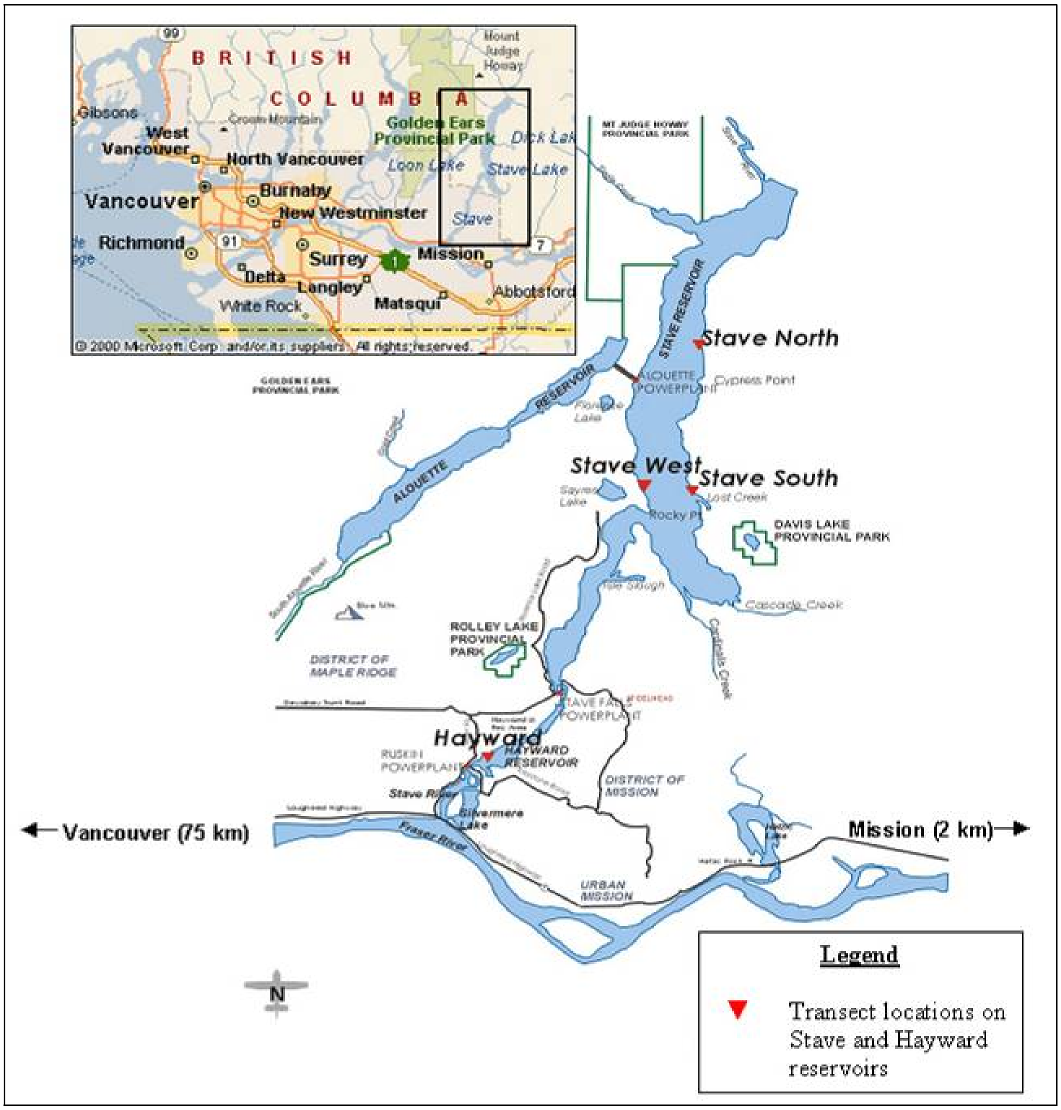


Table 2.2: GPS Coordinates of Transect Locations

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)

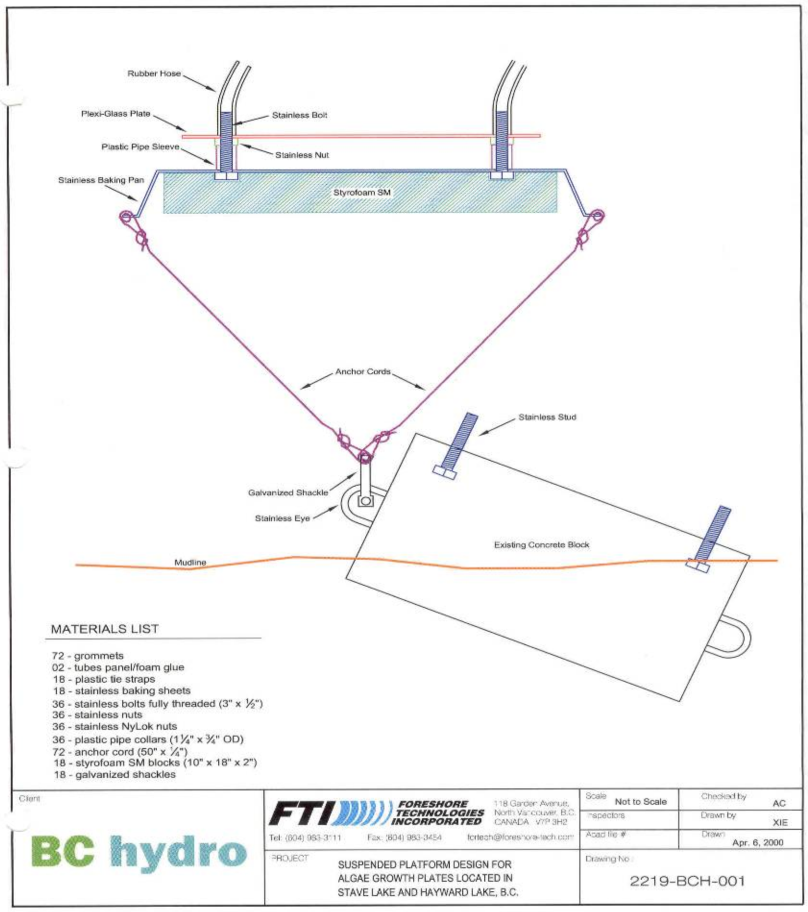
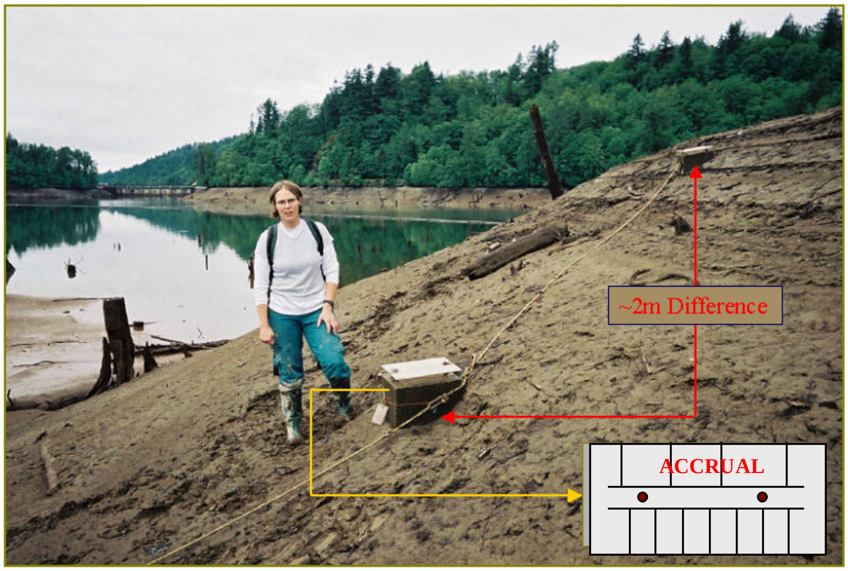


Figure 2.9: Littoral Sampling Design (Pre-2011)



3. Pelagic and Littoral Monitoring Programs for 2013

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. Five incubations were conducted in 2013.

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 (dewatered) for periods of zero to 40 days. In 2013, a study to look at the impact of varying levels of light on periphyton growth was implemented. Details of the study are provided in sections 3.2 and 4.0 of this report. A summary of both pelagic and littoral monitoring programs is provided in Table 3.1.

Table 3.1: Summary of 2013 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 spilling or 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	• Characterizes nutrient dynamics of each reservoir using a composite water sample from 1, 3, and 5 m. • Index of	• Periphyton sampling from artificial substrata located at all 4 transects, to provide estimates of primary	• AFDM - measures accrual of organic biomass for periphyton fractions above 0.45 µm • Discontinued spring

• chlorophyll-a concentrations	photosynthesis of plankton >0.45 µm taken from a composite 1,3,5 m water sample	production (ash-free dry mass (AFDM) accrual)	of 2010
• phytoplankton analyses	• estimates changes in density and biovolume of phytoplankton [pico, nano and micro size range (0.2-200 µm)] using a composite 1,3, 5 m sample	• ^{14}C incubation estimates of primary production are conducted each sampling trip from one plate at both Hayward and Stave North. The plate to be sampled is determined randomly.	• Discontinued at start of 2010 sampling season
• zooplankton analyses	• characterizes species and estimates abundance and biomass in the 200 µm- 2 mm size range • 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. • Carried out 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.	• (2013) Rates of periphyton survival/mortality will be examined under conditions of varying light.	• Quantify the survival of periphyton under low light conditions following a period of high growth. • field component completed summer/Fall2013 • Data analysis to be carried out in 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	Data collected as part of the Pelagic monitor is assumed to be applicable to the littoral monitor	

	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 2013 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 2013 are shown in Table 3.2.

Table 3.2: 2013 Pelagic Field Sampling Schedule and Reservoir Levels

Date	**Hayward Reservoir Level** (at noon, PST)	**Stave Reservoir Level** (at noon, PST)
2013-03-24	41.2	79.7
2013-05-04	41.0	76.3
2013-05-31	34.4	78.5
2013-07-06	36.7	81.4
2013-08-06	36.8	80.8
2013-09-13	39.5	78.2
2013-10-20	39.2	76.4
2013-11-27	37.1	76.0

3.2 Littoral Monitoring Program Methods and Study Design

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 , the goal of the monitor has shifted to addressing key data gaps relevant to application of the ELZ model. This includes periphyton survival following periods of dewatering as well as survival when light conditions are low, in particular when they approach the light compensation threshold (when growth can no longer keep pace with mortality). 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 valid, in particular during the summer. In 2013 an experiment was started to determine the rate of mortality/survival when periphyton are subjected to extended periods of little or no light, a condition that can occur when water levels rise, causing the light compensation depth with rise with it (the depth at which light intensity is such that periphyton growth no longer out paces mortality, leading to a net decline in periphyton biomass). This work is ongoing and the sections that follow describe the methods used in this most recent study work.

3.2.1 Study Design

The study was carried out in a sequence of phases, starting with an initial growth period to colonize a set of sampling strips followed by a treatment phase, during which the colonized strips were subjected to varying degrees of sunlight. Light exposure was controlled by installing light canopies that sat above the sampling grid while still allowing in-situ flow of water. During the treatment phase, the Plexiglas growth strips were sampled and analysed to track growth/survival using ^{14}C incubations and AFDM. The key metric of interest was 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.

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

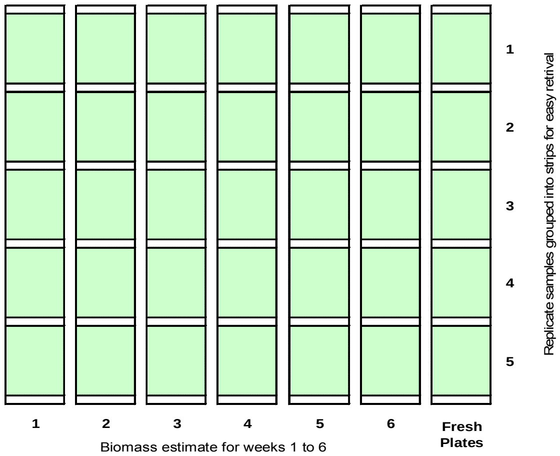
3.2.2 Experimental Design

3.2.2.1 Initial Growth Phase

Periphyton colonization occurred 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 had five etched quadrants (10cmx15cm) that will be the periphyton sampling area separated by a 5 cm gap. Seven strips were mounted to a grid for a total of 35 sampling quadrants to create a replicate grouping strategy for ease of sampling (Figure 3.1). 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. Initial sampling intervals were logarithmic (1, 3, 12, 25, 37 days) through September. In October and November sample sessions were roughly 3 weeks apart.

Prior to each treatment, the grids were installed off the edge of a log boom in the fore bay of Stave Falls Dam (across from the boat launch). They were 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 undergoing the various light treatments.

Figure 3.1: Sampling grid design



3.2.2.2 Treatment

Five grids underwent pre-treatment colonization after which each grid was fitted with a light canopy. The canopies were 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 actual light measurements will determine the exact light exposure for each grid. The canopy sat above each sampling grid without enclosing it, such that water circulation was not inhibited. Relative light was measured at each grid sight using HOBO Pendant temperature/light data recorders. The following five light treatments were 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

Each sampling day, a single Plexiglas growth strip (i.e. 5 replicate samples) were collected from each treatment grid. A single 75cm^2 area was sampled into a jar and analysed in the lab for AFDW. A second 75cm^2 area was split into two jars, one light and one dark bottle and analysed for carbon uptake in the lab. This method was preferred over diluting the sample to a known volume with distilled water and then splitting it in the laboratory as described in the original proposal, as it allocated a more accurate proportion of the periphyton into each sampling bottle. Sample jars were transported in coolers to the laboratory and processed immediately.

The study took place from June through November 2013.

3.2.3 Laboratory Analyses

Once collected, periphyton samples were stored cold and dark for transport back to the laboratory. In the lab, 5 replicate samples from each strip were 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 intended technique for carbon analyses was to split the carbon primary production sample in the laboratory. It proved to be more difficult than expected to divide the sample into two equal parts. As a result, the method was altered such that the periphyton was split based on the growth area on the plate. The second 75cm^2 area was split in the field into one dark and one clear bottle (37.5 cm^2 each). In the laboratory, each bottle was topped up to 100ml volume with distilled deionized water then inoculated with 1ml of 5µCi ^{14}C. The inoculated bottles were placed on a specifically designed shaker table (Figure 3.2) and incubated for a fixed duration (3 hours) under artificial grow lights (Sunblaster T5 High Output Florescent). During the incubation period the samples were gently agitated to prevent settling of the periphytic material to the bottom of the sample jar. Immediately after the incubation period, samples were filtered and acid added to stop further ^{14}C uptake. Once filtered, 5 ml of Ecolite+ scintillation cocktail was added to each sample. After a minimum of 24 hours, the samples were analysed at UBC Radiation Safety Office Laboratory in a Beckman LS6500 scintillation counter.

Figure 3.2: Shaker Table with light and dark bottles

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 3.3: 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 ALS Laboratory (Burnaby, BC) for total phosphorus, total dissolved phosphorus, nitrate, and chlorophyll *a*. A reference to 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, then transported promptly to the laboratory for analyses.

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 3.4: 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 3.5: Light Intensity Profile Being Measured on Stave Reservoir

4. Monitoring Results for 2013

Results are presented for data collected in 2013.

4.1 Littoral Peripyton Survival Study Under Varying Light Conditions

The field component of the study examining periphyton survival under varying light conditions was carried out from June to November of 2013. This included all laboratory work that measured Ash-Free Dry weight of the periphyton samples and Carbon 14 incubations that were used to estimate primary production. Results of this work are presented in Appendix 4 (a and b) and await final data checking to confirm ^{14}C results. Preliminary findings have found the ^{14}C data to vary unexpectedly and it is unclear at this time whether this is due to a methodology error or some environmental factor that was not considered in this study (e.g., the possible effect of photo-inhibition during the light treatment period. Complete analyses and results of this work will be presented later in 2014, and may include recommendations for follow up field studies.

4.2 Light

Light profiles for Stave and Hayward on each of the sampling days in 2013 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

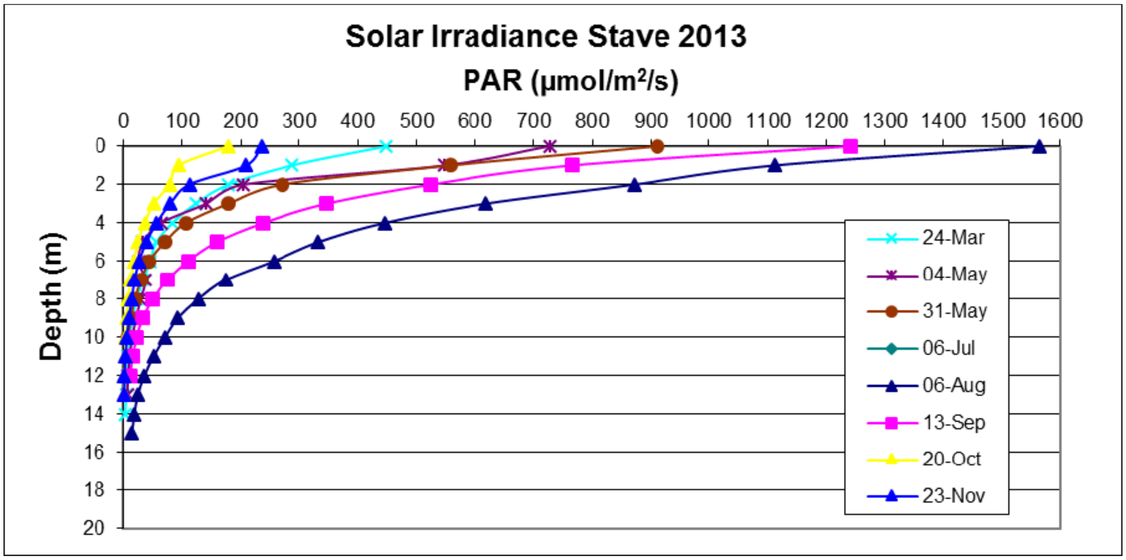
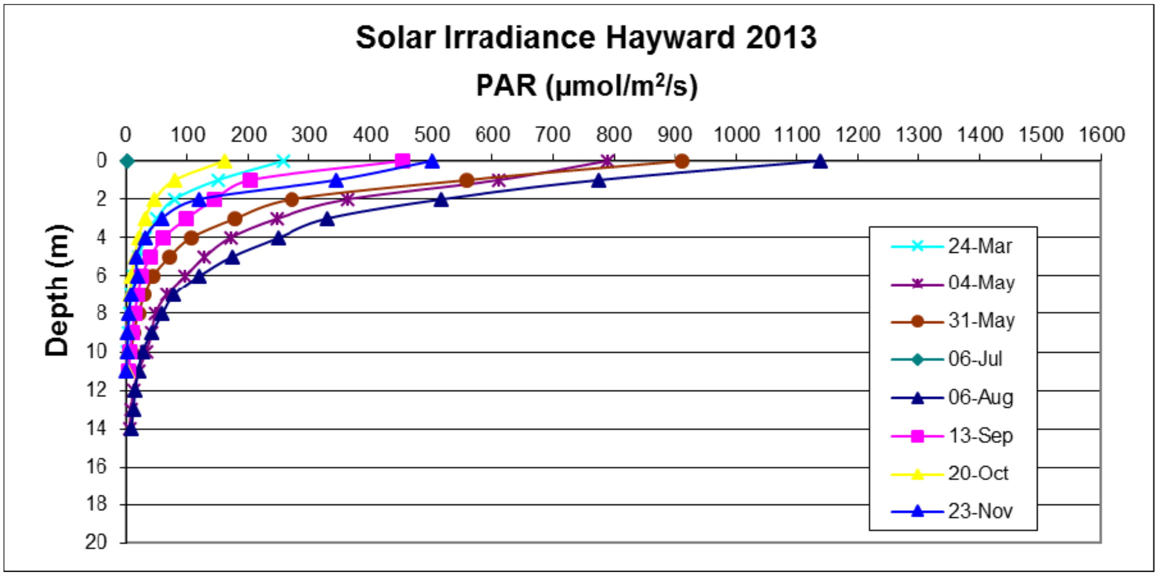


Figure 4.2: Hayward Solar Irradiance



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 2013 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 (2013)

Date	Hayward	Stave
Mar 24	0.46	0.34
May 04	0.35	0.37
May 31	0.46	0.37
Jul 06	Licor not working	
Aug 06	0.35	0.31
Sep 13	0.40	0.39
Oct 20	0.44	0.36
Nov 27	0.59	0.39

Secchi depths for each sample day on Stave and Hayward are presented in Figure 4.3 below. As a reference, secchi depths measured in phase 1 (2002 and 2003) are presented in Figure 4.4 and secchi depths throughout phase 2 (2006-2013) are presented in Figure 4.5.

Figure 4.3: Secchi Depths for Stave and Hayward

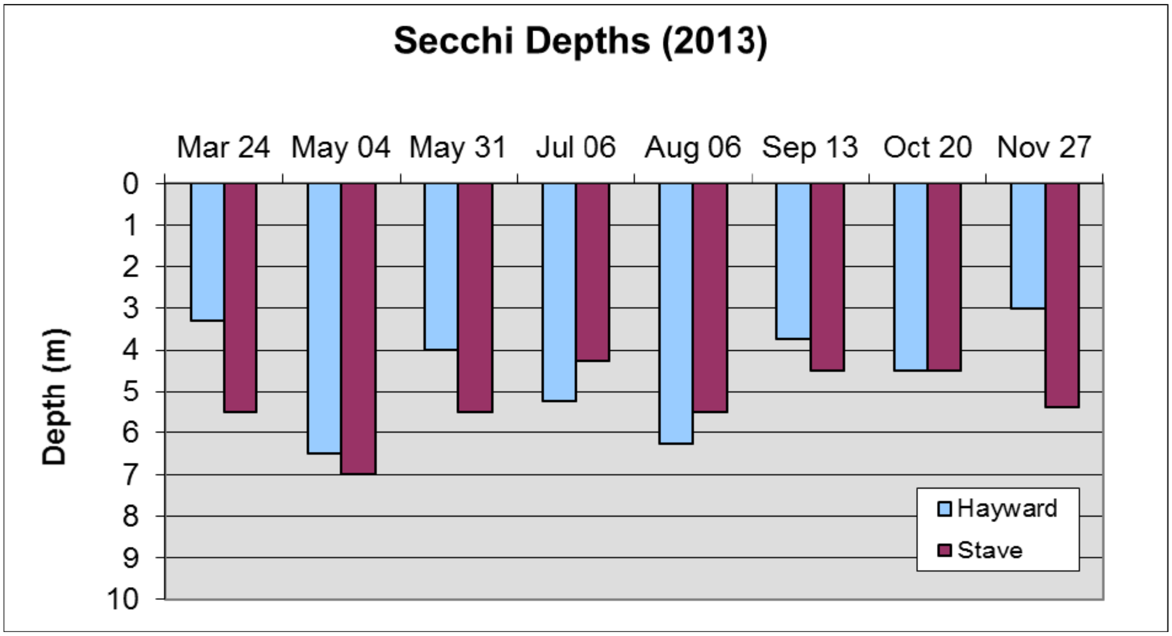


Figure 4.4: Phase 1 (2002-2003) Secchi Depths for Stave and Hayward

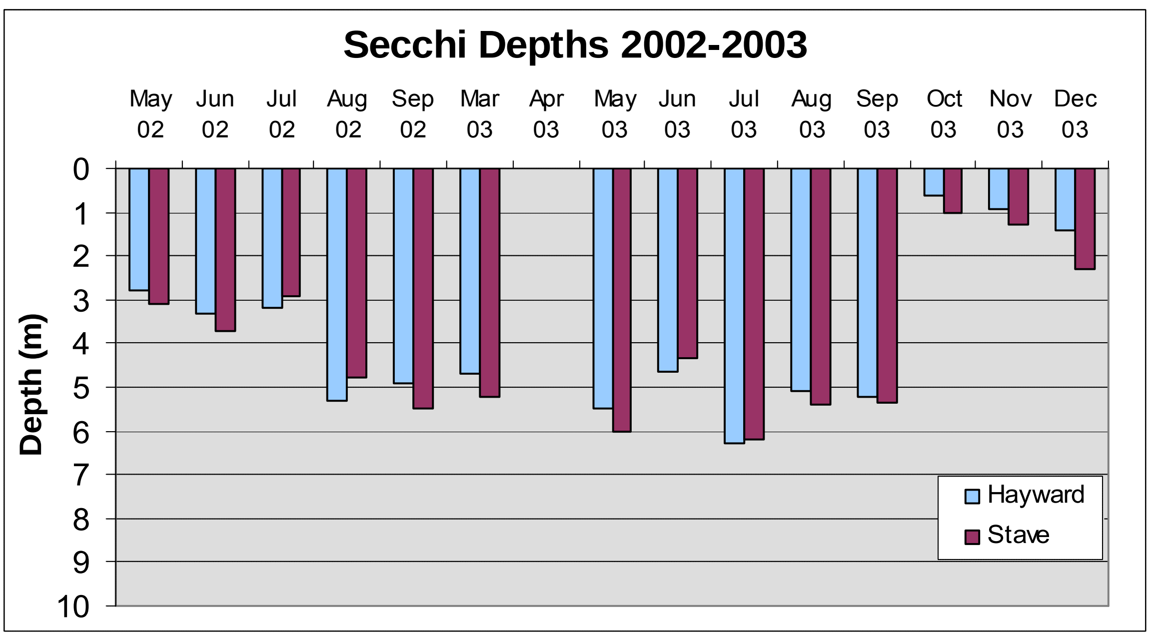
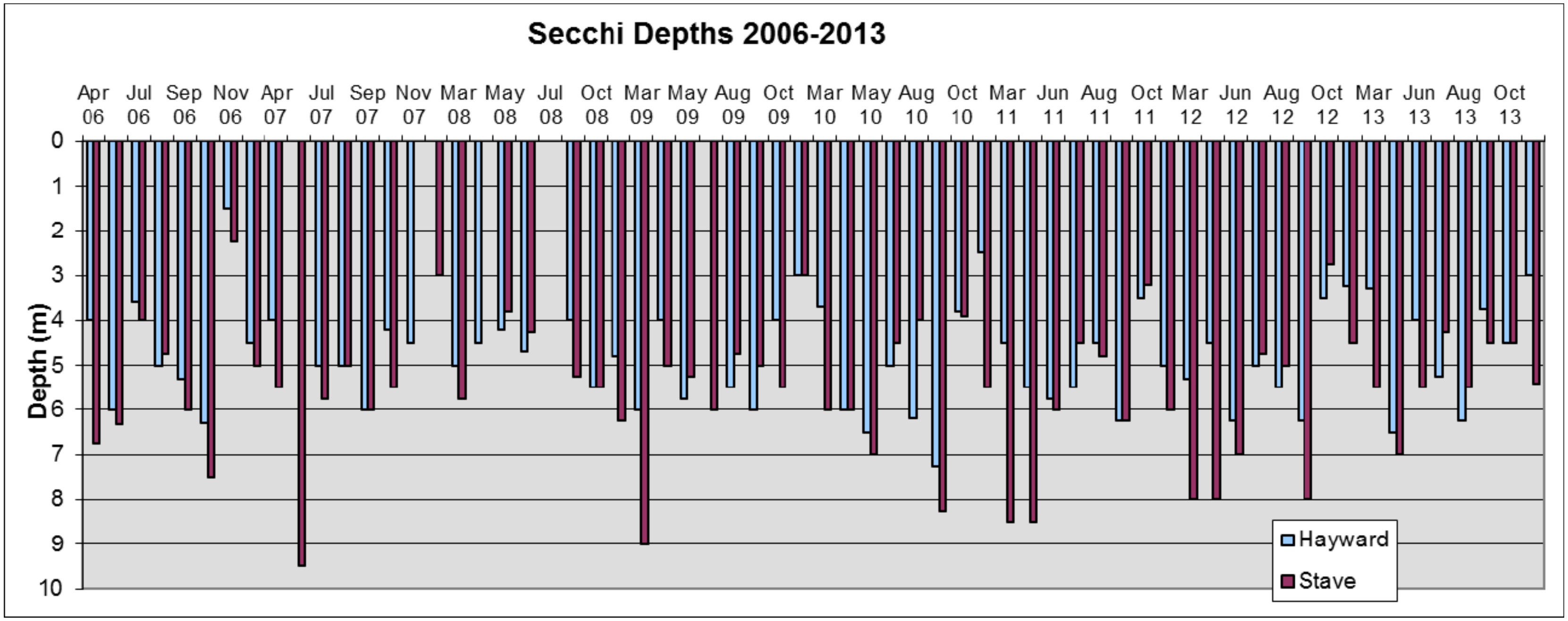


Figure 4.5: Phase 2 (2006-2013) Secchi Depths for Stave and Hayward



Surface solar radiation throughout 2013 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)

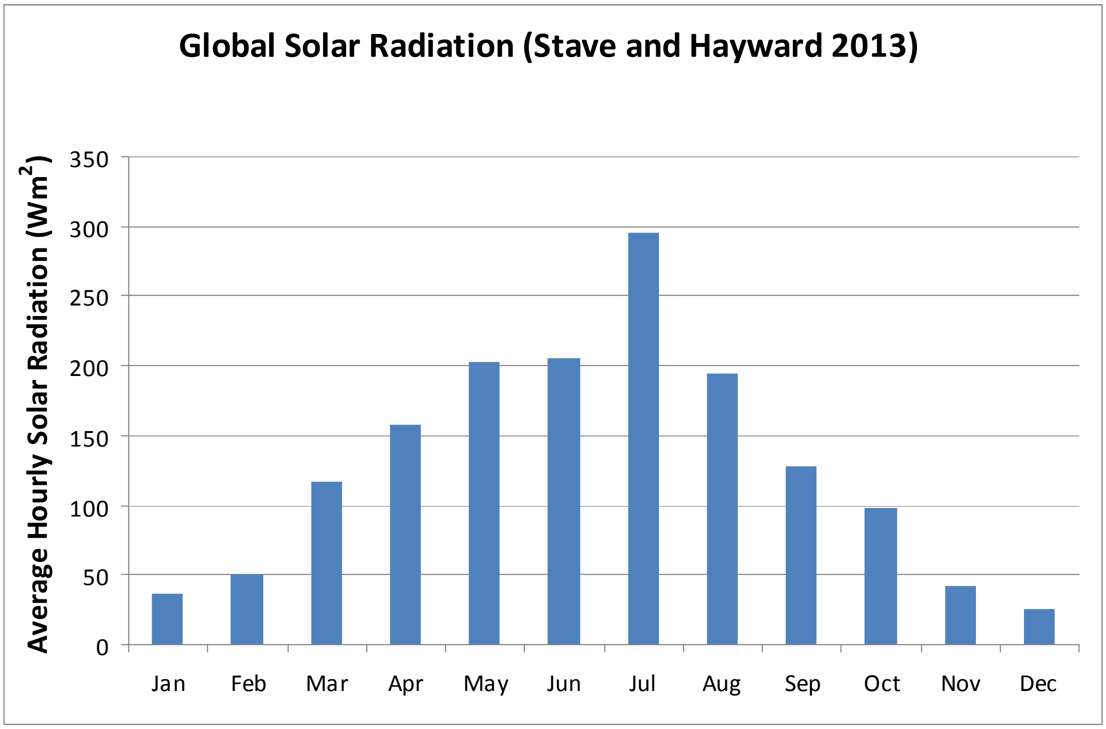
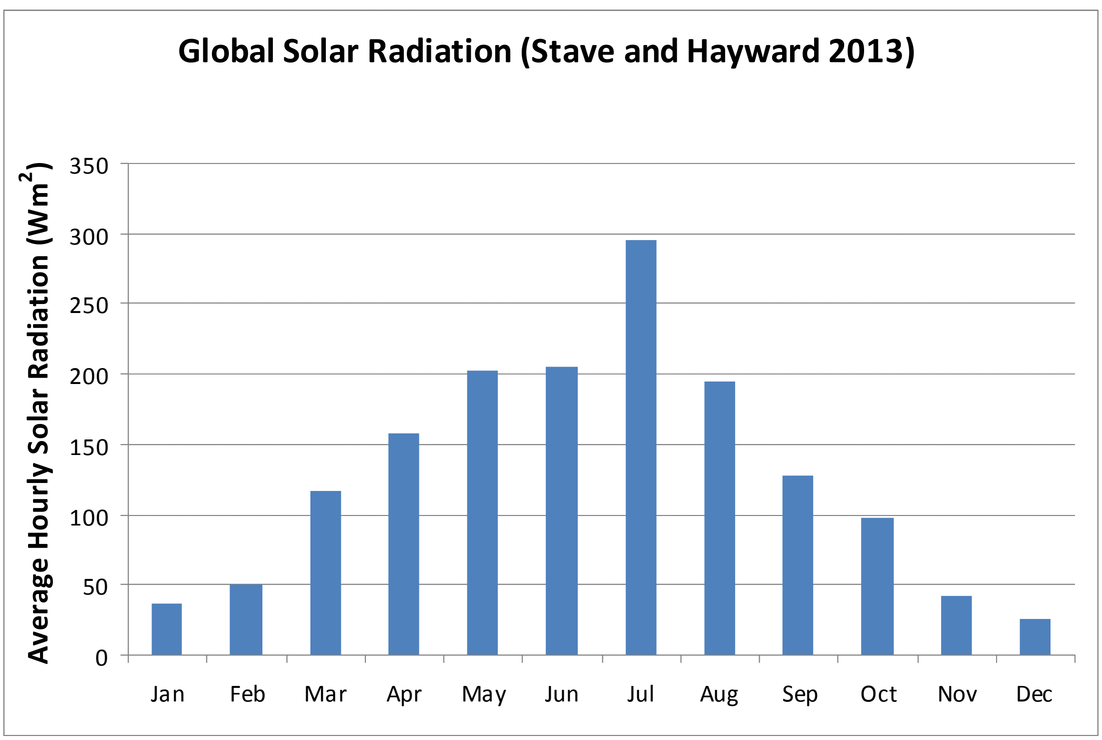


Figure 4.7: Global Solar Radiation (by month)



4.2 Water Temperature Profiles

Water temperature profiles for Hayward and Stave on each of the sampling days in 2013 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. 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 12 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

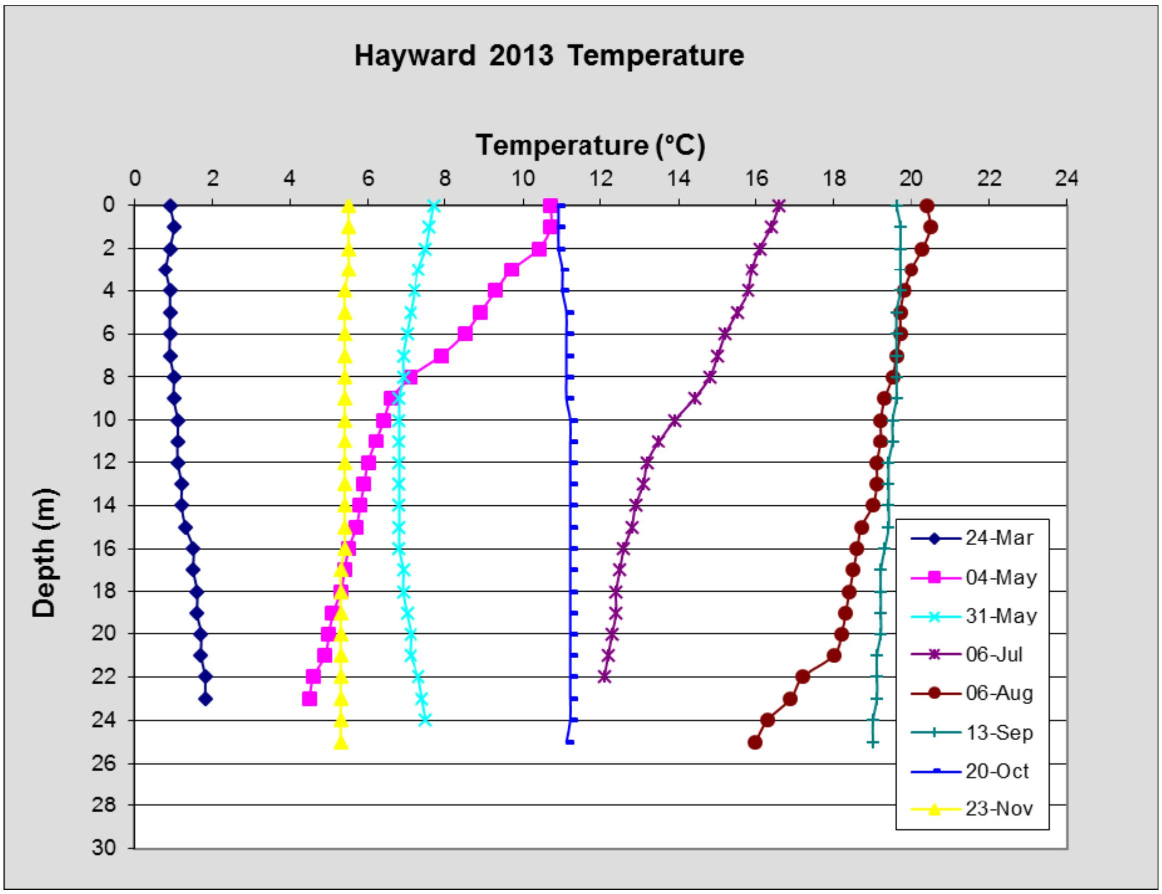
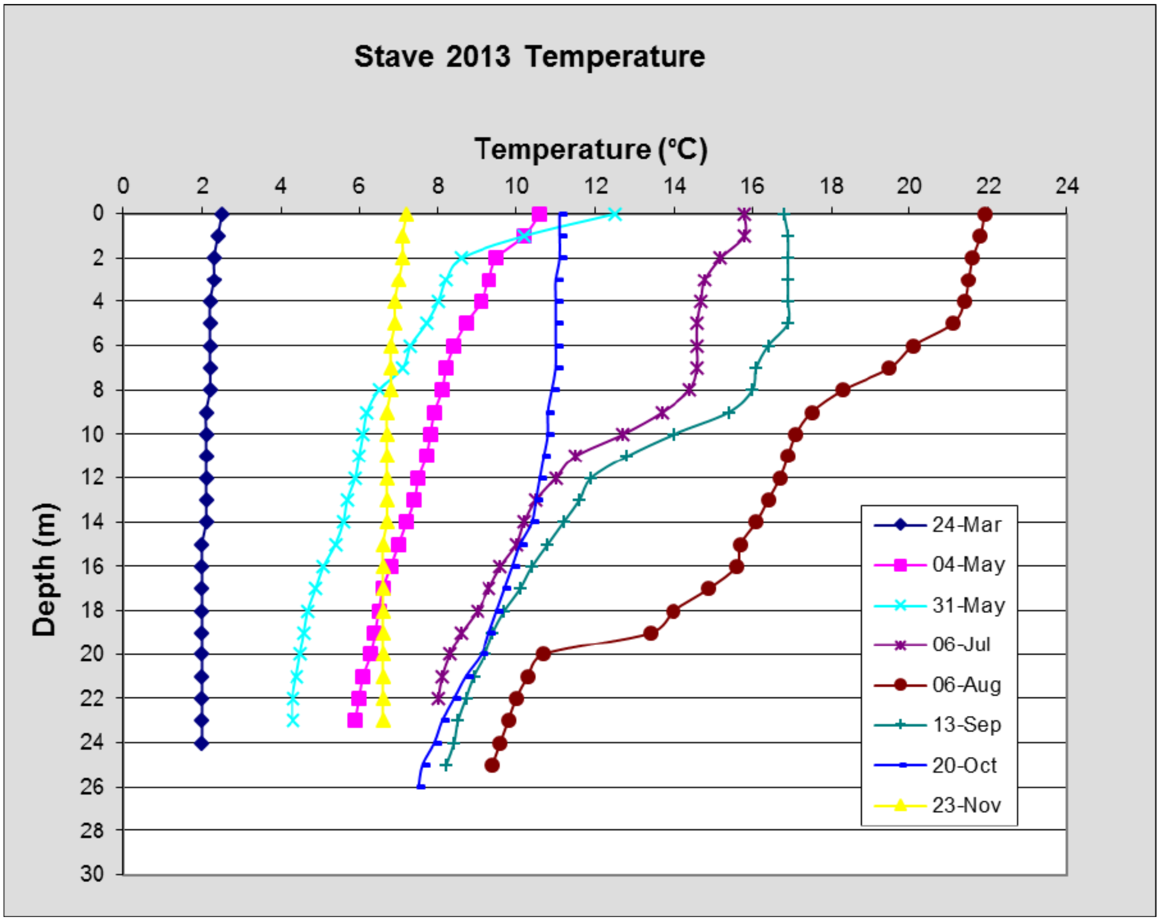


Figure 4.9: Stave Temperature Profile



4.3 Surface Water Elevation

Figure 4.10 shows daily averaged water levels in Hayward (blue, right axis) and Stave (green, left axis) from 2000 to 2003 (phase 1) through 2013 (phase 2 – 2005 to 2013). 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. In 2013 the drawdown took place from May 19 and was held relatively constant at approximately 34 m through June and July, after which surface water elevation was increased to 37 m through to mid-September and returned to normal operating levels (39-40 m) by September 14 (Figure 4.11). Hayward underwent a second brief drawdown from November 15-30th where water levels dropped to 37m.

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 4.10 shows daily average water levels from 2000-2013, including the drawdown periods in Hayward. Figure 4.11 shows the daily average water levels in 2013 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 2013)

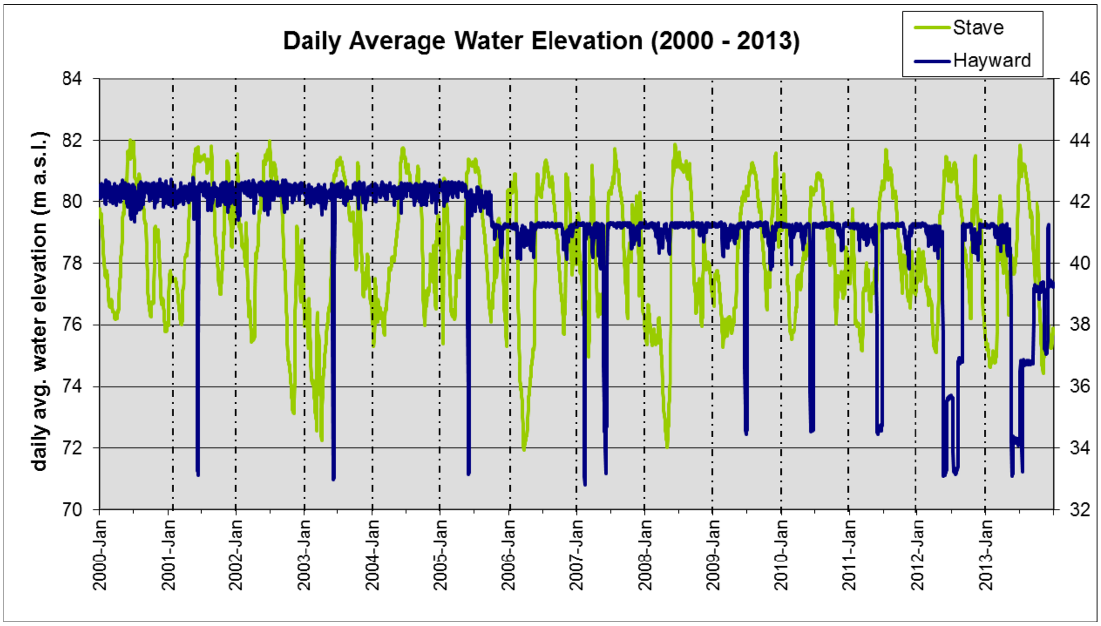
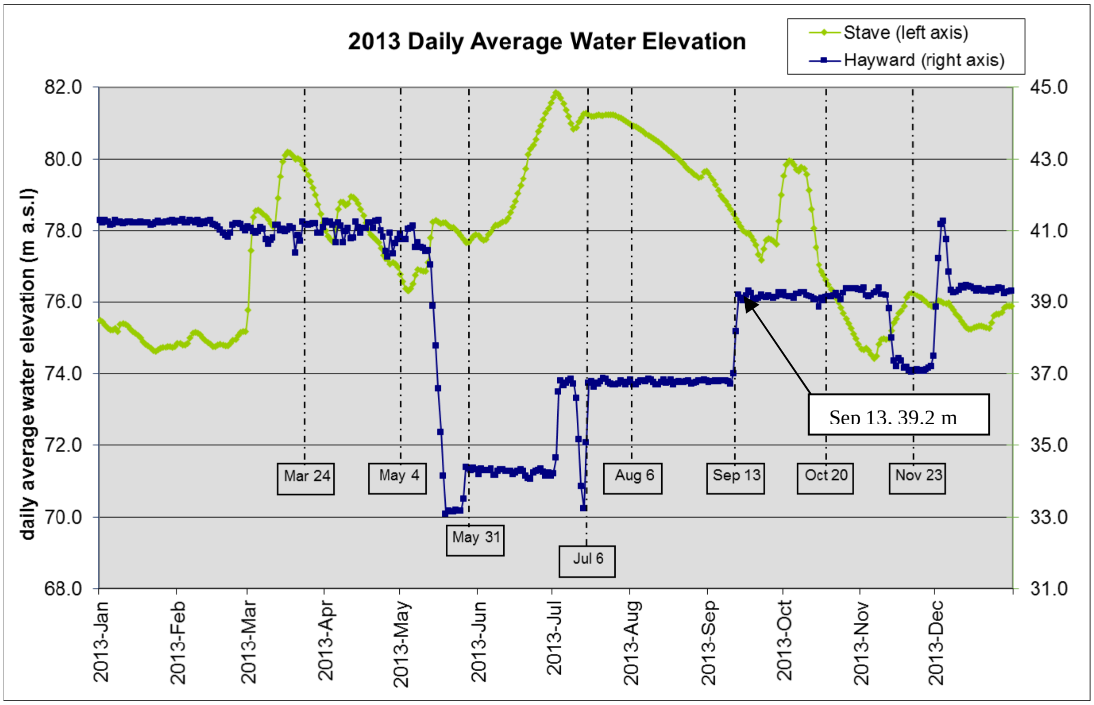


Figure 4.11: Daily Average Water Elevation (2013)



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 from 2005-2012. Due to the closure of the DFO Laboratory, 2013 analyses were conducted by ALS laboratory in Burnaby, BC. ALS was selected to conduct the analyses in part because the lab was able provide lower detection levels for phosphates (0.001mg/L) and nitrates (0.003mg/L). Figures 4.12-4.15 show graphically the total phosphorus (TP), total dissolved phosphorus (TDP), nitrates and chlorophyll-*a* values from 2005 through 2013, providing a record of the nutrient profiles in Stave and Hayward reservoirs. Tabular results from 2013 are presented in Appendix 5.

The general trends in nitrate concentrations measured in 2013 are similar to previous years, exhibiting 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. High values of approximately 130 µg/L occurred in both Stave and Hayward in winter through spring. Low values measured in 2013 are slightly lower than in previous years with late summer values of 25 µg/L, dropping to 15 µg/L later in the fall.

Stave and Hayward both exhibited low concentrations of phosphorus with TP ranging from <1 µg/L to approximately 4 µg/L in Hayward in fall. Stave exhibits a peak of 6.6 µg/L during the same time period. TDP concentrations remained at less than 1 µg/L throughout most of the growing season increasing in the fall to 2.7 and 1.8 µg/L in Stave and Hayward respectively. 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 late fall high of 1.1 µg/L L to a winter low of 0.1 µg/L. Stave reservoir ranged from 0.9 µg/L to 0.04 µg/L. Both reservoirs exhibited peaks in biomass production in the fall, which is likely indicative of the extended period of sunny weather into the fall.

Figure 4.12: Nitrate Concentrations

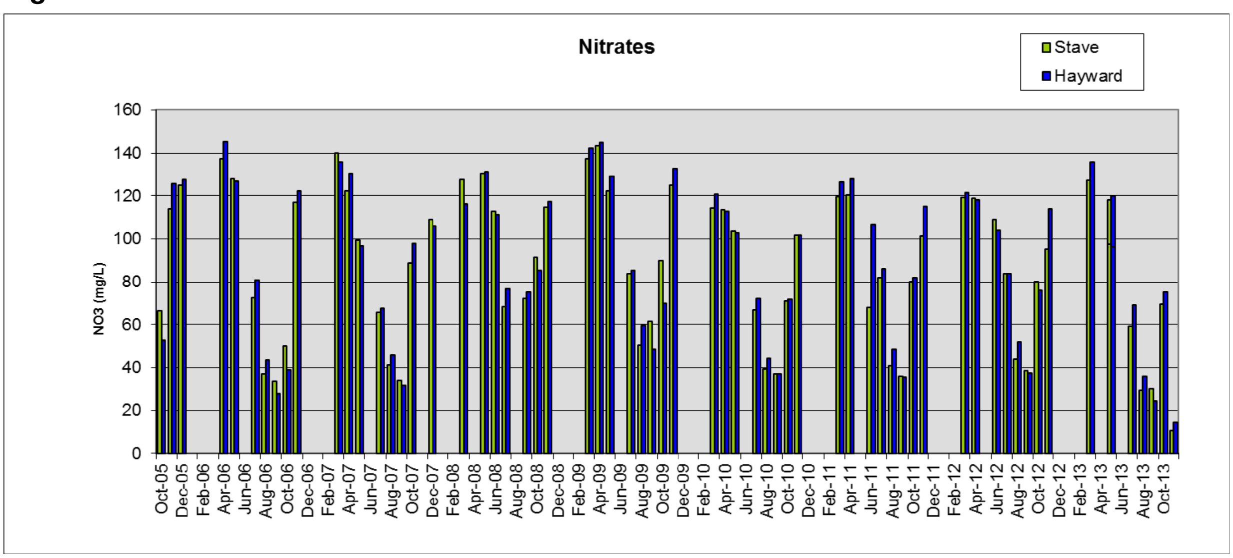


Figure 4.13: Total Phosphorus Concentrations

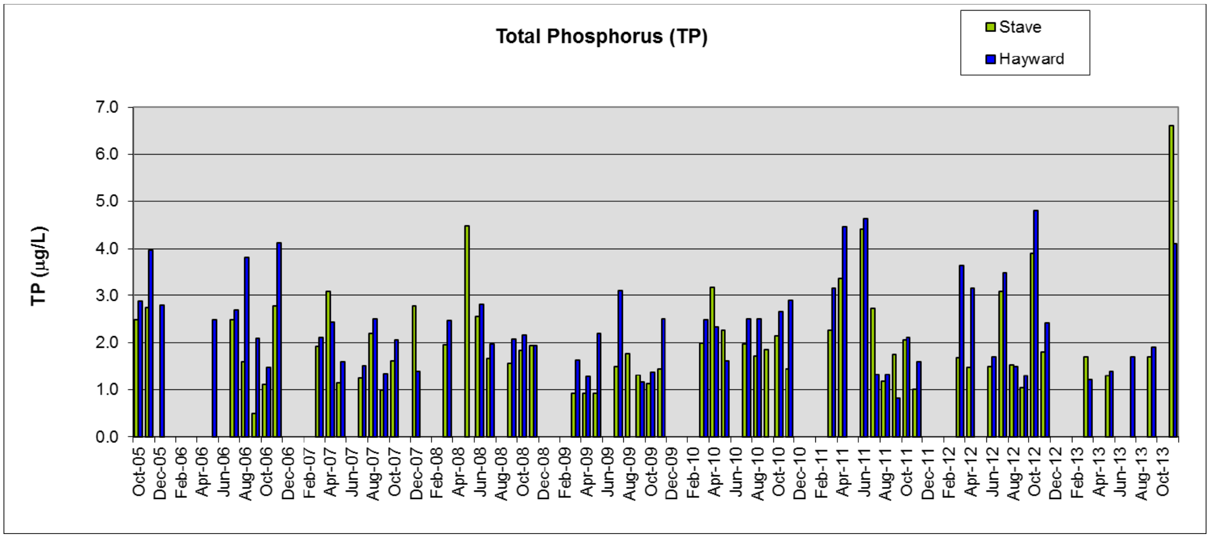


Figure 4.14: Total Dissolved Phosphorus Concentrations

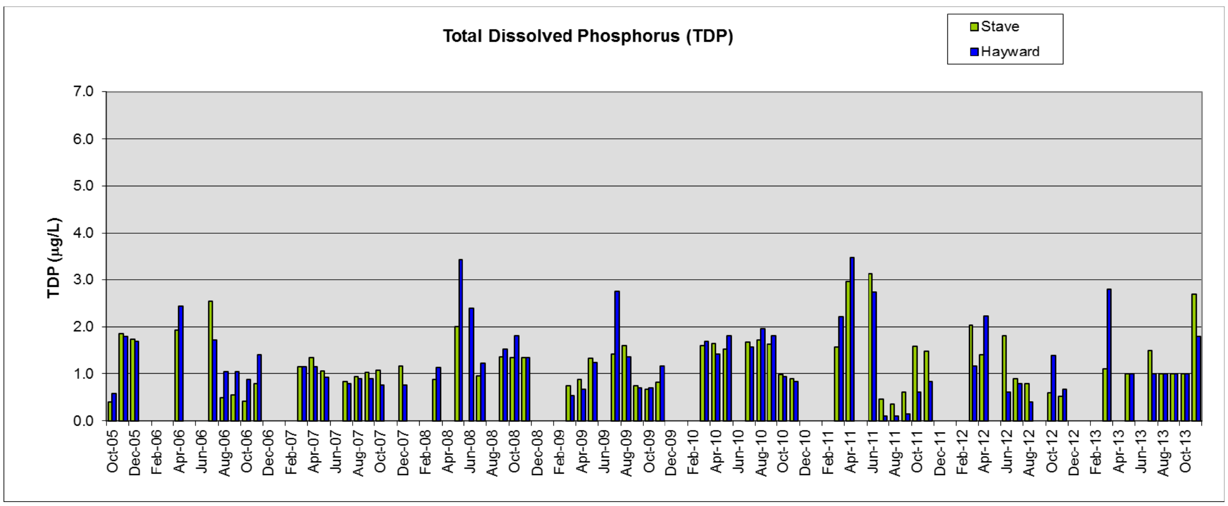
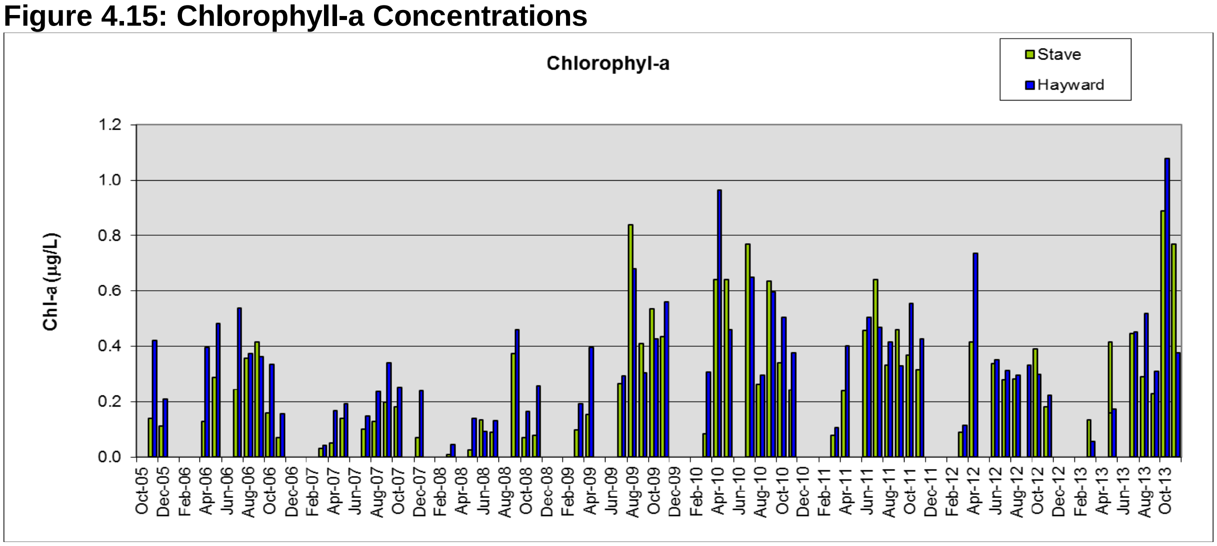


Figure 4.15: Chlorophyll-a Concentrations



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 (Figure 4.16), providing a general picture of the number of species present and how they vary seasonally. Tabular results of counts conducted in 2013 are presented in Appendix 6. The average seasonal phytoplankton densities were low ranging 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 2005-2013. Generally speaking, values exhibited in 2013 are similar to those in previous years. The first notable presence of Merismopedia sp. occurred in October 2012 in both Stave and Hayward. 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.). In fall 2013, densities in both Stave and Hayward appear high due to the occurrence of many small Synechococcus rods, Merismopedia colonies discussed above, and Aphanothecae colonies, but due to their small size the high cell count adds relatively little additional biomass.

Figures 4.18-4.21 show edible vs. in-edible plankton biovolumes and densities in Stave and Hayward Reservoirs. In Stave reservoir, species of phytoplankton that may be either edible or inedible exhibit the highest densities (cell/mL) occurring in the late fall. In summer there was a peak of in-edible plankton (August) while spring was dominated by edible species. In terms of phytoplankton biomass in Stave (mm^3/L), edible species were constant at approximately 0.1000 mm^3/L throughout the growing season with peaks in August (0.200 mm^3/L) and September (0.4500 mm^3/L) of species that could be either edible or in-edible. In Hayward, densities of plankton that can be either edible or in-edible show a clear dominance throughout the growing season. Whereas, biovolumes (mm^3/L) in Hayward show that edible phytoplankton dominate, except in September where species that can be either edible or inedible peak.

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.

Figure 4.16: Total Abundance of Phytoplankton (2005-2013)

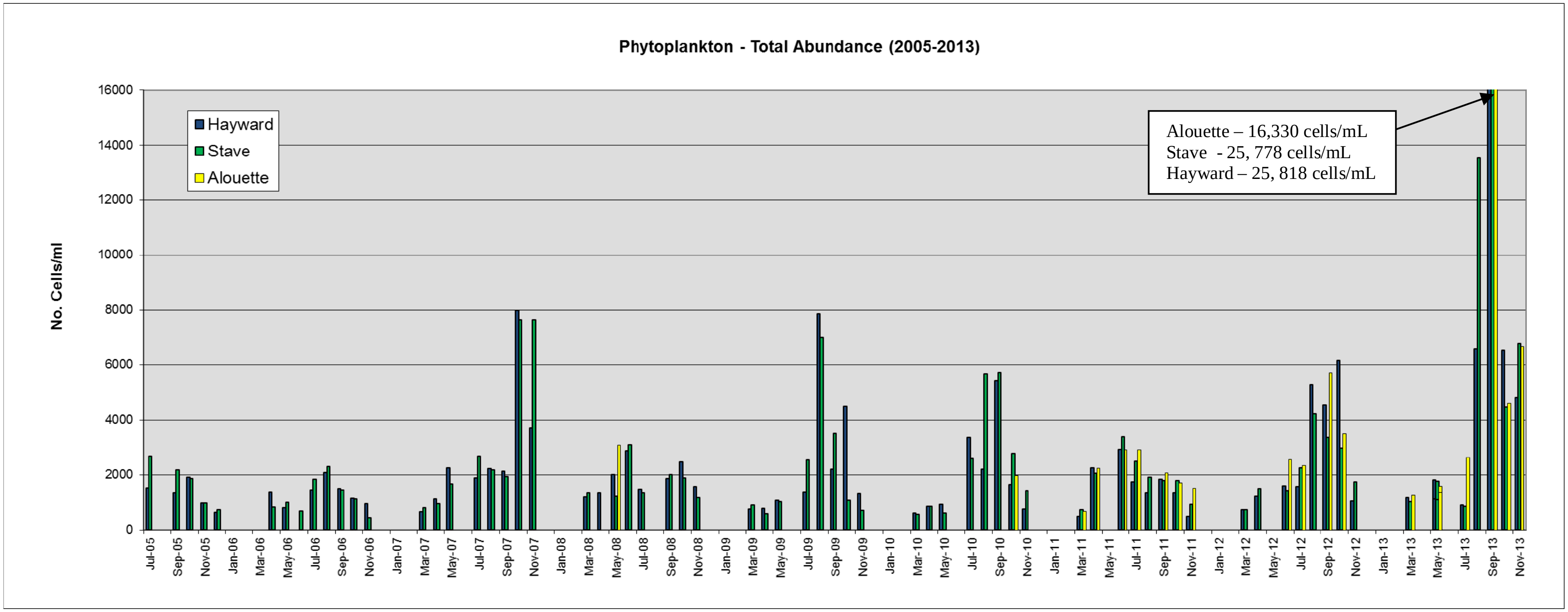


Figure 4.17: Total Biovolume of Phytoplankton (2005-2013)

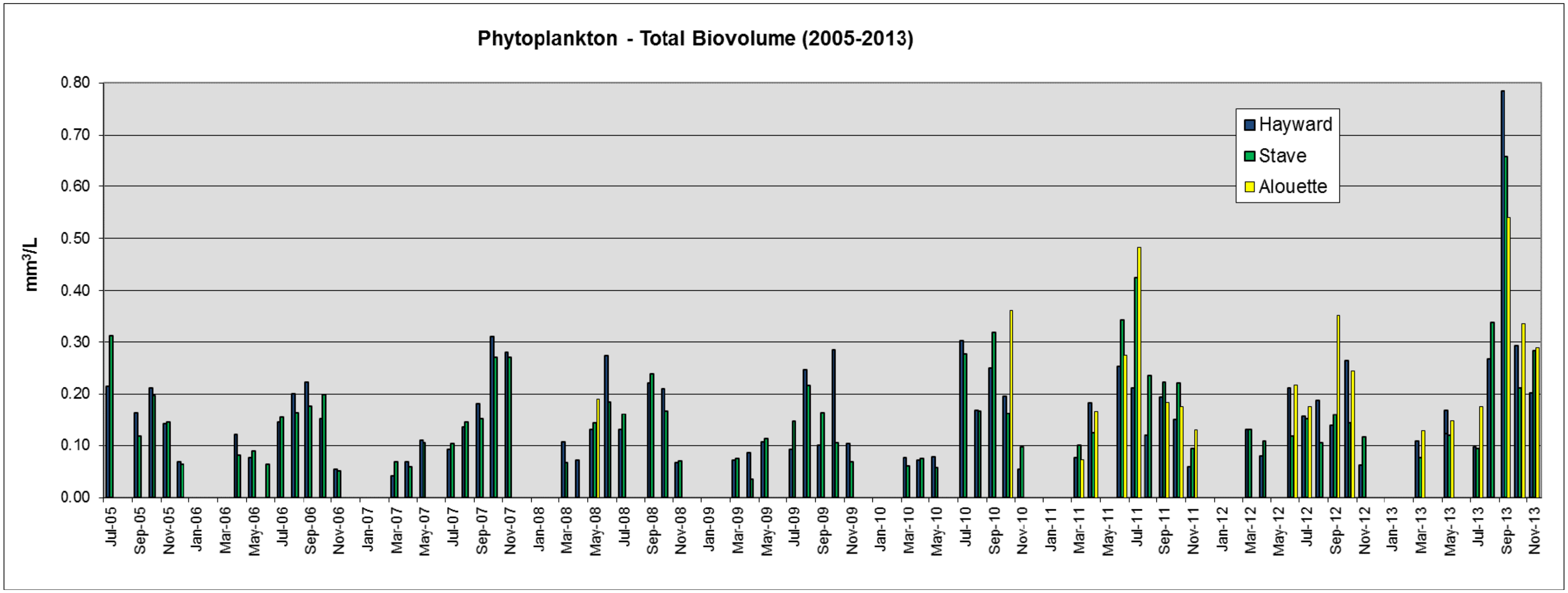


Figure 4.18: Stave Edible vs. In-Edible Phytoplankton Biovolume

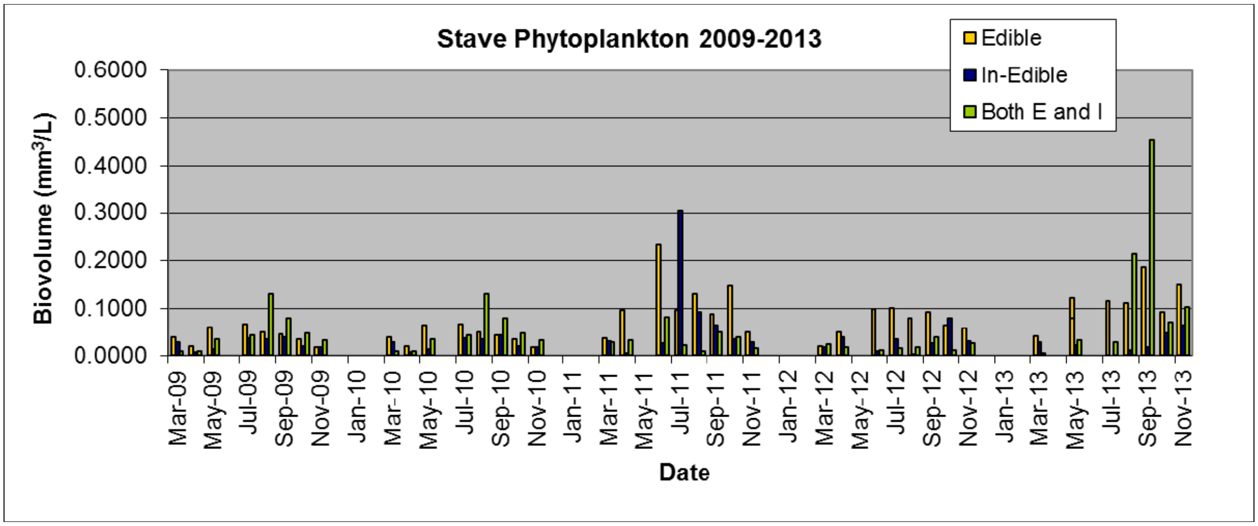


Figure 4.19: Stave Edible vs. In-Edible Phytoplankton Density

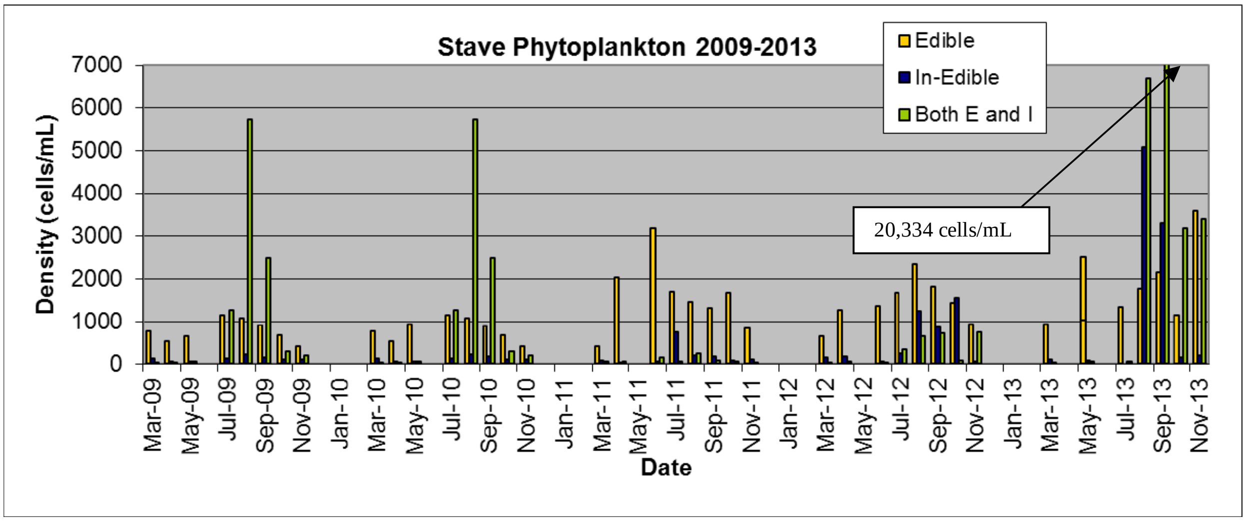


Figure 4.20: Hayward Edible vs. In-Edible Phytoplankton Biovolume

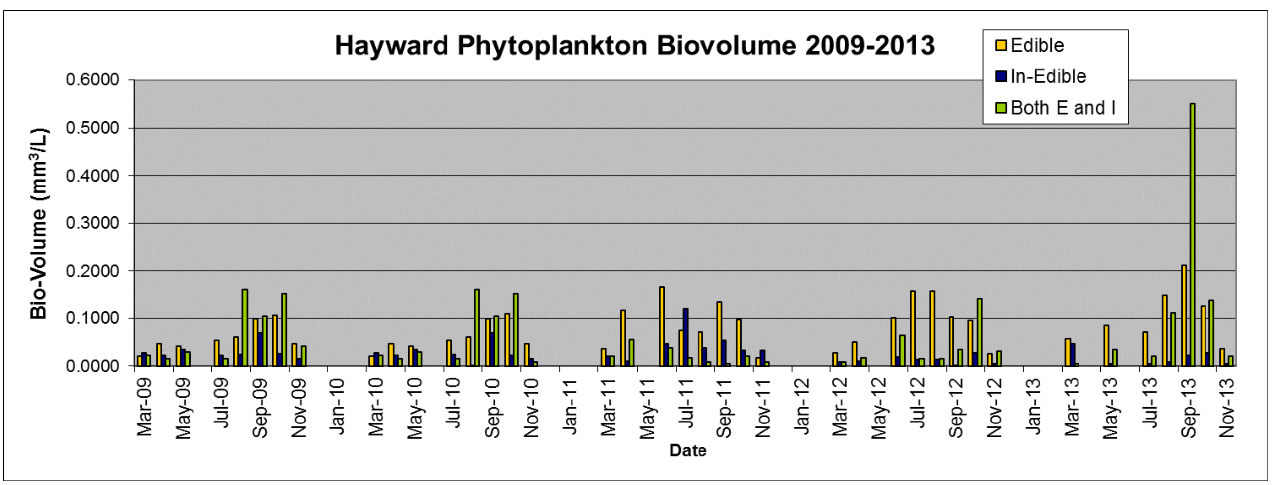
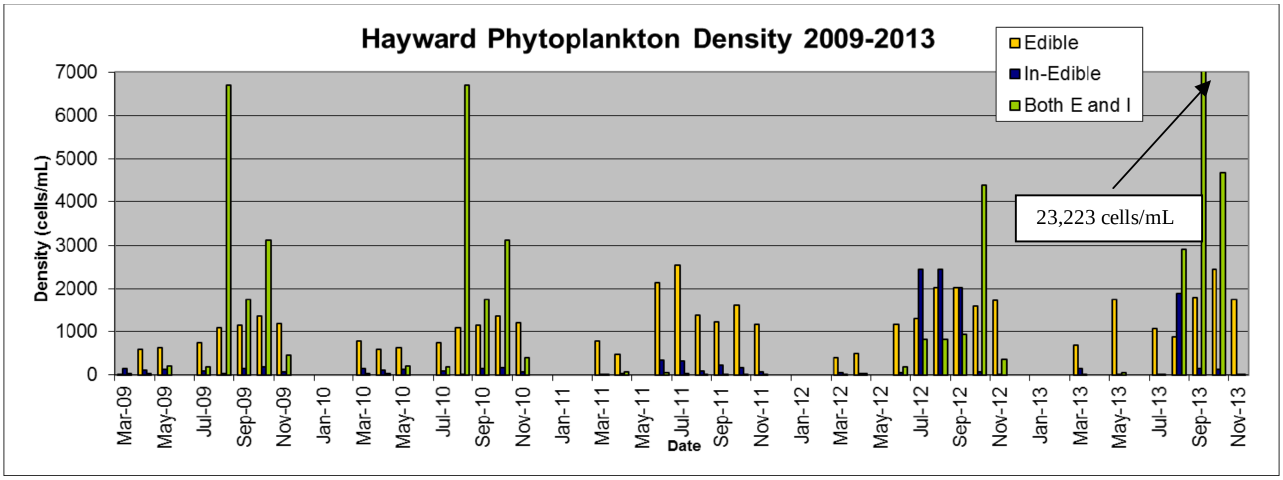


Figure 4.21: Hayward Edible vs. In-Edible Phytoplankton Density



Picoplankton were collected and counted for the first time in 2010 from Stave and Hayward reservoirs and at the Alouette outfall when it was spilling. The original rationale for sampling the inputs from Alouette into Stave centered around the possibility that Alouette may be a source of nutrients, carbon and transport of inedible algal species into the Stave system that would not otherwise be prevalent. These measurements provide an opportunity for comparison between these two systems in terms of nutrient loading from Alouette (N and P), as well as plankton (phyto and pico) entrainment. Tabular results of the 2013 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. Counts of heterotrophic bacteria from Stave and Hayward were similar with densities of approximately 500,000 cells/mL at their peak in late summer and into the fall. Counts from Alouette outfall were consistently higher than in Stave and Hayward in 2013 with peak counts of 700,000 cells/mL measured in September. In terms of biovolume, plankton densities in Stave and Hayward peak in October with counts of approximately 200,000 cells/mL and 135,000 cells/mL respectively. Counts in Allouette are consistently higher than in Stave or Hayward with a peak of 218,000 cells/ml occurring in September. Alouette was not sampled in August. In October, counts in Alouette dropped to 104,000 cells.mL and then rebound to 230,000 cells/mL in November. These patterns in pico plankton density measured at the Alouette outfall may support the idea that fertilization of the Alouette system may account for the overall higher counts of pico plankton but that may be dependent to some degree on what organisms are more easily entrained and transported.

Figure 4.22: Heterotrophic Bacteria - Biovolume

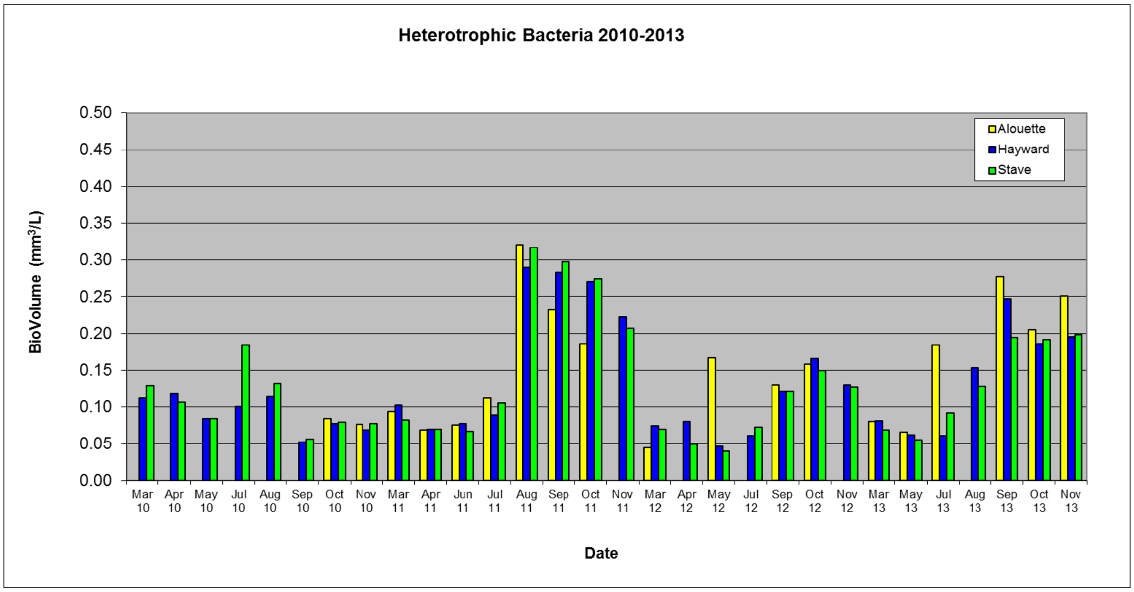


Figure 4.23: Heterotrophic Bacteria – Density

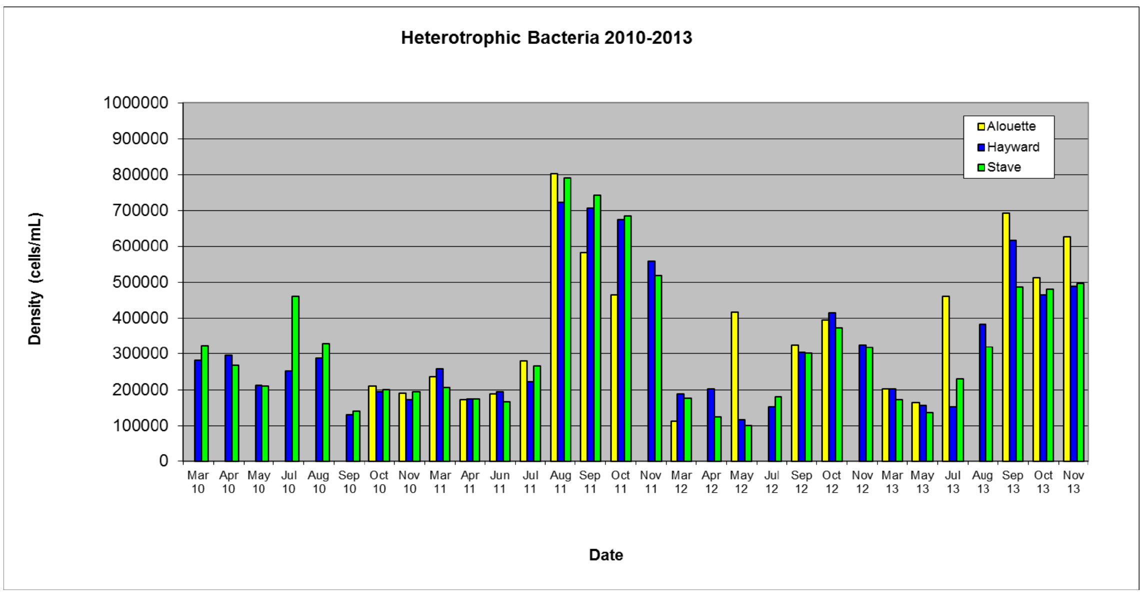


Figure 4.24: Pico-Cyano Bacteria - Biovolume

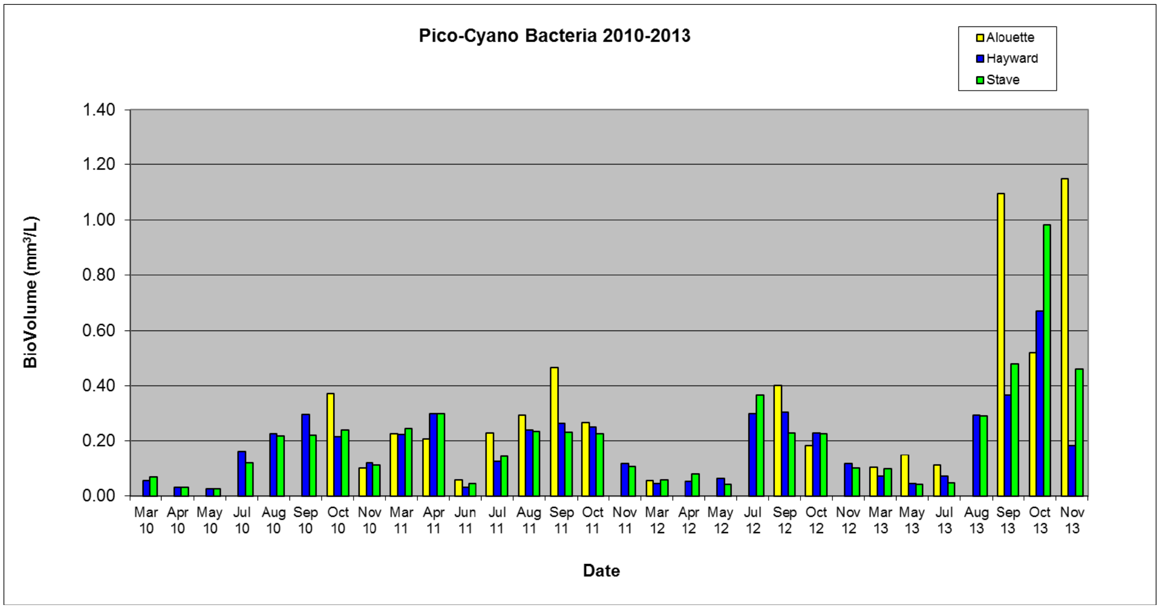
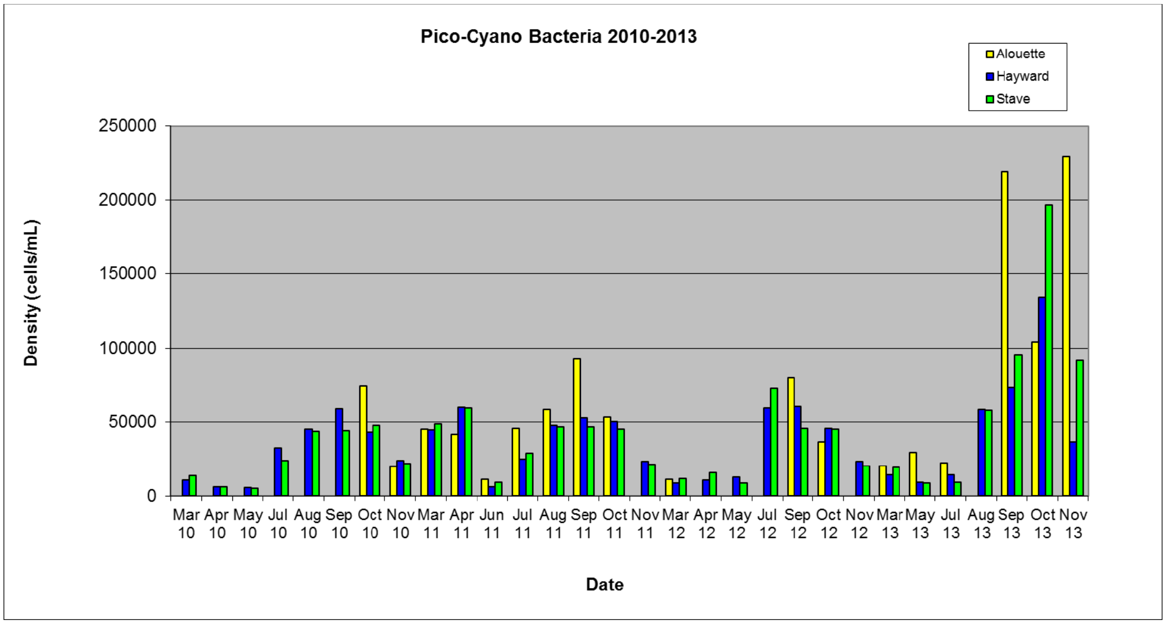


Figure 4.25: Pico-Cyano Bacteria - Density



4.6 Zooplankton Analyses

Figures 4.26 and 4.27 show total zooplankton biomass and densities measured over the 2013 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 2013. 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 2013 an average of the 5 samples is graphed. Zooplankton exhibit a seasonal trend peaking in late summer/early fall at about 35-55 µg/L biomass and 10-15 individuals/L density. Hayward exhibits a sharp drop both in term so biovolume and density, with density going from nearly 15 individuals/L to less than 5 individuals/L in September. This result may be being influenced by sampling during a period of increasing water levels (September 13, see figure 4.11) after a lengthy period of drawdown. From 2010 through 2013 densities seem to be higher than in previous years of data which may be a reflection of the increased replicate sampling.

Figure 4.30 and 4.31 shows zooplankton and daphnia densities from surrounding BC reservoirs (Stockner 2012) that have 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 all of which are fertilized systems, but are lower than Lower Arrow and Kootenay Lakes and somewhat higher than densities reported for Coquitlam reservoir. Daphnia densities in Stave and Hayward are more comparable to other unfertilized systems such as Coquitlam and Kootenay lakes.

Figure 4.32 shows average biomass data for individual species from 2010-2013. 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 µg/L and occasional spikes of individuals > 5µg/L. Complete zooplankton counts from samples collected in 2011 are presented in Appendix 8.

Figure 4.26: Total Zooplankton Biomass 2013

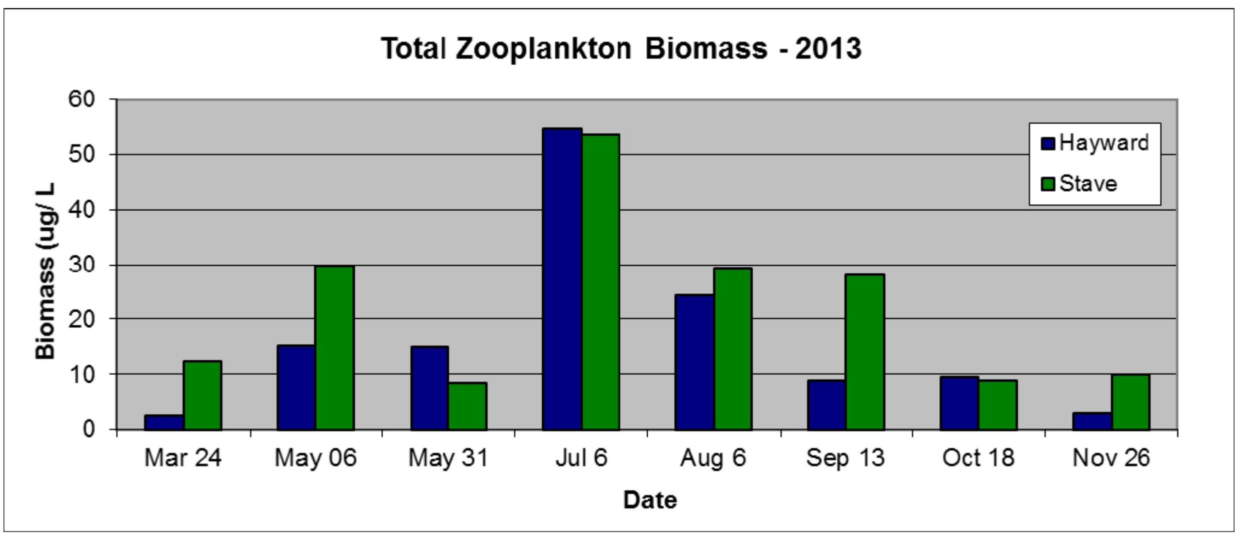


Figure 4.27: Total Zooplankton Density 2013

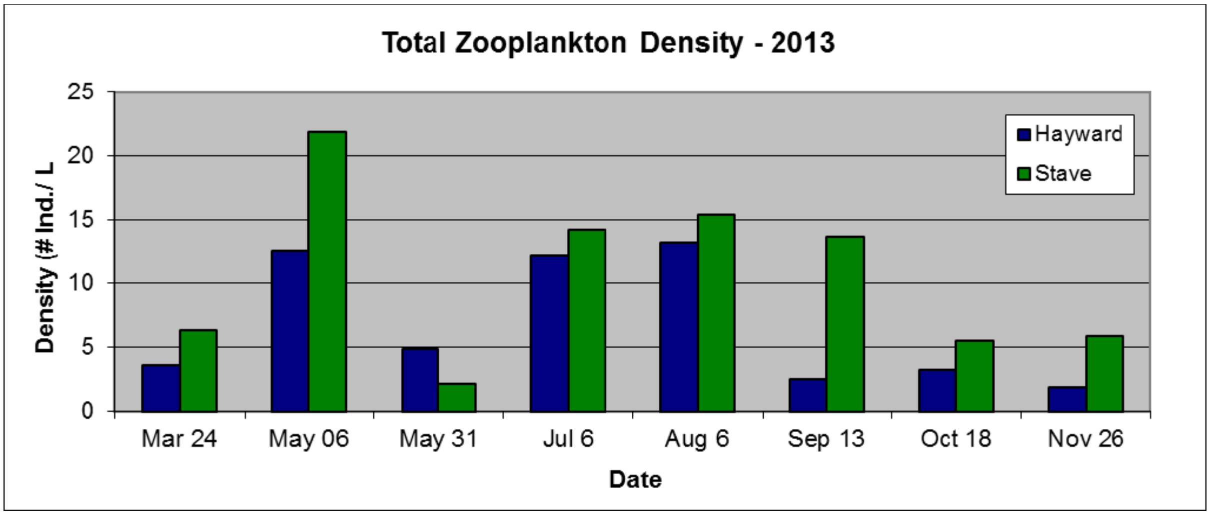


Figure 4.28: Total Zooplankton Biomass 2007-2013

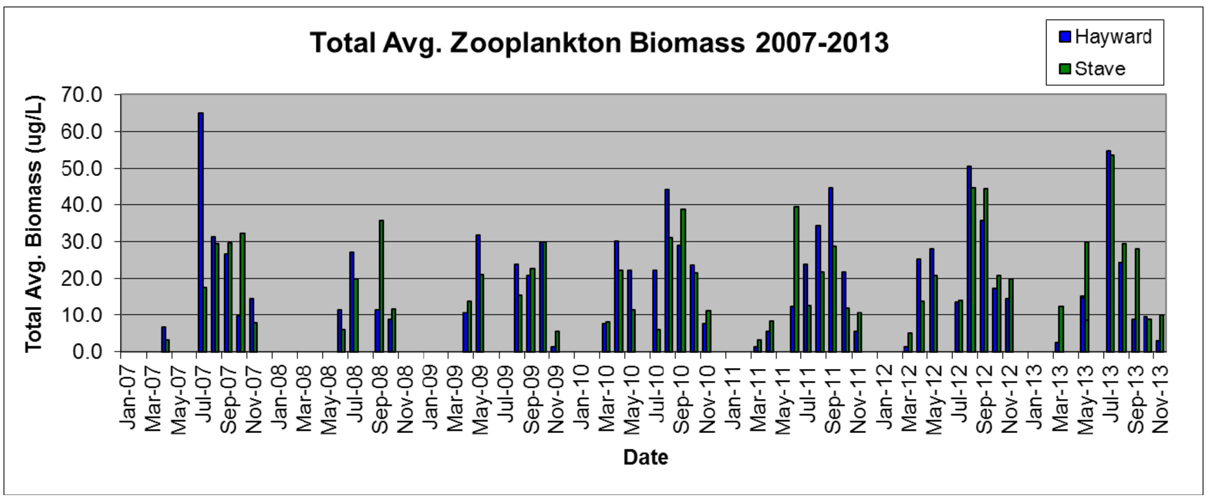


Figure 4.29: Total Zooplankton Density 2007-2013

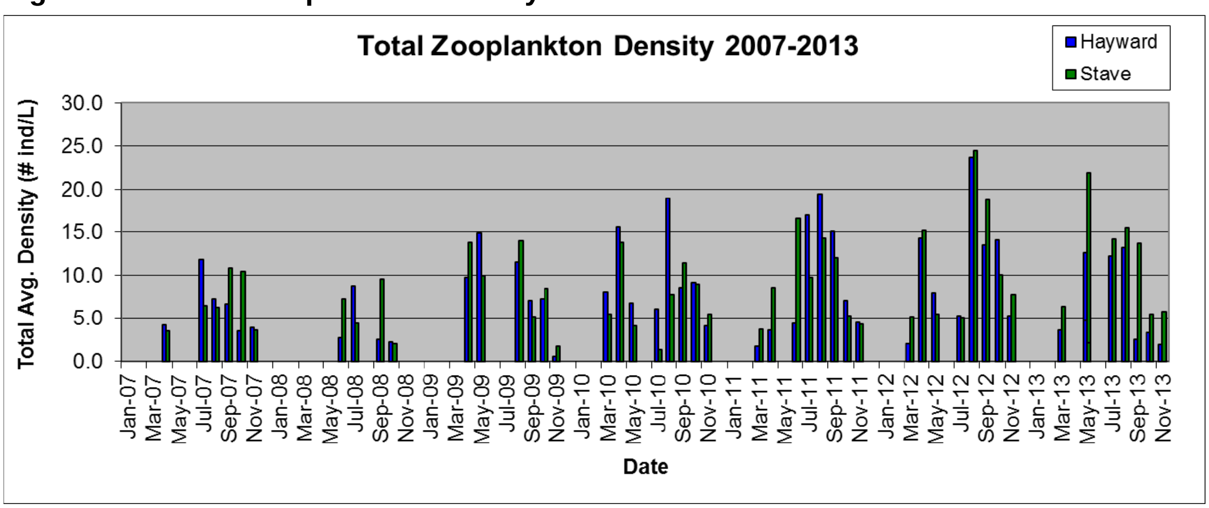


Figure 4.30: Zooplankton Densities from BC Reservoirs Including Stave and Hayward

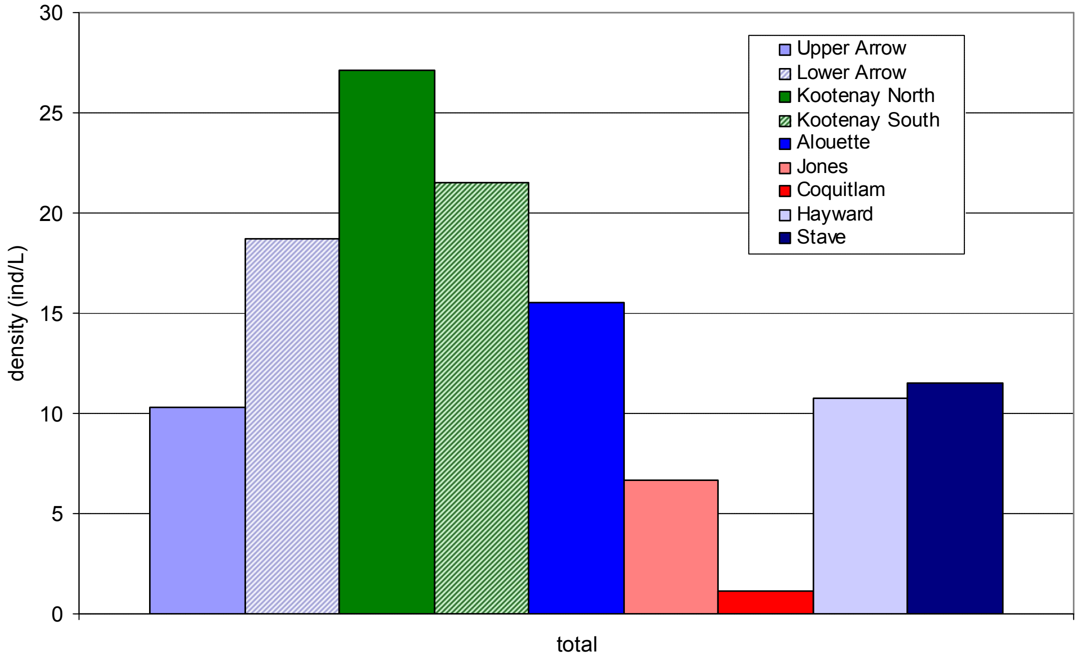


Figure 4.31: Daphnia Densities from BC Reservoirs Including Stave and Hayward

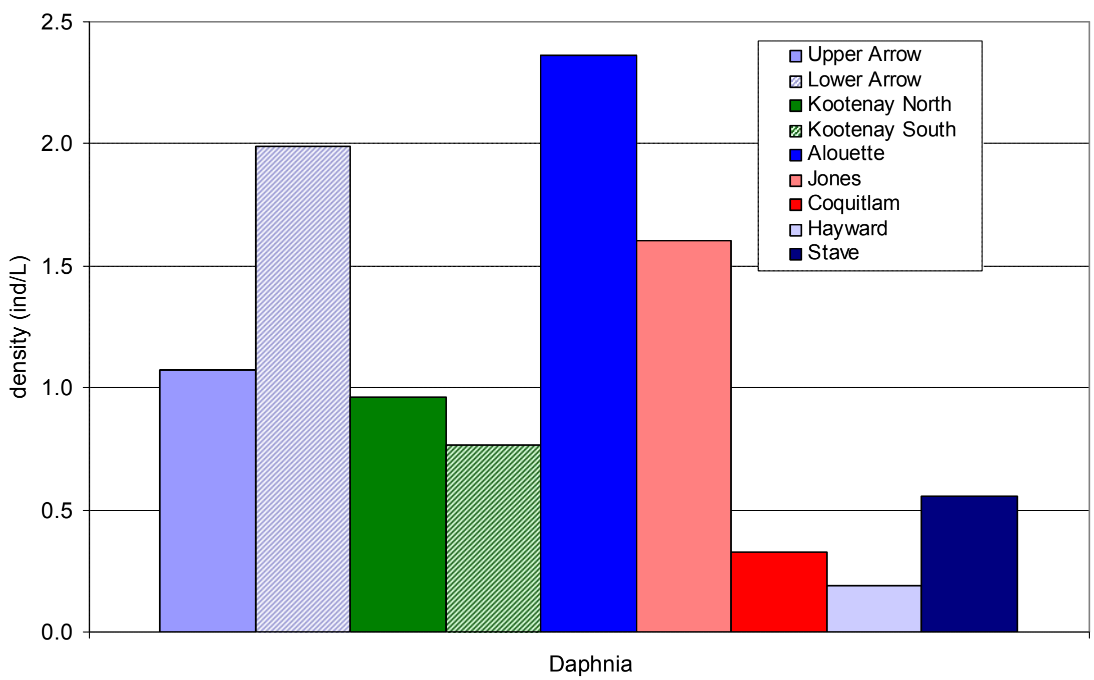
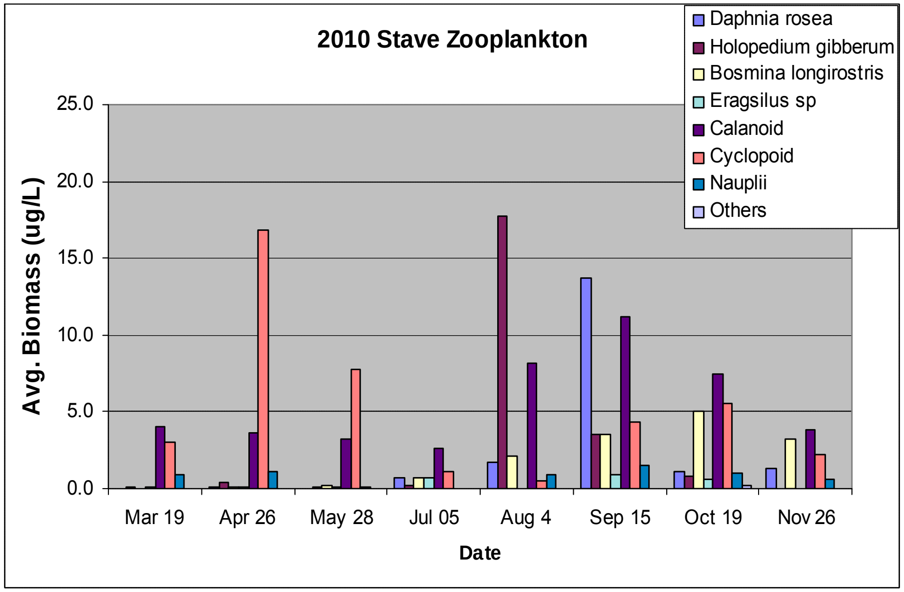
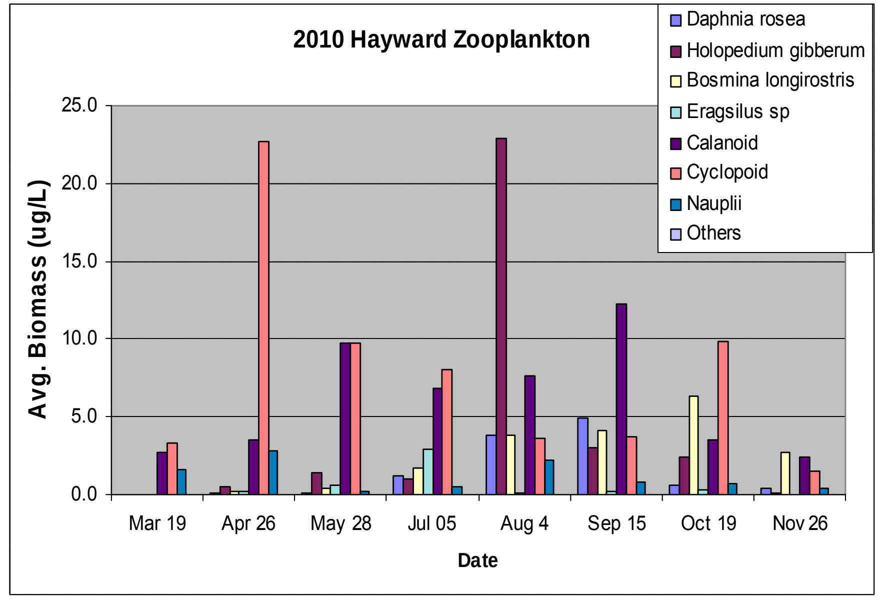
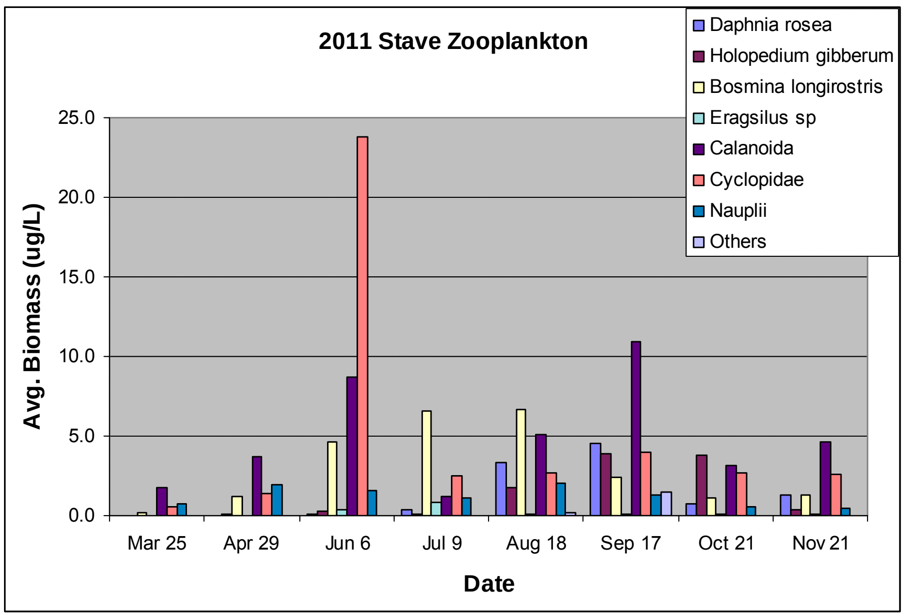
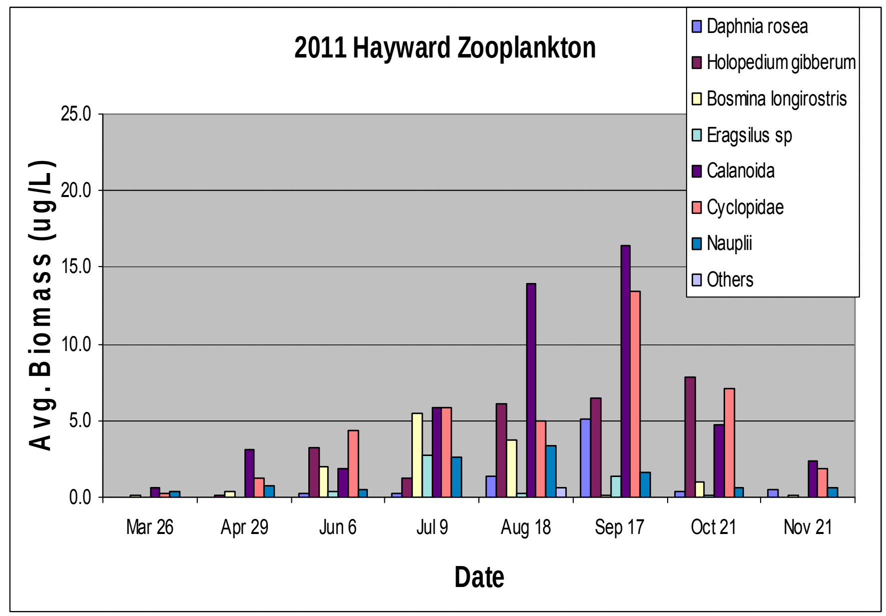


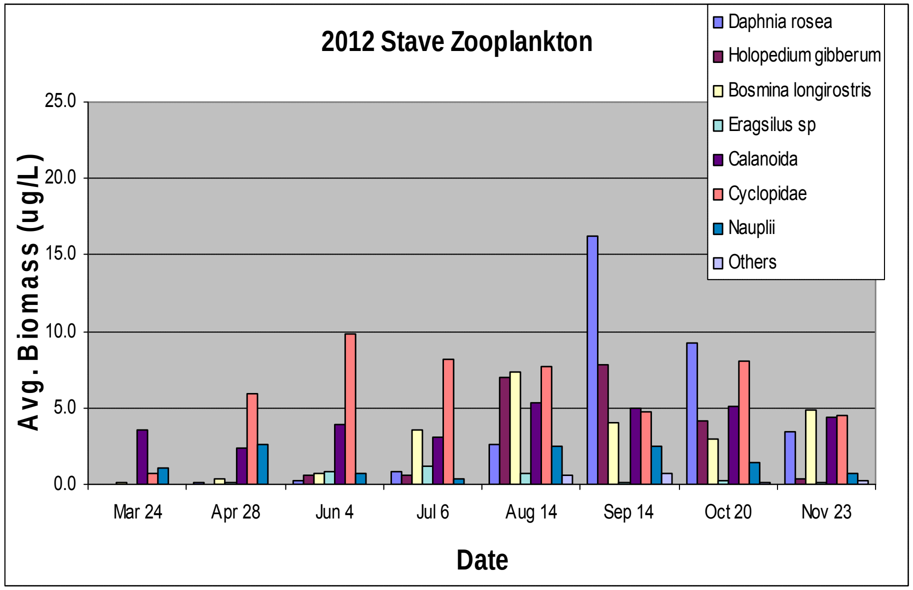
Figure 4.32: Stave and Hayward Zooplankton Species 2010, 2011 and 2012

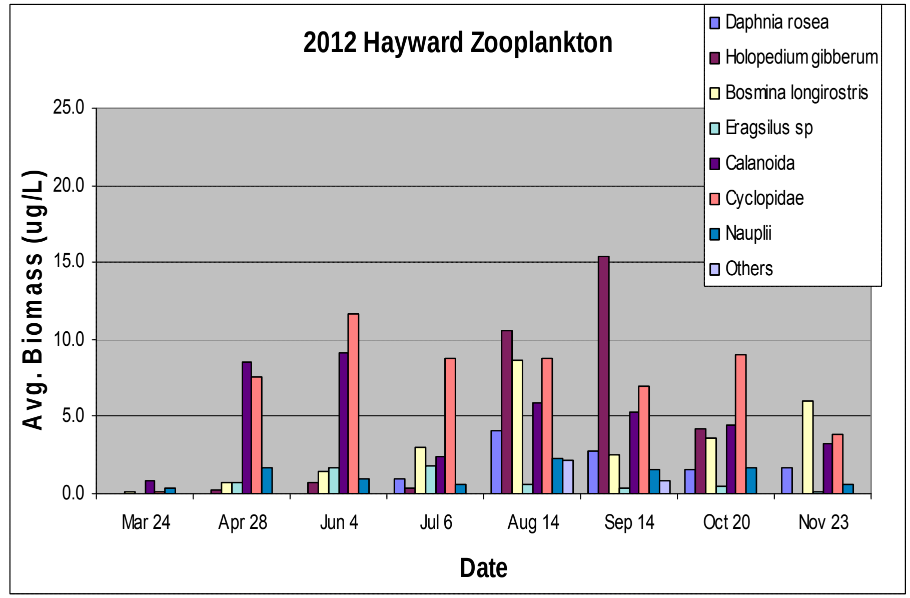


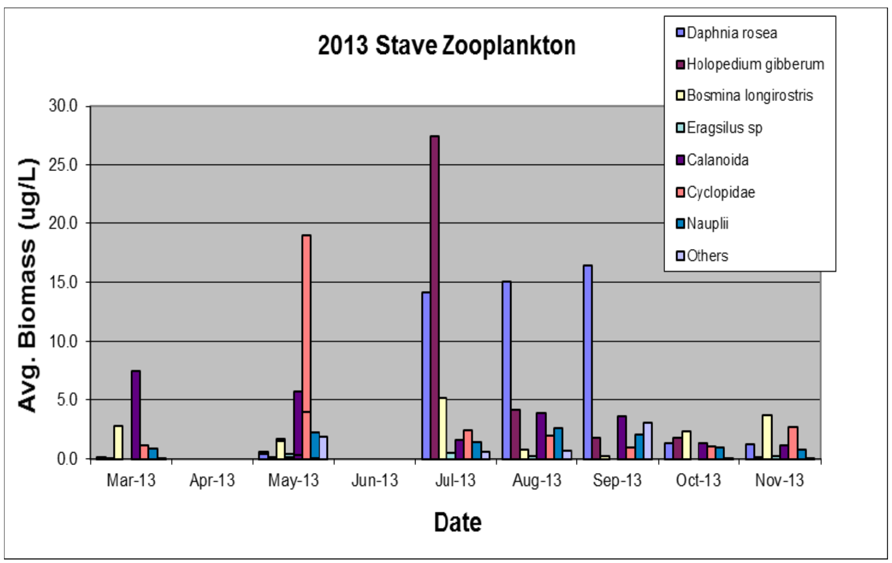


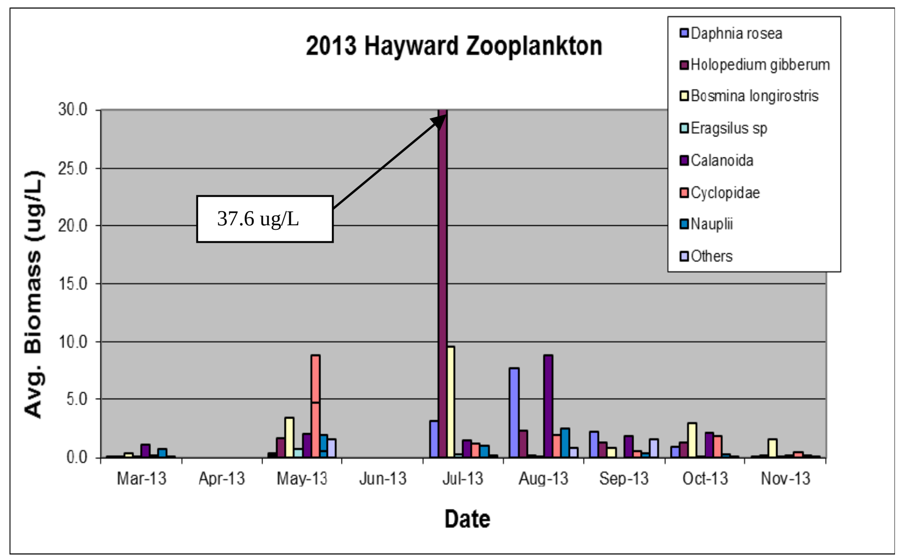





2012 Stave Zooplankton
Daphnia rosea
Holopedium gibberum
Bosmina longirostris
Eragsilus sp
Calanoida
Cyclopidae
Nauplii
Others
Avg. Biomass (ug/L)
25.0
20.0
15.0
10.0
5.0
0.0
Mar 24
Apr 28
Jun 4
Jul 6
Aug 14
Sep 14
Oct 20
Nov 23
Date


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


2013 Stave Zooplankton
Daphnia rosea
Holopedium gibberum
Bosmina longirostris
Eragsilus sp
Calanoida
Cyclopidae
Nauplii
Others
Avg. Biomass (ug/L)
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Mar-13
Apr-13
May-13
Jun-13
Jul-13
Aug-13
Sep-13
Oct-13
Nov-13
Date


2013 Hayward Zooplankton
37.6 ug/L
Daphnia rosea
Holopedium gibberum
Bosmina longirostris
Eragsilus sp
Calanoida
Cyclopidae
Nauplii
Others
Avg. Biomass (ug/L)
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Mar-13
Apr-13
May-13
Jun-13
Jul-13
Aug-13
Sep-13
Oct-13
Nov-13
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.

In 2013, five sampling trips were conducted to measure primary production in June, July, August, September and October. Extended good weather in the fall of 2013 provided a chance to sample into October. Results and data from 2013 are not included in this report. In the spring of 2013, all water chemistry data analyses were shifted from DFO Cultus Lake Laboratory to ALS Environmental in Burnaby. It was found that there is a discrepancy in measures of alkalinity such that all previous data sets require review and possible correction to account for the discrepancy. This review will be conducted over the coming months and additional measurements of alkalinity conducted during the 2014 sampling season in order to resolve these discrepancies. Final results will be reported on as part of the final data report in 2015 and as part of the meta analyses being conducted as part of the completion of this monitor.

It is also noteworthy that fractionated production measurements made in 2013 were found to be unreliable. Ness is working to find out what caused the unusual results in this data set. As a result, production values for 2013 will be reported as total production but will not be broken into size classes as was done in previous sample years.

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 unnatural water level fluctuations. These fluctuations have been unusually substantial in Hayward reservoir in recent years, which has undergone long and more extensive periods of drawdown over the productive summer months due to the requirements of seismic upgrade works occurring at Ruskin Dam.

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. While Stave and Hayward share a common water body, there are other significant differences in the physical characteristics and variables that influence comparisons between them. Stave reservoir is 25 km long with a surface area of 58 km^2, while Hayward is approximately 6 km long and has a surface area of 2.9 km^2. Hayward as a run of the river system has a flushing rate of just under two days while Stave has a residence time of approximately 80 days. In Stave water resides for long enough periods that nutrients and organism stratify with depth particularly in late summer with the development of thermocline. In Hayward the water moves through the system in a period of days, providing a constant albeit low source of nutrients and flushing organisms through the system into downstream water bodies.

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, 2012 and 2013. According to the original Terms of Reference for this study, the results for Hayward reservoir were intended to represent pelagic and littoral productivity under a more stable reservoir management strategy. However, the periods of atypical drawdown observed throughout the study period have compromised the applicability of Hayward results for this purpose.

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 μmol/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, Alouette 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 balance between littoral and pelagic habitat carbon contributions to overall C-production within these systems.

5. References

Beer, J.A. 2004. Littoral Zone Primary Production in a Coastal Reservoir Ecosystem. Master's thesis, University of British Columbia.

BC Hydro 2003. Stave River Water Use Plan (Stave Falls and Ruskin Projects) Revised for Acceptance by the Comptroller of Water Rights, December 15, 2003, p 8.

BC Hydro, 2005. Stave River Water Use Plan: Monitoring Program Terms of Reference. June 13, 2005.

BC Hydro, 2011. Proposal for a change in the Stave WUP Littoral Productivity Monitor: Effect of increasing dewater exposure periods on the growth of periphyton on artificial substrate (DRAFT). Prepared by Bruce, J. and McArthur, M.

Canter-Lund, H., and J.W.G. Lund. 1995. Freshwater Algae – their microscopic world explored. BioPress Ltd., Bristol, UK, 360p

Carr, W. W., and A. Moody. 2000. Strategic Plan for Reservoir and Drawdown Zone Revegetation within BC Hydro. BC Hydro.

Gasith, A., and Sarig Gafny. 1990. Effects of Water Level Fluctuation on the Structure and Function of the Littoral Zone, p. P156-171. In M. M. a. C. S. Tilzer [ed.], Large Lakes Ecological Structure and Function - Chapter 8. Springer- Verlag.

Godshalk, G. L. A. J. W. Barko 1985. Vegetative succession and decomposition in reservoirs, p. 59-78. In D. Gunnison [ed.], Microbial processes in Reservoirs. Dr. W. Junk, Kluwer Academic Publishers group.

Jackson, J. L. 1994. Stave Falls Powerplant Replacement Project Environmental Impact Management Plan, p. p83. British Columbia Hydro Environmental Affairs.

Joint, I.R., and Pomroy, A.J. 1983. Production of picoplankton and small nanoplankton in the Celtic Sea. Marine Biology **77**: 19-27.

Koenings, J. P., J. A. Edmundson, G. B. Kyle, and J. M. Edmundson. 1987. Limnology field and laboratory manual: methods for assessing aquatic production. Alaska Department of Fish and Game, Division of Fisheries Rehabilitation, Enhancement and Development. Juneau, Alaska.

Licor Inc., 2004. LI-250A Light Meter Instruction Manual. Publication Number 984-07507.

Lund J.G., Kipling C. and E.D. LeCren. 1958. The inverted microscope method of estimating algal numbers and the statistical basis of estimations by counting. Hydrobiologia 11: 143-170.

McCauley, E. 1984. The estimation of the abundance and biomass of zooplankton in samples. In Downing, J.A. and Riger, F.H. (eds), Secondary Productivity in Fresh Waters. IBP Handbook 17. Blackwell Scientific Publication, Oxford, Chapter 7: 228-265.

Parsons, T.K., Y. Maita, and C.M. Lalli. 1984. A Manual of Chemical and Biological Methods for Seawater Analysis. Pergamon Press.

Pieters, R., L. Thompson, L. Vidmanic, M. Roushorne, J. Stockner, K. Hall, M. Young, S. Pond, M. Derham, K. Ashley, B. Lindsay, G. Lawrence, H. Andrusak, D. Sebastian, and G. Sholten. 2000. Arrow Reservoir Fertilization Experiment Year 1 (1999/2000) Report. Fisheries Branch, Ministry of Environment, Lands and Parks.

Stephens, K., and Brandstaetter, R. 1983. A laboratory manual: collected methods for the analysis of water. Can. Tech. Rep. Fish. Aquat. Sci. 1159:68 p.

Stockner, J.G. 1987. Lake fertilization: The enrichment cycle and lake sockeye salmon (Oncorhynchus nerka) production, p. 198-215. In: H.D. Smith, L. Margolis and C.C. Wood (eds.). Sockeye salmon (Oncorhynchus nerka) population biology and future management. Can. Spec. Publ. Fish. Aquat. Sci. 96, 486 p.

Stockner, J.G. 1991. Autotrophic picoplankton in freshwater ecosystems: The view from the summit. Int. Rev. gesamten Hydrobiol. 76: 483-492.

Stockner, J.G. 2012. Coquitlam Reservoir Final Report. BC Hydro.

Stockner, J.G., and Beer, J.A. 2004. The limnology of Stave/Hayward reservoirs: With a perspective on carbon production. Report to BC Hydro.

Stockner, J.G., and Armstrong, F.A.J. 1971. Periphyton of the Experimental Lakes Area, Northwestern Ontario. J. Fish. Res. Board Can. **28**: 215–229.

Thornton, K. W., Bruce L. Kimmel, and Forrest E. Payne, E. (ED.). 1990. Reservoir Limnology: Ecological Perspectives. Wiley.

Thorp, J.H., Covich, A.P., Eds. 2001. Ecology and Classification of North American Freshwater Invertebrates, 2nd Edition. Academic Press. San Diego, CA., 1056 pgs.

Utermohl, H. 1958. Zur Vervollkommnung der quantitativen Phytoplankton methodik. Int. Verein. Limnol. Mitteilungen No. **9**.

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

Water Chemistry Data from 2005-2012 was conducted by Spa Chemtest DFO Laboratory at Cultus Lake, BC. Methods for these analyses are provided in the 2012 Pelagic Monitor and Littoral Primary Production Monitor. Water Chemistry data analyses from 2013 were analysed by ALS Laboratory in Burnaby, BC using the methods identified below.

ALS Quote Number: Q38378
CASH CLIENTS - VANCOUVER
13-FEB-13
Page 6 of 6

Quoted Parameters with Detection Limits

Parameter	Method Reference	Report D.L.	Units
Water - Anions and Nutrients			
Alkalinity, Total (as CaCO3)	EPA 310.2	2.0	mg/L
Nitrate (as N)	EPA 300.0	0.0050	mg/L
Orthophosphate-Dissolved (as P)	APHA 4500-P Phosphorous	0.0010	mg/L
Phosphorus (P)-Total	APHA 4500-P Phosphorous	0.0020	mg/L
Water - Plant Pigments			
Chlorophyll a	EPA 445.0	0.010	ug

Methodology

Product	Matrix	Product Description	Analytical Method Reference
ALK-COL-VA	Water	Alkalinity by Colourimetric (Automated)	EPA 310.2
ANIONS-NO3-IC-VA	Water	Nitrate in Water by Ion Chromatography	EPA 300.0
CHLOROA-VA	Water	Chlorophyll a by Fluorometer	EPA 445.0
P-T-COL-VA	Water	Total P in Water by Colour	APHA 4500-P Phosphorous
PO4-DO-COL-VA	Water	Diss. Orthophosphate in Water by Colour	APHA 4500-P Phosphorous
SAMPLE-DISPOSAL-VA	Misc.	Sample Handling and Disposal Fee	
VOLUME FILTERED-VA	Water	Volume Filtered (mL)	

ALK-COL-VA: This analysis is carried out using procedures adapted from EPA Method 310.2 "Alkalinity". Total Alkalinity is determined using the methyl orange colourimetric method.

ANIONS-NO3-IC-VA: This analysis is carried out using procedures adapted from EPA Method 300.0 "Determination of Inorganic Anions by Ion Chromatography". Nitrate is detected by UV absorbance.

CHLOROA-VA: This analysis is done using procedures modified from EPA Method 445.0. Chlorophyll-a is determined by a routine acetone extraction followed with analysis by fluorometry using the non-acidification procedure. This method is not subject to interferences from chlorophyll b.

P-T-COL-VA: This analysis is carried out using procedures adapted from APHA Method 4500-P "Phosphorus". Total Phosphorous is determined colourimetrically after persulphate digestion of the sample.

PO4-DO-COL-VA: This analysis is carried out using procedures adapted from APHA Method 4500-P "Phosphorus". Dissolved Orthophosphate is determined colourimetrically on a sample that has been lab or field filtered through a 0.45 micron membrane filter.

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 4A: Littoral Periphyton Survival Study: Collected Data and Preliminary Analyses – Carbon Incubations

Note: these analyses are subject to possible change

Primary Productivity Calculations for Stave Littoral Light Limitation Study - Summer 2013

Cf = (Bl - Bd) * At * (Vi / Va) * 1.064 * 1000 / S * T * 200

LL1= clear
LL2= 25% limitation
LL3 = 50% limitation
LL4= 75% limitation
LL5= dark

Where		
	Cf =	gross primary productivity (mg/m3/hr)
	Bl =	average light bottle DPM counting rate
	Bd =	average dark bottle DPM counting rate
	At =	Alkalinity (mg C/L)
	Vi =	volume of incubation bottle (mL) (100)
	Va =	area scraped and added to inoculated aliquot (cm2)
	1.064 =	isotopic preference factor
	1000 =	factor to convert mg/L to mg/m3
	S =	reference vials DPM average
	T =	time of incubation (hr), that is, time of acidification midpoint minus time of

Sample ID = light limitation factor (LL1, LL2,LL3,LL4, LL5) where 1=clear and 5=dark

NOTES:

Lake	Date	Filter (size)	Reference Vial DPM Avg. **(S)**	Incubation Depth (m)	sample ID	Area scraped (cm^2)	sample #	Light Bottle DPM Avg. **(Bl)**	Dark Bottle DPM Avg. **(Bd)**	**(Bl - Bd)**	Alkalinity (mgC/L) **(At)**	Vol. of Inc. Bot. / Vol. of Acid. Aliq. **(Vi / Va)**	Isotopic Preference Factor **(1.064)**	Factor to Convert mg/L to mg/m3 **(1000)**	**(Bl - Bd) * At * (Vi/Va) * 1.064 * 1000**	Time of Incubation (hr) **(T)**	**(S * T)**	Primary Productivity (Col. P / Col. R) **(Cf)**	Primary Productivity per Day **(Cf) P*3.28(daylight hours/5)*4(assumed 25% of productivity occurs in increments 2 and 3)**
Stave	26-Jul-13	0.2	7520479.7	lab	LL4	150	1	59159.39	6602.02	52557.37	0.342	0.7	1.064	1000	12749997.5	3.00	22561439	0.565	5.54
Stave	26-Jul-13	0.2	7520479.7	lab	LL4	150	2	22702.02	8947.21	13754.81	0.342	0.7	1.064	1000	3336806.868	3.00	22561439	0.148	1.45
Stave	26-Jul-13	0.2	7520479.7	lab	LL4	150	3	35288.99	7237.58	28051.41	0.342	0.7	1.064	1000	6805047.655	3.00	22561439	0.302	2.96
Stave	26-Jul-13	0.2	7520479.7	lab	LL4	150	4	35907.01	7540.64	27748.35	0.342	0.7	1.064	1000	6731527.723	3.00	22561439	0.298	2.92
Stave	26-Jul-13	0.2	7520479.7	lab	LL4	150	5	36396.73	9835.24	25453.75	0.342	0.7	1.064	1000	6174876.12	3.00	22561439	0.274	2.68
Stave	26-Jul-13	0.2	7520479.7	lab	LL2	150	6	24062.59	2107.80	21954.79	0.342	0.7	1.064	1000	5326056.416	3.00	22561439	0.236	2.31
Stave	26-Jul-13	0.2	7520479.7	lab	LL2	150	7	23011.04	3711.66	19299.38	0.342	0.7	1.064	1000	4681875.193	3.00	22561439	0.208	2.03
Stave	26-Jul-13	0.2	7520479.7	lab	LL2	150	8	19486.65	3917.47	15569.18	0.342	0.7	1.064	1000	3776958.515	3.00	22561439	0.167	1.64
Stave	26-Jul-13	0.2	7520479.7	lab	LL2	150	9	12720.68	3271.57	9449.11	0.342	0.7	1.064	1000	2292278.493	3.00	22561439	0.102	1.00
Stave	26-Jul-13	0.2	7520479.7	lab	LL2	150	10	19831.43	4090.02	15741.41	0.342	0.7	1.064	1000	3818740.135	3.00	22561439	0.169	1.66
Stave	26-Jul-13	0.2	7520479.7	lab	LL3	150	11	36502.12	7605.95	28896.17	0.342	0.7	1.064	1000	7009979.673	3.00	22561439	0.311	3.04
Stave	26-Jul-13	0.2	7520479.7	lab	LL3	150	12	21848.07	4460.13	17387.94	0.342	0.7	1.064	1000	4218175.14	3.00	22561439	0.187	1.83
Stave	26-Jul-13	0.2	7520479.7	lab	LL3	150	13	34434.68	3958.74	30475.94	0.342	0.7	1.064	1000	7393219.236	3.00	22561439	0.328	3.21
Stave	26-Jul-13	0.2	7520479.7	lab	LL3	150	14	33392.86	7885.21	25507.65	0.342	0.7	1.064	1000	6187951.829	3.00	22561439	0.274	2.69
Stave	26-Jul-13	0.2	7520479.7	lab	LL3	150	15	30046.54	5562.66	24483.88	0.342	0.7	1.064	1000	5939593.417	3.00	22561439	0.263	2.58
Stave	26-Jul-13	0.2	7520479.7	lab	LL5	150	16	39335.07	6760.73	32574.34	0.342	0.7	1.064	1000	7902274.289	3.00	22561439	0.350	3.43
Stave	26-Jul-13	0.2	7520479.7	lab	LL5	150	17	30641.46	5884.17	24757.29	0.342	0.7	1.064	1000	6005920.496	3.00	22561439	0.266	2.61
Stave	26-Jul-13	0.2	7520479.7	lab	LL5	150	18	15837.26	5595.15	10242.11	0.342	0.7	1.064	1000	2484653.949	3.00	22561439	0.110	1.08
Stave	26-Jul-13	0.2	7520479.7	lab	LL5	150	19	41235.05	6904.18	34330.87	0.342	0.7	1.064	1000	8328394.415	3.00	22561439	0.369	3.62
Stave	26-Jul-13	0.2	7520479.7	lab	LL5	150	20	20537.21	5618.00	14919.21	0.342	0.7	1.064	1000	3619280.992	3.00	22561439	0.160	1.57
Stave	26-Jul-13	0.2	7520479.7	lab	LL1	150	21	40974.13	8984.47	31989.66	0.342	0.7	1.064	1000	7760435.599	3.00	22561439	0.344	3.37
Stave	26-Jul-13	0.2	7520479.7	lab	LL1	150	22	43859.11	8216.49	35642.62	0.342	0.7	1.064	1000	8646614.471	3.00	22561439	0.383	3.76
Stave	26-Jul-13	0.2	7520479.7	lab	LL1	150	23	30933.19	7920.00	23013.19	0.342	0.7	1.064	1000	5582815.788	3.00	22561439	0.247	2.43
Stave	26-Jul-13	0.2	7520479.7	lab	LL1	150	24	33380.39	7515.35	25865.04	0.342	0.7	1.064	1000	6274651.784	3.00	22561439	0.278	2.73
Stave	26-Jul-13	0.2	7520479.7	lab	LL1	150	25	25418.38	9240.17	16178.21	0.342	0.7	1.064	1000	3924704.32	3.00	22561439	0.174	1.70

Stave	29-Jul-13	0.2	8397700.7	lab	LL4	75	1	57993.23	8205.94	49787.29	0.342	1.3	1.064	1000	24155996.51	3.00	25193102	0.959	9.40
Stave	29-Jul-13	0.2	8397700.7	lab	LL4	75	2	43885.03	6268.87	37616.16	0.342	1.3	1.064	1000	18250758.97	3.00	25193102	0.724	7.10
Stave	29-Jul-13	0.2	8397700.7	lab	LL4	75	3	66046.40	6488.37	59558.03	0.342	1.3	1.064	1000	28896603.23	3.00	25193102	1.147	11.24
Stave	29-Jul-13	0.2	8397700.7	lab	LL4	75	4	28055.72	4964.34	23091.38	0.342	1.3	1.064	1000	11203568.11	3.00	25193102	0.445	4.36
Stave	29-Jul-13	0.2	8397700.7	lab	LL4	75	5	27530.03	6221.20	21308.83	0.342	1.3	1.064	1000	10338703.37	3.00	25193102	0.410	4.02
Stave	29-Jul-13	0.2	8397700.7	lab	LL2	75	6	24557.13	2467.29	22089.84	0.342	1.3	1.064	1000	10717636.93	3.00	25193102	0.425	4.17
Stave	29-Jul-13	0.2	8397700.7	lab	LL2	75	7	43739.53	2816.17	40923.36	0.342	1.3	1.064	1000	19855359.5	3.00	25193102	0.788	7.72
Stave	29-Jul-13	0.2	8397700.7	lab	LL2	75	8	44730.15	3181.12	41549.03	0.342	1.3	1.064	1000	20158924.57	3.00	25193102	0.800	7.84
Stave	29-Jul-13	0.2	8397700.7	lab	LL2	75	9	27980.92	2466.18	25514.74	0.342	1.3	1.064	1000	12379343.61	3.00	25193102	0.491	4.82
Stave	29-Jul-13	0.2	8397700.7	lab	LL2	75	10	22258.87	4186.40	18072.47	0.342	1.3	1.064	1000	8768473.284	3.00	25193102	0.348	3.41
Stave	29-Jul-13	0.2	8397700.7	lab	LL3	75	11	35329.06	4038.17	31290.89	0.342	1.3	1.064	1000	15181839.17	3.00	25193102	0.603	5.91
Stave	29-Jul-13	0.2	8397700.7	lab	LL3	75	12	43520.15	3906.86	39613.29	0.342	1.3	1.064	1000	19219734.5	3.00	25193102	0.763	7.48
Stave	29-Jul-13	0.2	8397700.7	lab	LL3	75	13	38377.33	3802.65	34574.68	0.342	1.3	1.064	1000	16775081.54	3.00	25193102	0.666	6.53
Stave	29-Jul-13	0.2	8397700.7	lab	LL3	75	14	54293.74	5390.56	48903.18	0.342	1.3	1.064	1000	23727040.49	3.00	25193102	0.942	9.23
Stave	29-Jul-13	0.2	8397700.7	lab	LL3	75	15	31069.83	2905.8	28164.03	0.342	1.3	1.064	1000	13664736.73	3.00	25193102	0.542	5.32
Stave	29-Jul-13	0.2	8397700.7	lab	LL5	75	16	33558.44	11440.62	22117.82	0.342	1.3	1.064	1000	10731212.38	3.00	25193102	0.426	4.17
Stave	29-Jul-13	0.2	8397700.7	lab	LL5	75	17	21100.91	7053.32	14047.59	0.342	1.3	1.064	1000	6815665.907	3.00	25193102	0.271	2.65
Stave	29-Jul-13	0.2	8397700.7	lab	LL5	75	18	53950.70	6242.09	47708.61	0.342	1.3	1.064	1000	23147454.23	3.00	25193102	0.919	9.00
Stave	29-Jul-13	0.2	8397700.7	lab	LL5	75	19	27995.26	9837.86	18157.40	0.342	1.3	1.064	1000	8809679.962	3.00	25193102	0.350	3.43
Stave	29-Jul-13	0.2	8397700.7	lab	LL5	75	20	35109.26	5757.86	29351.40	0.342	1.3	1.064	1000	14240829.66	3.00	25193102	0.565	5.54
Stave	29-Jul-13	0.2	8397700.7	lab	LL1	75	21	61943.70	2779.75	59163.95	0.342	1.3	1.064	1000	28705401.92	3.00	25193102	1.139	11.17
Stave	29-Jul-13	0.2	8397700.7	lab	LL1	75	22	38356.14	2641.08	35715.06	0.342	1.3	1.064	1000	17328375.67	3.00	25193102	0.688	6.74
Stave	29-Jul-13	0.2	8397700.7	lab	LL1	75	23	25028.81	16055.72	8973.09	0.342	1.3	1.064	1000	4353599.699	3.00	25193102	0.173	1.69
Stave	29-Jul-13	0.2	8397700.7	lab	LL1	75	24	60718.89	4643.76	56075.13	0.342	1.3	1.064	1000	27206755.87	3.00	25193102	1.080	10.58
Stave	29-Jul-13	0.2	8397700.7	lab	LL1	75	25	27070.65	3733.52	23337.13	0.342	1.3	1.064	1000	11322802.08	3.00	25193102	0.449	4.40
Stave	06-Aug-13	0.2	8811717.0	lab	LL4	75	1	42039.25	5126.45	36912.80	0.342	1.3	1.064	1000	17909499.96	3.00	26435151	0.677	6.64
Stave	06-Aug-13	0.2	8811717.0	lab	LL4	75	2	26337.65	9544.02	16793.63	0.342	1.3	1.064	1000	8148000.578	3.00	26435151	0.308	3.02
Stave	06-Aug-13	0.2	8811717.0	lab	LL4	75	3	38790.08	6817.11	31972.97	0.342	1.3	1.064	1000	15512773.48	3.00	26435151	0.587	5.75
Stave	06-Aug-13	0.2	8811717.0	lab	LL4	75	4	35161.65	13259.38	21902.27	0.342	1.3	1.064	1000	10626630.97	3.00	26435151	0.402	3.94
Stave	06-Aug-13	0.2	8811717.0	lab	LL4	75	5	41795.54	8668.03	33127.51	0.342	1.3	1.064	1000	16072937.81	3.00	26435151	0.608	5.96
Stave	06-Aug-13	0.2	8811717.0	lab	LL2	75	6	52733.42	6276.51	46456.91	0.342	1.3	1.064	1000	22540149.42	3.00	26435151	0.853	8.36
Stave	06-Aug-13	0.2	8811717.0	lab	LL2	75	7	59103.69	25309.23	33794.46	0.342	1.3	1.064	1000	16396531.28	3.00	26435151	0.620	6.08
Stave	06-Aug-13	0.2	8811717.0	lab	LL2	75	8	42129.38	10102.8	32026.58	0.342	1.3	1.064	1000	15538784.19	3.00	26435151	0.588	5.76
Stave	06-Aug-13	0.2	8811717.0	lab	LL2	75	9	45587.33	6977.37	38609.96	0.342	1.3	1.064	1000	18732934.83	3.00	26435151	0.709	6.94
Stave	06-Aug-13	0.2	8811717.0	lab	LL2	75	10	23600.77	5057	18543.77	0.342	1.3	1.064	1000	8997140.504	3.00	26435151	0.340	3.34
Stave	06-Aug-13	0.2	8811717.0	lab	LL3	75	11	40920.81	5869	35051.81	0.342	1.3	1.064	1000	17006577.38	3.00	26435151	0.643	6.30
Stave	06-Aug-13	0.2	8811717.0	lab	LL3	75	12	38088.84	7329.88	30758.96	0.342	1.3	1.064	1000	14923755.25	3.00	26435151	0.565	5.53
Stave	06-Aug-13	0.2	8811717.0	lab	LL3	75	13	44320.16	7349.14	36971.02	0.342	1.3	1.064	1000	17937747.37	3.00	26435151	0.679	6.65
Stave	06-Aug-13	0.2	8811717.0	lab	LL3	75	14	39888.72	6841.26	33047.46	0.342	1.3	1.064	1000	16034098.83	3.00	26435151	0.607	5.94
Stave	06-Aug-13	0.2	8811717.0	lab	LL3	75	15	63153.07	14413.83	48739.24	0.342	1.3	1.064	1000	23647499.42	3.00	26435151	0.895	8.77
Stave	06-Aug-13	0.2	8811717.0	lab	LL5	75	16	19078.02	5742.84	13335.18	0.342	1.3	1.064	1000	6470015.973	3.00	26435151	0.245	2.40
Stave	06-Aug-13	0.2	8811717.0	lab	LL5	75	17	15026.08	5862.51	9163.57	0.342	1.3	1.064	1000	4446017.547	3.00	26435151	0.168	1.65
Stave	06-Aug-13	0.2	8811717.0	lab	LL5	75	18	16112.82	6907.19	9205.63	0.342	1.3	1.064	1000	4466424.386	3.00	26435151	0.169	1.66
Stave	06-Aug-13	0.2	8811717.0	lab	LL5	75	19	15580.96	7761.03	7819.93	0.342	1.3	1.064	1000	3794104.917	3.00	26435151	0.144	1.41
Stave	06-Aug-13	0.2	8811717.0	lab	LL5	75	20	14171.68	7577.86	6593.82	0.342	1.3	1.064	1000	3199215.963	3.00	26435151	0.121	1.19
Stave	06-Aug-13	0.2	8811717.0	lab	LL1	75	21	50756.43	7584.54	43171.89	0.342	1.3	1.064	1000	20946310.28	3.00	26435151	0.792	7.77
Stave	06-Aug-13	0.2	8811717.0	lab	LL1	75	22	35722.04	9686.75	26035.29	0.342	1.3	1.064	1000	12631906.14	3.00	26435151	0.478	4.68
Stave	06-Aug-13	0.2	8811717.0	lab	LL1	75	23	28002.22	10120.8	17881.42	0.342	1.3	1.064	1000	8675778.881	3.00	26435151	0.328	3.22
Stave	06-Aug-13	0.2	8811717.0	lab	LL1	75	24	42550.11	11270.59	31279.52	0.342	1.3	1.064	1000	15176322.63	3.00	26435151	0.574	5.63
Stave	06-Aug-13	0.2	8811717.0	lab	LL1	75	25	30983.14	8679.49	22303.65	0.342	1.3	1.064	1000	10821374.12	3.00	26435151	0.409	4.01

Stave	19-Aug-13	0.2	8641859.0	lab	LL4	75	1	49263.80	3551.48	45712.32	0.342	1.3	1.064	1000	22178886.27	3.00	25925577	0.855	8.38
Stave	19-Aug-13	0.2	8641859.0	lab	LL4	75	2	27522.79	8258.91	19263.88	0.342	1.3	1.064	1000	9346526.354	3.00	25925577	0.361	3.53
Stave	19-Aug-13	0.2	8641859.0	lab	LL4	75	3	36674.82	8094.14	28580.68	0.342	1.3	1.064	1000	13866888.65	3.00	25925577	0.535	5.24
Stave	19-Aug-13	0.2	8641859.0	lab	LL4	75	4	32992.21	5394.9	27597.31	0.342	1.3	1.064	1000	13389773.26	3.00	25925577	0.516	5.06
Stave	19-Aug-13	0.2	8641859.0	lab	LL4	75	5	34588.36	4040.36	30548.00	0.342	1.3	1.064	1000	14821400.83	3.00	25925577	0.572	5.60
Stave	19-Aug-13	0.2	8641859.0	lab	LL2	75	6	55979.64	4483.54	51496.10	0.342	1.3	1.064	1000	24985083.78	3.00	25925577	0.964	9.44
Stave	19-Aug-13	0.2	8641859.0	lab	LL2	75	7	25511.25	4044.72	21466.53	0.342	1.3	1.064	1000	10415216.89	3.00	25925577	0.402	3.94
Stave	19-Aug-13	0.2	8641859.0	lab	LL2	75	8	51677.67	2976.34	48701.33	0.342	1.3	1.064	1000	23629106.09	3.00	25925577	0.911	8.93
Stave	19-Aug-13	0.2	8641859.0	lab	LL2	75	9	32280.22	2294.59	29985.63	0.342	1.3	1.064	1000	14548547.91	3.00	25925577	0.561	5.50
Stave	19-Aug-13	0.2	8641859.0	lab	LL2	75	10	24052.22	3127.35	20924.87	0.342	1.3	1.064	1000	10152412.13	3.00	25925577	0.392	3.84
Stave	19-Aug-13	0.2	8641859.0	lab	LL3	75	11	39044.20	2954.26	36089.94	0.342	1.3	1.064	1000	17510261.45	3.00	25925577	0.675	6.62
Stave	19-Aug-13	0.2	8641859.0	lab	LL3	75	12	43629.36	2516.67	41112.69	0.342	1.3	1.064	1000	19947219.38	3.00	25925577	0.769	7.54
Stave	19-Aug-13	0.2	8641859.0	lab	LL3	75	13	41384.07	3388.35	37995.72	0.342	1.3	1.064	1000	18434915.41	3.00	25925577	0.711	6.97
Stave	19-Aug-13	0.2	8641859.0	lab	LL3	75	14	26722.68	2193.21	24529.47	0.342	1.3	1.064	1000	11901306.37	3.00	25925577	0.459	4.50
Stave	19-Aug-13	0.2	8641859.0	lab	LL3	75	15	50346.38	2985.35	47361.03	0.342	1.3	1.064	1000	22978813.98	3.00	25925577	0.886	8.69
Stave	19-Aug-13	0.2	8641859.0	lab	LL5	75	16	7608.81	1003.13	6605.68	0.342	1.3	1.064	1000	3204970.245	3.00	25925577	0.124	1.21
Stave	19-Aug-13	0.2	8641859.0	lab	LL5	75	17	6819.42	1730.05	5089.37	0.342	1.3	1.064	1000	2469280.894	3.00	25925577	0.095	0.93
Stave	19-Aug-13	0.2	8641859.0	lab	LL5	75	18	4220.05	1904.6	2315.45	0.342	1.3	1.064	1000	1123419.293	3.00	25925577	0.043	0.42
Stave	19-Aug-13	0.2	8641859.0	lab	LL5	75	19	6632.88	1516.52	5116.36	0.342	1.3	1.064	1000	2482376.01	3.00	25925577	0.096	0.94
Stave	19-Aug-13	0.2	8641859.0	lab	LL5	75	20	8955.78	1719.37	7236.41	0.342	1.3	1.064	1000	3510990.349	3.00	25925577	0.135	1.33
Stave	19-Aug-13	0.2	8641859.0	lab	LL1	75	21	25217.12	2835.09	22382.03	0.342	1.3	1.064	1000	10859402.84	3.00	25925577	0.419	4.10
Stave	19-Aug-13	0.2	8641859.0	lab	LL1	75	22	19027.22	3221.46	15805.76	0.342	1.3	1.064	1000	7668701.86	3.00	25925577	0.296	2.90
Stave	19-Aug-13	0.2	8641859.0	lab	LL1	75	23	13591.56	2083.09	11508.47	0.342	1.3	1.064	1000	5583725.508	3.00	25925577	0.215	2.11
Stave	19-Aug-13	0.2	8641859.0	lab	LL1	75	24	22726.00	2750.66	19975.34	0.342	1.3	1.064	1000	9691715.363	3.00	25925577	0.374	3.66
Stave	19-Aug-13	0.2	8641859.0	lab	LL1	75	25	23186.36	4115.01	19071.35	0.342	1.3	1.064	1000	9253113.878	3.00	25925577	0.357	3.50
Stave	17-Sep-13	0.2	9038150.7	lab	LL4	37.5	1	11700.01	5901.76	5798.25	0.342	2.7	1.064	1000	5626436.256	3.00	27114452	0.208	2.03
Stave	17-Sep-13	0.2	9038150.7	lab	LL4	37.5	2	33860.27	11432.09	22428.18	0.342	2.7	1.064	1000	21763588.17	3.00	27114452	0.803	7.87
Stave	17-Sep-13	0.2	9038150.7	lab	LL4	37.5	3	15256.56	4632.98	10623.58	0.342	2.7	1.064	1000	10308782.08	3.00	27114452	0.380	3.73
Stave	17-Sep-13	0.2	9038150.7	lab	LL4	37.5	4	27295.64	3164.98	24130.66	0.342	2.7	1.064	1000	23415620.28	3.00	27114452	0.864	8.46
Stave	17-Sep-13	0.2	9038150.7	lab	LL4	37.5	5	15274.58	2055.56	13219.02	0.342	2.7	1.064	1000	12827314	3.00	27114452	0.473	4.64
Stave	17-Sep-13	0.2	9038150.7	lab	LL2	37.5	6	23282.88	3701.4	19581.48	0.342	2.7	1.064	1000	19001241.58	3.00	27114452	0.701	6.87
Stave	17-Sep-13	0.2	9038150.7	lab	LL2	37.5	7	20493.21	5375.23	15117.98	0.342	2.7	1.064	1000	14670004.02	3.00	27114452	0.541	5.30
Stave	17-Sep-13	0.2	9038150.7	lab	LL2	37.5	8	21475.01	5050.68	16424.33	0.342	2.7	1.064	1000	15937644.25	3.00	27114452	0.588	5.76
Stave	17-Sep-13	0.2	9038150.7	lab	LL2	37.5	9	47526.48	5094.52	42431.96	0.342	2.7	1.064	1000	41174616.16	3.00	27114452	1.519	14.88
Stave	17-Sep-13	0.2	9038150.7	lab	LL2	37.5	10	23719.22	4896.75	18822.47	0.342	2.7	1.064	1000	18264722.57	3.00	27114452	0.674	6.60
Stave	17-Sep-13	0.2	9038150.7	lab	LL3	37.5	11	25586.07	3230.7	22355.37	0.342	2.7	1.064	1000	21692935.68	3.00	27114452	0.800	7.84
Stave	17-Sep-13	0.2	9038150.7	lab	LL3	37.5	12	22466.29	3455.89	19010.40	0.342	2.7	1.064	1000	18447083.83	3.00	27114452	0.680	6.67
Stave	17-Sep-13	0.2	9038150.7	lab	LL3	37.5	13	35119.71	4252.86	30866.85	0.342	2.7	1.064	1000	29952203.5	3.00	27114452	1.105	10.83
Stave	17-Sep-13	0.2	9038150.7	lab	LL3	37.5	14	18897.02	3150.37	15746.65	0.342	2.7	1.064	1000	15280045.27	3.00	27114452	0.564	5.52
Stave	17-Sep-13	0.2	9038150.7	lab	LL3	37.5	15	32649.62	7151.37	25498.25	0.342	2.7	1.064	1000	24742685.86	3.00	27114452	0.913	8.94
Stave	17-Sep-13	0.2	9038150.7	lab	LL5	37.5	16	5450.67	3087.73	2362.94	0.342	2.7	1.064	1000	2292921.362	3.00	27114452	0.085	0.83
Stave	17-Sep-13	0.2	9038150.7	lab	LL5	37.5	17	2876.53	1907.16	969.37	0.342	2.7	1.064	1000	940645.6282	3.00	27114452	0.035	0.34
Stave	17-Sep-13	0.2	9038150.7	lab	LL5	37.5	18	5452.36	4472.14	980.22	0.342	2.7	1.064	1000	951174.121	3.00	27114452	0.035	0.34
Stave	17-Sep-13	0.2	9038150.7	lab	LL5	37.5	19	5373.93	4983.4	390.53	0.342	2.7	1.064	1000	378957.815	3.00	27114452	0.014	0.14
Stave	17-Sep-13	0.2	9038150.7	lab	LL5	37.5	20	5326.98	3580.68	1746.30	0.342	2.7	1.064	1000	1694553.638	3.00	27114452	0.062	0.61
Stave	17-Sep-13	0.2	9038150.7	lab	LL1	37.5	21	36259.03	2814.29	33444.74	0.342	2.7	1.064	1000	32453705.46	3.00	27114452	1.197	11.73
Stave	17-Sep-13	0.2	9038150.7	lab	LL1	37.5	22	23692.51	2014.29	21678.22	0.342	2.7	1.064	1000	21035850.98	3.00	27114452	0.776	7.60
Stave	17-Sep-13	0.2	9038150.7	lab	LL1	37.5	23	24834.64	4391.58	20443.06	0.342	2.7	1.064	1000	19837291.25	3.00	27114452	0.732	7.17
Stave	17-Sep-13	0.2	9038150.7	lab	LL1	37.5	24	32823.64	2951.58	29872.06	0.342	2.7	1.064	1000	28986891.12	3.00	27114452	1.069	10.48
Stave	17-Sep-13	0.2	9038150.7	lab	LL1	37.5	25	47534.65	2787.93	44746.72	0.342	2.7	1.064	1000	43420785.19	3.00	27114452	1.601	15.69

Stave	13-Nov-13	0.2	8398320.7	lab	LL4	37.5	1	87068.00	8642.6	78425.40	0.342	2.7	1.064	1000	76101498.55	3.00	25194962	3.021	29.60
Stave	13-Nov-13	0.2	8398320.7	lab	LL4	37.5	2	70444.62	10901.75	59542.87	0.342	2.7	1.064	1000	57778495.68	3.00	25194962	2.293	22.47
Stave	13-Nov-13	0.2	8398320.7	lab	LL4	37.5	3	57915.79	6578.39	51337.40	0.342	2.7	1.064	1000	49816170.16	3.00	25194962	1.977	19.38
Stave	13-Nov-13	0.2	8398320.7	lab	LL4	37.5	4	71526.52	10602.84	60923.68	0.342	2.7	1.064	1000	59118389.51	3.00	25194962	2.346	23.00
Stave	13-Nov-13	0.2	8398320.7	lab	LL4	37.5	5	90918.55	15641.55	75277.00	0.342	2.7	1.064	1000	73046391.94	3.00	25194962	2.899	28.41
Stave	13-Nov-13	0.2	8398320.7	lab	LL2	37.5	6	75964.11	6426.11	69538.00	0.342	2.7	1.064	1000	67477449.98	3.00	25194962	2.678	26.25
Stave	13-Nov-13	0.2	8398320.7	lab	LL2	37.5	7	73044.15	6378.91	66665.24	0.342	2.7	1.064	1000	64689815.61	3.00	25194962	2.568	25.16
Stave	13-Nov-13	0.2	8398320.7	lab	LL2	37.5	8	100585.00	6721.01	93863.99	0.342	2.7	1.064	1000	91082612.25	3.00	25194962	3.615	35.43
Stave	13-Nov-13	0.2	8398320.7	lab	LL2	37.5	9	96750.23	8080.82	88669.41	0.342	2.7	1.064	1000	86041958.04	3.00	25194962	3.415	33.47
Stave	13-Nov-13	0.2	8398320.7	lab	LL2	37.5	10	100834.10	8702.99	92131.11	0.342	2.7	1.064	1000	89401080.95	3.00	25194962	3.548	34.77
Stave	13-Nov-13	0.2	8398320.7	lab	LL3	37.5	11	104831.00	3102.53	101728.47	0.342	2.7	1.064	1000	98714051.98	3.00	25194962	3.918	38.40
Stave	13-Nov-13	0.2	8398320.7	lab	LL3	37.5	12	103124.30	7041.35	96082.95	0.342	2.7	1.064	1000	93235820.03	3.00	25194962	3.701	36.27
Stave	13-Nov-13	0.2	8398320.7	lab	LL3	37.5	13	94863.58	7946.36	86917.22	0.342	2.7	1.064	1000	84341688.94	3.00	25194962	3.348	32.81
Stave	13-Nov-13	0.2	8398320.7	lab	LL3	37.5	14	130085.20	6548.99	123536.21	0.342	2.7	1.064	1000	119875585	3.00	25194962	4.758	46.63
Stave	13-Nov-13	0.2	8398320.7	lab	LL3	37.5	15	93262.12	3710.97	89551.15	0.342	2.7	1.064	1000	86897570.32	3.00	25194962	3.449	33.80
Stave	13-Nov-13	0.2	8398320.7	lab	LL5	37.5	16	42851.49	2921.69	39929.80	0.342	2.7	1.064	1000	38746600.17	3.00	25194962	1.538	15.07
Stave	13-Nov-13	0.2	8398320.7	lab	LL5	37.5	17	46617.50	3022.77	43594.73	0.342	2.7	1.064	1000	42302930.96	3.00	25194962	1.679	16.45
Stave	13-Nov-13	0.2	8398320.7	lab	LL5	37.5	18	28780.95	1963.05	26817.90	0.342	2.7	1.064	1000	26023231.99	3.00	25194962	1.033	10.12
Stave	13-Nov-13	0.2	8398320.7	lab	LL5	37.5	19	32349.57	2510.05	29839.52	0.342	2.7	1.064	1000	28955315.34	3.00	25194962	1.149	11.26
Stave	13-Nov-13	0.2	8398320.7	lab	LL5	37.5	20	29742.78	3658.48	26084.30	0.342	2.7	1.064	1000	25311370.02	3.00	25194962	1.005	9.85
Stave	13-Nov-13	0.2	8398320.7	lab	LL1	37.5	21	129893.00	4909.76	124983.24	0.342	2.7	1.064	1000	121279736.6	3.00	25194962	4.814	47.17
Stave	13-Nov-13	0.2	8398320.7	lab	LL1	37.5	22	94659.65	9099.2	85560.45	0.342	2.7	1.064	1000	83025122.75	3.00	25194962	3.295	32.29
Stave	13-Nov-13	0.2	8398320.7	lab	LL1	37.5	23	153345.20	6666.03	146679.17	0.342	2.7	1.064	1000	142332772.8	3.00	25194962	5.649	55.36
Stave	13-Nov-13	0.2	8398320.7	lab	LL1	37.5	24	430285.60	7567.15	422718.45	0.342	2.7	1.064	1000	410192456.9	3.00	25194962	16.281	159.55
Stave	13-Nov-13	0.2	8398320.7	lab	LL1	37.5	25	180493.80	6539.97	173953.83	0.342	2.7	1.064	1000	168799230.1	3.00	25194962	6.700	65.66

Appendix 4B: Littoral Periphyton Survival Study: Ash Free Dry Weight

Date	Sample #	Sample ID	Area scraped (cm^2)	total dilution (250 ml)	vol filtered (ml)	Filter Wt (g)	Oven WT (g)	Muffle WT (g)	AFDM (g)	AFDM (mg)
26-Jun-13	1	LL4	150	250	50	0.1337	0.1882	0.1808	0.0074	7.4
26-Jun-13	2	LL4	150	250	50	0.1337	0.1798	0.1675	0.0123	12.3
26-Jun-13	3	LL4	150	250	50	0.1337	0.1663	0.1584	0.0079	7.9
26-Jun-13	4	LL4	150	250	50	0.1337	0.1603	0.1517	0.0086	8.6
26-Jun-13	5	LL4	150	250	50	0.1337	0.1708	0.1608	0.0100	10.0
26-Jun-13	6	LL2	150	250	50	0.1337	0.1577	0.1509	0.0068	6.8
26-Jun-13	7	LL2	150	250	50	0.1337	0.1527	0.1473	0.0054	5.4
26-Jun-13	8	LL2	150	250	50	0.1337	0.1479	0.1428	0.0051	5.1
26-Jun-13	9	LL2	150	250	50	0.1337	0.1460	0.1419	0.0041	4.1
26-Jun-13	10	LL2	150	250	50	0.1337	0.1433	0.1402	0.0031	3.1
26-Jun-13	11	LL3	150	250	50	0.1337	0.1660	0.1574	0.0086	8.6
26-Jun-13	12	LL3	150	250	50	0.1337	0.1710	0.1601	0.0109	10.9
26-Jun-13	13	LL3	150	250	50	0.1337	0.1702	0.1594	0.0108	10.8
26-Jun-13	14	LL3	150	250	50	0.1337	0.1708	0.1605	0.0103	10.3
26-Jun-13	15	LL3	150	250	50	0.1337	0.1765	0.1640	0.0125	12.5
26-Jun-13	16	LL5	150	250	50	0.1337	0.1760	0.1640	0.0120	12.0
26-Jun-13	17	LL5	150	250	50	0.1337	0.1704	0.1598	0.0106	10.6
26-Jun-13	18	LL5	150	250	50	0.1337	0.1663	0.1561	0.0102	10.2
26-Jun-13	19	LL5	150	250	50	0.1337	0.1773	0.1638	0.0135	13.5
26-Jun-13	20	LL5	150	250	50	0.1337	0.1622	0.1545	0.0077	7.7
26-Jun-13	21	LL1	150	250	50	0.1337	0.1768	0.1643	0.0125	12.5
26-Jun-13	22	LL1	150	250	50	0.1337	0.1672	0.1573	0.0099	9.9
26-Jun-13	23	LL1	150	250	50	0.1337	0.1729	0.1612	0.0117	11.7
26-Jun-13	24	LL1	150	250	50	0.1337	0.1694	0.1591	0.0103	10.3
26-Jun-13	25	LL1	150	250	50	0.1337	0.1768	0.1650	0.0118	11.8
29-Jun-13	1	LL4	75	not diluted		0.1341	0.1905	0.1740	0.0165	16.5
29-Jun-13	2	LL4	75	entire sample filtered		0.1342	0.1854	0.1695	0.0159	15.9
29-Jun-13	3	LL4	75			0.1336	0.1747	0.1623	0.0124	12.4
29-Jun-13	4	LL4	75			0.1342	0.1876	0.1721	0.0155	15.5
29-Jun-13	5	LL4	75			0.1337	0.1788	0.1652	0.0136	13.6
29-Jun-13	6	LL2	75			0.1332	0.1973	0.1779	0.0194	19.4
29-Jun-13	7	LL2	75			0.1337	0.1933	0.1756	0.0177	17.7
29-Jun-13	8	LL2	75			0.1328	0.1951	0.1756	0.0195	19.5
29-Jun-13	9	LL2	75			0.1340	0.2039	0.1827	0.0212	21.2
29-Jun-13	10	LL2	75			0.1320	0.1959	0.1774	0.0185	18.5
29-Jun-13	11	LL3	75			0.1328	0.1984	0.1787	0.0197	19.7
29-Jun-13	12	LL3	75			0.1336	0.1952	0.1767	0.0185	18.5
29-Jun-13	13	LL3	75			0.1341	0.1926	0.1756	0.0170	17.0
29-Jun-13	14	LL3	75			0.1348	0.2021	0.1821	0.0200	20.0
29-Jun-13	15	LL3	75			0.1337	0.1948	0.1765	0.0183	18.3
29-Jun-13	16	LL5	75			0.1333	0.1854	0.1711	0.0143	14.3
29-Jun-13	17	LL5	75			0.1346	0.1994	0.1806	0.0188	18.8
29-Jun-13	18	LL5	75			0.1332	0.1954	0.1769	0.0185	18.5
29-Jun-13	19	LL5	75			0.1335	0.1908	0.1739	0.0169	16.9
29-Jun-13	20	LL5	75			0.1337	0.1943	0.1765	0.0178	17.8
29-Jun-13	21	LL1	75			0.1345	0.1864	0.1694	0.0170	17.0
29-Jun-13	22	LL1	75			0.1343	0.1891	0.1721	0.0170	17.0
29-Jun-13	23	LL1	75			0.1335	0.1904	0.1725	0.0179	17.9
29-Jun-13	24	LL1	75			0.1336	0.1872	0.1693	0.0179	17.9
29-Jun-13	25	LL1	75			0.1340	0.1837	0.1679	0.0158	15.8

06-Aug-13	1	LL4	75			0.1340	0.1873	0.1724	0.0149	14.9
06-Aug-13	2	LL4	75			0.1346	0.1853	0.1709	0.0144	14.4
06-Aug-13	3	LL4	75			0.1340	0.1816	0.1681	0.0135	13.5
06-Aug-13	4	LL4	75			0.1347	0.1805	0.1676	0.0129	12.9
06-Aug-13	5	LL4	75			0.1343	0.1899	0.1735	0.0164	16.4
06-Aug-13	6	LL2	75			0.1350	0.2000	0.1803	0.0197	19.7
06-Aug-13	7	LL2	75			0.1343	0.1970	0.1769	0.0201	20.1
06-Aug-13	8	LL2	75			0.1341	0.1982	0.1786	0.0196	19.6
06-Aug-13	9	LL2	75			0.1339	0.1911	0.1736	0.0175	17.5
06-Aug-13	10	LL2	75			0.1352	0.1967	0.1785	0.0182	18.2
06-Aug-13	11	LL3	75			0.1349	0.1932	0.1759	0.0173	17.3
06-Aug-13	12	LL3	75			0.1347	0.1985	0.1802	0.0183	18.3
06-Aug-13	13	LL3	75			0.1344	0.1938	0.1759	0.0179	17.9
06-Aug-13	14	LL3	75			0.1348	0.1944	0.1756	0.0188	18.8
06-Aug-13	15	LL3	75			0.1346	0.1962	0.1769	0.0193	19.3
06-Aug-13	16	LL5	75			0.1341	0.1848	0.1704	0.0144	14.4
06-Aug-13	17	LL5	75			0.1344	0.1844	0.1704	0.0140	14.0
06-Aug-13	18	LL5	75			0.1341	0.1919	0.1756	0.0163	16.3
06-Aug-13	19	LL5	75			0.1337	0.1813	0.1676	0.0137	13.7
06-Aug-13	20	LL5	75			0.1342	0.1797	0.1654	0.0143	14.3
06-Aug-13	21	LL1	75			0.1340	0.1853	0.1690	0.0163	16.3
06-Aug-13	22	LL1	75			0.1341	0.1868	0.1698	0.0170	17.0
06-Aug-13	23	LL1	75			0.1338	0.1887	0.1706	0.0181	18.1
06-Aug-13	24	LL1	75			0.1341	0.1893	0.1713	0.0180	18.0
06-Aug-13	25	LL1	75			0.1345	0.1907	0.1725	0.0182	18.2
19-Aug-13	1	LL4	75			0.1344	0.2056	0.1842	0.0214	21.4
19-Aug-13	2	LL4	75			0.1326	0.1977	0.1775	0.0202	20.2
19-Aug-13	3	LL4	75			0.1344	0.1964	0.1777	0.0187	18.7
19-Aug-13	4	LL4	75			0.1335	0.1896	0.1726	0.0170	17.0
19-Aug-13	5	LL4	75			0.1344	0.1832	0.1688	0.0144	14.4
19-Aug-13	6	LL2	75			0.1335	0.1957	0.1768	0.0189	18.9
19-Aug-13	7	LL2	75			0.1344	0.1861	0.1701	0.0160	16.0
19-Aug-13	8	LL2	75			0.1342	0.1956	0.1761	0.0195	19.5
19-Aug-13	9	LL2	75			0.1328	0.1948	0.1759	0.0189	18.9
19-Aug-13	10	LL2	75			0.1339	0.2022	0.1814	0.0208	20.8
19-Aug-13	11	LL3	75			0.1335	0.1973	0.1784	0.0189	18.9
19-Aug-13	12	LL3	75			0.1340	0.2030	0.1819	0.0211	21.1
19-Aug-13	13	LL3	75			0.1332	0.2138	0.1884	0.0254	25.4
19-Aug-13	14	LL3	75			0.1340	0.1846	0.1690	0.0156	15.6
19-Aug-13	15	LL3	75			0.1341	0.1816	0.1672	0.0144	14.4
19-Aug-13	16	LL5	75			0.1338	0.1982	0.1820	0.0162	16.2
19-Aug-13	17	LL5	75			0.1338	0.1973	0.1799	0.0174	17.4
19-Aug-13	18	LL5	75			0.1338	0.1895	0.1750	0.0145	14.5
19-Aug-13	19	LL5	75			0.1338	0.1777	0.1654	0.0123	12.3
19-Aug-13	20	LL5	75			0.1338	0.1894	0.1752	0.0142	14.2
19-Aug-13	21	LL1	75			0.1338	0.1708	0.1592	0.0116	11.6
19-Aug-13	22	LL1	75			0.1338	0.1841	0.1686	0.0155	15.5
19-Aug-13	23	LL1	75			0.1338	0.1954	0.1760	0.0194	19.4
19-Aug-13	24	LL1	75			0.1338	0.1804	0.1657	0.0147	14.7
19-Aug-13	25	LL1	75			0.1338	0.1936	0.1759	0.0177	17.7

17-Sep-13	1	LL4	75			0.1345	0.1393	0.1366	0.0027	2.7
17-Sep-13	2	LL4	75			0.1339	0.1446	0.1397	0.0049	4.9
17-Sep-13	3	LL4	75			0.1329	0.1418	0.1371	0.0047	4.7
17-Sep-13	4	LL4	75			0.1336	0.1509	0.1436	0.0073	7.3
17-Sep-13	5	LL4	75			0.1335	0.1430	0.1387	0.0043	4.3
17-Sep-13	6	LL2	75			0.1349	0.1390	0.1360	0.0030	3.0
17-Sep-13	7	LL2	75			0.1329	0.1371	0.1343	0.0028	2.8
17-Sep-13	8	LL2	75			0.1334	0.1368	0.1346	0.0022	2.2
17-Sep-13	9	LL2	75			0.1337	0.1398	0.1359	0.0039	3.9
17-Sep-13	10	LL2	75			0.1337	0.1395	0.1363	0.0032	3.2
17-Sep-13	11	LL3	75			0.1334	0.1383	0.1357	0.0026	2.6
17-Sep-13	12	LL3	75			0.1337	0.1400	0.1366	0.0034	3.4
17-Sep-13	13	LL3	75			0.1345	0.1404	0.1370	0.0034	3.4
17-Sep-13	14	LL3	75			0.1329	0.1404	0.1362	0.0042	4.2
17-Sep-13	15	LL3	75			0.1337	0.1415	0.1374	0.0041	4.1
17-Sep-13	16	LL5	75			0.1333	0.1362	0.1339	0.0023	2.3
17-Sep-13	17	LL5	75			0.1334	0.1372	0.1347	0.0025	2.5
17-Sep-13	18	LL5	75			0.1351	0.1405	0.1373	0.0032	3.2
17-Sep-13	19	LL5	75			0.1342	0.1425	0.1378	0.0047	4.7
17-Sep-13	20	LL5	75			0.1342	0.1396	0.1363	0.0033	3.3
17-Sep-13	21	LL1	75			0.1335	0.1905	0.1713	0.0192	19.2
17-Sep-13	22	LL1	75			0.1346	0.1768	0.1617	0.0151	15.1
17-Sep-13	23	LL1	75			0.1330	0.1769	0.1623	0.0146	14.6
17-Sep-13	24	LL1	75			0.1337	0.1540	0.1456	0.0084	8.4
17-Sep-13	25	LL1	75			0.1349	0.1450	0.1395	0.0055	5.5
10-Oct-13	1	LL4	75			0.1339	0.1552	0.1496	0.0056	5.6
10-Oct-13	2	LL4	75			0.1340	0.1635	0.1554	0.0081	8.1
10-Oct-13	3	LL4	75			0.1337	0.1738	0.1639	0.0099	9.9
10-Oct-13	4	LL4	75			0.1342	0.1601	0.1532	0.0069	6.9
10-Oct-13	5	LL4	75			0.1339	0.1716	0.1628	0.0088	8.8
10-Oct-13	6	LL2	75			0.1350	0.1636	0.1560	0.0076	7.6
10-Oct-13	7	LL2	75			0.1331	0.1566	0.1502	0.0064	6.4
10-Oct-13	8	LL2	75			0.1338	0.1679	0.1588	0.0091	9.1
10-Oct-13	9	LL2	75			0.1321	0.1558	0.1487	0.0071	7.1
10-Oct-13	10	LL2	75			0.1353	0.1600	0.1528	0.0072	7.2
10-Oct-13	11	LL3	75			0.1327	0.1512	0.1457	0.0055	5.5
10-Oct-13	12	LL3	75			0.1345	0.1730	0.1630	0.0100	10.0
10-Oct-13	13	LL3	75			0.1332	0.1635	0.1562	0.0073	7.3
10-Oct-13	14	LL3	75			0.1327	0.1561	0.1499	0.0062	6.2
10-Oct-13	15	LL3	75			0.1332	0.1549	0.1490	0.0059	5.9
10-Oct-13	16	LL5	75			0.1329	0.1431	0.1400	0.0031	3.1
10-Oct-13	17	LL5	75			0.1341	0.1422	0.1392	0.0030	3.0
10-Oct-13	18	LL5	75			0.1338	0.1477	0.1427	0.0050	5.0
10-Oct-13	19	LL5	75			0.1339	0.1396	0.1374	0.0022	2.2
10-Oct-13	20	LL5	75			0.1331	0.1429	0.1397	0.0032	3.2
10-Oct-13	21	LL1	75			0.1334	0.1787	0.1665	0.0122	12.2
10-Oct-13	22	LL1	75			0.1333	0.1639	0.1548	0.0091	9.1
10-Oct-13	23	LL1	75			0.1338	0.1581	0.1504	0.0077	7.7
10-Oct-13	24	LL1	75			0.1341	0.1591	0.1511	0.0080	8.0
10-Oct-13	25	LL1	75			0.1339	0.1592	0.1511	0.0081	8.1

08-Nov-13	1	LL4	75			0.1355	0.2053	0.1882	0.0171	17.1
08-Nov-13	2	LL4	75			0.1344	0.1727	0.1625	0.0102	10.2
08-Nov-13	3	LL4	75			0.1342	0.1748	0.1640	0.0108	10.8
08-Nov-13	4	LL4	75			0.1336	0.1707	0.1614	0.0093	9.3
08-Nov-13	5	LL4	75			0.1332	0.1872	0.1723	0.0149	14.9
08-Nov-13	6	LL2	75			0.1338	0.2011	0.1855	0.0156	15.6
08-Nov-13	7	LL2	75			0.1345	0.2095	0.1927	0.0168	16.8
08-Nov-13	8	LL2	75			0.1341	0.2205	0.1998	0.0207	20.7
08-Nov-13	9	LL2	75			0.1336	0.1996	0.1842	0.0154	15.4
08-Nov-13	10	LL2	75			0.1344	0.2188	0.1994	0.0194	19.4
08-Nov-13	11	LL3	75			0.1333	0.2280	0.2075	0.0205	20.5
08-Nov-13	12	LL3	75			0.1341	0.2046	0.1885	0.0161	16.1
08-Nov-13	13	LL3	75			0.1341	0.2170	0.1987	0.0183	18.3
08-Nov-13	14	LL3	75			0.1340	0.2096	0.1924	0.0172	17.2
08-Nov-13	15	LL3	75			0.1334	0.1950	0.1817	0.0133	13.3
08-Nov-13	16	LL5	75			0.1329	0.1708	0.1622	0.0086	8.6
08-Nov-13	17	LL5	75			0.1345	0.1780	0.1684	0.0096	9.6
08-Nov-13	18	LL5	75			0.1350	0.1713	0.1626	0.0087	8.7
08-Nov-13	19	LL5	75			0.1335	0.1675	0.1596	0.0079	7.9
08-Nov-13	20	LL5	75			0.1329	0.1727	0.1639	0.0088	8.8
08-Nov-13	21	LL1	75			0.1327	0.2165	0.1978	0.0187	18.7
08-Nov-13	22	LL1	75			0.1340	0.2166	0.1991	0.0175	17.5
08-Nov-13	23	LL1	75			0.1339	0.2096	0.1926	0.0170	17.0
08-Nov-13	24	LL1	75			0.1326	0.1994	0.1844	0.0150	15.0
08-Nov-13	25	LL1	75			0.1337	0.2652	0.2355	0.0297	29.7
13-Nov-13	1	LL4	75			0.1264	0.2099	0.1900	0.0199	19.9
13-Nov-13	2	LL4	75			0.1273	0.2013	0.1791	0.0222	22.2
13-Nov-13	3	LL4	75			0.1267	0.2449	0.2163	0.0286	28.6
13-Nov-13	4	LL4	75			0.1261	0.2350	0.2085	0.0265	26.5
13-Nov-13	5	LL4	75			0.1254	0.2334	0.2094	0.0240	24.0
13-Nov-13	6	LL2	75			0.1259	0.1732	0.1632	0.0100	10.0
13-Nov-13	7	LL2	75			0.1253	0.1736	0.1631	0.0105	10.5
13-Nov-13	8	LL2	75			0.1255	0.1853	0.1727	0.0126	12.6
13-Nov-13	9	LL2	75			0.1254	0.1846	0.1723	0.0123	12.3
13-Nov-13	10	LL2	75			0.1251	0.1831	0.1709	0.0122	12.2
13-Nov-13	11	LL3	75			0.1261	0.1712	0.1616	0.0096	9.6
13-Nov-13	12	LL3	75			0.1262	0.1837	0.1718	0.0119	11.9
13-Nov-13	13	LL3	75			0.1270	0.1917	0.1772	0.0145	14.5
13-Nov-13	14	LL3	75			0.1256	0.1760	0.1665	0.0095	9.5
13-Nov-13	15	LL3	75			0.1247	0.1660	0.1572	0.0088	8.8
13-Nov-13	16	LL5	75			0.1257	0.1589	0.1510	0.0079	7.9
13-Nov-13	17	LL5	75			0.1249	0.1620	0.1543	0.0077	7.7
13-Nov-13	18	LL5	75			0.1271	0.1700	0.1603	0.0097	9.7
13-Nov-13	19	LL5	75			0.1271	0.1822	0.1694	0.0128	12.8
13-Nov-13	20	LL5	75			0.1261	0.1808	0.1677	0.0131	13.1
13-Nov-13	21	LL1	75			0.1259	0.2412	0.2180	0.0232	23.2
13-Nov-13	22	LL1	75			0.1267	0.2441	0.2196	0.0245	24.5
13-Nov-13	23	LL1	75			0.1265	0.2426	0.2175	0.0251	25.1
13-Nov-13	24	LL1	75			0.1245	0.2167	0.1968	0.0199	19.9
13-Nov-13	25	LL1	75			0.1268	0.2116	0.1927	0.0189	18.9

Appendix 5: 2013 Water Chemistry Results

Station	Date	Depth m	NO3 mg/L	TDP mg/L	TP mg/L	Chl a ug/L	Chl a ug/L	Alkalinity mgCaCO3/L
Hayward	24-MAR-13	Comp	0.136	0.0012	0.0028	0.056	.	.
Stave	24-MAR-13	Comp	0.127	0.0011	0.0017	0.134	.	.
Alouette	24-MAR-13	Comp	0.13	0.0017	0.0019	<0.010		
Hayward	04-MAY-13	Comp	0.12	<0.0010	0.0014	0.037	.	.
Stave	04-MAY-13	Comp	0.118	<0.0010	0.0013	0.415	.	.
Alouette	04-MAY-13	Comp	0.12	<0.0010	<0.0010	0.224	.	.
Hayward	31-MAY-13	Comp	0.0964	<0.0010	<0.0010	0.173	.	.
Hayward	31-MAY-13	1	.	.	.	.	0.118	3.1
Hayward	31-MAY-13	3	.	.	.	.	0.394	.
Hayward	31-MAY-13	5	.	.	.	.	0.044	.
Hayward	31-MAY-13	7	.	.	.	.	0.249	.
Hayward	31-MAY-13	10	.	.	.	.	0.332	2.8
Stave	31-MAY-13	Comp	0.0976	<0.0010	<0.0010	0.16	.	.
Stave	31-MAY-13	1	.	.	.	.	0.091	7.5
Stave	31-MAY-13	3	.	.	.	.	0.414	.
Stave	31-MAY-13	5	.	.	.	.	0.069	.
Stave	31-MAY-13	7	.	.	.	.	0.086	.
Stave	31-MAY-13	10	.	.	.	.	0.062	2.7
Alouette	31-MAY-13	ns						
Hayward	06-JUL-13	Comp	0.0692	0.001	0.0017	0.451	.	.
Hayward	06-JUL-13	1	.	.	.	.	0.307	3.3
Hayward	06-JUL-13	3	.	.	.	.	0.237	.
Hayward	06-JUL-13	5	.	.	.	.	0.204	.
Hayward	06-JUL-13	7	.	.	.	.	0.363	.
Hayward	06-JUL-13	10	.	.	.	.	0.532	3.1
Stave	06-JUL-13	Comp	0.0591	0.0015	<0.0010	0.466	.	.
Stave	06-JUL-13	1	.	.	.	.	0.441	3.7
Stave	06-JUL-13	3	.	.	.	.	0.266	.
Stave	06-JUL-13	5	.	.	.	.	0.32	.
Stave	06-JUL-13	7	.	.	.	.	0.44	.
Stave	06-JUL-13	10	.	.	.	.	0.691	2.9
Alouette	06-JUL-13	Comp	0.0602	0.0016	0.0018	0.205	.	.
Hayward	06-AUG-13	Comp	0.036	<0.0010	<0.0010	0.517	.	.
Hayward	06-AUG-14	1	.	.	.	.	0.331	3.3
Hayward	06-AUG-13	3	.	.	.	.	0.569	.
Hayward	06-AUG-14	5	.	.	.	.	0.502	.
Hayward	06-AUG-13	7	.	.	.	.	0.51	.
Hayward	06-AUG-14	10	.	.	.	.	0.588	3
Stave	06-AUG-13	Comp	0.0296	<0.0010	<0.0010	0.292	.	.
Stave	06-AUG-14	1	.	.	.	.	0.307	3.3
Stave	06-AUG-13	3	.	.	.	.	0.429	.

Station	Date	Depth m	NO3 mg/L	TDP mg/L	TP mg/L	Chl a ug/L	Chl a ug/L	Alkalinity mgCaCO3/L
Stave	06-AUG-14	5	.	.	.	.	0.441	.
Stave	06-AUG-13	7	.	.	.	.	0.584	.
Stave	06-AUG-14	10	.	.	.	.	0.719	2.9
Alouette	06-AUG-13	ns					.	.
Hayward	13-SEP-13	Comp	0.0242	<0.0010	0.0019	0.311	.	.
Hayward	13-SEP-13	1	.	.	.	.	0.331	3.8
Hayward	13-SEP-13	3	.	.	.	.	0.527	.
Hayward	13-SEP-13	5	.	.	.	.	0.258	.
Hayward	13-SEP-13	7	.	.	.	.	0.279	.
Hayward	13-SEP-13	10	.	.	.	.	0.324	3.8
Stave	13-SEP-13	Comp	0.0302	<0.0010	0.0017	0.228	.	.
Stave	13-SEP-13	1	.	.	.	.	0.304	4.5
Stave	13-SEP-13	3	.	.	.	.	0.219	.
Stave	13-SEP-13	5	.	.	.	.	0.336	.
Stave	13-SEP-13	7	.	.	.	.	0.137	.
Stave	13-SEP-13	10	.	.	.	.	0.384	3.5
Alouette	13-SEP-13	.	0.0304	<0.0010	0.0026	0.36	.	.
Hayward	20-OCT-13	.	0.0752	<0.0010	<0.0010	1.08	.	.
Hayward	20-OCT-13	1	.	.	.	.	0.832	3.2
Hayward	20-OCT-13	3	.	.	.	.	0.782	.
Hayward	20-OCT-13	5	.	.	.	.	1.08	.
Hayward	20-OCT-13	7	.	.	.	.	0.982	.
Hayward	20-OCT-13	10	.	.	.	.	0.569	3.1
Stave	20-OCT-13	Comp	0.0694	<0.0010	<0.0010	0.889	.	.
Stave	20-OCT-13	1	.	.	.	.	0.777	2.8
Stave	20-OCT-13	3	.	.	.	.	0.497	.
Stave	20-OCT-13	5	.	.	.	.	1.01	.
Stave	20-OCT-13	7	.	.	.	.	0.46	.
Stave	20-OCT-13	10	.	.	.	.	0.64	2.6
Alouette	20-OCT-13	Comp	0.0522	0.0013	0.0021	0.665	.	.
Hayward	27-NOV-13	Comp	0.142	0.0018	0.0041	0.378	.	.
Stave	27-NOV-13	Comp	0.105	0.0027	0.0066	0.77	.	.
Alouette	27-NOV-13		0.0848	0.001	0.0023	0.75		

Appendix 6: 2013 Phytoplankton Results

Hayward

Class	Size category	Species	Edible/ In-edible/ Both	24-Mar-13 BioV. mm3/L	04-May-13 BioV. mm3/L	31-May-13 BioV. mm3/L	06-Jul-13 BioV. mm3/L	06-Aug-13 BioV. mm3/L	13-Sep-13 BioV. mm3/L	18-Oct-13 BioV. mm3/L	26-Nov-13 BioV. mm3/L		24-Mar-13 No. Cells/mL	04-May-13 No. Cells/mL	31-May-13 No. Cells/mL	06-Jul-13 No. Cells/mL	06-Aug-13 No. Cells/mL	13-Sep-13 No. Cells/mL	18-Oct-13 No. Cells/mL	26-Nov-13 No. Cells/mL
Bacillariophyceae (diatoms)	nano	*Achnanthidium spp.*	e	0.0057	0.0032	0.0008	0.0008	0.0008	0.0008	0.0016	0.0016		70.96	40.55	10.14	10.14	10.14	10.14	20.27	20.27
Bacillariophyceae (diatoms)	nano	*Fragilaria construens*	e	0.0016									20.27							
Bacillariophyceae (diatoms)	macro	*Cyclotella stelligera*	e	0.0015	0.0015								10.14	10.14						
Bacillariophyceae (diatoms)	nano	*Cyclotella glomerata*	e		0.0025				0.0010		0.0005			50.68				20.27		10.14
Chlorophyceae (coccoid greens, desmids, etc.)		*Scenedesmus sp.*	e					0.0012	0.0006	0.0012							20.27	10.14	20.27	
Chlorophyceae (coccoid greens, desmids, etc.)		*Sphaerocystis sp.*	e						0.0091									30.41		
Chlorophyceae (coccoid greens, desmids, etc.)		*Cosmarium sp.*	e																	
Chlorophyceae (coccoid greens, desmids, etc.)		*Coccomyxa sp.*	e						0.0016									20.27		
Chlorophyceae (coccoid greens, desmids, etc.)	nano	*Ankistrodesmus sp.*	e	0.0008		0.0008	0.0008	0.0016		0.0016			10.14		10.14	10.14	20.27		20.27	
Chlorophyceae (coccoid greens, desmids, etc.)	nano	*Elakatothrix sp.*	e			0.0014									70.96					
Chlorophyceae (coccoid greens, desmids, etc.)	macro	*Chlorella sp.*	e	0.0010	0.0010	0.0023	0.0012	0.0018	0.0022	0.0010			50.68	50.68	10.14	60.82	91.23	111.51	50.68	
Chlorophyceae (coccoid greens, desmids, etc.)	nano	*Tetraedron sp.*	e			0.0020									30.41					
Chlorophyceae (coccoid greens, desmids, etc.)	nano	*Monoraphidium sp.*	e																	
Chlorophyceae (coccoid greens, desmids, etc.)	macro	*Clamydocapsa sp.*	e																	
Chlorophyceae (coccoid greens, desmids, etc.)	macro	*Oocystis sp.*	e					0.0101	0.0355	0.0101							20.27	70.96	20.27	
Chlorophyceae (coccoid greens, desmids, etc.)	nano	*Gleotila sp.*	e																	
Chlorophyceae (coccoid greens, desmids, etc.)	nano	*Stichococcus minutissimus*	e																	
Chlorophyceae (coccoid greens, desmids, etc.)	macro	*Coelastrum sp.*	e					0.0051	0.0101								10.14	20.27		
Chlorophyceae (coccoid greens, desmids, etc.)	macro	*Planctosphaeria sp.*	e																	
Chlorophyceae (coccoid greens, desmids, etc.)		*Gyromitus sp.*	e		0.0023			0.0023	0.0046	0.0023				10.14			10.14	20.27	10.14	
Chlorophyceae (coccoid greens, desmids, etc.)		*Botryococcus sp.*	e	0.0066									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	0.0025	0.0025				10.14			10.14	20.27	20.27	
Chlorophyceae (coccoid greens, desmids, etc.)		*Scourfieldia sp.*	e	0.0013	0.0020		0.0020	0.0026	0.0013	0.0013			20.27	30.41		30.41	40.55	20.27	20.27	
Chryso- & Cryptophyceae (flagellates)		*Pseudokephrion sp.*	e		0.0010				0.0010					10.14				10.14		
Chryso- & Cryptophyceae (flagellates)	nano	*Chromulina sp.*	e	0.0004	0.0006	0.0010	0.0012	0.0045	0.0008	0.0004	0.0004		20.27	30.41	50.68	60.82	223.01	40.55	20.27	20.27
Chryso- & Cryptophyceae (flagellates)	nano	*Chrysochromulina sp.*	e	0.0053	0.0099	0.0015	0.0015	0.0030	0.0030	0.0023	0.0023		70.96	131.78	20.27	20.27	40.55	40.55	30.41	30.41
Chryso- & Cryptophyceae (flagellates)	nano	*Chryptomonas spp.*	e	0.0051	0.0051	0.0051	0.0101	0.0051	0.0051	0.0051	0.0051		10.14	10.14	10.14	20.27	10.14	10.14	10.14	10.14
Chryso- & Cryptophyceae (flagellates)	nano	*Boda spp.*	e					0.0038									50.68			
Chryso- & Cryptophyceae (flagellates)	nano	*Ochromonas sp.*	e	0.0152	0.0583	0.0482	0.0253	0.0887	0.1014	0.0405	0.0076		60.82	233.15	192.60	101.37	354.79	405.47	162.19	30.41
Chryso- & Cryptophyceae (flagellates)	nano	*Mallomonas sp.*	e		0.0071			0.0015						10.14			30.41			
Chryso- & Cryptophyceae (flagellates)	nano	*Kephyrion sp.*	e		0.0005	0.0010	0.0010	0.0030	0.0015					10.14	20.27	20.27	30.41	30.41		
Chryso- & Cryptophyceae (flagellates)	nano	*Dinobryon sp.*	e		0.0122	0.0020	0.0061	0.0073		0.0264				60.82	10.14	30.41	486.57		131.78	
Chryso- & Cryptophyceae (flagellates)	nano	*Small microflagellates*	e	0.0062	0.0082	0.0040	0.0030		0.0088	0.0050	0.0076		415.61	547.39	263.56	202.74		587.94	334.52	506.84
Chryso- & Cryptophyceae (flagellates)		*Chroomonas acuta*	e	0.0030	0.0053	0.0084	0.0068		0.0046	0.0076	0.0053		40.55	70.96	111.51	91.23		60.82	101.37	70.96
Chryso- & Cryptophyceae (flagellates)		*Chrysococcus sp.*	e		0.0020	0.0020	0.0030		0.0020	0.0030	0.0041			20.27	20.27	30.41		20.27	30.41	40.55
Chryso- & Cryptophyceae (flagellates)		*Uroglena sp.*	e				0.0018									10.14				
Chryso- & Cryptophyceae (flagellates)		*Komma spp.*	e		0.0010	0.0010	0.0010			0.0010	0.0020			10.14	10.14	10.14			10.14	20.27
Cyanophyceae (blue-greens)	pico	*Synechococcus sp. (coccoid)*	e	0.0004	0.0008	0.0005	0.0002	0.0003	0.0007	0.0005			70.96	162.19	101.37	30.41	60.82	141.92	91.23	
Cyanophyceae (blue-greens)	pico	*Synechococcus sp (rod)*	e	0.0024	0.0045	0.0020	0.0016	0.0041	0.0124	0.0118			121.64	223.01	101.37	81.09	202.74	618.35	587.94	
Cyanophyceae (blue-greens)	nano	*Synechocystis sp.*	e	0.0002		0.0003	0.0004	0.0008	0.0013	0.0005			20.27		30.41	40.55	81.09	131.78	50.68	
		Total		0.0568	0.1334	0.0843	0.0711	0.1490	0.2121	0.1258	0.0365		1023.8	1743.5	1074.5	871.8	1804.4	2453.1	1743.5	760.3

Hayward

Class	Size category	Species	Edible/ In-edible/ Both	24-Mar-13 BioV. mm3/L	04-May-13 BioV. mm3/L	31-May-13 BioV. mm3/L	06-Jul-13 BioV. mm3/L	06-Aug-13 BioV. mm3/L	13-Sep-13 BioV. mm3/L	18-Oct-13 BioV. mm3/L	26-Nov-13 BioV. mm3/L		24-Mar-13 No. Cells/mL	04-May-13 No. Cells/mL	31-May-13 No. Cells/mL	06-Jul-13 No. Cells/mL	06-Aug-13 No. Cells/mL	13-Sep-13 No. Cells/mL	18-Oct-13 No. Cells/mL	26-Nov-13 No. Cells/mL
Bacillariophyceae (diatoms)		*Asterionella formosa*	i																	
Bacillariophyceae (diatoms)	macro	*Fragilaria capucina*	i	0.0010	0.0010								10.14	10.14						
Bacillariophyceae (diatoms)	macro	*Fragilaria crotonensis*	i																	
Bacillariophyceae (diatoms)	macro	*Synedra nana*	i																	
Bacillariophyceae (diatoms)	macro	*Synedra acus*	i																	
Bacillariophyceae (diatoms)		*Synedra acus var angustissima*	i																	
Bacillariophyceae (diatoms)	macro	*Navicula sp.*	i		0.0051	0.0051	0.0051		0.0051	0.0101	0.0051			10.14	10.14	10.14		10.14	20.27	10.14
Bacillariophyceae (diatoms)	macro	*Frustrulia spp.*	i																	
Bacillariophyceae (diatoms)		*Pinnularia sp.*	i																	
Bacillariophyceae (diatoms)		*Rhizosolenia sp.*	i																	
Bacillariophyceae (diatoms)		*Tabellaria fenestrata*	i	0.0152					0.0051	0.0101			30.41					10.14	20.27	
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																	
Cyanophyceae (blue-greens)	macro	*Gomphosphaeria sp.*	i																	
Cyanophyceae (blue-greens)	macro	*Lyngbya sp.*	i																	
Cyanophyceae (blue-greens)	macro	*Aphanothecae sp.*	i					0.0061	0.0122	0.0081							60.82	121.64	81.09	
Cyanophyceae (blue-greens)	macro	*Microcystis sp.*	i					0.0018									1824.64			
Cyanophyceae (blue-greens)	macro	*Gomphosphaeria sp.*	i																	
Cyanophyceae (blue-greens)		*Pseudoanabaena sp.*	i	0.0304	0.0091								101.37	30.41						
		Synedra ulna	i																	
		Limnothrix redekei	i																	
		Total		0.0466	0.0152	0.0051	0.0051	0.0079	0.0223	0.0284	0.0051		141.9	50.7	10.1	10.1	1885.5	141.9	121.6	10.1
Bacillariophyceae (diatoms)		*Cyclotella comta*	i/e																	
Bacillariophyceae (diatoms)	macro	*Eunotia sp.*	i/e							0.0025									10.14	
Bacillariophyceae (diatoms)	macro	*Cymbella sp.*	i/e																	
Cyanophyceae (blue-greens)	macro	*Merismopedia sp.*	i/e					0.0568	0.4622	0.0924							2838.32	23112.07	4622.41	
Cyanophyceae (blue-greens)	macro	*Chroococcus sp.*	i/e					0.0152	0.0380	0.0152							20.27	50.68	20.27	
Dinophyceae (dinoflagellates)	macro	*Peridinium spp.*	i/e			0.0035		0.0035		0.0035					10.14		10.14		10.14	
Dinophyceae (dinoflagellates)	macro	*Gymnodinium sp. (large).*	i/e	0.0051	0.0152	0.0152	0.0152	0.0304	0.0304	0.0152	0.0152		10.14	10.14	10.14	10.14	20.27	20.27	10.14	10.14
Dinophyceae (dinoflagellates)	macro	*Gymnodinium sp. (small)*	i/e		0.0051	0.0152	0.0051	0.0051	0.0203	0.0101	0.0051			10.14	30.41	10.14	10.14	40.55	20.27	10.14
		Total		0.0051	0.0203	0.0340	0.0203	0.1110	0.5509	0.1391	0.0203		10.14	20.27	50.68	20.27	2899.15	23223.57	4693.37	20.27

Stave

Class	Size category	Species	Edible/ In-edible/ Both	24-Mar-13 BioV. mm3/L	04-May-13 BioV. mm3/L	31-May-13 BioV. mm3/L	06-Jul-13 BioV. mm3/L	06-Aug-13 BioV. mm3/L	13-Sep-13 BioV. mm3/L	18-Oct-13 BioV. mm3/L	26-Nov-13 BioV. mm3/L		24-Mar-13 No. Cells/mL	04-May-13 No. Cells/mL	31-May-13 No. Cells/mL	06-Jul-13 No. Cells/mL	06-Aug-13 No. Cells/mL	13-Sep-13 No. Cells/mL	18-Oct-13 No. Cells/mL	26-Nov-13 No. Cells/mL
Bacillariophyceae (diatoms)	nano	*Achnanthidium spp.*	e	0.0016	0.0041	0.0016	0.0008	0.0008	0.0008	0.0008	0.0008		20.27	50.68	20.27	10.14	10.14	10.14	10.14	10.14
Bacillariophyceae (diatoms)	nano	*Fragilaria construens*	e	0.0008	0.0020						0.0015		10.14	20.27						30.41
Bacillariophyceae (diatoms)	macro	*Cyclotella stelligera*	e		0.0015	0.0030								10.14	20.27					
Bacillariophyceae (diatoms)	nano	*Cyclotella glomerata*	e		0.0005	0.0030								10.14	60.82					
Chlorophyceae (coccoid greens, desmids, etc.)	nano	*Ankistrodesmus sp.*	e	0.0008	0.0008	0.0008	0.0008	0.0016	0.0016	0.0008	0.0016		10.14	10.14	10.14	10.14	20.27	20.27	10.14	20.27
Chlorophyceae (coccoid greens, desmids, etc.)	nano	*Elakatothrix sp.*	e					0.0051			0.0025						20.27			10.14
Chlorophyceae (coccoid greens, desmids, etc.)	macro	*Chlorella sp.*	e	0.0006	0.0014	0.0018	0.0014	0.0022	0.0012	0.0010	0.0012		30.41	70.96	91.23	70.96	111.51	60.82	50.68	60.82
Chlorophyceae (coccoid greens, desmids, etc.)	nano	*Tetraedron sp.*	e																	
Chlorophyceae (coccoid greens, desmids, etc.)	nano	*Monoraphidium sp.*	e	0.0020									10.14							
Chlorophyceae (coccoid greens, desmids, etc.)	macro	*Clamydocapsa sp.*	e						0.0056									10.14		
Chlorophyceae (coccoid greens, desmids, etc.)	macro	*Oocystis sp.*	e						0.0152	0.0152								30.41	30.41	
Chlorophyceae (coccoid greens, desmids, etc.)	nano	*Gleotila sp.*	e																	
Chlorophyceae (coccoid greens, desmids, etc.)	nano	*Stichococcus minutissimus*	e																	
Chlorophyceae (coccoid greens, desmids, etc.)	macro	*Coelastrum sp.*	e		0.0051					0.0051				10.14					10.14	
Chlorophyceae (coccoid greens, desmids, etc.)	macro	*Planctosphaeria sp.*	e																	
Chlorophyceae (coccoid greens, desmids, etc.)	macro	*Sphaerocystis sp.*	e																	
Chlorophyceae (coccoid greens, desmids, etc.)		*Staurastrum sp.*	e								0.0152									10.14
Chlorophyceae (coccoid greens, desmids, etc.)		*Nephroselmis sp.*	e					0.0013	0.0025	0.0025							10.14	20.27	20.27	
Chlorophyceae (coccoid greens, desmids, etc.)		*Gyromitus sp.*	e			0.0046									20.27					
Chlorophyceae (coccoid greens, desmids, etc.)		*Monomastic sp.*	e				0.0030									10.14				
Chlorophyceae (coccoid greens, desmids, etc.)		*Botryococcus sp.*	e					0.0066		0.0066							10.14		10.14	
Chlorophyceae (coccoid greens, desmids, etc.)		*Gyromitus sp.*	e		0.0023			0.0023	0.0023	0.0023				10.14			10.14	10.14	10.14	
Chlorophyceae (coccoid greens, desmids, etc.)		*Scourfieldia sp.*	e				0.0013	0.0033	0.0020	0.0020						20.27	50.68	30.41	30.41	
Chlorophyceae (coccoid greens, desmids, etc.)		*Pyramimonas sp.*	e																	
Chryso- & Cryptophyceae (flagellates)	nano	*Chromulina sp.*	e	0.0004	0.0004	0.0006	0.0004	0.0028	0.0014	0.0006	0.0002		20.27	20.27	30.41	20.27	141.92	70.96	30.41	10.14
Chryso- & Cryptophyceae (flagellates)	nano	*Chrysochromulina sp.*	e	0.0038	0.0061	0.0038	0.0023	0.0038	0.0015	0.0008	0.0008		50.68	81.09	50.68	30.41	50.68	20.27	10.14	10.14
Chryso- & Cryptophyceae (flagellates)	nano	*Chryptomonas spp.*	e		0.0041	0.0051	0.0051	0.0051	0.0051	0.0051	0.0152			40.55	10.14	10.14	10.14	10.14	10.14	30.41
Chryso- & Cryptophyceae (flagellates)	nano	*Boda spp.*	e		0.0038		0.0010			0.0046	0.0020			50.68		10.14			60.82	20.27
Chryso- & Cryptophyceae (flagellates)	nano	*Ochromonas sp.*	e	0.0152	0.0203		0.0023	0.0532	0.1166	0.0279	0.0046		60.82	81.09		30.41	212.87	466.30	111.51	60.82
Chryso- & Cryptophyceae (flagellates)	nano	*Mallomonas sp.*	e		0.0010		0.0228			0.0005	0.0076			20.27		91.23			10.14	30.41
Chryso- & Cryptophyceae (flagellates)	nano	*Kephyrion sp.*	e		0.0010	0.0015	0.0010	0.0005	0.0005	0.0041	0.0030			10.14	30.41	20.27	10.14	10.14	20.27	30.41
Chryso- & Cryptophyceae (flagellates)	nano	*Dinobryon sp.*	e		0.0020	0.0041	0.0020			0.0010	0.0030			10.14	20.27	20.27			10.14	202.74
Chryso- & Cryptophyceae (flagellates)	nano	*Small microflagellates*	e	0.0062	0.0078	0.0036	0.0122	0.0078	0.0094	0.0030	0.0364		415.61	516.98	243.28	60.82	516.98	628.49	202.74	395.34
Chryso- & Cryptophyceae (flagellates)	nano	*Isthmochloron sp.*	e		0.0008		0.0010							10.14		10.14				
Chryso- & Cryptophyceae (flagellates)	nano	*Bitrichia sp.*	e		0.0472		0.0029							841.36		192.60				
Chryso- & Cryptophyceae (flagellates)		*Chroomonas acuta*	e	0.0053		0.0084	0.0530	0.0023	0.0046				70.96		111.51	496.71	30.41	60.82		
Chryso- & Cryptophyceae (flagellates)		*Chrysococcus sp.*	e	0.0010		0.0329		0.0041	0.0041				10.14		131.78		40.55	40.55		
Chryso- & Cryptophyceae (flagellates)		*Uroglena sp.*	e			0.0010									10.14					
Chryso- & Cryptophyceae (flagellates)		*Pseudokephrion sp.*	e																	
Cyanophyceae (blue-greens)	pico	*Synechococcus sp. (coccoid)*	e	0.0002	0.0008	0.0004	0.0002	0.0005	0.0006	0.0004	0.0013		40.55	162.19	81.09	40.55	91.23	121.64	70.96	253.42
Cyanophyceae (blue-greens)	pico	*Synechococcus sp (rod)*	e	0.0026	0.0081	0.0006	0.0022	0.0061	0.0075	0.0077	0.0446		131.78	405.47	30.41	111.51	304.11	375.06	385.20	2230.11
Cyanophyceae (blue-greens)	nano	*Synechocystis sp.*	e	0.0003	0.0005	0.0002	0.0004	0.0010	0.0011	0.0004	0.0014		30.41	50.68	20.27	40.55	101.37	111.51	40.55	141.92
		Komma spp.	e	0.0010		0.0010		0.0010	0.0020				10.14		10.14		10.14	20.27		
		Carteria sp.	e																	
		Scenedesmus sp.	e		0.0007	0.0020	0.0012	0.0006	0.0006		0.0012			10.14	30.41	20.27	10.14	10.14		20.27
		Phacus sp.	e								0.0071									10.14
		Total		0.0420	0.1221	0.0801	0.1174	0.1119	0.1862	0.0922	0.1514		922.5	2503.8	1034.0	1327.9	1774.0	2138.9	1145.5	3588.5

Stave

Class	Size category	Species	Edible/ In-edible/ Both	24-Mar-13 BioV. mm3/L	04-May-13 BioV. mm3/L	31-May-13 BioV. mm3/L	06-Jul-13 BioV. mm3/L	06-Aug-13 BioV. mm3/L	13-Sep-13 BioV. mm3/L	18-Oct-13 BioV. mm3/L	26-Nov-13 BioV. mm3/L		24-Mar-13 No. Cells/mL	04-May-13 No. Cells/mL	31-May-13 No. Cells/mL	06-Jul-13 No. Cells/mL	06-Aug-13 No. Cells/mL	13-Sep-13 No. Cells/mL	18-Oct-13 No. Cells/mL	26-Nov-13 No. Cells/mL
Bacillariophyceae (diatoms)		*Asterionella formosa*	i																	
Bacillariophyceae (diatoms)	macro	*Fragilaria capucina*	i	0.0051							0.0203		10.14							40.55
Bacillariophyceae (diatoms)	macro	*Fragilaria crotonensis*	i																	
Bacillariophyceae (diatoms)	macro	*Synedra acus var angustissima*	i																	
Bacillariophyceae (diatoms)	macro	*Synedra nana*	i		0.0008									10.14						
Bacillariophyceae (diatoms)		*Synedra ulna*	i																	
Bacillariophyceae (diatoms)	macro	*Synedra acus*	i		0.0010									10.14						
Bacillariophyceae (diatoms)	macro	*Navicula sp.*	i		0.0152	0.0051			0.0051					30.41	10.14			10.14		
Bacillariophyceae (diatoms)	macro	*Frustrulia spp.*	i																	
Bacillariophyceae (diatoms)	macro	*Amphora sp.*	i																	
Bacillariophyceae (diatoms)		*Tabellaria fenestrata*	i							0.0405									81.09	
Bacillariophyceae (diatoms)		*Rhizosolenia sp.*	i																	
Cyanophyceae (blue-greens)	macro	*Gomphosphaeria sp.*	i																	
Cyanophyceae (blue-greens)	macro	*Lyngbya sp.*	i						0.0101		0.0355							101.37		70.96
Cyanophyceae (blue-greens)	macro	*Aphanothecae sp.*	i					0.0061		0.0071	0.0091						60.82		70.96	91.23
Cyanophyceae (blue-greens)	macro	*Microcystis sp.*	i					0.0050	0.0032								5017.75	3193.11		
Cyanophyceae (blue-greens)	macro	*Gomphosphaeria sp.*	i																	
Cyanophyceae (blue-greens)	macro	*Anabaena spp.*	i																	
Cyanophyceae (blue-greens)	macro	*Rhaphidiopsis sp.*	i																	
Cyanophyceae (blue-greens)		*Pseudoanabaena sp.*	i	0.0243	0.0061								81.09	20.27						
		Total		0.0294	0.0231	0.0051	0.0000	0.0111	0.0184	0.0476	0.0649		91.2	71.0	10.1	0.0	5078.6	3304.6	152.1	202.7
Bacillariophyceae (diatoms)	macro	*Cyclotella comta*	i/e																	
Bacillariophyceae (diatoms)	macro	*Eunotia sp.*	i/e																	
Bacillariophyceae (diatoms)	macro	*Cymbella sp.*	i/e																	
Cyanophyceae (blue-greens)	macro	*Merismopedia sp.*	i/e					0.1314	0.4055	0.0633	0.0665						6568.69	20273.74	3162.70	3324.89
Cyanophyceae (blue-greens)	macro	*Chroococcus sp.*	i/e					0.0380	0.0228		0.0228						50.68	30.41		30.41
Dinophyceae (dinoflagellates)	macro	*Peridinium spp.*	i/e			0.0035	0.0035			0.0035	0.0035				10.14	10.14			10.14	10.14
Dinophyceae (dinoflagellates)	macro	*Gymnodinium sp. (large).*	i/e	0.0051	0.0152	0.0152	0.0152	0.0304	0.0152	0.0051			10.14	10.14	10.14	10.14	20.27	10.14	10.14	
Dinophyceae (dinoflagellates)	macro	*Gymnodinium sp. (small)*	i/e		0.0051	0.0152	0.0101	0.0152	0.0101		0.0101			10.14	30.41	20.27	30.41	20.27		20.27
		Total		0.0051	0.0203	0.0340	0.0289	0.2150	0.4536	0.0719	0.1030		10.1	20.3	50.7	40.5	6670.1	20334.6	3183.0	3385.7

Appendix 7: Picoplankton Results

Heterotrophic Bacteria

Lake	Date	Station	cells/ml	Biovolume (mm3/L)
Alouette	24/03/2013	Alouette	201683.7	0.0807
Alouette	24/03/2013	Alouette (SPL)	168897.7	0.0676
Hayward	24/03/2013	Hayward	202677.2	0.0811
Stave	24/03/2013	Stave	172871.7	0.0691
Alouette	04/05/2013	Alouette	163930.1	0.0656
Hayward	04/05/2013	Hayward	155982.0	0.0624
Hayward	04/05/2013	Hayward (SPL)	121871.3	0.0487
Stave	04/05/2013	Stave	137502.6	0.0550
Stave	04/05/2013	Stave (SPL)	165321.0	0.0661
Alouette	31/05/2013	Alouette	157969.0	0.0632
Alouette	06/07/2013	Alouette	460991.3	0.1844
Hayward	06/07/2013	Hayward	152007.9	0.0608
Stave	06/07/2013	Stave	229502.1	0.0918
Hayward	06/08/2013	Hayward	383497.0	0.1534
Stave	06/08/2013	Stave	319912.0	0.1280
Alouette	13/09/2013	Alouette	693076.5	0.2772
Hayward	13/09/2013	Hayward	616774.5	0.2467
Stave	13/09/2013	Stave	486425.3	0.1946
Alouette	18/10/2013	Alouette	512654.1	0.2051
Hayward	18/10/2013	Hayward	464965.3	0.1860
Stave	18/10/2013	Stave	480861.6	0.1923
Alouette	26/11/2013	Alouette	627901.9	0.2512
Hayward	26/11/2013	Hayward	488809.7	0.1955
Stave	26/11/2013	Stave	496757.8	0.1987

Pico-cyanobacteria

Lake	Date	Station	cells/ml	Biovolume (mm3/L)
Alouette	24/03/2013	Aloutte	20532.7	0.1027
Alouette	24/03/2013	Aloutte (SPL)	21857.3	0.1093
Hayward	24/03/2013	Hayward	14240.4	0.0712
Stave	24/03/2013	Stave	19539.1	0.0977
Alouette	04/05/2013	Aloutte	29639.9	0.1482
Hayward	04/05/2013	Hayward	9107.2	0.0455
Hayward	04/05/2013	Hayward (SPL)	6623.4	0.0331
Stave	04/05/2013	Stave	8610.5	0.0431
Stave	04/05/2013	Stave (SPL)	10045.5	0.0502
Alouette	31/05/2013	Aloutte	14682.0	0.0734
Alouette	06/07/2013	Aloutte	22298.9	0.1115
Hayward	06/07/2013	Hayward	14019.6	0.0701
Stave	06/07/2013	Stave	9383.2	0.0469
Hayward	06/08/2013	Hayward	58551.2	0.2928
Stave	06/08/2013	Stave	58021.3	0.2901
Alouette	13/09/2013	Alouette	218904.6	1.0945
Hayward	13/09/2013	Hayward	73122.8	0.3656
Stave	13/09/2013	Stave	95642.4	0.4782
Alouette	18/10/2013	Alouette	104319.1	0.5216
Hayward	18/10/2013	Hayward	134124.6	0.6706
Stave	18/10/2013	Stave	196716.1	0.9836
Alouette	26/11/2013	Alouette	229502.1	1.1475
Hayward	26/11/2013	Hayward	36649.7	0.1832
Stave	26/11/2013	Stave	91734.6	0.4587

Appendix 8: 2013 Hayward Zooplankton Results

									Daphnia rosea				Holopedium gibberum			
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)
24-Mar-13	0-15	15	1	60	60	NA	50.00	529.88	0	0.000	2.87	0.00	5	0.009	1.65	0.02
24-Mar-13	0-15	15	2	60	16	NA	50.00	529.88	1	0.007	3.06	0.02	3	0.021	1.10	0.02
24-Mar-13	0-15	15	3	60	60	NA	50.00	529.88	3	0.006	6.47	0.04	4	0.008	1.64	0.01
24-Mar-13	0-15	15	4	60	60	NA	50.00	529.88	5	0.009	2.70	0.03	5	0.009	0.99	0.01
24-Mar-13	0-15	15	5	60	60	NA	50.00	529.88	4	0.008	3.75	0.03	5	0.009	1.73	0.02
04-May-13	0-15	15	1	60	4	NA	50.00	529.88	1	0.028	3.25	0.09	9	0.255	2.64	0.67
04-May-13	0-15	15	2	90	4	NA	50.00	529.88	1	0.042	1.92	0.08	2	0.085	5.58	0.47
04-May-13	0-15	15	3	80	4	NA	50.00	529.88	2	0.075	10.17	0.77	1	0.038	1.93	0.07
04-May-13	0-15	15	4	90	4	NA	50.00	529.88	1	0.042	1.92	0.08	2	0.085	4.88	0.41
04-May-13	0-15	15	5	60	4	NA	50.00	529.88	4	0.113	6.41	0.73	1	0.028	1.93	0.05
31-May-13	0-15	15	1	80	8	NA	50.00	529.88	2	0.038	2.40	0.09	10	0.189	5.45	1.03
31-May-13	0-15	15	2	80	8	NA	50.00	529.88	3	0.057	4.76	0.27	14	0.264	7.66	2.02
31-May-13	0-15	15	3	80	8	NA	50.00	529.88	2	0.038	4.43	0.17	12	0.226	6.87	1.56
31-May-13	0-15	15	4	80	8	NA	50.00	529.88	2	0.038	3.59	0.14	17	0.321	6.69	2.15
31-May-13	0-15	15	5	80	8	NA	50.00	529.88	2	0.038	8.03	0.30	12	0.226	7.98	1.81
06-Jul-13	0-15	15	1	125	4	NA	50.00	529.88	7	0.413	4.63	1.91	113	6.664	8.78	58.51
06-Jul-13	0-15	15	2	120	4	NA	50.00	529.88	10	0.566	6.77	3.83	70	3.963	9.54	37.81
06-Jul-13	0-15	15	3	120	4	NA	50.00	529.88	7	0.396	9.96	3.95	71	4.020	7.94	31.92
06-Jul-13	0-15	15	4	100	4	NA	50.00	529.88	10	0.472	7.69	3.63	74	3.491	7.06	24.65
06-Jul-13	0-15	15	5	100	4	NA	50.00	529.88	6	0.283	9.07	2.57	86	4.058	8.70	35.30
06-Aug-13	0-15	15	1	60	4	NA	50.00	529.88	46	1.302	8.34	10.86	11	0.311	8.72	2.72
06-Aug-13	0-15	15	2	60	4	NA	50.00	529.88	37	1.047	7.68	8.04	6	0.170	4.95	0.84
06-Aug-13	0-15	15	3	60	4	NA	50.00	529.88	30	0.849	6.79	5.77	13	0.368	9.18	3.38
06-Aug-13	0-15	15	4	60	4	NA	50.00	529.88	29	0.821	6.85	5.62	11	0.311	11.52	3.59
06-Aug-13	0-15	15	5	60	4	NA	50.00	529.88	34	0.962	8.50	8.18	7	0.198	5.02	0.99
13-Sep-13	0-15	15	1	60	60	NA	50.00	529.88	116	0.219	8.05	1.76	101	0.191	6.00	1.14
13-Sep-13	0-15	15	2	60	12	NA	50.00	529.88	31	0.293	10.19	2.98	23	0.217	5.50	1.19
13-Sep-13	0-15	15	3	60	12	NA	50.00	529.88	31	0.293	5.39	1.58	25	0.236	5.19	1.22
13-Sep-13	0-15	15	4	60	12	NA	50.00	529.88	37	0.349	7.04	2.46	29	0.274	6.63	1.81
13-Sep-13	0-15	15	5	60	12	NA	50.00	529.88	30	0.283	8.40	2.38	25	0.236	5.81	1.37
18-Oct-13	0-15	15	1	100	16	NA	50.00	529.88	9	0.106	7.26	0.77	16	0.189	4.92	0.93
18-Oct-13	0-15	15	2	60	8	NA	50.00	529.88	6	0.085	10.56	0.90	20	0.283	6.78	1.92
18-Oct-13	0-15	15	3	60	8	NA	50.00	529.88	9	0.127	6.90	0.88	15	0.212	4.97	1.06
18-Oct-13	0-15	15	4	60	8	NA	50.00	529.88	9	0.127	6.36	0.81	12	0.170	7.89	1.34
18-Oct-13	0-15	15	5	60	8	NA	50.00	529.88	11	0.156	7.19	1.12	12	0.170	6.58	1.12
26-Nov-13	0-15	15	1	60	16	NA	50.00	529.88	3	0.021	13.22	0.28	1	0.007	1.93	0.01
26-Nov-13	0-15	15	2	60	12	NA	50.00	529.88	4	0.038	3.79	0.14	4	0.038	9.67	0.36
26-Nov-13	0-15	15	3	60	16	NA	50.00	529.88	2	0.014	6.30	0.09	5	0.035	9.55	0.34
26-Nov-13	0-15	15	4	60	16	NA	50.00	529.88	2	0.014	2.09	0.03	1	0.007	8.82	0.06
26-Nov-13	0-15	15	5	60	16	NA	50.00	529.88	2	0.014	3.16	0.04	7	0.050	6.46	0.32

Bosmina longriostris				Ergasilus sp				Calanoida: Diaptomus(oregonensis cf)				Cyclopidae: (Mircrocyclops rubellus cf)				Nauplii				Others			
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)
31	0.059	3.07	0.18	1	0.002	4.38	0.01	53	0.100	7.54	0.75	58	0.109	1.36	0.15	1365	2.576	0.22	0.57	5	0.009	1.50	0.01
22	0.156	3.30	0.51	0	0.000	0.00	0.00	24	0.170	8.01	1.36	26	0.184	1.61	0.30	522	3.694	0.21	0.78	4	0.028	0.68	0.02
48	0.091	4.41	0.40	1	0.002	4.19	0.01	89	0.168	8.62	1.45	85	0.160	1.20	0.19	1695	3.199	0.24	0.77	12	0.023	1.00	0.02
45	0.085	4.55	0.39	1	0.002	4.77	0.01	62	0.117	8.77	1.03	64	0.121	1.79	0.22	1680	3.171	0.26	0.82	7	0.013	0.40	0.01
44	0.083	4.35	0.36	1	0.002	5.18	0.01	64	0.121	8.46	1.02	66	0.125	1.52	0.19	1740	3.284	0.24	0.79	15	0.028	1.04	0.03
20	0.566	4.53	2.56	5	0.142	4.46	0.63	64	1.812	0.83	1.50	180	5.096	1.68	8.56	244	6.907	0.34	2.35	6	0.170	0.34	0.06
10	0.425	4.08	1.73	1	0.042	4.77	0.20	34	1.444	1.92	2.77	126	5.350	1.42	7.60	140	5.945	0.33	1.96	0	0.000	0.00	0.00
7	0.264	3.98	1.05	1	0.038	4.00	0.15	21	0.793	1.77	1.40	141	5.322	1.54	8.20	137	5.171	0.37	1.91	1	0.038	0.47	0.02
8	0.340	5.22	1.77	1	0.042	4.57	0.19	31	1.316	1.94	2.55	122	5.180	2.45	12.69	132	5.605	0.34	1.91	2	0.085	0.20	0.02
9	0.255	5.20	1.32	0	0.000	0.00	0.00	22	0.623	1.67	1.04	144	4.076	1.64	6.69	177	5.011	0.34	1.70	0	0.000	0.00	0.00
35	0.661	5.68	3.75	7	0.132	4.89	0.65	19	0.359	5.89	2.11	66	1.246	3.64	4.53	111	2.095	0.31	0.65	6	0.113	13.54	1.53
51	0.962	4.46	4.29	10	0.189	4.59	0.87	25	0.472	4.54	2.14	71	1.340	3.64	4.88	126	2.378	0.30	0.71	2	0.038	13.76	0.52
34	0.642	2.47	1.58	9	0.170	4.66	0.79	20	0.377	5.81	2.19	51	0.962	3.81	3.67	89	1.680	0.25	0.42	5	0.094	14.45	1.36
46	0.868	5.06	4.39	12	0.226	3.88	0.88	20	0.377	5.35	2.02	82	1.548	3.88	6.00	89	1.680	0.25	0.42	11	0.208	11.91	2.47
44	0.830	3.95	3.28	5	0.094	4.62	0.44	16	0.302	5.07	1.53	69	1.302	3.54	4.61	67	1.264	0.32	0.40	6	0.113	16.39	1.86
41	2.418	4.36	10.54	0	0.000	0.00	0.00	14	0.826	1.16	0.96	2	0.118	7.37	0.87	66	3.892	0.25	0.97	1	0.059	0.37	0.02
28	1.585	4.43	7.02	0	0.000	0.00	0.00	21	1.189	1.04	1.24	6	0.340	1.97	0.67	66	3.737	0.24	0.90	1	0.057	5.46	0.31
26	1.472	5.27	7.76	2	0.113	4.67	0.53	21	1.189	2.09	2.48	8	0.453	3.86	1.75	64	3.623	0.25	0.91	1	0.057	6.73	0.38
58	2.736	3.99	10.92	1	0.047	4.97	0.23	24	1.132	1.57	1.78	5	0.236	4.79	1.13	87	4.105	0.32	1.31	0	0.000	0.00	0.00
45	2.123	5.55	11.78	3	0.142	4.57	0.65	20	0.944	1.20	1.13	8	0.377	4.41	1.66	83	3.916	0.25	0.98	1	0.047	6.37	0.30
2	0.057	2.20	0.12	1	0.028	4.97	0.14	85	2.406	3.71	8.93	35	0.991	2.27	2.25	283	8.011	0.31	2.48	1	0.028	30.69	0.87
2	0.057	3.84	0.22	1	0.028	3.31	0.09	105	2.972	2.87	8.53	54	1.529	1.49	2.28	261	7.389	0.38	2.81	4	0.113	10.33	1.17
3	0.085	2.04	0.17	2	0.057	4.00	0.23	107	3.029	2.16	6.54	36	1.019	1.69	1.72	348	9.851	0.28	2.76	1	0.028	15.34	0.43
6	0.170	3.08	0.52	0	0.000	0.00	0.00	99	2.803	3.62	10.15	26	0.736	1.61	1.18	213	6.030	0.29	1.75	3	0.085	18.18	1.54
1	0.028	2.59	0.07	0	0.000	0.00	0.00	90	2.548	3.89	9.91	45	1.274	1.91	2.43	296	8.379	0.32	2.68	0	0.000	0.00	0.00
118	0.223	1.66	0.37	0	0.000	0.00	0.00	195	0.368	2.79	1.03	76	0.143	1.97	0.28	350	0.661	0.33	0.22	55	0.104	14.11	1.46
31	0.293	3.25	0.95	0	0.000	0.00	0.00	53	0.500	4.34	2.17	17	0.160	2.32	0.37	71	0.670	0.46	0.31	20	0.189	13.04	2.46
37	0.349	2.48	0.87	0	0.000	0.00	0.00	42	0.396	5.15	2.04	27	0.255	2.92	0.74	107	1.010	0.36	0.36	12	0.113	11.11	1.26
30	0.283	2.98	0.84	0	0.000	0.00	0.00	44	0.415	3.72	1.54	26	0.245	2.26	0.55	131	1.236	0.38	0.47	10	0.094	9.68	0.91
41	0.387	3.45	1.33	0	0.000	0.00	0.00	56	0.528	4.74	2.50	30	0.283	2.77	0.78	113	1.066	0.31	0.33	18	0.170	10.60	1.80
54	0.637	4.69	2.99	1	0.012	4.97	0.06	50	0.590	4.15	2.45	36	0.425	3.24	1.38	67	0.790	0.33	0.26	1	0.012	10.11	0.12
48	0.679	4.08	2.77	1	0.014	4.38	0.06	45	0.637	2.52	1.61	47	0.665	3.86	2.57	77	1.090	0.26	0.28	1	0.014	21.49	0.30
59	0.835	4.02	3.36	0	0.000	0.00	0.00	52	0.736	3.90	2.87	32	0.453	3.66	1.66	92	1.302	0.27	0.35	1	0.014	0.30	0.00
56	0.793	4.12	3.27	2	0.028	4.47	0.13	33	0.467	3.06	1.43	44	0.623	3.23	2.01	64	0.906	0.29	0.26	1	0.014	12.11	0.17
56	0.793	3.27	2.59	2	0.028	4.48	0.13	35	0.495	4.29	2.13	47	0.665	2.34	1.56	71	1.005	0.33	0.33	0	0.000	0.00	0.00
70	0.495	3.67	1.82	2	0.014	5.72	0.08	6	0.042	4.11	0.17	28	0.198	2.55	0.51	118	0.835	0.21	0.18	1	0.007	13.27	0.09
65	0.613	2.86	1.75	3	0.028	5.18	0.15	7	0.066	2.26	0.15	40	0.377	1.35	0.51	184	1.736	0.19	0.33	1	0.009	18.52	0.17
65	0.460	3.41	1.57	0	0.000	0.00	0.00	6	0.042	5.47	0.23	23	0.163	2.29	0.37	128	0.906	0.22	0.20	2	0.014	14.23	0.20
75	0.531	3.00	1.59	2	0.014	5.83	0.08	5	0.035	6.04	0.21	28	0.198	3.05	0.60	121	0.856	0.21	0.18	1	0.007	14.84	0.11
46	0.326	3.32	1.08	0	0.000	0.00	0.00	8	0.057	4.92	0.28	31	0.219	2.07	0.45	130	0.920	0.22	0.20	0	0.000	0.00	0.00

2013 Stave Zooplankton Results

Date	Sample Depth (m)	Tow Length(m)	Station	Dilution (mL)	Sub-sample Vol. (mL)	Flow	Net Eff. (%)	Tot Vol. (L)	Daphnia rosea Count	Daphnia rosea #/L	Daphnia rosea Day Wt (ug)	Daphnia rosea Biomass (ug/L)	Holopedium gibberum Count	Holopedium gibberum #/L	Holopedium gibberum Day Wt (ug)	Holopedium gibberum Biomass (ug/L)
24-Mar-13	0-20	20	1	60	8	NA	50.00	706.50	3	0.032	4.24	0.14	2	0.021	3.01	0.06
24-Mar-13	0-20	20	2	60	8	NA	50.00	706.50	3	0.032	1.76	0.06	0	0.000	0.00	0.00
24-Mar-13	0-20	20	3	60	8	NA	50.00	706.50	2	0.021	4.11	0.09	0	0.000	0.00	0.00
24-Mar-13	0-20	20	4	60	8	NA	50.00	706.50	5	0.053	4.92	0.26	1	0.011	1.35	0.01
24-Mar-13	0-20	20	5	60	8	NA	50.00	706.50	2	0.021	3.30	0.07	0	0.000	0.00	0.00
04-May-13	0-20	20	1	60	2	NA	50.00	706.50	1	0.042	1.65	0.07	1	0.042	2.28	0.10
04-May-13	0-20	20	2	60	2	NA	50.00	706.50	5	0.212	5.24	1.11	2	0.085	2.68	0.23
04-May-13	0-20	20	3	80	2	NA	50.00	706.50	1	0.057	7.79	0.44	1	0.057	0.88	0.05
04-May-13	0-20	20	4	80	2	NA	50.00	706.50	2	0.113	6.30	0.71	2	0.113	3.71	0.42
04-May-13	0-20	20	5	80	2	NA	50.00	706.50	1	0.057	9.64	0.55	0	0.000	0.00	0.00
31-May-13	0-20	20	1	60	8	NA	50.00	706.50	8	0.085	6.91	0.59	3	0.032	3.45	0.11
31-May-13	0-20	20	2	60	8	NA	50.00	706.50	9	0.096	6.68	0.64	5	0.053	6.53	0.35
31-May-13	0-20	20	3	60	8	NA	50.00	706.50	5	0.053	4.86	0.26	0	0.000	0.00	0.00
31-May-13	0-20	20	4	60	8	NA	50.00	706.50	7	0.074	2.75	0.20	2	0.021	3.01	0.06
31-May-13	0-20	20	5	60	8	NA	50.00	706.50	6	0.064	7.61	0.48	3	0.032	6.39	0.20
06-Jul-13	0-20	20	1	150	4	NA	50.00	706.50	30	1.592	9.71	15.46	47	2.495	10.08	25.15
06-Jul-13	0-20	20	2	100	4	NA	50.00	706.50	45	1.592	6.03	9.60	104	3.680	7.87	28.96
06-Jul-13	0-20	20	3	120	4	NA	50.00	706.50	48	2.038	9.07	18.49	85	3.609	9.64	34.79
06-Jul-13	0-20	20	4	120	4	NA	50.00	706.50	32	1.359	9.71	13.19	61	2.590	8.75	22.66
06-Jul-13	0-20	20	5	120	4	NA	50.00	706.50	43	1.826	7.65	13.97	59	2.505	10.30	25.80
06-Aug-13	0-20	20	1	60	4	NA	50.00	706.50	90	1.911	9.76	18.65	16	0.340	9.31	3.16
06-Aug-13	0-20	20	2	60	4	NA	50.00	706.50	73	1.550	6.50	10.07	29	0.616	9.23	5.68
06-Aug-13	0-20	20	3	60	4	NA	50.00	706.50	83	1.762	8.57	15.10	20	0.425	13.72	5.83
06-Aug-13	0-20	20	4	60	4	NA	50.00	706.50	92	1.953	8.80	17.19	13	0.276	8.72	2.41
06-Aug-13	0-20	20	5	60	4	NA	50.00	706.50	80	1.699	8.40	14.27	10	0.212	17.35	3.68
13-Sep-13	0-20	20	1	60	4	NA	50.00	706.50	87	1.847	11.11	20.52	23	0.488	5.13	2.51
13-Sep-13	0-20	20	2	60	4	NA	50.00	706.50	81	1.720	12.84	22.08	13	0.276	4.66	1.29
13-Sep-13	0-20	20	3	60	4	NA	50.00	706.50	66	1.401	8.37	11.73	13	0.276	6.54	1.81
13-Sep-13	0-20	20	4	60	4	NA	50.00	706.50	74	1.571	9.79	15.38	14	0.297	6.06	1.80
13-Sep-13	0-20	20	5	60	4	NA	50.00	706.50	82	1.741	7.27	12.66	11	0.234	5.72	1.34
18-Oct-13	0-20	20	1	60	8	NA	50.00	706.50	15	0.159	7.66	1.22	15	0.159	11.60	1.85
18-Oct-13	0-20	20	2	60	8	NA	50.00	706.50	16	0.170	8.78	1.49	27	0.287	9.79	2.81
18-Oct-13	0-20	20	3	60	8	NA	50.00	706.50	15	0.159	7.99	1.27	16	0.170	7.75	1.32
18-Oct-13	0-20	20	4	60	8	NA	50.00	706.50	16	0.170	8.30	1.41	15	0.159	8.94	1.42
18-Oct-13	0-20	20	5	60	8	NA	50.00	706.50	17	0.180	7.60	1.37	18	0.191	8.87	1.69
26-Nov-13	0-20	20	1	60	4	NA	50.00	706.50	7	0.149	4.64	0.69	0	0.000	0.00	0.00
26-Nov-13	0-20	20	2	60	8	NA	50.00	706.50	15	0.159	5.79	0.92	1	0.011	2.10	0.02
26-Nov-13	0-20	20	3	60	8	NA	50.00	706.50	19	0.202	4.88	0.98	2	0.021	12.83	0.27
26-Nov-13	0-20	20	4	60	8	NA	50.00	706.50	35	0.372	4.97	1.85	4	0.042	5.46	0.23
26-Nov-13	0-20	20	5	60	8	NA	50.00	706.50	31	0.329	4.75	1.56	1	0.011	17.79	0.19

Bosmina longriostris				Ergasilus sp				Calanoida: Diaptomus(oregonensis cf)				Cyclopidae: (Mircrocyclops rubellus cf)				Nauplii				Others			
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)
60	0.637	4.46	2.84	0	0.000	0.00	0.00	112	1.189	8.97	10.66	52	0.552	2.83	1.56	513	5.446	0.23	1.25	0	0.000	0.00	0.00
36	0.382	4.43	1.69	0	0.000	0.00	0.00	64	0.679	7.82	5.31	47	0.499	1.76	0.88	410	4.352	0.18	0.78	1	0.011	0.30	0.00
82	0.870	5.28	4.60	0	0.000	0.00	0.00	72	0.764	8.55	6.54	55	0.584	1.96	1.14	341	3.620	0.22	0.80	0	0.000	0.00	0.00
60	0.637	4.26	2.71	0	0.000	0.00	0.00	93	0.987	7.91	7.81	48	0.510	2.24	1.14	449	4.766	0.21	1.00	0	0.000	0.00	0.00
49	0.520	4.48	2.33	0	0.000	0.00	0.00	79	0.839	8.13	6.82	32	0.340	2.51	0.85	319	3.386	0.22	0.75	0	0.000	0.00	0.00
12	0.510	2.28	1.16	3	0.127	4.02	0.51	36	1.529	3.37	5.15	369	15.669	1.37	21.47	164	6.964	0.28	1.95	0	0.000	0.00	0.00
17	0.722	2.98	2.15	1	0.042	4.57	0.19	35	1.486	4.30	6.39	232	9.851	1.58	15.57	165	7.006	0.35	2.45	0	0.000	0.00	0.00
10	0.566	3.01	1.70	0	0.000	0.00	0.00	23	1.302	4.29	5.59	172	9.738	2.00	19.48	124	7.021	0.34	2.39	0	0.000	0.00	0.00
14	0.793	2.64	2.09	2	0.113	4.67	0.53	27	1.529	3.04	4.65	226	12.795	1.45	18.55	118	6.681	0.26	1.74	0	0.000	0.00	0.00
10	0.566	2.80	1.59	3	0.170	4.44	0.75	33	1.868	3.57	6.67	239	13.531	1.48	20.03	145	8.209	0.35	2.87	0	0.000	0.00	0.00
35	0.372	2.87	1.07	3	0.032	3.89	0.12	7	0.074	5.02	0.37	115	1.221	2.97	3.63	22	0.234	0.26	0.06	9	0.096	14.48	1.38
33	0.350	5.55	1.94	1	0.011	4.19	0.04	5	0.053	5.00	0.27	131	1.391	3.20	4.45	8	0.085	0.26	0.02	20	0.212	16.15	3.43
37	0.393	3.00	1.18	1	0.011	4.38	0.05	6	0.064	7.33	0.47	118	1.253	3.23	4.05	17	0.180	0.23	0.04	10	0.106	13.85	1.47
32	0.340	4.40	1.49	2	0.021	4.57	0.10	8	0.085	6.19	0.53	126	1.338	2.78	3.72	24	0.255	0.24	0.06	10	0.106	14.85	1.58
36	0.382	5.16	1.97	7	0.074	4.47	0.33	4	0.042	5.33	0.23	111	1.178	3.33	3.92	14	0.149	0.22	0.03	10	0.106	15.11	1.60
23	1.221	2.79	3.41	3	0.159	4.84	0.77	12	0.637	0.94	0.60	12	0.637	5.03	3.20	111	5.892	0.22	1.30	1	0.053	0.09	0.00
50	1.769	3.74	6.62	3	0.106	4.71	0.50	26	0.920	1.11	1.02	13	0.460	5.36	2.47	226	7.997	0.19	1.52	0	0.000	0.00	0.00
46	1.953	3.10	6.06	1	0.042	4.38	0.19	19	0.807	1.59	1.28	10	0.425	4.98	2.11	150	6.369	0.22	1.40	0	0.000	0.00	0.00
31	1.316	4.44	5.84	4	0.170	4.48	0.76	26	1.104	2.00	2.21	9	0.382	4.97	1.90	141	5.987	0.24	1.44	1	0.042	11.35	0.48
34	1.444	2.76	3.98	3	0.127	4.33	0.55	28	1.189	2.47	2.94	11	0.467	5.53	2.58	143	6.072	0.26	1.58	1	0.042	65.09	2.76
8	0.170	3.51	0.60	3	0.064	4.39	0.28	47	0.998	4.16	4.15	32	0.679	3.31	2.25	528	11.210	0.30	3.36	1	0.021	21.49	0.46
14	0.297	3.85	1.14	3	0.064	4.40	0.28	38	0.807	4.21	3.40	44	0.934	3.17	2.96	546	11.592	0.22	2.55	1	0.021	23.42	0.50
11	0.234	3.11	0.73	3	0.064	4.84	0.31	32	0.679	4.94	3.36	27	0.573	3.04	1.74	488	10.361	0.19	1.97	3	0.064	22.28	1.42
7	0.149	3.46	0.51	3	0.064	4.58	0.29	43	0.913	4.83	4.41	22	0.467	2.42	1.13	540	11.465	0.20	2.29	2	0.042	19.63	0.83
10	0.212	4.06	0.86	3	0.064	4.38	0.28	40	0.849	4.83	4.10	21	0.446	3.52	1.57	612	12.994	0.21	2.73	1	0.021	22.05	0.47
3	0.064	2.74	0.17	0	0.000	0.00	0.00	41	0.870	4.77	4.15	21	0.446	3.02	1.35	478	10.149	0.20	2.03	7	0.149	19.67	2.92
8	0.170	2.24	0.38	0	0.000	0.00	0.00	28	0.594	6.60	3.92	19	0.403	1.77	0.71	614	13.036	0.21	2.74	8	0.170	20.59	3.50
4	0.085	4.47	0.38	0	0.000	0.00	0.00	26	0.552	6.31	3.48	20	0.425	2.10	0.89	579	12.293	0.19	2.34	13	0.276	17.90	4.94
6	0.127	2.48	0.32	0	0.000	0.00	0.00	31	0.658	5.85	3.85	22	0.467	2.39	1.12	304	6.454	0.19	1.23	6	0.127	17.93	2.28
6	0.127	1.58	0.20	0	0.000	0.00	0.00	20	0.425	6.17	2.62	12	0.255	2.24	0.57	473	10.042	0.20	2.01	4	0.085	17.24	1.46
42	0.446	3.49	1.56	0	0.000	0.00	0.00	24	0.255	5.33	1.36	29	0.308	3.12	0.96	278	2.951	0.24	0.71	0	0.000	0.00	0.00
67	0.711	3.29	2.34	0	0.000	0.00	0.00	30	0.318	4.61	1.47	25	0.265	2.45	0.65	357	3.790	0.24	0.91	0	0.000	0.00	0.00
81	0.860	2.98	2.56	0	0.000	0.00	0.00	38	0.403	5.59	2.25	49	0.520	2.98	1.55	459	4.873	0.27	1.32	0	0.000	0.00	0.00
59	0.626	4.53	2.84	0	0.000	0.00	0.00	21	0.223	4.18	0.93	36	0.382	3.19	1.22	351	3.726	0.23	0.86	1	0.011	15.84	0.17
67	0.711	3.06	2.18	0	0.000	0.00	0.00	15	0.159	4.05	0.64	30	0.318	2.78	0.89	357	3.790	0.23	0.87	0	0.000	0.00	0.00
75	1.592	3.44	5.48	2	0.042	5.39	0.23	22	0.467	4.28	2.00	74	1.571	2.86	4.49	173	3.673	0.22	0.81	0	0.000	0.00	0.00
90	0.955	4.58	4.38	4	0.042	4.99	0.21	26	0.276	5.82	1.61	72	0.764	3.11	2.38	345	3.662	0.23	0.84	0	0.000	0.00	0.00
75	0.796	4.86	3.87	4	0.042	5.24	0.22	13	0.138	6.23	0.86	69	0.732	2.00	1.46	329	3.493	0.23	0.80	0	0.000	0.00	0.00
80	0.849	2.38	2.02	6	0.064	5.43	0.35	16	0.170	3.80	0.65	90	0.955	2.97	2.84	269	2.856	0.24	0.69	0	0.000	0.00	0.00
91	0.966	2.79	2.70	5	0.053	4.89	0.26	10	0.106	5.41	0.57	79	0.839	2.73	2.29	259	2.749	0.22	0.60	2	0.021	17.93	0.38