Lake Tahoe Water Quality Investigations

Algal Growth Potential assays • Phytoplankton • Periphyton

Final Report:
July 1, 2013– June 30, 2016

Submitted to:
State Water Resources Control Board
Lahontan Regional Water Quality Control Board

By:

UCDAVIS
TAHOE ENVIRONMENTAL RESEARCH CENTER

November 9, 2016

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Submitted by:
Tahoe Environmental Research Center
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Disclosure Statement

This report was prepared through Agreement #13-038-160 with the State Water Resources Control Board, Lahontan Regional Water Quality Control Board. The total amount of funding under this agreement, for work done by the U.C. Davis Tahoe Environmental Research Center for a three year term (July 1, 2013 to June 30, 2016) was $450,000.

Executive Summary

This document provides a report of work completed by the U.C. Davis – Tahoe Environmental Research Center (TERC) between July 1, 2014 and June 30, 2016 under Agreement No. 13-038-160: Lake Tahoe Water Quality Investigations. Three primary areas of investigation or tasks were undertaken in this study, which were primarily related to algae growth in the nearshore zone of Lake Tahoe: (1) algal growth potential assays; (2) phytoplankton identification and enumeration; and (3) quantification of periphyton (attached algae) in the littoral zone.

Results from July 1, 2013-May 30, 2016 investigations together with information on project quality assurance and quality control are detailed in the main body of the report. Highlights, including findings from this period, management implications, and recommendations are summarized in this executive summary.

AGP Assays

The purpose of the Algal Growth Potential (AGP) assay task is to compare levels of algal growth potential in the nearshore to identify emerging problem areas. The Algal Growth Potential (AGP) assay test was conducted as part of the California-Nevada-Federal Joint Water Quality Investigations in the late 1960's and early 1970's (California Department of Water Resources "DWR", 1970-75) to assess the maximum amount of algal growth supported by available nutrients in sampled waters. The Lahontan Regional Water Quality Control Board has an existing water quality standard which states that *mean annual AGP at a site should not be greater than two times the mean annual AGP at a mid-lake reference station"*. Sites with samples having repeatedly high AGP, or which exceed this standard repeatedly would deserve closer scrutiny of algae growth levels, and the environmental factors contributing to that growth.

We evaluated the AGP data relative to the Lahontan Standard for the two complete calendar years of data (2014 and 2015) obtained during this study period. The results of these analyses indicated there were no violations of the Lahontan AGP standard if all four tests during a calendar year were used in calculation of annual means. However, DWR in the 1960's and 1970's typically calculated their annual means based on AGP tests done during the May-Aug. period. Using a nearly similar period (May – Sept.) for calculation of the mean annual AGP in our study, violations of the Lahontan standard were found in 2015, but not 2014. Two sites violated the standard in 2015 (Tahoe City and Timber Cove). AGP at Tahoe City was 2.51 times the mid-lake annual mean, and AGP at Timber Cove was 2.65 times the annual mean. AGP data collected in Sept. 2016 will provide another full year of data to get a better sense for whether annual violations of the AGP standard are frequently observed at Tahoe City and Timber Cove.

Levels of AGP tended to be variable in the experiments with no sites having consistently high or low AGP through all the tests. However, when the AGP levels were ranked (highest to lowest AGP for each sample date) Timber Cove and Tahoe City, along with Tahoe Keys and Emerald Bay were sites more frequently in the "top 3". Tahoe City, Timber Cove, and Tahoe Keys were each in the "top 3" in 4 of 11 tests, Emerald Bay was in the "top 3" (in 6 of 11 tests). Sites more frequently in the "bottom 3" with the lowest AGP levels included: Glenbrook (6 of 11 tests), Mid-lake North (5 of 11 tests) and Rubicon Bay (5 of 11 tests).

The four sites which typically were among the highest AGP may be responding to greater availability or input of nutrients. The Tahoe City site is located in the nearshore on an extensive shallow shelf near the Tahoe City Boat ramp slightly east of the entrance to Star Harbor. Nutrients from Star Harbor and its tributaries (Burton and Polaris creeks) may contribute to the elevated AGP at this site. Proximity to the boat ramp and boating activity (which can stir up sediments, nutrients and algae) may also impact AGP levels at the Tahoe City site. The Timber Cove site is located on an extensive shallow shelf area, offshore of the Timber Cove pier. That site may be affected by several sources of nutrients including: nearby stream inflows from the U.Truckee/Trout watersheds; nearby urban runoff inputs; localized nutrient inputs from Asian clams (which are abundant in the area); and boating activity and human activities in the nearshore which potentially stir up sediments, nutrients and algae into the water column. The Emerald Bay site is located at the back of Emerald Bay near the inlet of Eagle Cr. which may contribute nutrients. Finally, the Tahoe Keys site is located on the shallow shelf area offshore of the Tahe Keys and may be impacted by inputs from the Upper Truckee River as well as water, nutrients and phytoplankton from the Tahoe Keys channels nearby. There is also much boating activity in this area which can stir up sediments, nutrients and algae.

Levels of nutrients (NO_3-N, NH_4-N, SRP and TP) were analyzed in initial lake water from AGP monitoring sites in a portion of the experiments. In general, nutrient levels tended to be very low at the sites with no obvious site to site trends which might be associated with AGP or initial chlorophyll *a*. The nutrients present in lake water are subject to rapid biological uptake (i.e. the nutrients may be removed from the water rapidly by algae and bacteria), and tend not to show large variations from site to site. It is important to note that sites with increased AGP may have greater availability or input of nutrients, but the nutrients may be removed rapidly from the waters by algae and/or bacteria and so not show up as elevated in the chemistry results. Some variation in nutrient levels was observed. For instance, TP tended to be somewhat elevated at most sites in the bioassays in Aug. 2014 and June 2015. The highest TP was measured at Timber Cove in Aug. 2014. NO_3-N tended to be elevated at most sites (except in Emerald Bay) in the March 2016.

AGP experiments done in early winter (December) tended to show little if any additional growth relative to initial chlorophyll *a* levels. In many cases, chlorophyll *a* decreased from initial levels and the initial chlorophyll *a* represented the maximum algal growth potential. With generally little or no growth observed in the Dec. tests done 2013-2015, it may not be worthwhile to carry out the AGP experiments at this time of year. Consideration should be given to possibly eliminating the December AGP test and/or replacing it with an additional test at another time of the year.

After three years of use of the AGP method, some of the challenges related to use and interpretation of the method have become apparent. First, as with other laboratory bottle algal bioassay methods, the AGP method is a test which relies on incubation of algae in flasks under controlled conditions in the lab. The results of the test are constrained to some extent by bottle effects and conditions of incubation. Algae in the flasks do not experience similar conditions of water circulation, nutrient availability, light intensity, presence of UV, exposure to grazers and many other factors which occur in natural waters. With laboratory incubation, factors may be removed which may constrain growth in the lake (e.g. presence of UV light may inhibit algal growth in shallow portions of the lake, whereas in laboratory incubation, the algae could potentially show growth when this UV inhibition is removed). This is a challenge of using bottle bioassays to provide information on the much more complex system of the lake. It is best to use information from such tests in combination with other physical, chemical and biological data to draw conclusions on conditions in the lake.

At times it was difficult to interpret the results of the AGP tests. For instance one site, Timber Cove had very low initial chlorophyll *a* biomass on several dates yet also had high growth potential as observed in a large increase in chlorophyll *a*. If the algae had high AGP, why wasn't it observed at the site in the form of high biomass at the time of collection? Removal of algae by grazing (either zooplankton or Asian clams) could be one explanation. Movement of water with lower algae content and elevated nutrients into an area (i.e. through upwelling or stream inputs) could be another explanation. There may also be other factors which constrain growth naturally in that area, i.e.: effects of high light/UV over the shallow shelf and inability of algae to ciculate or move away from the high UV , unfavorable temperature or chemical conditions, or competition for nutrients from benthic algae and bacteria. Removal of these factors in laboratory incubation conditions could promote increases in chlorophyll *a*. This raises the question of the significance of some of the AGP test results if under certain natural conditions, growth of the algae is normally constrained in the lake and the algal growth potential is not normally achieved.

Further examination of the utility of the AGP tests in combination with data currently collected for the nearshore would be useful, as well as examination of what other methods might be used to assess algal growth potential *in situ*.

Phytoplankton Enumeration

Characterization of phytoplankton species and abundance provides important data with regard to the base of the food web and nearshore condition in Lake Tahoe. Changes in the number and biodiversity of phytoplankton are indicators of nutrient loading, eutrophication and trophic status. Additionally, data and information generated through this task helps managers to determine if new and undesirable species (e.g. bloom-forming organisms, taste and odor species, or species that indicate a move away from the lake's current ultra-oligotrophic status) are colonizing the lake. Furthermore, these organisms influence lake clarity.

From Aug. 2013- March, 2016 eleven near-shore sites and two open water (mid-lake) sites were sampled quarterly for phytoplankton identification and enumeration. The phytoplankton data for this period indicated that although there was some variation in the proportions and overall amount of various groups contributing to biomass on particular dates, the patterns seen in many of the nearshore stations were similar to those observed at the two stations at mid-lake. There were no nearshore areas that were *always* substantially different with respect to phytoplankton composition or biovolume (an estimate of the amount of algae present) relative to the mid-lake sites. One site, Emerald Bay, frequently (but not always) had predominant algal types that differed from the main body of the lake and also had higher biovolumes. Some other sites with occasionally elevated biovolumes include Tahoe City and Tahoe Keys. These elevated biovolumes may be a response to increased nutrient availability.

Sites occasionally had contributions to the biovolume and abundance from one or more of three groups (cyanobacteria, green algae and euglenophytes) which can be associated with more fertile conditions in Lake Tahoe. However, the amount of these groups in most cases was only a very small portion of the overall biovolume and there generally were only a small number of species.

In 2015 there was an unusual occurrence of one type of blue-green species *Aphanothece* over widespread regions of the lake. *Aphanothece sp*., is a very small (3µm) solitary cell which has the capacity to fix nitrogen from the atmosphere. *Aphanothece sp*. has been present in the past but its abundance in 2015 was remarkable. These cells prefer high light, low nitrogen, high temperature and sources of inorganic carbon to enhance their ability of aerobic nitrogen fixation (Reddy et al 1993). Their abundance is indicative of waters which lack nitrogen. In February and May 2015 *Aphanothece* greatly influenced the total bio-volume at many stations including the mid-lake stations.

The other odd occurrence seen in February 2015 was the dominance of a small centric diatom, *Cyclotella gordonensis*, which typically is seen only during summer stratified months of July and August. These cells are excellent competitors during low nutrient, high light and warmer temperature conditions (Winder and Hunter, 2008 and Winder et. al. 2009). Their habitat preferences suggest all the stations in February, at shallow depths were stable and nutrient deficient, which would be a consequence of little precipitation runoff and mixing. The presence of *Cyclotella sp*. was a lake-wide event, unusual for February.

During the period 2013-2016 however, there was no indication of a general shift in phytoplankton groups or species groups, which might indicate a general change in trophic state of the nearshore. 2013-2016 was a prolonged drought period when generally low levels of nutrients were contributed to the lake. This likely had an impact on patterns for algal groups and levels of algae in the nearshore and at mid-lake. Levels of phytoplankton biovolume and abundance in the nearshore may show different patterns during years of heavier precipitation and increased nutrient inputs.

Periphyton Quantification

The purpose of the periphyton quantification task is to assess biomass levels of nearshore attached algae (periphyton) around the lake. Excessive attached algae biomass coats the rocks in the spring in many areas around the lake and bright green filamentous algae occur along portions of the shoreline in the summer. Nearshore periphyton can adversely impact the aesthetic, beneficial use of the shore zone in areas where thick growth develops. The amount of periphyton biomass can reflect local nutrient loading and also be affected by long-term environmental changes. Monitoring trends in periphyton biomass is important in assessing local and lake-wide nutrient loading trends.

Generally low to moderate levels of periphyton were observed at the nine routine monitoring sites in WY 2014 and 2015. These years were the third and fourth years of below normal precipitation in the basin. The generally low periphyton growth likely was a response to reduced nutrients inputs. Periphyton biomass levels increased in 2016 at many sites. The increase in peak annual biomass was the greatest for 3 sites along the west shore (Rubicon Pt., Sugar Pine Pt. and Pineland) and at the Incline West site on the north shore. At Incline West, the peak spring chlorophyll *a* level was among the highest observed since 2000. WY 2016 was a year of near normal precipitation, and the increase in periphyton may have been a response to increased nutrient inputs to the lake compared with the previous two low precipitation years.

Once each spring an intensive synoptic sampling is done in which levels of periphyton at approximately 50 sites are assessed using a rapid assessment method called the Periphyton Biomass Index (PBI). This sampling provides essentially a “snapshot” of the levels of periphyton around the lake during the period of peak spring biomass. Generally light PBI was observed along much of the shoreline during the 2014 and 2015 synoptics, with some areas of greater biomass. The generally low levels observed were likely associated with decreased nutrient inputs during the prolonged drought. In the 2016 synoptic, moderate levels of PBI were found along portions the west side of the lake, with several areas of relatively heavy PBI (e.g. at South Fleur du lac, Ward Cr., Pineland, North Sunnyside, Tahoe City Tributary, Tahoe City Boat Ramp, and South Dollar Cr.). Chlorophyll *a* was measured at about a third of all sites and the highest level measured was 141 mg/m^2 at the Tahoe City tributary site. Generally light PBI was observed along the east side of the lake, with a couple of regions of elevated PBI in 2016.

The spring synoptic monitoring has been useful for identifying sites which frequently have quite high periphyton biomass in the spring. Sites with more frequent incidences of heavy periphyton PBI include: Ward Cr. mouth, Pineland, Tahoe City, Tahoe City Tributary and South Dollar Cr, on the northwest shore and Timber Cove Rocks along the south shore. Several of these areas are near tributaries which may provide nutrient inputs. Periphyton PBI levels were lower at many of these sites in 2014 and 2015 but increased in 2016. Exceptions to the pattern were the Tahoe City Tributary site which had elevated PBI throughout the three years and Timber Cove which had extremely low PBI in 2016. It would be valuable to better understand the primary factors contributing to the heavy periphyton growth at these sites (a study by USGS and the University of Nevada Reno, (supported by Lahontan and the USGS), focusing on specific factors affecting periphyton growth at the Pineland site was done in 2016 which should contribute significantly to this understanding; there is also a substantial body of information from earlier studies by TERC and TRG which provides much background understanding of periphyton at this site), and to have a better sense for the extent to which management actions might help reduce these levels.

While the results from monitoring in 2016 indicated generally increased periphyton amounts in a year of more normal precipitation relative to levels in the two previous dry years, the results over the longer period 2012-2016, showed that a “drier than normal year” doesn’t necessarily always equate to a low periphyton year. WY 2012 and 2013 were years of relatively low precipitation, yet annual maximum biomass was quite high at Pineland and Tahoe City in both years. Rubicon Pt. was also high in 2012 and Dollar Pt. high in 2013. WY 2012 followed an extremely wet year in 2011. WY 2013 started out very “wet” as much precipitation occurred in Nov. and Dec. however very dry conditions prevailed the rest of the WY. The timing of when precipitation occurs during a year, carryover conditions from the previous year (i.e. the degree of soil saturation and ground water levels), lake level and other factors may also play a role in addition to nutrient inputs in determining the biomass level in any year.

In addition to the sites described above with frequent, heavy periphyton growth, an additional site with unusually heavy periphyton biomass was identified adjacent to one of the spring synoptic monitoring sites. This site is located to the west of the Garwood’s synoptic site. The heavy periphyton growth at this site (which included *Cladophora* and *Gomphoneis sp.*) was very striking relative to the very low amounts of periphyton along the shoreline to either side of the site and around much of the lake in general in spring of 2015. Heavy algal growth has been observed there also in some previous years. In 2015, steady inflow apparent groundwater or subsurface water was observed along the stretch of shoreline with heavy periphyton growth. This water was found to have slightly elevated levels of both nitrate nitrogen (NO_3-N= 86µg/l) and phosphorus (SRP=29 µg/l). It would be desirable to learn more about the factors contributing to the heavy growth there.

The lake level was extremely low during WY 2015 which had an impact on the predominant algae observed during this period. Lake surface elevation was below the natural rim (6223 ft.) for the majority of WY 2015 and the 0.5m sampling depth was 1.64 ft. (or 0.5m) below this. Sampling at 0.5m resulted in collection of algae from the cyanobacteria (blue-green algae) zone of periphyton growth at most sites. This was the algae that also contributed to a dark-colored, slimy band of material on rocks and boulders above the receding waterline along portions of the lake (including portions of the north and east shores), in late summer 2015. This band of algae was primarily due to the falling lake level (i.e. the normally deeper blue-green algae were located near the surface) and not necessarily related to nutrient inputs. With the lowering lake level accumulations of small granular, cork-like material were also observed by some members of the public, in the water and along beaches in several nearshore areas. This material was composed of pieces the cyanobacteria periphyton mat which had apparently sloughed (broke off or released) from shallow or exposed rocks in the nearshore. This was the first time we had seen such accumulations of sloughed cyanobacteria material (it also was likely associated with the lowered lake-level), although accumulations of sloughed diatoms and filamentous green algae are commonly observed in the nearshore.

Finally, in 2016 TERC prepared an intensive analysis for the Tahoe Regional Planning Agency of the trends for periphyton biomass (Hackley et al., 2016). This analysis utilized much of the routine and synoptic monitoring data collected by the periphyton monitoring program through the years up to 2015. This was the first time the historical periphyton data were statistically evaluated for presence of trends. This analysis indicated that the majority (8 out of 10) routine sites showed no statistically significant upward or downward trend for biomass associated with the stalked diatoms and filamentous green algae during 2000-2015. Two of the sites (Pineland along the west shore and Incline West along the north shore) did show positive (upward) trends for Chlorophyll *a* biomass during 2000-2015. Although the trends were statistically significant, analysis of the data showed relatively small increases in mean levels of periphyton biomass.

Introduction

This report presents the results of work completed by the U.C. Davis – Tahoe Environmental Research Center (TERC) between July 1, 2013 and May 30, 2016 under Agreement No. 13-038-160: Lake Tahoe Water Quality Investigations. Three primary areas of investigation or tasks were undertaken in this study, which were primarily related to algae growth in the nearshore zone of Lake Tahoe: (1) algal growth potential assays; (2) phytoplankton identification and enumeration; and (3) quantification of periphyton (attached algae) in the littoral zone. The results from these investigations are detailed in the Sections I-III in the report. Quality assurance and quality control details for the investigations are presented in Section IV of the report. A detailed summary of Algal Growth Potential Assay data is presented in Appendix 1 and the phytoplankton enumeration standard operating procedure is presented in Appendix 2.

Section I. Algal Growth Potential Assays

With increasing focus on the environmental health of the nearshore the AGP test was included with monitoring work in August 2013 to evaluate algal growth potential at different nearshore and offshore stations around Lake Tahoe. The purpose of these experiments is to compare levels of algal growth in the nearshore and offshore to identify potential problem areas, and to evaluate conditions relative to an established water quality standard. Availability of the nutrients, nitrogen (N) and phosphorus (P) in the water, and levels of nutrients previously taken up by phytoplankton (known as luxury uptake) are important factors that contribute to growth.

Methods

AGP assay tests are performed on samples collected from 13 stations (Figure 1, Table 1) four times per year (early winter, late winter/early spring and late spring/early summer, and late summer/early fall). Samples of lake water (usually from a depth between 0.5-1.5m) are collected from a boat, using a Van Dorn water sampler. Many of the current sites are in proximity to sites sampled by DWR in their study of Lake Tahoe in the 1970's (DWR, 1970-1975). Two open-water reference sites are also sampled, one near mid-lake north (U.C. Davis's MLTP station), and the other a mid-lake south site (similar to that used by DWR). A sample for phytoplankton identification and enumeration is also collected directly from the Van Dorn sampler and treated with Lugol's reagent at the time water is collected for the AGP assay. Lake water from each site for the AGP assay is filtered through an 80 µm size mesh netting to remove large zooplankton, and collected in 4 liter HDPE bottles. The samples are kept near lake temperature in the dark in a cooler and returned to the lab at TERC where the experiment is usually started the same day.

In the AGP experiment, lake water from each site is divided into duplicate flasks and incubated under controlled light (CW fluorescent light with intensity ~ 74 μ E m^{-2} sec^{-1}), standard light cycle (i.e. 16 hour light, 8 hour dark) and at ambient lake temperature.[1] Algal biomass changes are measured by tracking *in vivo* chlorophyll *a* fluorescence in water from the flasks throughout the experiment using a Turner Designs 10AU fluorometer (configured for *in vivo* and extractable chlorophyll *a* measurement). On one or more days of the experiment, typically near the growth peak, subsamples are also filtered for later chlorophyll *a* extraction and analysis. Equations relating *in vivo* fluorescence measurements to extracted chlorophyll *a* are determined. The equations may then be used to calculate chlorophyll *a* on days when *in vivo* fluorescence peaks and extracted chlorophyll *a* was not measured. The peak chlorophyll *a* value achieved during the assay is considered the Algal Growth Potential (AGP).

[1] These methods differ slightly from the early DWR studies with respect to: lighting (DWR used a light intensity of 700 foot candles or ~91 μ E m^{-2} sec^{-2}) and temperature (DWR used a constant temperature of 20° C) However, we think incubation at 20° C might adversely affect some cold water species represented in the winter community.

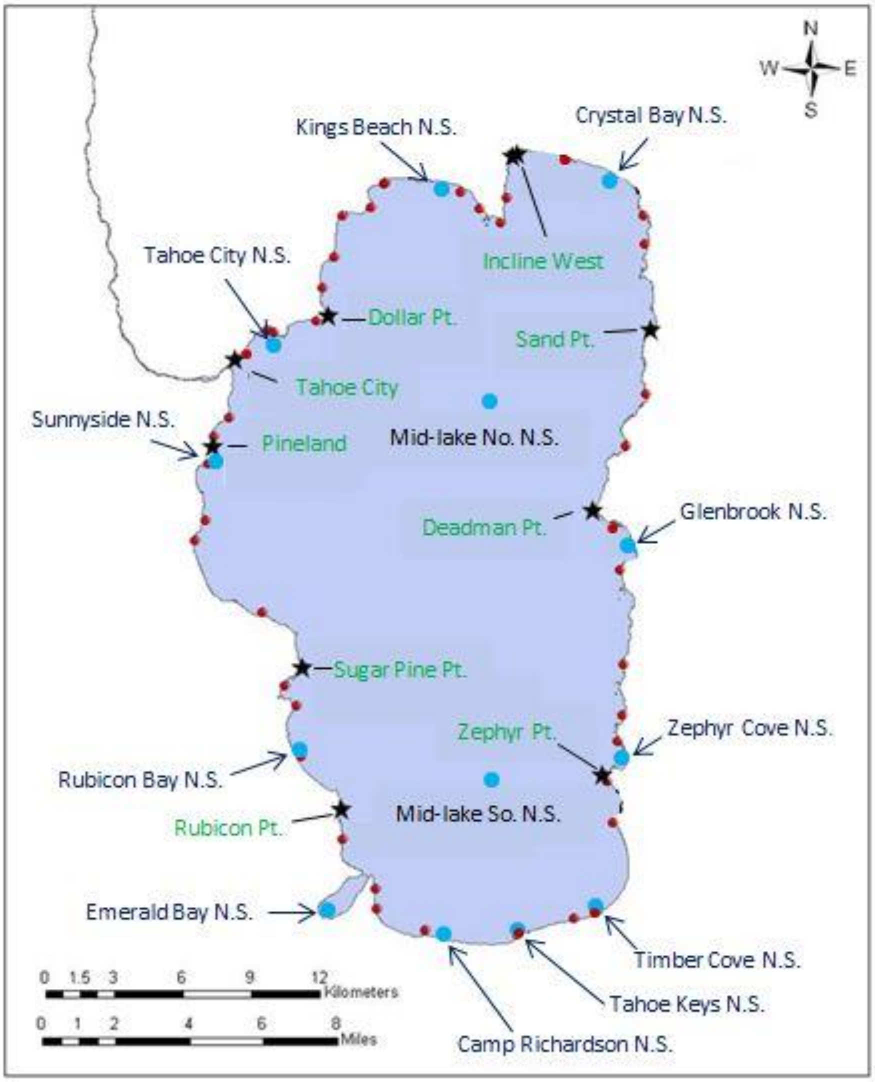


Figure 1. Map showing locations of AGP nearshore stations (light blue dots), routine periphyton monitoring stations (green text, black stars) and spring synoptic periphyton stations (red dots).

Table 1. Description of AGP and phytoplankton monitoring sites.

Site	Coordinates	Site Description	Water Depth at Station
Nearshore Sites			
Sunnyside	N39 07.805 W120 09.216	~ 15 m from first pier just north of Ward Cr.	~ 3m
Tahoe City	N39 10.808 W120 07.173	~18-27 m outside of entrance to Tahoe City Boat Ramp area and pier	~2.5m
Kings Beach	N39 14.179 W120 02.207	~ 70 m from shore, offshore of "Lake Point Pier" slightly east of "Heritage Cove" condominiums	~ 2m
Crystal Bay	N39 14.258 W119 56.798	~45 m offshore of mouth of Incline Cr., Crystal Bay	~2.5m
Glenbrook	N39 05.371 W119 56.489	~ 15 m from right side "T" of old pilings, near piling at boundary of swim area,~70 m from shore, Glenbrook	~2.5m
Zephyr Cove	N39 00.512 W119 56.993	Off first set of beach stairs north of Zephyr Cove pier, ~27 m outside of swim area boundary, ~90 m from shore.	~2.5m
Timber Cove	-	~45-70 m northwest of end of Timber Cove pier	~2m
Tahoe Keys Nearshore	N38 56.423 W120 00.574	~70 m offshore of lake-side pier at Tahoe Keys, (Note-site for AGP#1 was ~115 m further offshore)	~1.5-2m
Camp Richardson	N38 56.531 W120 03.383	Adjacent to end of Camp Richardson pier	2-3m
Emerald Bay	N38 57.187 W120 06.367	Adjacent to either the pier or near north edge of swim area boundary, both near Vikingsholm	~4-5m
Rubicon Bay	N39 00.875 W120 06.840	~70 m offshore of pier in shallow area	~2-3m
Mid-lake Sites			
Mid-lake North	N39 09.255 W120 00.478	Location of TERC MLTP station in north mid-lake, approx. 10.5 km east of Tahoe City	>450m
Mid-lake South	N38 59.641 W120 00.080	South mid-lake approximately 6.5 km north of Pope Beach.	>400m

Extracted chlorophyll *a* is analyzed fluorometrically using a Turner Designs 10AU fluorometer, calibrated with pure chlorophyll *a* from *Anacystis nidulans* algae. Frozen sample filters containing algae are thawed and extracted overnight at 4°C, in 100% methanol, then fluorescence before and after acidification with 0.05ml of 0.3N HCl is measured. Chlorophyll *a* and pheophytin concentrations are determined using the following equations:

Chlorophyll *a* (µg/l) = (r/(r-1)) x (R_b-R_a) x V_{ex}/V_{fil}
Pheophytin (µg/l) = (r/(r-1)) x (rR_a-R_b) x $V_{ex}/V_{fil.}$
R_b= Fluorescence of sample extract before acidification (minus) fluorescence of filter blank
R_a= Fluorescence of sample extract after acidification (minus) fluorescence of filter blank
V_{fil}= Volume of lake water filtered (Liters), usually 0.1 L
V_{ex} = Volume of methanol used for extraction (Liters), usually 0.005L
r = mean of R_b/R_a values for a range of pure chlorophyll standards.
(r = 2.475 for current calibration)

Additional field and lab data collected for these experiments includes: lake surface water temperature at time of collection; background fluorescence of the initial water collected (fluorescence of GF/F filtered water); and results of chemical analysis of N and P in the initial lake water for a portion of the experiments (not part of contracted work; however, this was done to provide supplementary information on nutrients in water at time of sampling).

AGP Assay Results July 2013 - March 2016:

This report presents the results of 11 AGP assay tests were done on lake between July, 2013 and March, 2016. An additional test was scheduled to be done in June 2016 (after preparation of this report). Table 2 presents a summary of initial lake chlorophyll *a* and AGP test results for the sites. Figures 2.a-2.k present the initial chlorophyll *a* and AGP results for each experiment graphically for the three years of the study. Detailed summaries of AGP bioassay data are also presented in Appendix 1.

The following section presents a summary of AGP test results for each individual test, along with a description of some of the lake and weather conditions prior to the test. A summary of general patterns in the AGP test results follows this section.

Summary of Results by AGP Assay:

AGP Assay #1 (8/15/13)
This was a late summer sampling. Lake surface temperature was warm and ranged between 18-20 °C. Lake chlorophyll *a* concentrations were generally low at most sites (between 0.2 to 0.31µg/l) with Tahoe City having a slightly higher chlorophyll *a* of 0.41 µg/l. In the Algal Growth Potential assay, highest AGP levels occurred at 3 sites along the northwest shore (Sunnyside, Kings Beach and Tahoe City) where AGP ranged from 0.84-0.99 µg/l and 4 sites on the south shore (Bijou, C.R/Taylor Cr., Zephyr Cove and Tahoe Keys) where AGP ranged from 0.81-1.15 µg/l (Table 2, Figure 2.a). AGP at the Mid-lake reference stations ranged from 0.50 µg/l at Mid-lake South to 0.64 µg/l at Mid-lake North.

Table 2. Summary of initial chlorophyll *a* and AGP results for AGP tests done 8/5/13-3/23/16.

	Station Initial Chl. a (µg/l)	AGP Peak Chl.a (µg/l)	Station Initial Chl. a (µg/l)	AGP Peak Chl. a (µg/l)	Station Initial Chl. a (µg/l)	AGP Peak Chl.a (µg/l)	Station Initial Chl. a (µg/l)	AGP Peak Chl. a (µg/l)	Station Initial Chl. a (µg/l)	AGP Peak Chl. a (µg/l)	Station Initial Chl. a (µg/l)	AGP Peak Chl. a (µg/l)
Station	8/15/13	8/15/13	12/12/13	12/12/13	2/20/14	2/20/14	6/9/14	6/9/14	8/29/14	8/29/14	12/9/14	12/9/14
Sunnyside	.25	.84	.44	.44	0.63	.63	0.14	.69	0.19	.42	0.52	.52
Tahoe City	.43	.99	.39	.39	0.24	.69	0.31	.61	0.41	.82	0.46	.46
Kings Beach	.28	.85	.41	.41	0.58	.87	0.17	.37	0.4	.48	0.45	.45
Crystal Bay	.26	.64	.45	.45	0.81	.81	0.18	.39	0.17	.43	0.61	.61
Glenbrook	.27	.64	.34	.34	0.79	.79	0.11	.44	0.23	.40	0.46	.46
Zephyr Cove	.22	.89	.34	.34	0.96	.96	0.21	.50	0.18	.61	0.34	.39
Timber Cove			.41	.41	0.5	1.09	0.13	.50	0.11	.65	0.31	.39
Tahoe Keys	.27	1.15	.41	.41	0.6	1.08	0.3	.65	0.2	.56	0.53	.53
Camp Rich.			.42	.42	0.67	.83	0.24	.83	0.18	.45	0.43	.43
Emerald Bay			.69	.69	0.74	.77	0.42	.69	0.23	.39	0.52	.52
Rubicon Bay	.20	.55	.58	.58	0.41	.61	0.12	.26	0.16	.44	0.38	.38
Bijou	.27	.81										
Taylor Cr	.31	.85										
<u>Mid-Lake:</u>												
Mid-lake No.	.20	.64	.49	.49	0.87	0.87	0.12	.26	0.15	.44	0.53	.53
Mid-lake So.	.18	.50	.55	.55	0.87	0.87	0.17	.58	0.17	.37	0.43	.43

Table 2 continued. Summary of initial chlorophyll *a* and AGP results for AGP tests done 8/5/13-3/23/16.

	Station Initial Chl. a (µg/l)	AGP Peak Chl.a (µg/l)	Station Initial Chl. a (µg/l)	AGP Peak Chl. a (µg/l)	Station Initial Chl. a (µg/l)	AGP Peak Chl. a (µg/l)	Station Initial Chl. a (µg/l)	AGP Peak Chl. a (µg/l)	Station Initial Chl. a (µg/l)	AGP Peak Chl.a (µg/l)
Station	2/26/15	2/26/15	5/26/15	5/26/15	9/1/15	9/1/15	12/16/15	12/16/15	3/23/16	3/23/16
Sunnyside	.52	.71	.28	.44	.11	.23	.44	.44	.27	.79
Tahoe City	.35	.62	.63	.78	.17	.49	.50	.50	.26	.78
Kings Beach	.43	.83	.29	.44	.16	.28	.49	.49	.24	.82
Crystal Bay	.59	.84	.27	.43	.15	.24	.46	.46	.82	.93
Glenbrook	.42	.97	.25	.35	.14	.21	.46	.46	.58	.95
Zephyr Cove	.33	.94	.27	.46	.15	.22	.49	.49	.67	.98
Timber Cove	.17	1.08	.09	.88	.06	.46	.44	.44	.39	1.04
Tahoe Keys	.37	.90	.23	.39	.12	.35	.48	.48	.85	1.07
Camp Rich.	.48	.75	.27	.43	.10	.20	.49	.49	.33	.77
Emerald Bay	.98	.98	.49	.52	.20	.29	1.29	1.29	.84	.84
Rubicon Bay	.76	.76	.33	.38	.12	.25	.39	.39	.28	.56
<u>Mid-Lake:</u>										
Mid-lake No.	.63	.67	.22	.33	.15	.21	.63	.63	.79	.79
Mid-lake So.	.62	.76	.19	.24	.11	.23	.57	.57	.83	.83

Summary Figures for 2013-2016 AGP tests:

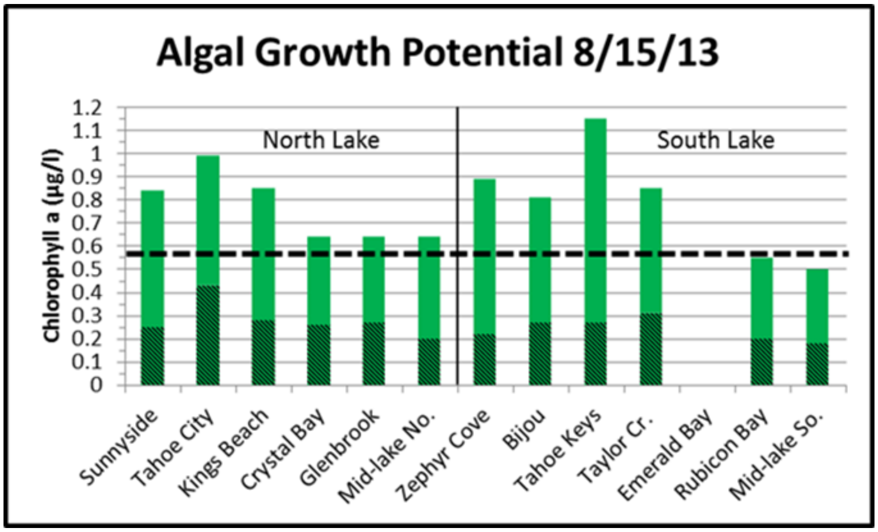


Figure 2.a. Late summer 2013 algal growth potential experiment (AGP#1). (Note in all figure 2 charts, dark shading is initial chlorophyll *a* concentration, light green is subsequent increase in chlorophyll *a* (if any) during experiment, total height of bar(s) (dark + light green) is algal growth potential, dashed line is mean of Mid-lake North and South AGP levels.) The Bijou and Taylor Cr. sites were replaced with Timber Cove and Camp Richardson sites in subsequent experiments and a site in Emerald Bay was added.

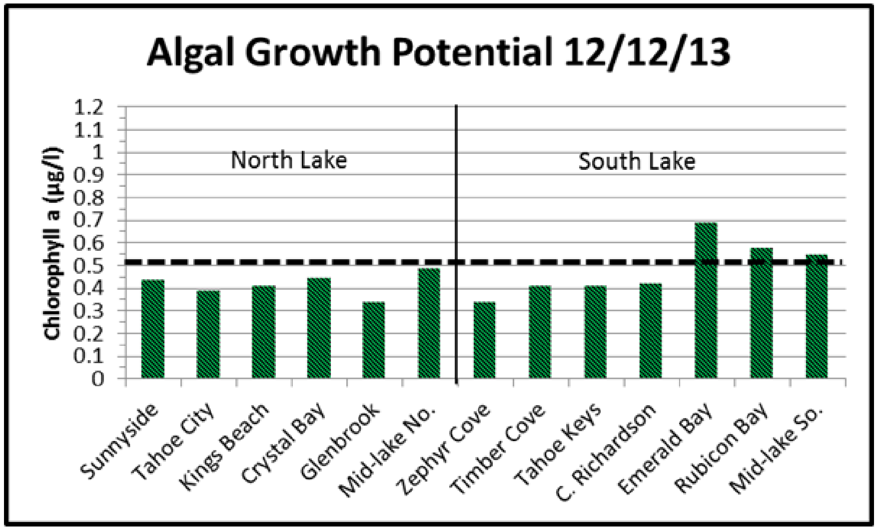


Fig. 2.b. Early winter 2013 AGP (#2) experiment.

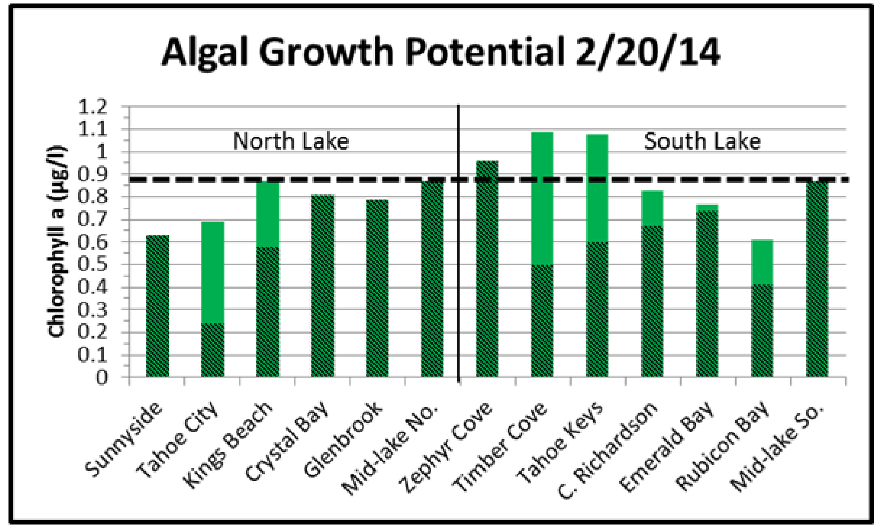


Fig. 2.c. Late winter/early spring 2014 AGP (#3) experiment.

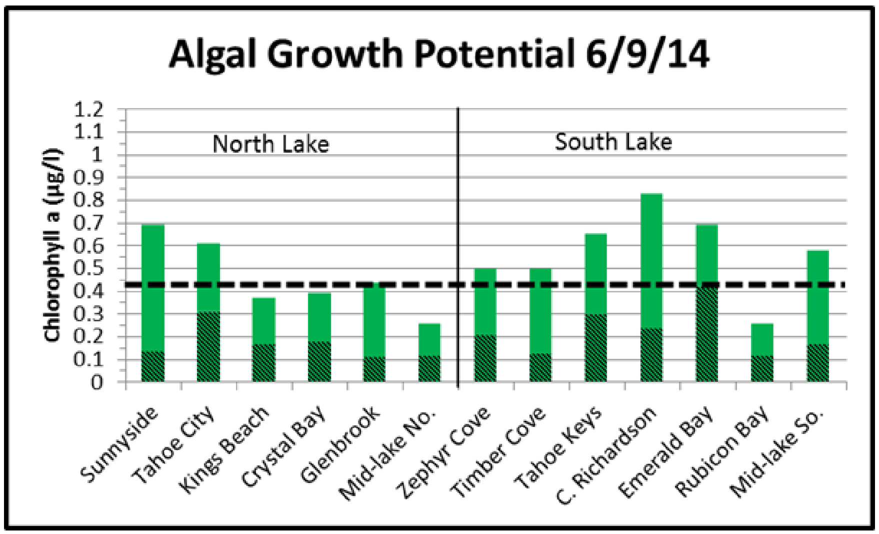


Fig. 2.d. Early summer 2014 AGP (#4) experiment.

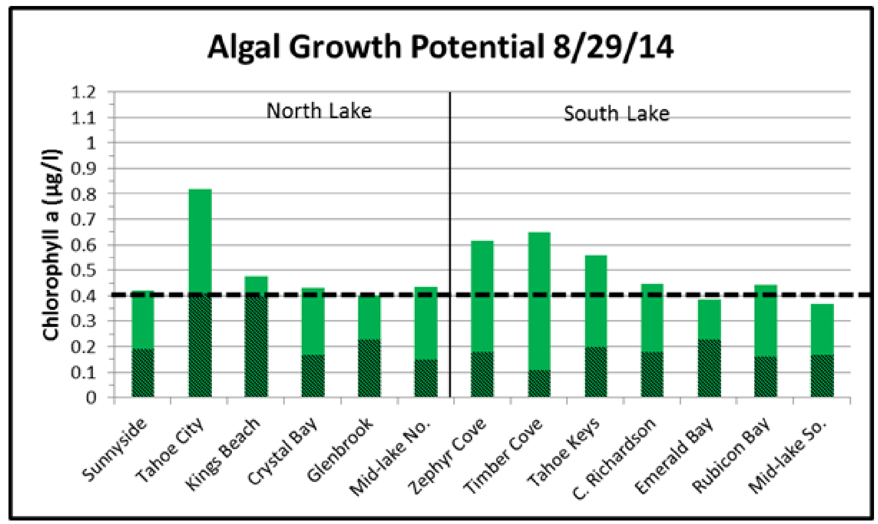


Fig. 2.e. Late summer 2014 AGP (#5) experiment.

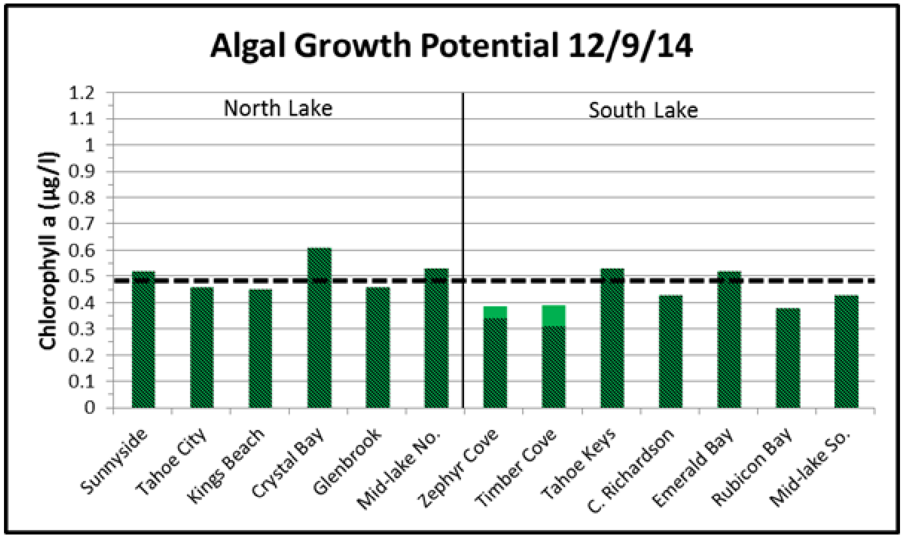


Fig. 2.f. Early winter 2014 AGP (#6) experiment.

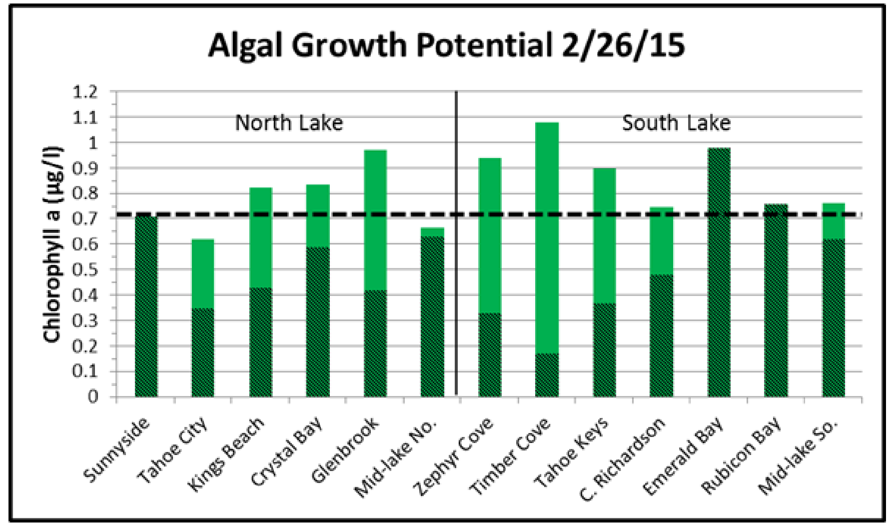


Fig. 2.g. Late winter/early spring 2015 AGP (#7) experiment.

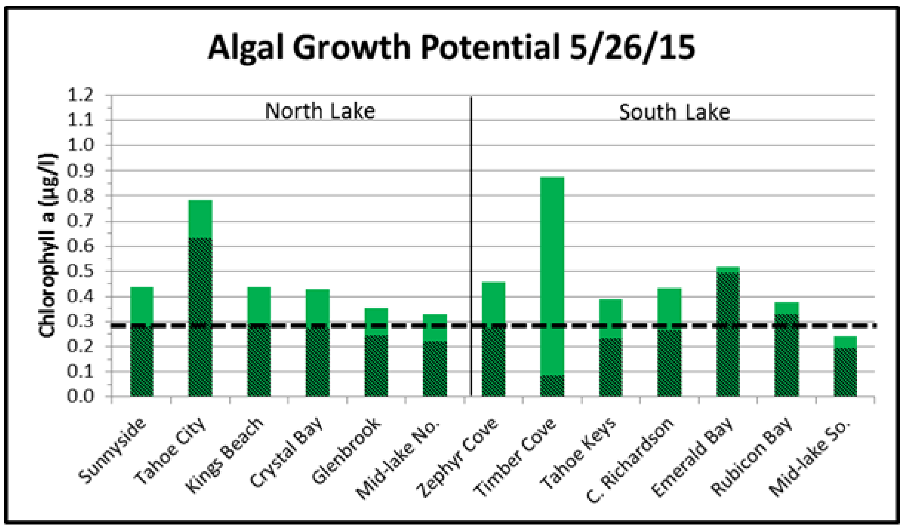


Fig. 2.h. Early summer 2015 AGP (#8) experiment.

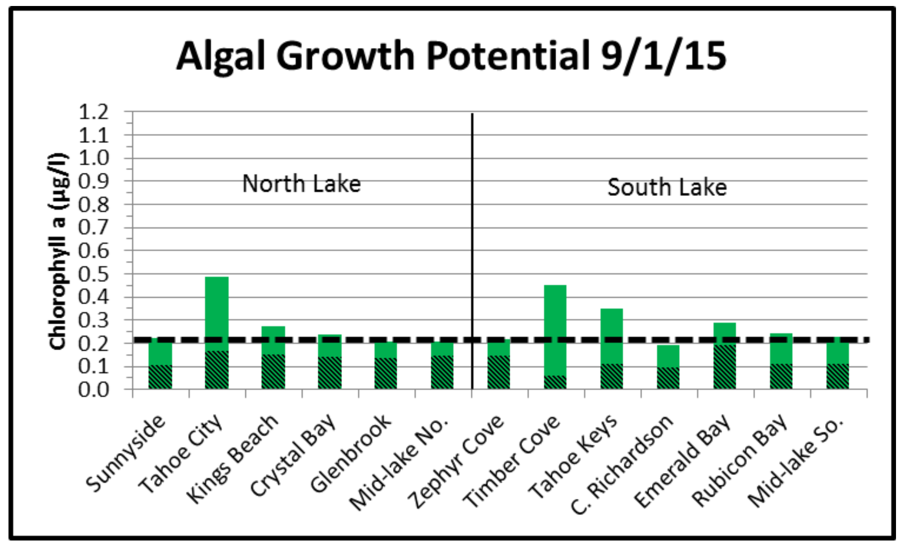


Fig. 2.i. Late summer 2015 AGP (#9)experiment.

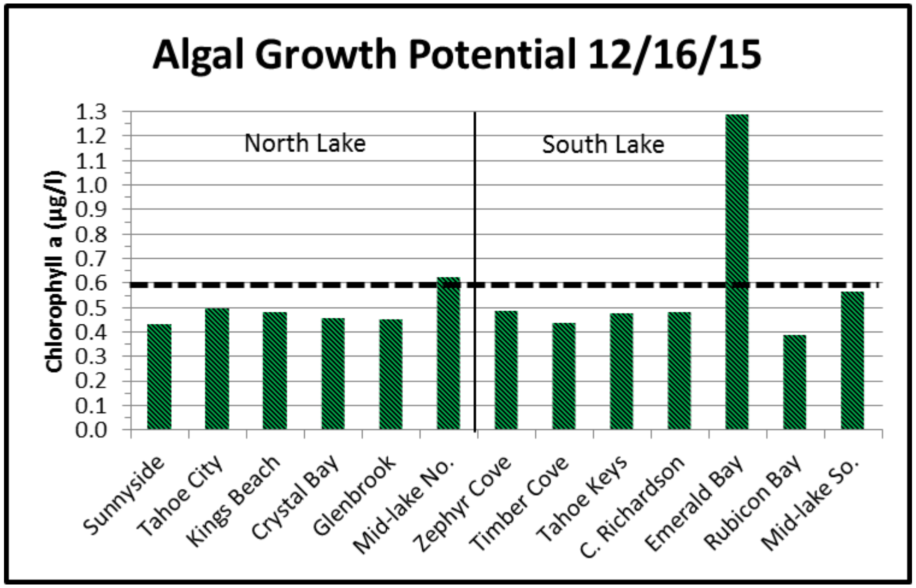


Fig. 2.j. Early winter 2015 AGP (#10) experiment.

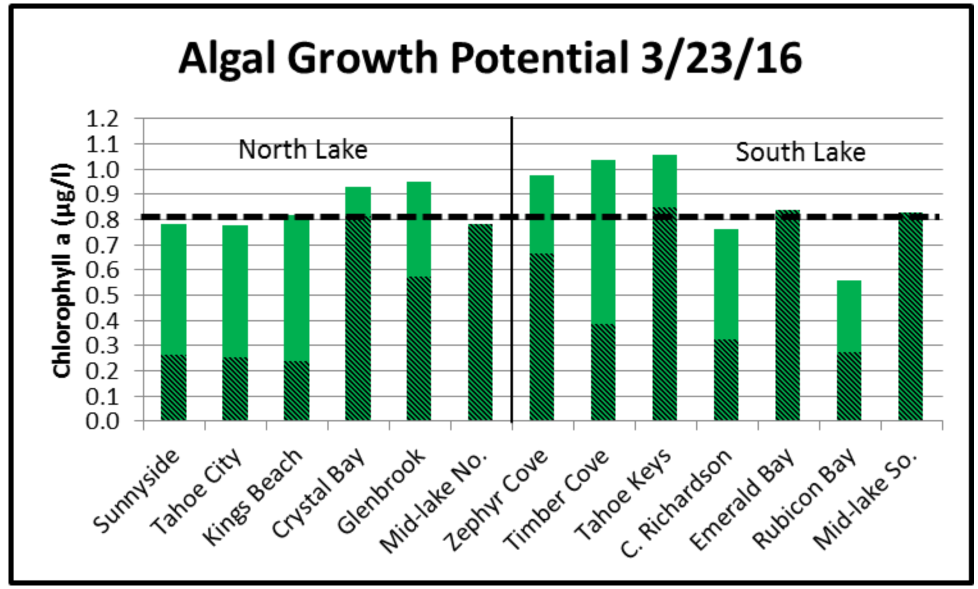


Fig. 2.k. Late winter/early spring 2016 AGP (#11) experiment.

AGP Assay #2 (12/12/13)
This was an early winter sampling. Lake surface temperature had cooled substantially and ranged from (6.0-8.0 °C). Very cold temperatures were observed in the basin for much of the period between 12/4-12/10/13 with some snow 12/4-12/5. In lake water samples collected, the highest initial chlorophyll *a* was observed at a new site in Emerald Bay (0.69 µg/l), Rubicon Bay was next highest (0.58 µg/l). Chlorophyll *a* at the other nearshore sites ranged from 0.34-0.44 µg/l and the mid-lake sites ranged from 0.49-0.55 µg/l. In this bioassay incubation was done under lights more intense lighting, (High Output T5 fluorescent lights with intensity ~120 µ E m^{-2} sec^{-1} were used in comparison to standard incubation with CW fluorescent light with intensity ~ 74 µ E m^{-2} sec^{-1}). This lighting though more intense had different spectral characteristics than the CW fluorescent lighting, this intense lighting may have detrimentally impacted certain algal species i.e. *Gymnodinium fuscum* and *Rhodamonas* sp. (see Hackley et al., 2014 for additional information) resulting in a decline in chlorophyll *a*. General declines in chlorophyll *a* biomass relative to initial chlorophyll levels were observed for samples during the course of the experiment. Following a convention used for the 1960's and 1970's AGP tests, the initial chlorophyll *a* level was considered the AGP value when chlorophyll *a* declined during the test. Since AGP tests done in December in subsequent years (2014, 2015) (using standard CW fluorescent lighting) also showed declines in chlorophyll from initial levels, we chose to include the results for AGP experiment #2 with all other test results in this report.

AGP Assay #3 (2/20/14)
This was a late winter/early spring sampling. Lake surface temperature ranged from 4.5-6°C. This was likely a dynamic period in the lake as a strong storm had recently occurred 2/8/14-2/10/14, with substantial rainfall and runoff at lake level and significant south- southwest wind events occurring on 2/8/14 and 2/15/14. Nearshore sites likely experienced different amounts of input of runoff water containing sediments and nutrients as well as experienced different degrees of wind-driven mixing and circulation of surface waters as a result of these events. Initial chlorophyll *a* in water collected from nearshore and mid-lake sites 2/20/14 showed quite a range in values from 0.24 µg/l to 0.96 µg/l at nearshore sites and 0.87 µg/l at the mid-lake sites. It is interesting the note that initial chlorophyll *a* had approximately doubled when Feb. 2014 samples were collected compared to December 2013 levels at several sites (Mid-lake North, Mid-lake South, Crystal Bay, Glenbrook and Zephyr Cove). In contrast Tahoe City and Rubicon Bay chlorophyll a levels were lower in February 2014 than in December 2013. Most of the other sites showed moderate increases in chlorophyll in February compared with December 2013. The differences in initial chlorophyll *a* may reflect a variety of factors including natural patchiness of the phytoplankton, differences in degree of mixing between mid-lake and nearshore areas, exposure to upwelled water and tributary inputs. The highest AGP levels occurred at two sites along the south shore, Tahoe Keys and Timber Cove where AGP were 1.09 µg/l and 1.08 µg/l respectively.

AGP Assay #4 (6/9/14)
This was a late spring/early summer sampling. Lake temperature was warming and ranged from 14.0-17.0°C. The timing of this sampling was at the end of a relatively low snowmelt runoff. Initial chlorophyll *a* at most nearshore sites had dropped substantially since February and was low ranging from 0.12-0.24 µg/l. Typically chlorophyll *a* is low in the upper water column during summer thermal stratification. The highest initial chlorophyll *a* levels were observed in

the nearshore at Emerald Bay (0.42 µg/l), Tahoe City (0.31 µg/l) and Tahoe Keys nearshore (0.30 µg/l) potentially indicating these areas are more productive. Similar to AGP test #1 all sites showed significant increases in chlorophyll *a* relative to the initial lake levels during the AGP incubation. This may have been a consequence of absence of potentially inhibitory effects of intense sunlight and UV radiation (in the laboratory incubator, compared with ambient conditions near the surface in the lake in the summer.) In the Algal Growth Potential test, Camp Richardson along the south shore had the highest AGP (0.83 µg/l), next highest AGP levels were Emerald Bay (0.69 µg/l) and Tahoe Keys (0.65 µg/l). The highest AGP among north shore sites were observed for Sunnyside (0.69 µg/l) and Tahoe City (0.61 µg/l).

AGP Assay #5 (8/29/14)
This was a late summer sampling. Lake surface temperature was still very warm and ranged between 17-19 °C. Lake chlorophyll *a* concentrations were generally low at most sites (between 0.1 to 0.25 µg/l) with only Tahoe City and Kings Beach having moderate chlorophyll *a* near 0.40 µg/l. The highest AGP was measured at Tahoe City (Chlorophyll *a* = 0.82 µg/l) in the north lake region and at three south shore sites (Zephyr Cove, Timber Cove and Tahoe Keys) with AGP chlorophyll *a* ranging between 56-61µg/l. AGP at the other sites were close to the mid-lake AGP chlorophyll *a* levels (e.g. near 0.40 µg/l).

AGP Assay #6 (12/9/14)
This was an early winter sampling. Lake surface temperature was still relatively warm for the time of year (8.0-9.0 °C). Some rain and snow occurred 12/2-12/4/14, however no large precipitation events preceded the sampling. Lake chlorophyll *a* concentrations showed slight variations among the sites ranging from 0.31 µg/l at Timber Cove to 0.61 µg/l at Crystal Bay). Chlorophyll *a* levels declined or showed no increase at many sites during the AGP test and AGP levels were considered the same as initial lake chlorophyll *a* concentrations. Two sites Timber Cove and Zephyr Cove showed very slight increases in chlorophyll *a* during the test. AGP for all sites were close to values observed at the two mid-lake stations (i.e. 0.43 at the South Mid-lake station and 0.53 µg/l at the North Mid-lake station).

AGP Assay #7 (2/26/15)
This was a late winter/early spring sampling. Lake surface temperature ranged from 6.0-7.0°C. The strongest storm of the year had occurred Feb. 6-9 contributing substantial rain and snow. Strong N-NE winds Feb. 21-23 preceded sampling for this AGP test. Initial lake chlorophyll *a* concentrations varied between sites (e.g. chlorophyll *a* ranged from a low of 0.17 µg/l at Timber Cove to a high of 0.98 µg/l at Emerald Bay, with the mid-lake stations having a chlorophyll *a* concentration of 0.62-0.63 µg/l). Various factors may have contributed to the observed distribution of chlorophyll *a* (see AGP#3 summary above). Most sites showed growth during the AGP test, and all nearshore sites ultimately had an AGP either close to or greater than the nearest mid-lake sampling site. The highest AGP was measured for the Timber Cove sample (1.08 µg/l), which is notable as this site had the lowest initial chlorophyll *a* concentration. Zephyr Cove, Tahoe Keys and Emerald Bay AGP (chlorophyll *a* range 0.90-0.98 µg/l) were also above the mid-lake South AGP of 0.76 µg/l. Kings Beach, Crystal Bay and Glenbrook sites had the highest AGP in the north portion of the lake ranging from 0.83-0.97 µg/l, all greater than AGP of the mid-lake north site (0.67 µg/l).

AGP Assay #8 (5/26/15)
This was a late spring/early summer sampling. Lake temperature was warming and ranged from 11.0-15.0°C. The timing of this sampling was at the end of a very meager snowmelt runoff, however the two weeks preceding sampling had periods of rain and snow (including some areas with thunderstorms the day before sampling, e.g., the Sunnyside/Ward Cr. area). Initial lake chlorophyll *a* levels were relatively similar and relatively low at most sites ranging between 0.19-0.33 µg/l. Notable exceptions were Timber Cove, which once again had the lowest chlorophyll *a* (0.09 µg/l) and moderately high levels at Emerald Bay (0.49 µg/l) and Tahoe City (0.63 µg/l). All sites showed increases in chlorophyll *a* during the AGP test. Timber Cove once again showed substantial growth from a very low initial chlorophyll *a* level, and had the highest AGP (0.88 µg/l) which was 3.67 times the AGP level at mid-lake south (0.24 µg/l). All other nearshore site AGP levels in the southern lake region were also higher than the mid-lake south AGP level. Along the north shore, Tahoe City had the highest AGP (0.78 µg/l), with Sunnyside, Kings Beach and Crystal Bay AGP (ranging from 0.43-0.44 µg/l), also higher than the mid-lake north AGP (0.33 µg/l).

AGP Assay #9 (9/1/15)
This was a late summer sampling. Lake surface temperature was still relatively warm and ranged between 16.5-18.5 °C. Lake chlorophyll *a* concentrations were generally low at all sites (ranging from 0.06 to 0.20 µg/l). The highest AGP was measured at Tahoe City (chlorophyll *a* = 0.49 µg/l), Timber Cove (chlorophyll *a* = 0.49 µg/l) and Tahoe Keys (chlorophyll *a* =0.35 µg/l). AGP at the other sites were near or slightly above the mean mid-lake AGP (mean chlorophyll *a* = 0.22 µg/l). It is interesting to note that in comparison of the mean mid-lake initial chlorophyll *a* for late summer bioassays a general decline in mean mid-lake AGP can be seen between 2013 to 2015 (i.e. mean mid-lake chlorophyll *a* was 0.57 µg/l 8/15/13, 0.41 µg/l in 8/29/14, and 0.22 µg/l on 9/1/15). This may reflect the cumulative impacts of low nutrient input years associated with the ongoing drought.

AGP Assay #10 (12/16/15)
This was an early winter sampling. Lake surface temperature was very cold at some nearshore sites (i.e. at Timber Cove and Tahoe City the surface temperature was near 2.5 °C, with some thin ice on the surface at Timber Cove) while the mid-lake temperature was between 6.5-7.0 °C. Some rain and snow had occurred on 12/10/15. Lake chlorophyll *a* concentrations ranged from 0.39-0.50 at nearshore sites, with the exception of Emerald Bay where chlorophyll *a* was relatively high (1.29 µg/l). Mean mid-lake chlorophyll *a* was 0.60 µg/l. Once again, chlorophyll *a* levels dropped during the experiment and AGP levels were considered to be the initial lake chlorophyll *a*.

AGP Assay #11 (3/23/16)
This was a late winter/early spring sampling. Lake surface temperature was still relatively cool and ranged from 4.0-7.0°C. There was a moderate rain and snow event prior to sampling on 3/20/16-3/21/16 which resulted in increased discharges from streams in the vicinity of some of the nearshore sites. Several sites had relatively low initial chlorophyll *a* ranging from 0.24-0.33 (these included Sunnyside, Tahoe City, Kings Beach, Camp Richardson and Rubicon Bay). Timber Cove, Glenbrook and Zephyr Cove had intermediate Chlorophyll *a* levels ranging from 0.39-0.67 µg/l included. Sites with relatively high initial chlorophyll *a* included the two Mid-

lake sites (ranging from 0.79-0.83 µg/l) and Crystal Bay, Emerald Bay and Tahoe Keys which had levels close to the mid-lake values. Various factors may have contributed to the observed distribution of chlorophyll *a*. We did analyze NO_3-N, NH_4-N, SRP, TP and specific conductance in initial water from these sites. Although nutrients were generally low at most sites (see Tables 3.a-3.d for summaries of nutrient analyses for select AGP tests), NO_3-N was elevated in samples from Sunnyside (14 µg/l) and Rubicon (11 µg/l) while the specific conductance was near the mid-lake mean of 92.4 µS/cm. This may indicate these sites were impacted by upwelling of lake water with high NO_3-N concentrations. Alternatively tributary inputs could also cause elevated NO_3-N but with tributary inputs might expect the conductivity to be different from typical lake levels. At Tahoe City SRP was elevated (9 µg/l), NO_3-N slightly elevated (5 µg/l) with a specific conductivity slightly elevated (94 µS/cm) which may indicate a tributary influence contributing P plus potential contributions of NO_3-N either from tributary or upwelling. Specific conductivity was substantially lowered relative to lake levels in samples from Tahoe Keys (76 µS/cm) and Emerald Bay (72 µS/cm) indicating a tributary influence, with slightly elevated NO_3-N (7 µg/l) and SRP (3µg/l) present in water at Tahoe Keys and very low levels NO_3-N (0 µg/l) and SRP (1µg/l)of nutrients in water at Emerald Bay. Even with this additional information it is difficult to say with certainty the primary factors resulting in the observed patterns for AGP. Chlorophyll *a* increased at many sites for which chlorophyll *a* had been below mid-lake chlorophyll *a* resulting in AGP levels near to the mean mid-lake level AGP of 0.81 µg/l. Sites with AGP slightly elevated above the mid-lake mean included Tahoe Keys, Timber Cove, Zephyr Cove, Glenbrook and Crystal Bay.

The results for AGP experiment #11 highlight some of the complexities in interpreting this test. Many sites in this experiment had initial chlorophyll *a* levels either substantially lower or moderately lower than the mid-lake reference stations. This seems to indicate conditions were more favorable for development of elevated algal biomass at the mid-lake stations than at the nearshore stations with lower initial chlorophyll *a*. However the AGP test indicated many of those same nearshore sites to have similar algal growth potential as the mid-lake sites. Timber Cove, which had low initial chlorophyll *a* had a higher AGP than mid-lake. The AGP results can be difficult to interpret.

General Patterns for AGP in tests done 2013-2016

In reviewing individual AGP experiments done 2013-2016 some general observations may be made on patterns observed.

Levels of AGP tended to be variable in the experiments with no sites having consistently high or low AGP through all the tests. However, in comparing the AGP levels from the sites some sites were more frequently in the “top 3” or “bottom 3” ranking relative to AGP levels for a test. Sites more frequently in the “top 3” with the highest 3 AGP levels included: Emerald Bay (6 of 11 tests), Tahoe Keys (4 of 11 tests), Tahoe City (4 of 11 tests) and Timber Cove (4 of 11 tests). Sites more frequently in the “bottom 3” with the lowest 3 AGP levels included: Glenbrook (6 of 11 tests), Mid-lake North (5 of 11 tests) and Rubicon Bay (5 of 11 tests).

The four sites which typically were among the highest AGP may be responding to greater availability or input of nutrients. The Tahoe City site is located in the nearshore on an extensive shallow shelf near the Tahoe City Boat ramp slightly east of the entrance to Star Harbor. Nutrients from Star Harbor and its tributaries (Burton and Polaris creeks) may contribute to the elevated AGP at this site. Proximity to the boat ramp and boating activity (which can stir up sediments, nutrients and algae) may also impact AGP levels at the Tahoe City site. The Timber Cove site is located on an extensive shallow shelf area, offshore of the Timber Cove pier. That site may be affected by several sources of nutrients including: nearby stream inflows from the U.Truckee/Trout watersheds; nearby urban runoff inputs; localized nutrient inputs from Asian clams (which are abundant in the area); and boating activity and human activities in the nearshore which potentially stir up sediments, nutrients and algae into the water column. The Emerald Bay site is located at the back of Emerald Bay near the inlet of Eagle Cr. which may contribute nutrients. Finally, the Tahoe Keys site is located on the shallow shelf area offshore of the Tahe Keys and may be impacted by inputs from the Upper Truckee River as well as water, nutrients and phytoplankton from the Tahoe Keys channels nearby. There is also much boating activity in this area which can stir up sediments, nutrients and algae.

There appeared to be some seasonal differences in the AGP tests:

(1) Experiments done in early winter (December) tended to show little if any additional growth relative to initial chlorophyll *a* levels. In many cases, chlorophyll *a* decreased from initial levels resulting in the initial chlorophyll being considered the AGP level. These December experiments may not provide useful information other than initial lake chlorophyll *a* and perhaps could be eliminated or moved to a different time of year.
(2) The experiments done in late winter/early spring tended to show quite variable initial chlorophyll *a* levels with the mid-lake levels often being among the highest levels. AGP for mid-lake sites tended to be the same or slightly more than initial chlorophyll *a* and AGP for many of the other sites was close to or slightly exceeded the mid-lake AGP.
(3) For early and late summer AGP tests, initial chlorophyll *a* was generally very low with 2 or 3 sites with slightly elevated chlorophyll *a*. Chlorophyll *a* generally increased from initial levels at all sites in these summer tests. These increases were lowest in summer of 2015, during a year of meager nutrient inputs from storms and spring runoff.

Nutrient Levels in Initial Lake Water Collected

Levels of nutrients (NO_3-N, NH_4-N, SRP and TP) were analyzed in initial lake water from AGP monitoring sites in a portion of the experiments. The results of these analyses are presented in Table 3.a-3.d. Though not part of the contracted work these analyses were done to provide supplementary information to aid in understanding the test results. In general, nutrient levels tended to be very low at the sites with no obvious site to site trends corresponding to the AGP or initial chlorophyll *a* results. The nutrients present in lake water are subject to rapid biological uptake, and may not show large variations from site to site. Some variation in nutrient levels was observed. For instance, NO_3-N levels were slightly elevated at many sites in the 3/23/16 test, potentially reflecting inputs associated with lake upwelling at some sites and potentially tributary inputs at some sites.

Table 3.a. Initial NO_3-N concentrations in lake samples collected for a portion of AGP bioassays (nutrients not analyzed for all bioassays). Specific conductance "SC" is also shown for the 3/23/16 sampling.

	NO_3-N	NO_3-N	NO_3-N	NO_3-N	NO_3-N	NO_3-N	NO_3-N	NO_3-N	S.C.
	8/15/13	6/9/14	8/29/14	12/9/14	2/26/15	5/26/15	9/1/15	3/23/16	3/23/16
Sunnyside	1	1	4	2	1	0	1	14	92.1
Tahoe City	2	1	3	2	1	2	2	5	94.3
Kings Beach	1	1	3	1	2	0	1	7	93.3
Crystal Bay	2	1	2	2	3	1	1	5	92.4
Glenbrook	1	1	3	1	4	0	1	4	95.8
Mid-lake No.	1	1	3	2	2	1	1	5	92.1
Zephyr Cove	1	1	3	2	4	1	1	4	92.8
Timber Cove		1	3	2	4	0	2	4	91.2
Tahoe Keys	1	1	3	1	2	2	2	7	75.6
C.Richardson		1	3	1	2	0	1	6	93.0
Emerald Bay		1	3	3	1	0	1	0	71.6
Rubicon Bay	1	1	3	2	1	0	2	11	92.5
Mid-lake So.	1	1	2	2	2	0	1	4	92.6

Table 3.b. Initial NH_4-N concentrations in lake samples collected for AGP bioassays.

	NH_4-N	NH_4-N	NH_4-N	NH_4-N	NH_4-N	NH_4-N	NH_4-N	NH_4-N
	8/15/13	6/9/14	8/29/14	12/9/14	2/26/15	5/26/15	9/1/15	3/23/16
Sunnyside	5	3	4	1	3	4	1	2
Tahoe City	5	4	8	4	5	4	4	0
Kings Beach	4	3	8	3	4	4	2	3
Crystal Bay	3	2	7	3	3	4	1	1
Glenbrook	4	3	9	2	2	4	2	1
Mid-lake No.	1	3	9	3	3	4	2	2
Zephyr Cove	4	4	7	3	2	4	3	1
Timber Cove		5	6	4	4	8	3	1
Tahoe Keys	4	3	4	3	4	5	2	1
C.Richardson		3	6	3	3	5	3	1
Emerald Bay		3	4	3	4	5	1	1
Rubicon Bay	3	3	4	3	4	5	2	2
Mid-lake So.	1	3	5	3	3	4	1	1

Table 3.c. Initial SRP concentrations in lake samples collected for AGP bioassays.

	SRP	SRP	SRP	SRP	SRP	SRP	SRP	SRP
	8/15/13	6/9/14	8/29/14	12/9/14	2/26/15	5/26/15	9/1/15	3/23/16
Sunnyside	1	2	1	2	1	1	0	1
Tahoe City	2	3	2	1	2	2	0	9
Kings Beach	2	1	2	1	2	2	0	1
Crystal Bay	1	1	2	1	2	2	0	2
Glenbrook	2	1	2	1	1	1	0	1
Mid-lake No.	1	1	2	1	1	1	0	1
Zephyr Cove	2	1	3	3	1	1	0	1
Timber Cove		1	2	3	1	1	3	2
Tahoe Keys	1	1	2	2	1	1	2	3
C.Richardson		1	2	2	1	1	0	2
Emerald Bay		1	1	2	1	1	0	1
Rubicon Bay	1	1	1	2	2	1	1	1
Mid-lake So.	1	1	2	3	1	2	0	1

Table 3.d . Initial TP concentrations in lake samples collected for AGP bioassays.

	TP	TP	TP	TP	TP	TP	TP	TP
	8/15/13	6/9/14	8/29/14	12/9/14	2/26/15	5/26/15	9/1/15	3/23/16
Sunnyside	2	4	27	5	2	11	0	9
Tahoe City	4	5	5	8	3	9	4	28
Kings Beach	4	3	18	6	3	10	4	12
Crystal Bay	4	3	30	6	3	10	6	14
Glenbrook	4	2	22	7	4	10	1	11
Mid-lake No.	4	3	17	6	3	2	3	11
Zephyr Cove	5	2	25	4	3	10	6	10
Timber Cove		4	40	3	3	9	5	8
Tahoe Keys	3	6	30	6	3	13	2	19
C.Richardson		4	17	3	3	9	4	9
Emerald Bay		4	12	5	3	10	5	11
Rubicon Bay	NA	3	23	6	3	9	2	7
Mid-lake So.	2	3	20	5	3	7	6	5

Levels of AGP and the Lahontan AGP Standard

The Lahontan standard for AGP states that mean annual AGP at a site should not be greater than two times the mean annual AGP at a mid-lake reference station. We evaluated the AGP data relative to the Lahontan Standard for the two complete calendar years of data (2014 and 2015) obtained during this study period. Tables 4 and 5 present the algal growth potential test results by date during these years, along with the mean annual values for annual data (including all four tests) and mean annual values for only the tests done during May – Aug. DWR in 1960's and 1970's typically calculated their annual means based on AGP tests during the May to Aug. period. The annual means for the nearshore sites were then divided by the annual means for the Mid-lake stations to determine whether the Lahontan standard of 2X the mean annual growth at the Mid-lake station was exceeded.

Table 4. Calendar Year 2014: Algal Growth Potential (AGP) test results by date; Mean Annual AGP; May-Sept. AGP; Station Mean Annual AGP ÷ Mid-lake Mean Annual; May-Sept. Station Mean AGP ÷ May-Sept. Mean Mid-lake AGP.

	AGP Peak Chl.a (µg/l)	AGP Peak Chl. a (µg/l)	AGP Peak Chl. a (µg/l)	AGP Peak Chl. a (µg/l)	Annual Mean AGP	May-Sept. Mean AGP	Annual Mean AGP ÷ Mid-lake Annual Mean AGP	May-Sept. Mean AGP ÷ May-Sept. Mid-lake Mean AGP
Water Coll. Date	2/20/14	6/9/14	8/29/14	12/9/14				
Sunnyside	.63	.69	.42	.52	0.57	0.56	1.04	1.35
Tahoe City	.69	.61	.82	.46	0.65	0.72	1.19	1.73
Kings Beach	.87	.37	.48	.45	0.54	0.43	1.00	1.03
Crystal Bay	.81	.39	.43	.61	0.56	0.41	1.03	0.99
Glenbrook	.79	.44	.40	.46	0.52	0.42	0.96	1.02
Zephyr Cove	.96	.50	.61	.39	0.62	0.56	1.13	1.35
Timber Cove	1.09	.50	.65	.39	0.66	0.58	1.21	1.39
Tahoe Keys	1.08	.65	.56	.53	0.71	0.61	1.30	1.47
Camp Rich.	.83	.83	.45	.43	0.64	0.64	1.17	1.55
Emerald Bay	.77	.69	.39	.52	0.59	0.54	1.09	1.31
Rubicon Bay	.61	.26	.44	.38	0.42	0.35	0.78	0.85
Mid-Lake:								
Mid-lake No.	0.87	.26	.44	.53	0.53	0.35		
Mid-lake So.	0.87	.58	.37	.43	0.56	0.48		
Mean Mid-lk					0.54	0.41		

Table 5. Calendar Year 2015: Algal Growth Potential (AGP) test results by date; Mean Annual AGP; May-Sept. AGP; Station Mean Annual AGP ÷ Mid-lake Mean Annual; May-Sept. Station Mean AGP ÷ May-Sept. Mean Mid-lake AGP.

	AGP Peak Chl.a (µg/l)	AGP Peak Chl. a (µg/l)	AGP Peak Chl. a (µg/l)	AGP Peak Chl. a (µg/l)	Annual Mean AGP	May-Sept. Mean AGP	Annual Mean AGP ÷ Mid-lake Annual Mean AGP	May-Sept. Mean AGP ÷ May-Sept. Mid-lake Mean AGP
Water Coll. Date	2/26/15	5/26/15	9/1/15	12/16/15				
Sunnyside	.71	.44	.23	.44	0.46	0.34	1.00	1.33
Tahoe City	.62	.78	.49	.50	0.60	0.64	1.31	2.51*
Kings Beach	.83	.44	.28	.49	0.51	0.36	1.12	1.43
Crystal Bay	.84	.43	.24	.46	0.49	0.34	1.08	1.33
Glenbrook	.97	.35	.21	.46	0.50	0.28	1.09	1.11
Zephyr Cove	.94	.46	.22	.49	0.53	0.34	1.16	1.35
Timber Cove	1.08	.88	.46	.44	0.72	0.67	1.57	2.65*
Tahoe Keys	.90	.39	.35	.48	0.53	0.37	1.16	1.47
Camp Rich.	.75	.43	.20	.49	0.47	0.32	1.03	1.25
Emerald Bay	.98	.52	.29	1.29	0.77	0.41	1.69	1.31
Rubicon Bay	.76	.38	.25	.39	0.45	0.32	0.98	1.25
Mid-Lake:								
Mid-lake No.	.67	.33	.21	.63	0.46	0.27		
Mid-lake So.	.76	.24	.23	.57	0.45	0.235		
Mean Mid-lk					0.455	0.2525		

Note- "*" and highlighted in gray, indicates mean May-Sept. AGP levels exceed the Lahontan Standard where mean annual AGP at a station is not to exceed twice the mean annual AGP at a mid-lake reference station.

The results of these analyses indicated there were no violations of the Lahontan AGP standard if all four tests during the calendar year were used in calculation of annual means. However, DWR in 1960's and 1970's typically calculated their annual means based on AGP tests done during the May-Aug. period. Using a nearly similar period May – Sept. for calculation of the mean annual AGP in our study, there were no violations of the Lahontan standard in 2014 but some violations in 2015. Two sites violated the standard in 2015 (Tahoe City and Timber Cove). AGP at Tahoe City was 2.51 times the mid-lake annual mean, and AGP at Timber Cove was 2.65 times the annual mean. Based on the 2015 data, Tahoe City and Timber Cove are areas to watch with respect to AGP.

Observations related to interpretations of the AGP tests

After three years of use of the AGP method, some of the challenges related to use and interpretation of the method have become apparent. First, as with other laboratory bottle algal bioassay methods, the AGP method is a test which relies on incubation of algae in flasks under controlled conditions in the lab. The results of the test are constrained to some extent by bottle effects and conditions of incubation. Algae in the flasks do not experience similar conditions of water circulation, nutrient availability, light intensity, presence of UV, exposure to grazers and many other factors which occur in natural waters. With laboratory incubation, factors may be removed which may constrain growth in the lake (e.g. presence of UV light may inhibit algal growth in shallow portions of the lake, whereas in laboratory incubation, the algae could potentially show growth when this UV inhibition is removed). This is a challenge of using bottle bioassays to provide information on the much more complex system of the lake. It is best to use information from such tests in combination with other physical, chemical and biological data to draw conclusions on conditions in the lake.

At times it was difficult to interpret the results of the AGP tests. For instance one site, Timber Cove had very low initial chlorophyll *a* biomass on several dates yet also had high growth potential as observed in a large increase in chlorophyll *a*. If the algae had high AGP, why wasn't it observed at the site in the form of high biomass at the time of collection? Removal of algae by grazing (either zooplankton or Asian clams) could be one explanation. Movement of water with lower algae content and elevated nutrients into an area (i.e. through upwelling or stream inputs) could be another explanation. There may also be other factors which constrain growth naturally in that area, i.e.: effects of high light/UV over the shallow shelf and inability of algae to ciculate or move away from the high UV , unfavorable temperature or chemical conditions, or competition for nutrients from benthic algae and bacteria. Removal of these factors in laboratory incubation conditions could promote increases in chlorophyll *a*. This raises the question of the significance of the AGP test results if under natural conditions, growth of the algae is normally constrained and the algal growth potential is not normally achieved.

Interesting patterns were also seen for initial lake chlorophyll *a* and AGP late winter/early spring samplings (2/20/14, 2/16/15, 3/23/16). The mid-lake sites and some of the nearshore sites (e.g. Crystal Bay and Emerald Bay) had the highest chlorophyll.*a*,. However chlorophyll *a* at many of the nearshore sites was much lower than that observed at the mid-lake. Chlorophyll *a* often increased during the AGP test for many of these nearshore sites resulting in AGP levels similar to or greater than the Mid-lake levels. There are several possible explanations for these patterns (i.e. grazing of phytoplankton nearshore, upwelling of deeper water containing lower algal biomass; inputs of dilute surface runoff) or some environmental factor is constraining nearshore biomass, which is removed in the laboratory incubations. The AGP test results in combination with other data (i.e. zooplankton data, primary production, phytoplankton data, water chemistry, etc.) might ultimately explain the patterns of lower chlorophyll *a* at many nearshore sites during this period.

Further examination of the utility of the AGP tests in combination with data currently collected for the nearshore would be useful, as well as examination of what other methods might be used to assess algal growth potential *in situ*.

Section II. Enumeration and Identification of Phytoplankton

This section summarizes the results for nearshore phytoplankton monitoring done August 2013-Dec., 2015. Phytoplankton are the free-floating algae in lakes. They typically form the base of the aquatic food web. They utilize energy from the sun, carbon dioxide and nutrients for production of biomass and growth. If changes occur in lake water quality, the phytoplankton are among the first indicators of that change. The abundance or numbers of the cells will change, the biodiversity may change, and these changes may trigger changes in other parts of the food web. When present in too high a level phytoplankton degrade water quality.

Phytoplankton consists of a diverse assemblage of many different major taxonomic groups (e.g. diatoms, chrysophytes, dinoflagellates, cryptomonads, greens, blue-green algae (cyanobacteria), haptophytes, euglenophytes and myocetes occur in Tahoe). The phytoplankton species which make up each of the different groups have characteristics common to the particular group (such as pigment composition, morphological characteristics, resource requirements, growth rates, sinking velocities). Their size can range over several orders of magnitude (~0.2-200 µm) (Heyvaert et al., 2013). As lake conditions change over the course of a year, the phytoplankton experience seasonal succession. Variation in algae may also occur in regions associated with localized nutrient inputs or other factors, resulting in differences in the algal community composition from other sites around the lake.

Monitoring done the last three years (2013-2016) was the first extensive nearshore monitoring in Lake Tahoe since the early 1980's. In 1981-82, nearshore monitoring of phytoplankton was done at 6 sites along the South Shore extending from Baldwin Beach to Stateline east, Zephyr Point and at two sites along the west shore, Rubicon Pt. and Sunnyside-Pineland (Eloronta and Loeb, 1984; Loeb, 1983). The results from that earlier study provide useful historical information on nearshore phytoplankton patterns. In general, the major taxonomic groups that dominated the littoral zone were found to be similar to those found in pelagic waters (Loeb, 1983). There were some differences in the algal assemblage in different nearshore areas possibly associated with different levels of fertility. Sites along the south shore were shown to have the highest species diversity and three groups which are most indicative of lake water fertility (green algae, cyanophytes and euglenoids) were more abundant at the south shore. Green algae were consistently more diverse along the south shore. Very little monitoring of the nearshore phytoplankton has been done since the study in the 1980's.

With increased interest in the state of the nearshore, nearshore phytoplankton monitoring was included as part of the Lake Tahoe Water Quality Investigations monitoring for 2013-2016. Phytoplankton samples were collected at the same time as water collected for the Algal Growth Potential experiments. Eleven near-shore sites and two open water (mid-lake) sites were sampled quarterly for phytoplankton identification and enumeration. Cells were counted and identified to species level when possible following established TERC protocol (see Appendix 2).

Nearshore Phytoplankton Monitoring Results Aug., 2013-Dec. 2015

Due to the large numbers of species associated with each sample, the summary of phytoplankton biovolume and abundance data by individual species is located on the TERC website (http://terc.ucdavis.edu at the links: "Publications" >"Lahontan Monitoring Reports"> "2013-2016 Lahontan Monitoring Data Updates">"TERC 2013-2016 Nearshore Phytoplankton"). This data was used to compile summary graphs of phytoplankton abundance and biovolume data by algal group (i.e. diatoms, chrysophytes, dinoflagellates, cryptomonads, greens, cyanophytes, haptophytes, euglenophytes and myocetes) which are presented in Figures 3.a-3.t. below.

The predominant phytoplankton groups showed seasonal variation. For instance, biovolume in 2013 and 2014 (Figures 3a, 3c, 3e, 3g) showed the following general patterns at a majority of sites: in Aug. 2013, dinoflagellates and diatoms made up a significant portion of the biovolume; by Dec. 2013 a mix of predominantly dinoflagellates, cryptomonads, chrysophytes and diatoms largely contributed to the biomass; by February, the contribution of cryptomonads and chrysophytes was increased; then by June, 2014 dinoflagellates contributed substantially to biomass at many sites, with greens also contributing at a couple sites (Tahoe Keys and Emerald Bay). In August of 2014, dinoflagellates and diatoms were once again present, with chrysophytes also contributing to the biovolume. Seasonal changes in phytoplankton numbers by algal group also occurred, however the algal groups predominant in cell numbers were not necessarily the same as those for biovolume. For instance note the predominance of diatoms and chrysophytes with respect to *cell numbers* in Aug. 2013, whereas dinoflagellates and diatoms predominated in biovolume. Dinoflagellates made a substantial contribution to biovolume due to their large sizes, chrysophytes were much more numerous during that same period, but due to their small size made up only a small portion of the biovolume.

Some general seasonal patterns were observed for the total biovolume amounts. In general, total biovolume levels tended to be lower in the winter samplings (Dec. and Feb.) and were often highest in the late spring and summer samplings. There were some exceptions to this pattern, as biovolume at Mid-lake North, Glenbrook, and Rubicon Bay tended to be higher in the late winter (February) samples. Typically spring and summer are the height of phytoplankton growth activity (Hackley et al., 2015).

Although there was some variation in the proportions of various groups contributing to biomass on particular dates, the patterns seen in many of the nearshore stations were similar to those observed at the two stations at mid-lake. This was similar to the pattern for biovolume in 1981-82 described by Loeb (1983) where the major taxonomic groups that dominated the littoral zone were found to be similar to those found in pelagic waters. In monitoring done 2013-2016, Individual sites did occasionally show distinct differences. For instance while dinoflagellates dominated the biovolume at most sites in June, 2014, the Tahoe Keys biovolume differed in that it was a mix predominantly of diatoms, greens and dinoflagellates. Emerald Bay was a mix of chrysophytes, dinoflagellates and greens during the same period.

One site, Emerald Bay, did frequently show differences from the other stations. On several dates the composition of predominant algal groups in Emerald Bay was quite different there from the other nearshore sites. For instance: on June 9, 2014 phytoplankton biovolume and abundance showed a greater proportion of green algae and chrysophytes than most other sites; then, in August 2014, Emerald Bay lacked the abundance of dinoflagellates that were dominant in the larger lake area; in February, 2015, Emerald Bay had fewer blue-greens than most sites around the lake; in May, 2015 Emerald Bay had its own phytoplankton bloom of Chrysophytes, not seen anywhere else in the lake; in September 2015, the green algae group comprised a substantial portion of the biovolume. However, Emerald Bay was also similar at times with respect to biovolume proportions of various algal groups (i.e. such was the case in Dec. 2015).

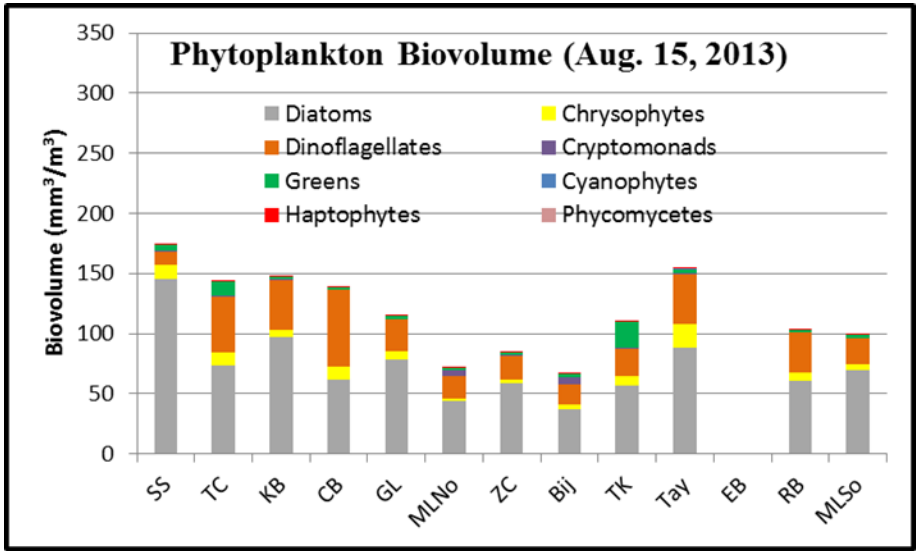
Sites occasionally had contributions to the biovolume and abundance from one or more of the three groups which can be associated with more fertile waters (cyanobacteria, green algae and euglenophytes). However, these groups in most cases were only a very small portion of the overall biovolume and there generally were only a few species. Lake Tahoe nearshore waters often exhibit characteristics of ultra-oligotrophic or oligotrophic waters with respect to: predominant species (diatom dominance, presence of chrysophytes and dinoflagellates); low biomass, relatively low species numbers per sample (i.e. 20-50 per sample) (see Table 14-2 in Heyvaert et al., (2013) for characteristics, including community composition of waters of various trophic states). Green algae occasionally contributed to the biovolume in proportions similar to some of the other more frequently observed algal groups (i.e. diatoms and dinoflagellates). This occurred primarily in the summer samplings. Greens were noticeable in the community composition at several of the south shore sites (i.e. Zephyr Cove, Timber Cove, Tahoe Keys, and Emerald Bay) and some north shore sites (i.e. Tahoe City and Sunnyside) on various summer sample collections. However, greens were not consistently observed in the phytoplankton at these sites each summer. As will be discussed below, an unusually high level of one type of cyanobacteria (*Aphanothece sp.*) was observed during Feb. and May 2015 over a wide region of the lake including the mid-lake regions. However, this elevated level of cyanobacteria may have been associated with particularly low nutrient conditions in the lake during the prolonged drought (this species can fix nitrogen). The cyanobacteria levels subsequently declined. Generally blue-greens comprised a very small portion of the biovolume and cell counts at sites. Some of the more frequently observed cyanobacteria species were *Aphanothece, Leptolyngbya*, *Chroococcus*, *Phormidium*, *Schizothrix*. Euglenoids were rarely seen in the phytoplankton counts.

As indicated above, in 2015 there was an unusual occurrence of the blue-green species *Aphanothece* over widespread regions of the lake. In February and May 2015 *Aphanothece* greatly influenced the total bio-volume at many stations including the mid-lake stations. *Aphanothece sp*., is a very small (3µm) solitary cell which has the capacity to fix nitrogen from the atmosphere. *Aphanothece sp*. has been present in the past but its abundance in 2015 was remarkable. These cells prefer high light, low nitrogen, high temperature and sources of inorganic carbon to enhance their ability of aerobic nitrogen fixation (Reddy et al 1993). The algal cells can be present without fixing nitrogen, since they have the ability to photosynthesize, but their abundance is indicative of waters which lack nitrogen. In February 2015, these blue-greens were obvious at all sites except Sunnyside and Mid-lake South. In May 2015 the blue-greens were seen predominantly at the South Tahoe stations with the Mid-lake North station being the only station in the north also having them. The unusual high abundance of *Apanothece sp*. certainly has implications on the biology and clarity of the lake, but very little can be said about the implication for the near-shore stations in particular.

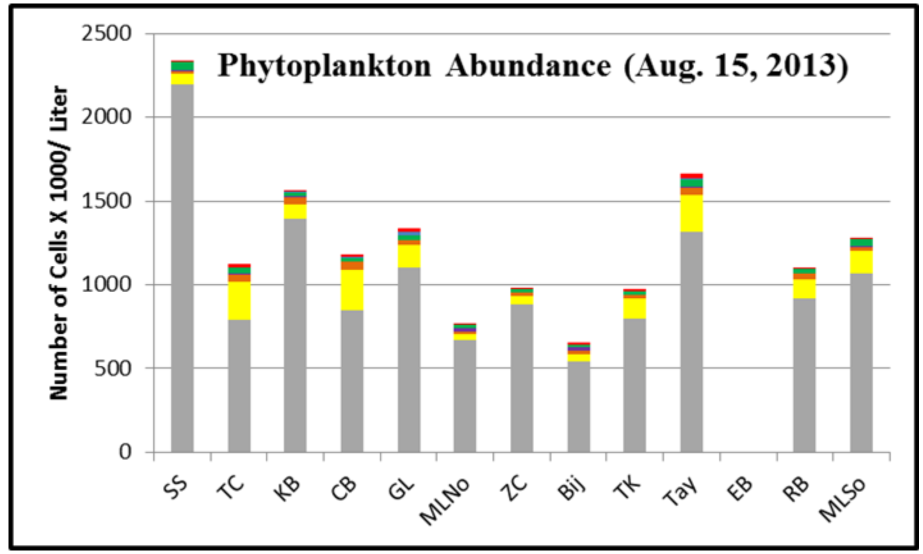
The other odd occurrence seen in February 2015 was the dominance of a small centric diatom, *Cyclotella gordonensis*, which typically is seen only during summer stratified months of July and August. These cells are excellent competitors during low nutrient, high light and warmer temperature conditions (Winder and Hunter, 2008 and Winder et. al. 2009). Their habitat preferences suggest all the stations in February, at shallow depths were stable and nutrient deficient, which would be a consequence of little precipitation runoff and mixing. The presence of *Cyclotella sp*. was a lake-wide event, unusual for February.

An interesting spatial difference in the distribution of the Cyclotella was observed in 2015.   The abundance of *Cyclotella sp*. between near shore stations was fairly consistent, 250,000-350,000 cells/l. At Timber Cove, however, the numbers of *Cyclotella sp*. (85,000 cells/l), were less than half the value of neighboring sites. At this near shore site the bottom topography is a shallow shelf extending from the beach outward for quite a distance. There are a number of Asian clams (*Corbicula fluminea*) in the sandy bottom substrate. It is possible that Asian clams are having an impact on the shallow water column in this area, filtering out phytoplankton as a food source from the ambient water (Boltovskoy et. al. 1995). Asian clams have the ability to both filter feed on material in the water column and pedal feed on deposited material in the sediments. Filtration rates for Corbicula sp. are highest with particles 3-5 µm, exactly the same size class as the abundant Cyclotella cells in Lake Tahoe.   When clams densely populate a near-shore area, they can potentially filter large volumes of water (Way et. al. 1990).   However there could also be other reasons for the lower levels of *Cyclotella* at Timber Cove.   One alternative explanation is that it is also possible greater nutrient enrichment at this site favored other algal species over *Cyclotella gordonensis*, which competes well in very low nutrient conditions - note that NH_4-N was slightly higher (8 µg/l at Timber Cove on 5/26/15 compared to 4-5 µg/l at all other sites). The fact that this site had higher AGP seems to support greater nutrient enrichment. However, the observation that initial chlorophyll *a* was the lowest of all sites at this site seems to counter the idea of greater enrichment. Other factors may also have contributed to the reduction. Additional study would be required to determine if the presence of Asian clams contributed to the reduction in *Cyclotella*.

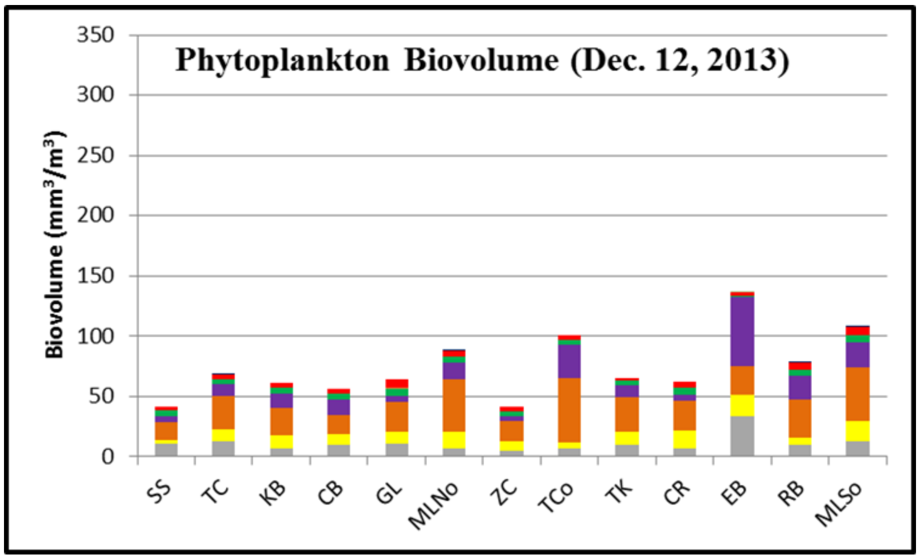
Figures 3.a – 3.t are presented in the following pages. Phytoplankton biovolume and abundance at nearshore and mid-lake stations during sample collections August 2013 to December 2016. Stations are shown along bottom in each graph and include: “SS”= Sunnyside; “TC”= Tahoe City; “KB”=Kings Beach; “CB”=Crystal Bay; “GL”=Glenbrook; “MLNo”=Mid-lake North; “ZC”=Zephyr Cove; “Bij”=Bijou (this site was replaced with Timber Cove site in Dec. 2013); “TCo”=Timber Cove; “TK”= Tahoe Keys nearshore; “Tay”=Taylor Cr. (this site was replaced with Camp Richardson in Dec. 2013); “CR”=Camp Richardson; “EB”=Emerald Bay (sampling began at this site in Dec. 2013); “RB”=Rubicon Bay; “MLSo”=Mid-lake South.



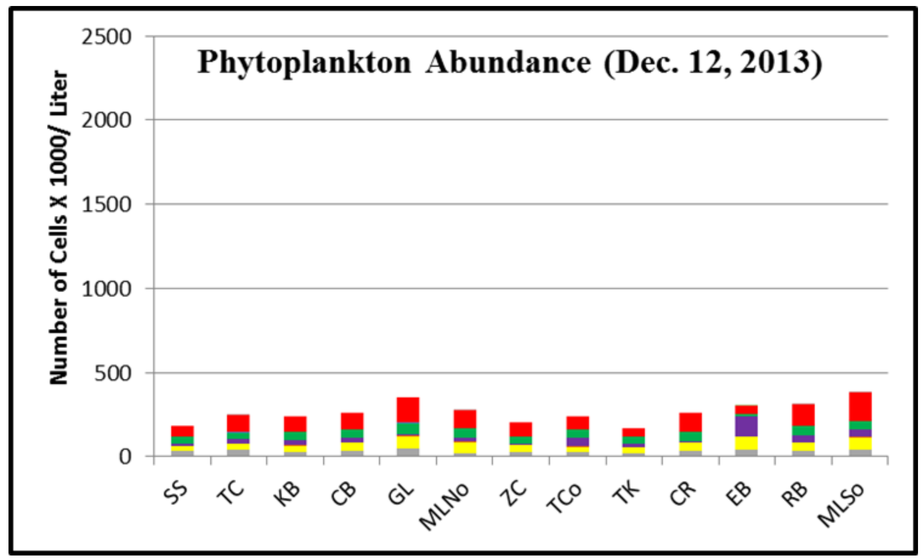
3.a) Phytoplankton Biovolume at nearshore sites 8/15/13 (site abbreviations are on previous page).



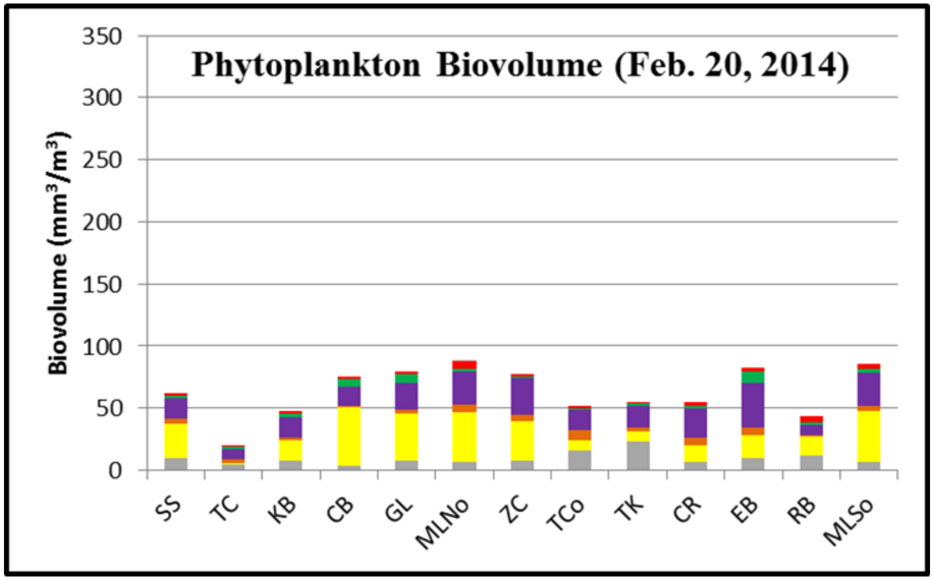
3.b) Phytoplankton Abundance (cell numbers) 8/15/13.



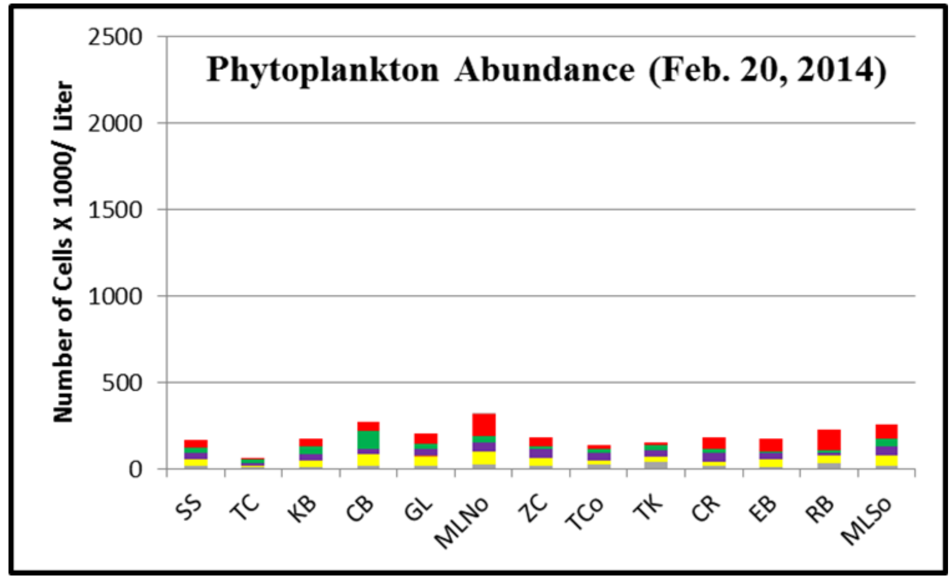
3.c) Phytoplankton Biovolume at nearshore sites 12/12/13



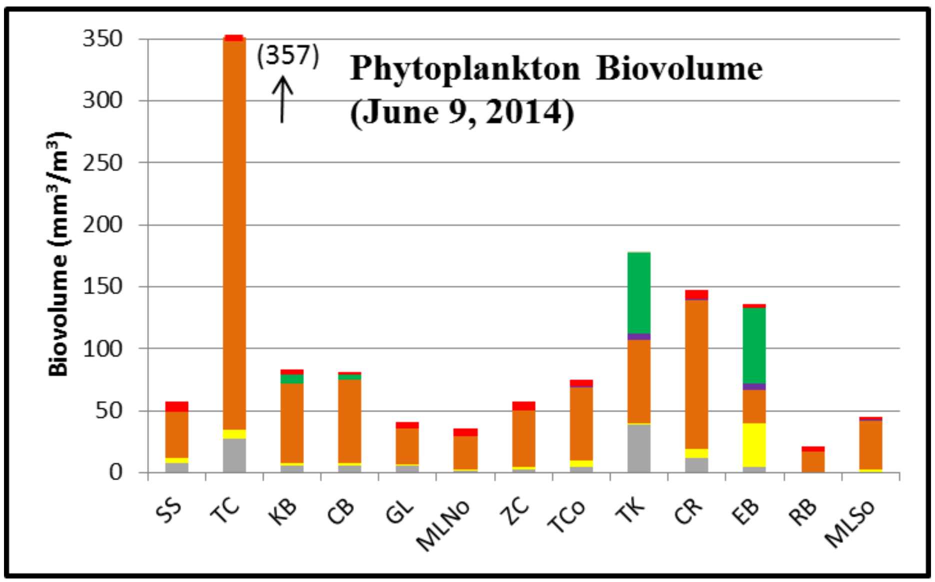
3.d) Phytoplankton Abundance (cell numbers) 12/12/13.



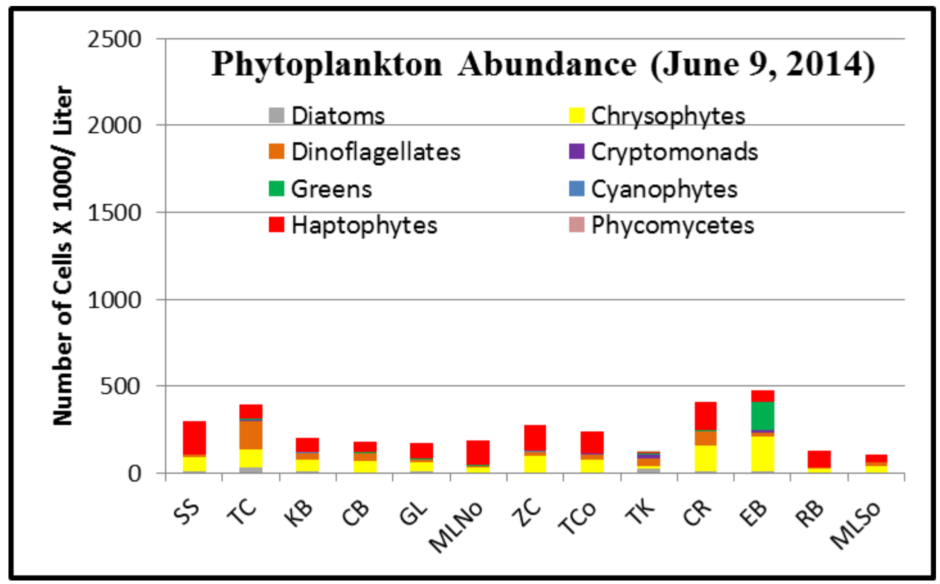
3.e) Phytoplankton Biovolume at nearshore sites 2/20/14



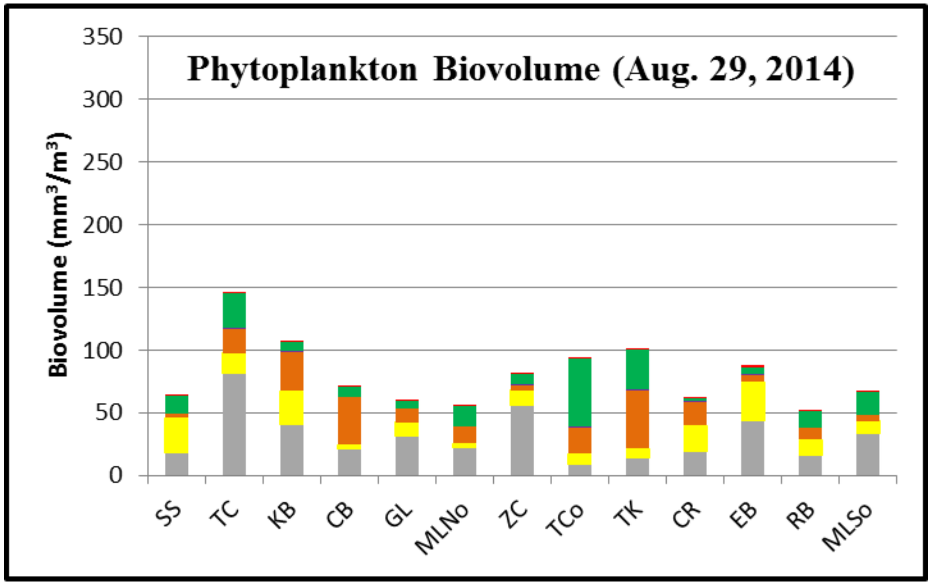
3.f) Phytoplankton Abundance (cell numbers) 2/20/14.



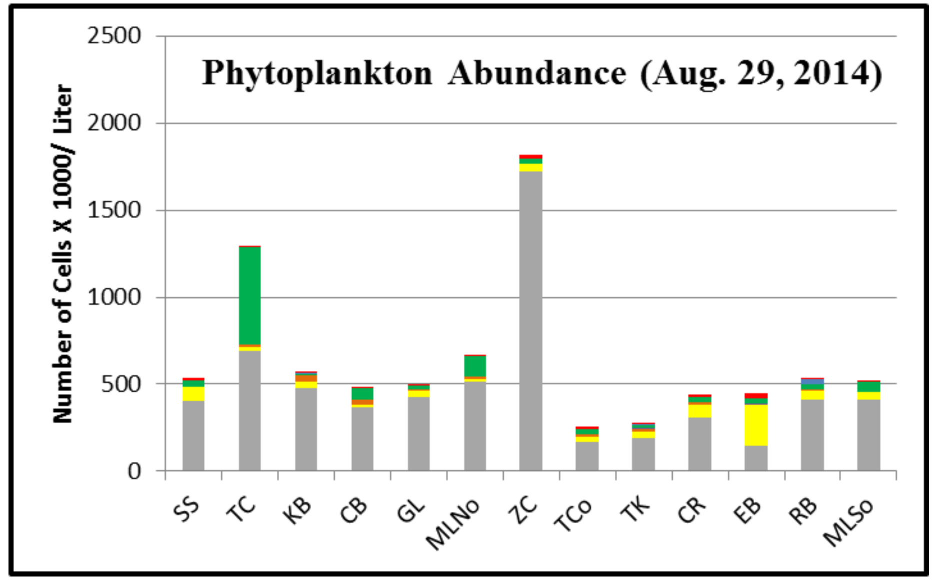
3.g) Phytoplankton Biovolume at nearshore sites 6/9/14



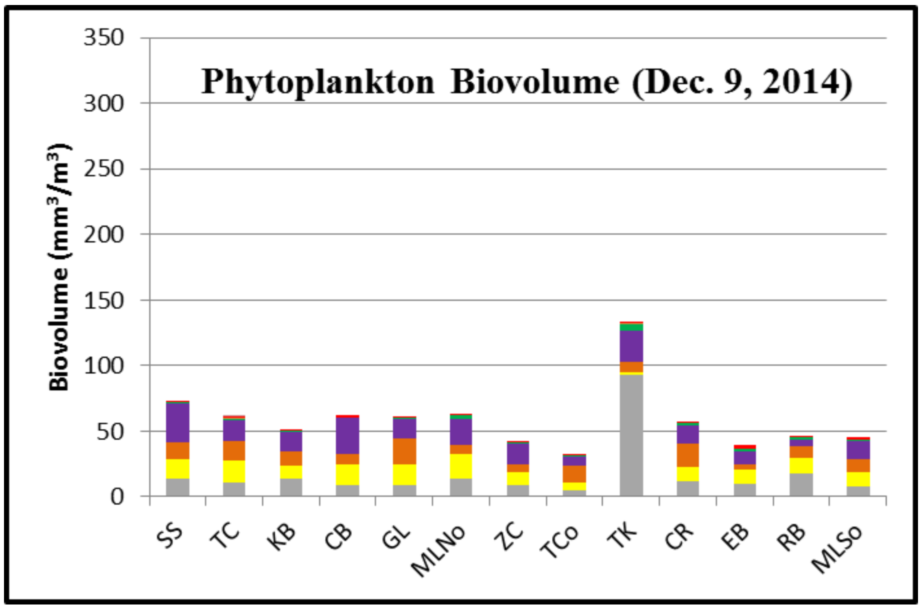
3.h) Phytoplankton Abundance (cell numbers) 6/9/14.



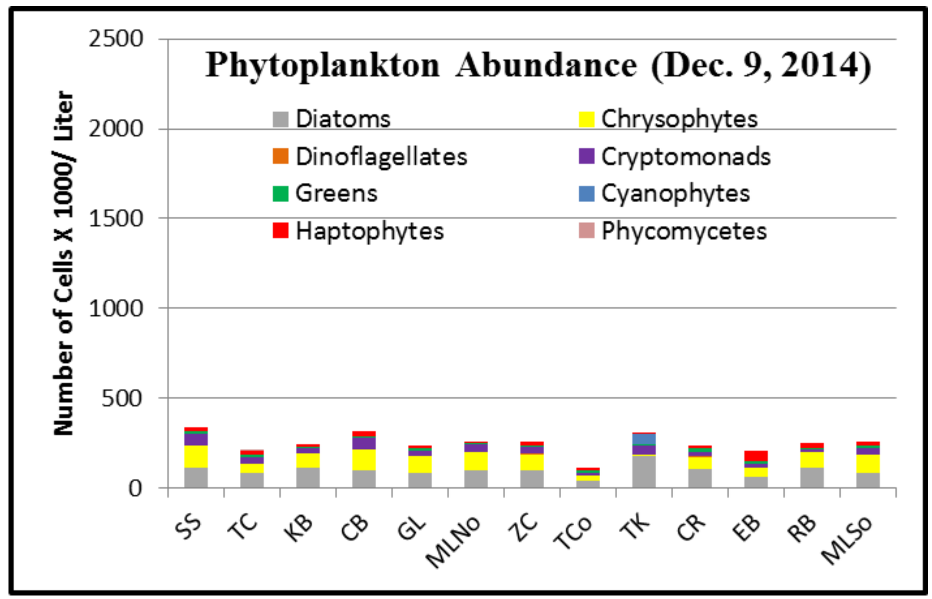
3.i) Phytoplankton Biovolume at nearshore sites 8/29/14



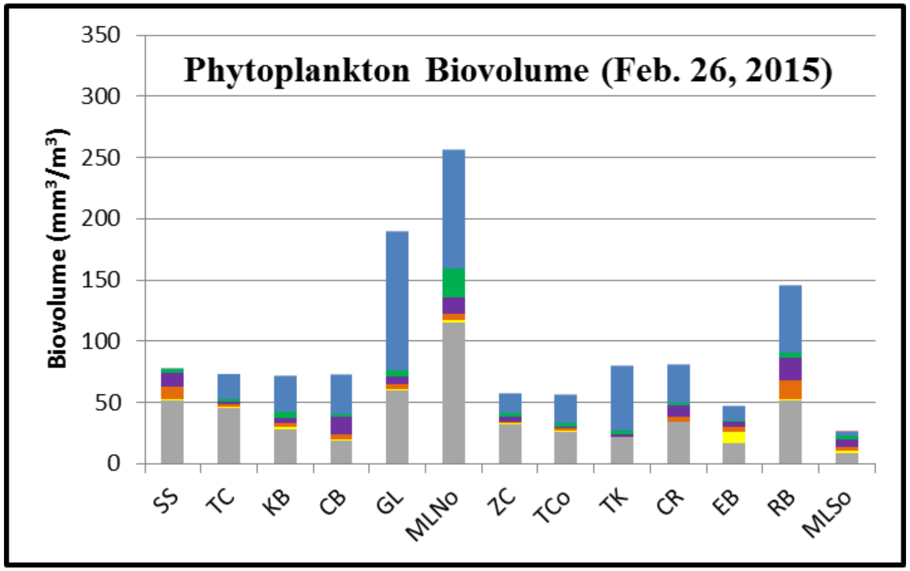
3.j) Phytoplankton Abundance (cell numbers) 8/29/14.



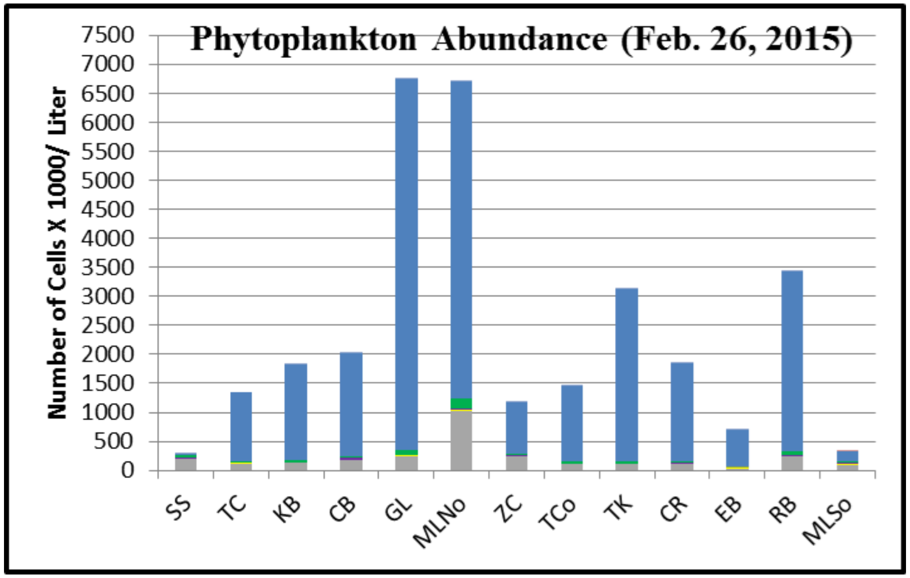
3.k) Phytoplankton Biovolume at nearshore sites 12/9/14



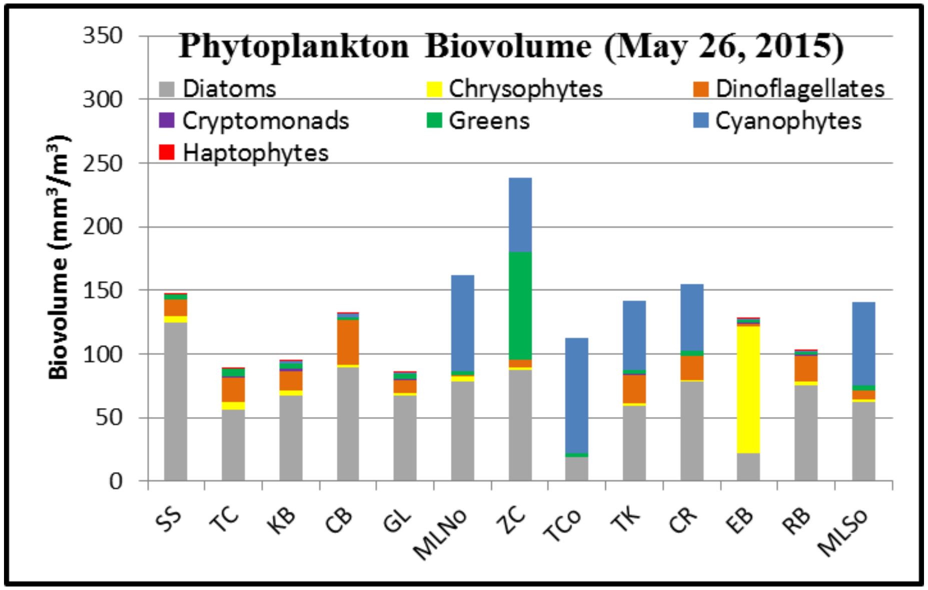
3.l) Phytoplankton Abundance (cell numbers) 12/9/14.



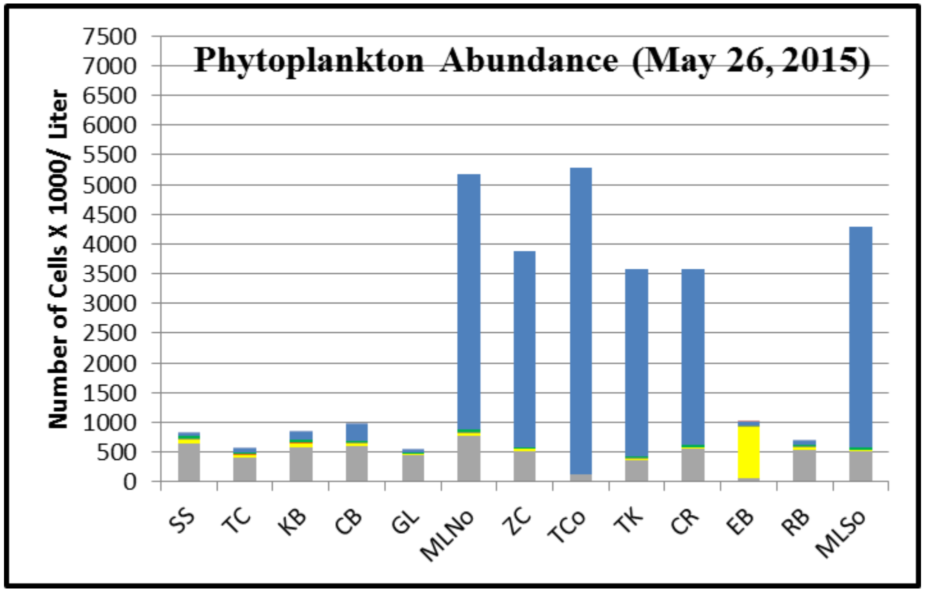
3.m) Phytoplankton Biovolume at nearshore sites 2/26/15



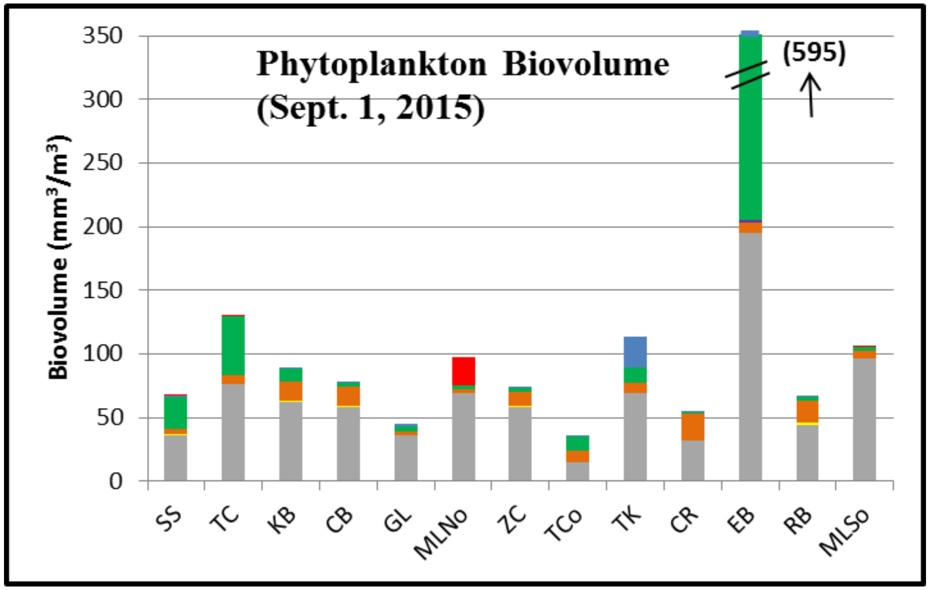
3.n) Phytoplankton Abundance (cell numbers) 2/26/15.



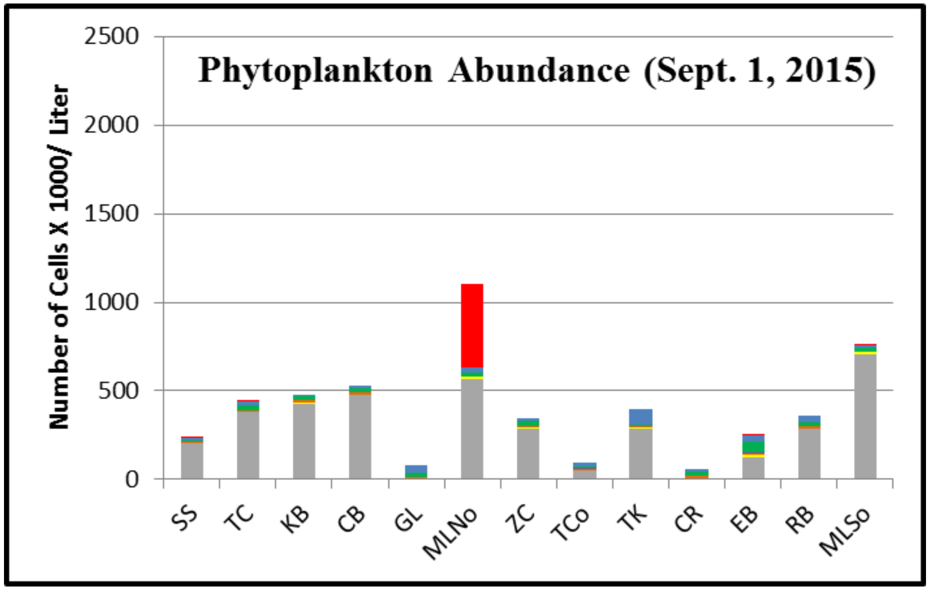
3.o) Phytoplankton Biovolume at nearshore sites 5/26/15



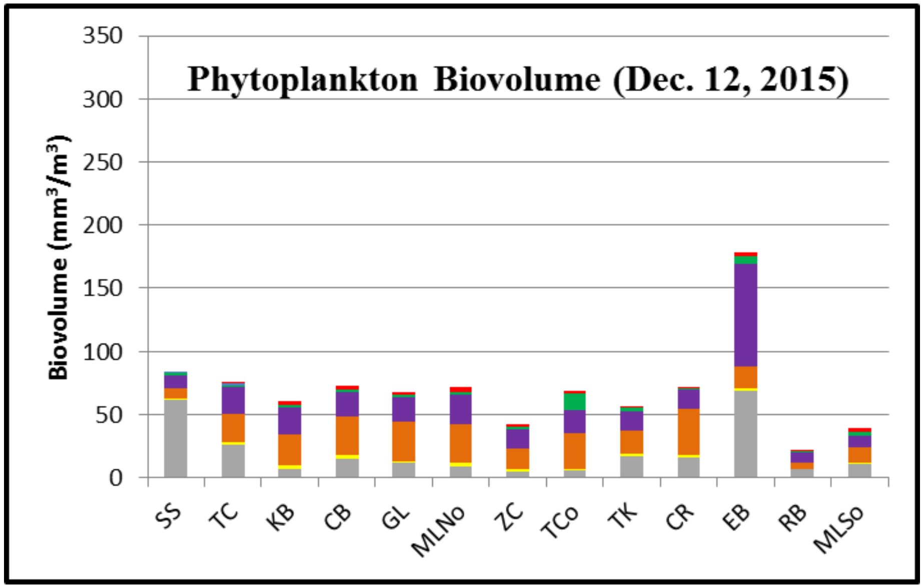
3.p) Phytoplankton Abundance (cell numbers) 5/26/15.



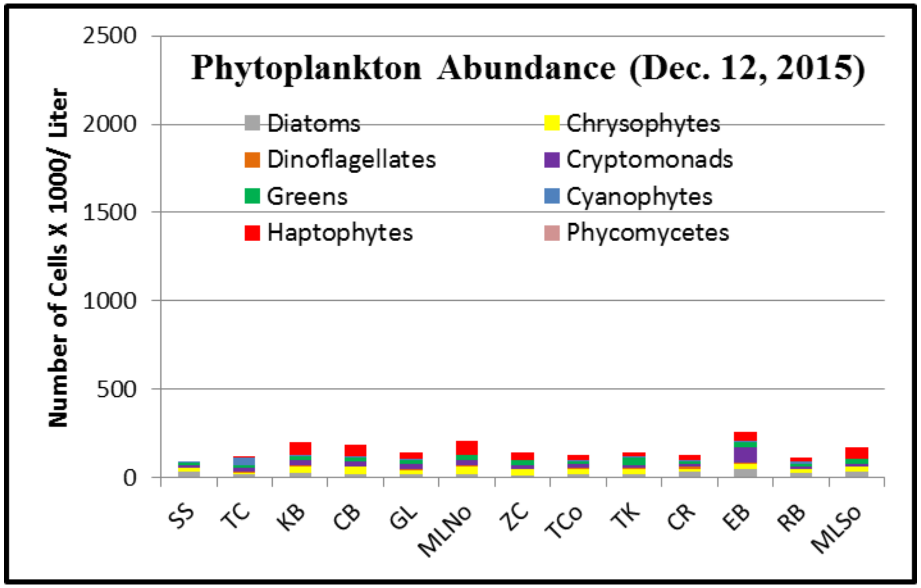
3.q) Phytoplankton Biovolume at nearshore sites 9/1/15



3.r) Phytoplankton Abundance (cell numbers) 9/1/15.



3.s) Phytoplankton Biovolume at nearshore sites 12/12/15



3.t) Phytoplankton Abundance (cell numbers) 12/12/15.

Species richness (number of different species) at a site provides some indication of the diversity of species among sites. Table 6 shows a summary of the mean numbers of species along with mean total cell numbers and mean biovolumes for the samples collected 2013-2015 from the sites. Tahoe City had the greatest mean (± Std. Dev.) number of species for samples (38±4 species), followed by Tahoe Keys (34±6 species), Emerald Bay (31± 7species) and Kings Beach (mean =30±4 species). In contrast, the two mid-lake sites had the lowest mean numbers of species (Mid-lake No. mean = 22±7 species; Mid-lake So.=22±5), followed by Rubicon Bay (23±8 species). In Table 14-2 of the Lake Tahoe Nearshore Evaluation and Monitoring Framework report, (Heyvaert et al., 2013), levels of number of species between 20-50 are characterized as levels associated with oligotrophic conditions, levels <20 species are characterized to be associated with ultra-oligotrophic conditions and levels50-100 with mesotrophic, and >100 with eutrophic conditions. The levels seen in recent nearshore monitoring would be characterized as in the oligotrophic range. It possible within this oligotrophic range, the sites with higher mean cell numbers may have somewhat greater productivity or alternatively greater exposure to sources which may contribute algae to the nearshore water. The sites at Tahoe City and Tahoe Keys are near obvious inlets of tributaries to the lake (Tahoe City near Burton Cr. and Star Harbor; and Tahoe Keys near the Upper Truckee River) which may deliver nutrients and phytoplankton to nearshore waters. Star Harbor is an embayment which may also allow some species of algae to develop in enriched waters. The Tahoe Keys site is near the Tahoe Keys east channel where some exchange of Tahoe Keys water and associated algae may occur. Tahoe City and Tahoe Keys nearshore site water showed strong growth potential in some of the algal growth potential tests.

Some stations were impacted by the presence of benthic periphyton and potentially metaphyton (collectively referred to as the 'benthic bias'), which do not typically 'live' in the plankton. Sites with rocky substrates and/or piers, aquatic plants and even the sand may have attached and /or benthic algae often diatoms associated with it. These algae may become detached from the substrate and mix into the water column during turbulence or wave activity. The metaphyton (algae that does not adhere to a substrate but are also not truly planktonic and often composed of filamentous green algae along the south shore) may also be suspended in the water column for periods. Algal cells may also be associated with bottom sands and sediments and become resuspended. The benthic algae cells are large and their presence in a sample can sway the bio-volume numbers significantly. In August 2014 (Fig. 3. i), for example, Tahoe Keys and Timber Cove had high bio-volumes of green algae (*Zygnem*a and *Spirogyra*). In both cases, benthic filamentous strands of cells contributed to increase the green color on the August 2014 graph. Tahoe City and Kings Beach were also impacted to a somewhat lesser degree, by the presence of benthic diatoms. In December, 2014 (Fig. 3. k) Tahoe Keys was once again subject to benthic bias, which contributed to the high diatom bio-volume, while in February 2015 (Fig. 3. m), this station had no notable benthic cells in the samples. By May 2015 (Fig. 3.o) the very visible green algae (*Mougeotia*), in Zephyr Cove, were responsible for this anomaly.

It is likely, to some extent the phytoplankton at Tahoe City and Tahoe Keys may be influenced by resuspension of benthic forms of algae contributing to greater number of species. The Tahoe City site is near a boat launch area with frequent boating activity, the Tahoe Keys site is near the east channel for the Tahoe Keys with significant boating activity and both sites are relatively shallow. Tahoe City, on each sampling date had the greatest number of species identified, with a presence of benthic diatoms, with only a few cells per species. The bulk of the phytoplankton at Tahoe City was usually confined to several dominant species.

Overall there were no areas that always had different phytoplankton composition or elevated biovolume. Although there was some variation in the proportions of various groups contributing to biomass on particular dates, the patterns seen in many of the nearshore stations were similar to those observed at the two stations at mid-lake. Emerald Bay frequently (but not always) had different predominant algal types that differed from the main body of the lake. It also had higher biovolumes than the other sites in the main body of the lake on several dates. The occasional elevated biovolumes at sites (i.e. Tahoe City, Emerald Bay, Tahoe Keys) may be a response to increased nutrient availability during certain periods. Resuspension of benthic cells also contributes to increased biovolumes at times. 2013-2016 was a prolonged drought period when generally low levels of nutrient were contributed to the lake. Levels of phytoplankton biovolume and abundance in the nearshore may show different patterns during years of heavier precipitation and increased nutrient inputs.

Table 6. Mean number of phytoplankton species, mean number of cells (abundance) and mean biovolume ± Std. Dev. (S.D.) for phytoplankton samples Aug. 2013 – Dec. 2015. Sample sites designated with "*"were not sampled on the first sampling in August 2013.

	Number of Species/ Date Mean ± S.D. (n)	Number of Cells/ Liter Mean ± S.D. (n)	Biovolume (mm^3/m^3) Mean ± S.D. (n)
Tahoe City	38 ± 4 (10)	579505 ± 492813 (10)	116 ± 94 (10)
Mid-lake North	22 ± 7 (10)	1566977 ± 2352424 (10)	99 ± 65 (10)
Kings Beach	30 ± 4 (10)	633429 ± 600584 (10)	81 ± 30 (10)
Crystal Bay	26 ± 5 (10)	639776 ± 592056 (10)	84 ± 28 (10)
Glenbrook	28 ± 6 (10)	1029319 ± 2040380 (10)	81 ± 44 (10)
Zephyr Cove	24 ± 3 (10)	925956 ± 1178673 (10)	80 ± 58 (10)
Mid-lake South	22 ± 5 (10)	834393 ± 1258345 (10)	80 ± 37 (10)
Timber Cove*	27 ± 5 (9)	881468 ± 1701829 (9)	70 ± 29 (9)
Tahoe Keys	34 ± 6 (10)	924373 ± 1306867 (10)	103 ± 40 (10)
Camp Richardson*	29 ± 6 (9)	792450 ± 1174829 (9)	83 ± 40 (9)
Emerald Bay*	31 ± 7 (9)	427132 ± 277143 (9)	159 ± 170 (9)
Rubicon Bay	23 ± 8 (10)	715482 ± 1003667 (10)	68 ± 40 (10)
Sunnyside	27 ± 4 (10)	527807 ± 667158 (10)	85 ± 42 (10)

Section III. Periphyton Results

The purpose of the periphyton monitoring task is to assess the levels of nearshore attached algae (periphyton) growing around the lake. As with phytoplankton, nutrient availability plays a large role in promoting periphyton growth. The amount of periphyton biomass can reflect local nutrient loading and also be affected by long-term environmental changes. Periphyton biomass is considered an important indicator, which together with nearshore chlorophyll, phytoplankton and macrophyte metrics provide information on the trophic status of the Lake Tahoe nearshore. Trophic status in turn, along with nearshore clarity, community structure and conditions for human health are considered primary indicators of nearshore condition or health as outlined in the Lake Tahoe nearshore monitoring framework (Heyvaert et al., 2013).

Periphyton grows in the littoral (shore) zone of Lake Tahoe, which may be divided into the eulittoral zone and the sublittoral zone, each with distinct periphyton communities. The eulittoral zone is the shallow area between the low and high lake level and is substantially affected by wave activity. Substrata within this region desiccate as the lake level declines, and periphyton must recolonize this area when lake level rises. The sublittoral zone extends from the bottom of the eulittoral to the maximum depth of photoautotrophic growth. The sublittoral zone remains constantly submerged and represents the largest littoral benthic region of Lake Tahoe.

The algal community in the eulittoral zone is typically comprised of filamentous green algae (i.e., *Ulothrix sp., Zygnema sp.*) and stalked diatom species (i.e., *Gomphoneis herculeana*). The attached algae in the eulittoral zone display substantial growth resulting in rapid colonization of suitable areas. These algae are able to take advantage of localized soluble nutrients, and can establish a thick cover over the substrate within a matter of months. Similarly, this community rapidly dies back as nutrient concentrations diminish and shallow nearshore water temperatures warm with the onset of summer. The algae can slough from the substrate and disperse into the open water, or wash onto the shore. In areas where biomass is high, the slimy coating on the rocks, and sloughed material that accumulates along shore can be a nuisance. The eulittoral zone periphyton has a substantial influence on the aesthetic condition of the shorezone. It is the strong response of eulittoral periphyton to localized nutrient inputs that lends particular value to monitoring this community as an indicator of localized differences in nutrient loading.

The sublittoral zone is made up of different algal communities down through the euphotic zone. Cyanobacteria (blue-green) algal communities make up a substantial portion of the uppermost sublittoral zone. These communities are slower growing and more stable than the filamentous and diatom species in the eulittoral zone.

Stations and Methods

Nine routine stations were monitored (Rubicon Pt., Sugar Pine Pt., Pineland, Tahoe City, Dollar Pt., Zephyr Pt., Deadman Pt., Sand Pt and Incline West). These nine sites are located around the lake (Figure 1 presents a map of locations and Table 7 provides coordinates of locations) and represent a range of backshore disturbance levels from relatively undisturbed land (Rubicon Point and Deadman Point) to a developed urban center (Tahoe City).

Table 7. Locations of Routine Periphyton Monitoring Stations

SITE NAME	LOCATION
Rubicon	N38 59.52; W120 05.60
Sugar Pine Point	N39 02.88; W120 06.62
Pineland	N39 08.14; W120 09.10
Tahoe City	N39 10.24; W120 08.42
Dollar Point	N39 11.15; W120 05.52
Zephyr Point	N39 00.10; W119 57.66
Deadman Point	N39 06.38; W11957.68
Sand Point	N39 10.59; W119 55.70
Incline West	N39 14.83; W119 59.75

A detailed description of the sample collection and analysis procedures is given in Hackley et al. (2004). Briefly, the method entails collection while snorkeling of duplicate samples of attached algae from a known area of natural rock substrate at a depth of 0.5m, using a syringe and toothbrush sampler. These samples are transported to the laboratory where the samples are processed and split, with one portion of the sample analyzed for Ash Free Dry Weight (AFDW) and the other portion frozen for later analysis of chlorophyll *a* concentration (both AFDW and chlorophyll *a* are used as measures of algal biomass). We also measure average filament length, percent algal coverage which are used to calculate the Periphyton Biomass Index PBI (which is the average filament length (cm) or height of the periphyton multiplied by the estimate of percent coverage of algae over the rock). The PBI provides a means to rapidly assess the level of periphyton biomass at a site. A subjective ranking of the level of periphyton at a site is also made, where 1 is least offensive appearing (usually natural rock surface with little or no growth) and 5 is the most offensive condition with very heavy growth. Finally, notes are made on which of three predominant algae types (stalked diatoms, filamentous green algae, or cyanobacteria (blue-green algae) are likely present based on observations underwater.

Results

<u>Monitoring at Routine Sites</u>

In this report we summarize the data collected during the period July 1, 2013 to May 30, 2016. Nine routine sites were sampled. All sites were sampled five times per year. Three of the five samplings were typically made between February and May when spring periphyton biomass typically peaks, with additional sampling circuits made during fall and early summer. Table 8 presents the results for biomass (chlorophyll *a* and Ash Free Dry Weight (AFDW)) and field observations (visual score, average filament length, percent algal coverage, biomass index and basic algal types) at the nine routine periphyton sites for the period November 2013 through May, 2016. The results for periphyton chlorophyll *a* biomass are also presented graphically in Figures 4 (a-i) together with earlier data collected since 2000. Figure 5 presents a graph of lake surface elevation and 0.5m sampling elevation Jan. 2000-May, 2016.

During 2013-2016, certain patterns for biomass were apparent at the routine sites. Comparing the data by water year, the patterns observed are presented below.

Water Year 2014 Patterns of Periphyton Biomass

WY 2014 was characterized by generally low periphyton biomass at the routine monitoring sites, with only modest spring increases at two sites in the NW portion of the lake and little or no increases at the other routine sites. Early in WY 2014 (in November), biomass was relatively low at all sites with Tahoe City having the highest chlorophyll *a* biomass (26 mg/m^2) and biomass at the other sites near or below 20 mg/m^2. By March 2014, slight to modest increases in biomass were observed at Pineland and Tahoe City in the NW portion of the lake. At Pineland, biomass peaked at a modest 40 mg/m^2, down substantially from the extremely high peak biomass of 242 mg/m^2 observed in spring 2013. Tahoe City had the highest highest peak biomass (65 mg/m^2), which was down from the 126 mg/m^2 peak observed in 2013. The remaining sites showed either small or no increases in the spring 2014.

Biomass at routine sites during lower growth periods (i.e. November 2013, late June/early July 2014) was generally similar to measurements made during the same periods in previous years (Figs. 4a-i). At most sites, chlorophyll *a* was slightly elevated (near or below 20 mg/m^2). At Tahoe City, chlorophyll *a* was slightly elevated in Nov. 2013 (Chl.=26.34 mg/m^2) relative to most years since 2000 and Deadman Pt. biomass was slightly elevated in late June/early July (chlorophyll *a*=30.84 mg/m^2).

Several factors may have contributed to the low biomasses observed in WY 2014. Among these factors, lower precipitation, lower nutrient inputs associated with runoff, less frequent storms, and possibly wind events may have played a role. WY 2014 was the third WY in a row of lower than average precipitation (see TERC, 2014) for precipitation trends at Tahoe City through WY 2013. There were no substantial runoff events until early February 2014 when a substantial storm with rain at lake level and higher elevation snow occurred. Also, a relatively small snowpack developed through the winter of 2014 which contributed to a relatively low spring runoff. Overall, runoff-associated nutrients contributed to the nearshore, were likely much reduced in 2014. With fewer storms in 2014, the degree of wind-mixing and potential upward mixing of nutrients may have been reduced. One other factor which may also have had an impact, from November 21-23 there was a strong north to northeast wind event. The waves generated were opposite the south or southwest wind direction typically occurring with winter storms. During this wind event, substantial wave activity resulted on the northwest and west shores of Lake Tahoe. It is possible this wave activity had some detrimental impact on early algal growth along the west and northwest shore through algal loss from wave action.

Water Year 2015 Patterns of Periphyton Biomass

WY 2015 was similar to WY 2014 in that generally low to moderate periphyton biomass was measured at the routine monitoring sites. Sites along the northwest shore (Pineland, Tahoe City and Dollar Pt.) ranged from low to moderate chlorophyll *a* biomass during WY2015 (i.e. Pineland chlorophyll *a* ranged from 15.88 to 47.49 mg/m^2, Tahoe City ranged from 5.63 to 35.64 mg/m^2 and Dollar Pt. ranged from 11 to 39.55 mg/m^2). Along the southwest shore, Rubicon Pt. ranged from 18.90 to 47.82 mg/m^2. At Sand Pt. along the east shore, chlorophyll *a* gradually increased through the WY from 17.86 to 34.57 mg/m^2. At the remaining routine sites, chlorophyll *a* remained relatively low (i.e. Sugar Pine Pt. ranged from 9.12 to 16.82 mg/m^2, Zephyr Pt. ranged from 10.58 to 18.55 mg/m^2 and Deadman Pt. ranged from 16.02 to 28.15 mg/m^2).

The relatively low biomass levels at sites in the northwest portion of the lake (Pineland, Tahoe City and Dollar Pt.) are interesting to note. These sites showed smaller spring biomass peaks than seen in previous years. It was likely this was a response to the continued below average precipitation and low inputs of nutrients to the lake's surface waters. WY 2015 was the fourth WY in a row of lower than average precipitation. Precipitation at Tahoe City in WY 2015 was only 52% of normal (www.cnrfc.noaa.gov/monthly_precip.php). There were infrequent storms with only one strong event which occurred Feb. 6-9, 2015 as significant rain with some snow. A very small snowpack accumulated for the WY which resulted in a very light spring snowmelt. Contribution of nutrients from stream and urban runoff was likely reduced compared to "wetter" years. Other factors may also have contributed. There was little early season precipitation to provide nutrients for initial periphyton growth, and storms were relatively infrequent potentially reducing the level of lake mixing and upwelled nutrients contributed to surface waters. The ongoing below average precipitation may have also resulted in reduced subsurface and groundwater inputs to the lake.

The lake level was extremely low during WY 2015, which had an impact on the predominant algae observed during this period. Lake surface elevation was below the natural rim (6223.00 ft.) for the majority of WY 2015 and the 0.5m sampling depth was 1.64 ft. (or 0.5m) below this. Sampling at 0.5m resulted in the collection of algae from a cyanobacteria (blue-green algae) zone of periphyton growth at most sites. The blue-green algae are a stable, slow-growing community typically found in the sublittoral zone, below1-2m deep, under more "normal" lake levels, but were located near the surface under the extremely low lake levels in 2015. Filamentous green algae were observed growing in association with the blue-green algae at many sites, particularly along the north, southwest and east shores. Stalked diatoms were observed primarily along the west and northwest sites this year (Sugar Pine Pt., Pineland, Tahoe City and Dollar Pt.). Tahoe City was the only site that appeared to have relatively little blue-green algae at 0.5m.

Two sites along the northeast shore (Sand Pt. and Deadman Pt.) showed slightly increased biomass relative to levels in 2012 and 2013. This was likely a consequence of sampling within the zone of thicker blue-green algal growth in 2015. With a much lower lake level in 2015, sampling was done in the area where the substrate had been submerged for many years (since previous record low lake levels in the early 1990's) and blue-greens were well established.

Water Year 2016 Patterns of Periphyton Biomass

In WY 2016 periphyton biomass showed moderate late winter/early spring increases at many sites. These increases resulted in peak biomasses that were higher than those observed in WY 2015. Maximum biomass levels reached along the northwest shore included: Pineland (85.56 mg/m^2), Tahoe City (56.47 mg/m^2); and Dollar Pt. (48.69 mg/m^2). Along the southwest shore, Rubicon Pt. increased steadily from Nov. to May (from 19.31 mg/m2 to 90.54 mg/m^2) and Sugar Pine Pt. peaked earlier, in Feb. (66.35 mg/m^2). The peak chlorophyll *a* levels reached at Rubicon, Sugar Pine and Pineland, were noticeably higher than during 2015. At Tahoe City and Dollar, chlorophyll *a* was only slightly higher. Stalked diatoms were an important contributor to biomass at most of these sites. Along the north shore at Incline West, chlorophyll *a* showed a moderate increase from 33.10 mg/m^2 in Feb. to 69.69 mg/m^{2}in May. Along the east shore (Sand Pt., Deadman Pt. and Zephyr Pt.) the increases were relatively small in magnitude and the biomass was only slightly higher at the peak than 2015 totals at Sand Pt. and Deadman and about the same at Zephyr Pt. The periphyton consisted primarily of blue-green algae with some filamentous greens at the north and east shore sites.

In WY 2016 there was a return to more "normal" precipitation levels in the Tahoe basin. The increased nutrient inputs associated with increased precipitation relative to the last couple of years likely contributed to increased periphyton growth. December, January and March were particularly "wet" months and overall precipitation through May has been slightly above average at some Tahoe Basin sites. For instance, at the "Ward #3" SNOTEL site (70.5 inches of precipitation has occurred through May, 2016 compared to 65.9 inches average (http://wcc.sc.egov.usda.gov/nwcc/site?sitenum=848). There were several storm events during the winter that contributed both rain and snow. Several events resulted in slight to modest increases in tributary runoff. A moderate snowpack developed through March, substantial snowmelt occurred during April and May. The runoff resulted in a lake level rise of over 2 feet by late May 2016, from a minimum lake level of 6221.33 ft. in early December 2015. This put the lake once again above the natural rim after remaining near or below the rim for over a year (since mid-October, 2014). Sampling remained within a zone characterized by presence of blue-green algae at many sites throughout May, so spring growth occurred in addition to some baseline biomass already present on the rocks.

The data for WY 2016 periphyton biomass at the routine sites is relatively similar to patterns observed since 2000 (Figures 4.a-4.i). There were not any obvious changes in pattern in 2016 apparent. In 2016 TERC prepared an intensive analysis for the Tahoe Regional Planning Agency of the trends for periphyton biomass (Hackley et al., 2016). This analysis utilized much of the routine and synoptic monitoring data collected by the periphyton monitoring program through the years up to 2015. This was the first time the historical periphyton data were statistically evaluated for presence of trends. This analysis indicated that the majority (8 out of 10) routine sites showed no statistically significant upward or downward trend for biomass associated with the stalked diatoms and filamentous green algae during 2000-2015. Two of the sites (Pineland along the west shore and Incline West along the north shore) did show positive (upward) trends for Chlorophyll a biomass during 2000-2015. Although the trends were statistically significant, analysis of the data indicates increases in mean levels of periphyton biomass through time were small. The 2016 data for Incline West, showed that spring chlorophyll a levels were among the highest observed at this site since 2000. This appears to be consistent with a general trend of increasing chlorophyll levels observed in the earlier data, however the 2016 data for Incline West biomass was impacted by presence of Blue-green algae. At Pineland, in 2016 there was a moderate increase in biomass relative to the past two low biomass years. However spring 2016 maximum biomass at Pineland (85.56 mg/m^2) was much less than the spring maximum in 2013 (242 mg/m^2). We did not statistically reevaluate long-term trends for data including the 2016 WY data, so we cannot comment on the presence of statistical trends through 2016 (only through 2015).

Table 8. Summary of eulittoral periphyton chlorophyll a (Chlor.a), Ash Free Dry Weight (AFDW), visual score from above and below water, average filament length, percent algal coverage, and predominant algal types estimated visually underwater (where SD= stalked diatoms; FG= filamentous greens; CY= blue-green algae) for routine periphyton monitoring sites during November, 2013-May, 2016. Note for chlorophyll *a* and AFDW, n=2 unless otherwise indicated (i.e. two replicate samples were taken and analyzed). Visual score is a subjective ranking of the aesthetic appearance of algal growth ("above" viewed above water; "below" viewed underwater) where 1 is the least offensive and 5 is the most offensive. Biomass Index is Filament Length times % Algal Cover. Also,"NA" = not available or not collected; "NES" = not enough sample for analysis; "Var." = variable amount of cover. Sampling depth and corresponding sampling elevation are also indicated.

Site	Date	Sampling Depth/Elev (m/ ft)	Chlor. *a* (mg/m^2)	Std Dev (mg/m^2)	AFDW (g/m^2)	Std Dev (g/m^2)	Above Visual Score	Below Visual Score	Avg. Fil. Length (cm)	Algal Cover (%)	Biomass Index	Algal Type
Rubicon Pt.	11/14/13	0.5/6222.34	15.07	3.61	15.91	2.01	3	3	0.8	85	0.68	SD,CY,FG
	3/4/14	0.5/6222.49	19.99	4.60	17.47	3.19	3	4	0.7	80	0.56	CY,FG
	4/11/14	0.5/6222.60	19.39	0.63	21.80	6.49	3	3.5	0.8	68	0.54	CY,FG
	5/21/14	0.5/6222.75	11.36	2.24	14.45	0.92	3	4	1.5	60	0.9	CY,FG
	7/2/14	0.5/6222.42	6.99	2.31	20.02	1.32	3.5	3	1.0	70	0.7	CY,FG
	11/11/14	0.5/6221.05	18.90	4.40	26.23	3.86	NA	NA	1.0	70	0.70	CY,FG
	2/20/15	0.5/6221.20	30.17	4.34	30.93	4.52	3	3	0.7	95	0.67	CY
	3/19/15	0.5/6221.19	26.71	0.95	26.88	3.31	2	3	0.5	100	0.50	CY,FG
	4/9/15	0.5/6221.14	26.76	3.36	30.71	4.37	3	3	0.6	90	0.54	SD,CY,FG
	6/16/15	0.5/6221.35	47.82	2.05	50.68	5.45	3.5	3.5	1.2	95	1.14	CY,FG
	11/19/15	0.5/6219.89	19.31	1.89	27.14	3.35	4	3	0.4	78	0.31	CY
	2/29/16	0.5/6220.60	48.63	5.91	50.48	4.05	3	3	0.4	90	0.36	CY,FG
	3/31/16	0.5/6221.22	64.54	20.52	45.85	13.40	3	3	0.6	95	0.57	SD,CY,FG
	5/4/16	0.5/6221.79	90.54	32.84	71.63	15.68	3	3	0.7	90	0.63	SD,CY,FG
Sugar Pine Pt.	11/14/13	0.5/6222.34	18.95	2.40	18.83	2.77	NA	2	0.2	80	0.16	CY,FG
	3/4/14	0.5/6222.49	4.29	1.46	NES	NES	NA	1	<0.1	<5	<0.005	-
	4/11/14	0.5/6222.60	9.74	2.52	NES	NES	NA	2	<0.1	70	<0.07	CY,SD
	5/21/14	0.5/6222.75	7.11	1.02	11.13	2.91	NA	3	0.3	80	0.24	CY,FG
	7/2/14	0.5/6222.42	9.57	1.18	NES	NES	NA	2	<0.1	20	0.02	FG
	11/11/14	0.5/6221.05	15.84	3.44	17.69	6.68	2	2	0.3	90	0.27	CY,FG
	2/20/15	0.5/6221.20	16.82	0.10	19.98	2.14	1	2	0.2	90	0.18	SD,CY
	3/19/15	0.5/6221.19	14.85	0.94	17.02	2.28	2	2	0.2	60	0.12	SD,CY
	4/9/15	0.5/6221.14	12.37	6.36	15.61	9.88	NA	2	0.2	40	0.08	SD
	6/16/15	0.5/6221.35	9.12	3.88	14.27	5.74	3	2	0.1	70	0.07	CY
	11/19/15	0.5/6219.89	31.04	5.93	33.22	13.26	3	2	0.2	95	0.19	CY
	2/29/16	0.5/6220.60	66.35	13.46	70.90	12.13	2	2	0.3	80	0.24	SD,CY
	3/31/16	0.5/6221.22	30.27	7.35	27.78	6.17	2	3	0.7	70	0.49	SD,CY,FG
	5/4/16	0.5/6221.79	30.29	11.24	41.07	15.40	3.5	3	1.0	75	0.75	SD,CY,FG

Site	Date	Sampling Depth/Elev (m/ ft)	Chlor. *a* (mg/m^2)	Std Dev (mg/m^2)	AFDW (g/m^2)	Std Dev (g/m^2)	Above Visual Score	Below Visual Score	Avg. Fil. Length (cm)	Algal Cover (%)	Biomass Index	Algal Type
Pineland	11/14/13	0.5/6222.34	20.74	1.09	21.84	2.84	2	2	0.1	73	0.07	CY
	3/4/14	0.5/6222.49	39.89	6.99	31.90	1.37	3	3.5	1.4	90	1.26	SD
	4/11/14	0.5/6222.60	31.96	10.70	32.26	4.44	3	4	1.5	65	0.98	SD,CY
	5/21/14	0.5/6222.75	11.76	7.18	10.23	5.94	2	4	1.0	80	0.80	SD,CY
	7/2/14	0.5/6222.42	21.18	2.06	31.85	0.03	2	3	0.5/0.1	30/70	0.22	SD,CY
	11/11/14	0.5/6221.05	25.15	6.36	33.72	11.05	2	2	0.5	70	0.35	SD,CY
	2/20/15	0.5/6221.20	47.49	15.11	45.81	6.10	2	3	1.0	48	0.48	SD,CY
	3/19/15	0.5/6221.19	18.19	10.10	12.67	5.01	2.5	3.5	1.5	60	0.90	SD,CY
	4/9/15	0.5/6221.14	32.07	14.96	31.75	9.90	2.5	3	1.4	45	0.63	SD,CY
	6/16/15	0.5/6221.35	15.88	2.83	11.81	(n=1)	2	3	0.3	48	0.14	CY,FG
	11/19/15	0.5/6219.89	32.20	4.36 (n=3)	40.59	5.39 (n=3)	2	3	0.4	42	0.17	SD,CY
	2/29/16	0.5/6220.60	72.36	11.37 (n=3)	50.40	5.80 (n=3)	4	4	2.0	100	2.0	SD,CY
	3/31/16	0.5/6221.22	85.56	19.29 (n=3)	68.68	26.06 (n=3)	5	5	4.5	99	4.46	SD
	5/4/16	0.5/6221.79	13.81	5.60 (n=3)	20.26	11.24 (n=3)	3.5	3.5	1.0	60	0.6	SD
Tahoe City	11/14/13	0.5/6222.34	26.34	4.59	25.55	5.39	2	2	0.1	60	0.06	SD,FG
	3/10/14	0.5/6222.54	38.45	5.54(n=3)	39.96	5.42(n=3)	3	3	1.7	70	1.19	SD
	4/11/14	0.5/6222.60	65.18	22.92(n=3)	70.15	14.69(n=3)	4	4	1.8	60	1.08	SD
	5/21/14	0.5/6222.75	16.49	0.46	17.60	3.64	NA	2	0.2	50	0.10	SD
	6/27/14	0.5/6222.45	11.74	2.27	13.48	0.89	2	2	0.1	70	0.07	SD
	11/11/14	0.5/6221.05	5.63	1.05	8.17	0.00	NA	NA	NA	NA	NA	NA
	2/20/15	0.5/6221.20	32.19	0.91	29.98	(n=1)	2	2	0.2	80	0.16	SD
	3/19/15	0.5/6221.19	35.64	1.27	53.38	7.23	2	3	1.4	25	0.35	SD
	4/9/15	0.5/6221.14	16.98	1.54	22.00	1.01	NA	3	0.5	35	0.18	SD
	6/16/15	0.5/6221.35	12.09	(n=1)	15.54	2.03	2.5	2.5	0.3	60	0.18	SD
	11/19/15	0.5/6219.89	23.99	6.18	22.30	0.98	2	2	0.2	80	0.16	SD,CY
	2/29/16	0.5/6220.60	53.49	24.84 (n=3)	87.88	43.83(n=3)	2	4	2.0	60	1.2	SD
	3/30/16	0.5/6221.22	56.47	2.96	70.92	6.42	4	4	2.0	50	1.0	SD
	5/4/16	0.5/6221.79	12.11	2.75	18.40	0.92	3	3	0.5	40	0.20	SD
Dollar Pt.	11/14/13	0.5/6222.34/	19.96	6.40	13.41	3.32	2	2	<0.1	60	<0.06	CY
	3/4/14	0.5/6222.49	8.99	5.12	9.28	(n=1)	2	2	0.1	80	0.08	SD
	4/11/14	0.5/6222.60	23.52	11.45	11.64	2.77	2	2.5	0.3	65	0.20	SD
	5/21/14	0.5/6222.75	16.14	NA**	18.68	5.31	2	2	0.2	80	0.16	SD,CY
	6/27/14	0.5/6222.45	12.09	2.81	13.94	2.84	2	2	0.3	60	0.18	SD
	11/11/14	0.5/6221.05	-	-	25.14*	(n=1)	2	2	0.3/0.1	30/80	0.14	CY,FG
	2/20/15	0.5/6221.20	11.00	(n=1)	10.62	2.14	2	2	0.1	90	0.09	SD,CY,FG

Site	Date	Sampling Depth/Elev (m/ ft)	Chlor. *a* (mg/m^2)	Std Dev (mg/m^2)	AFDW (g/m^2)	Std Dev (g/m^2)	Above Visual Score	Below Visual Score	Avg. Fil. Length (cm)	Algal Cover (%)	Biomass Index	Algal Type
Dollar Pt.	3/19/15	0.5/6221.19	12.11	1.66	9.37	0.75	3	3	0.8	70	0.56	SD
	4/9/15	0.5/6221.14	39.55	13.50	18.49	5.83	3	2	0.1	70	0.07	SD,CY
	6/16/15	0.5/6221.35	12.37	0.60	14.03	0.96	3	3	0.6	47	0.28	CY,FG
	11/19/15	0.5/6219.89	19.39	4.61	14.61	5.12	3	2	0.10	42	0.04	CY
	2/29/16	0.5/6220.60	41.30	19.66	33.18	5.24	3	3	0.7	50	0.35	SD,FG
	3/30/16	0.5/6221.22	48.69	5.63	33.24	2.93	2	3	0.8	70	.56	SD
	5/4/16	0.5/6221.79	28.27	1.86	35.03	3.24	3.5	3	1.0	75	0.75	SD,FG
Incline West	11/14/13	0.5/6222.34	11.70	4.70	17.40	8.41	2	3	0.2	70	0.14	CY
	3/4/14	0.5/6222.49	17.93	3.74	24.59	6.66	3	3	0.3	90	0.27	CY,FG
	4/11/14	0.5/6222.60	16.31	2.66	23.30	1.99	3	3	0.6	70	0.42	CY,FG
	5/21/14	0.5/6222.75	22.12	2.96	32.81	7.24	3	3.5	1.2/0.3	50/80	0.69	CY,FG
	7/2/14	0. 5/6222.42	21.40	3.59	33.19	8.02	3	3	0.5/0.1	30/70	0.22	CY,FG
	11/11/14	0.5/6221.05	30.17	2.40	42.19	2.00	NA	3	0.2	90	0.18	CY,FG
	2/20/15	0.5/6221.20	22.92	2.87	35.20	1.55	2	3	0.3	95	0.29	CY
	3/19/15	0.5/6221.19	40.12	0.81	58.46	1.42	3	3	0.5	80	0.40	CY,FG
	4/23/15	0.5/6221.09	18.98	5.90	36.99	15.20	3	3	1.0	90	0.90	CY,FG
	6/16/15	0.5/6221.35	37.77	3.32	62.41	3.05	3	3	1.1	90	0.99	CY,FG
	11/19/15	0.5/6219.89	36.01	1.37	63.07	4.55	3	3	0.4	95	0.38	CY
	2/29/16	0.5/6220.60	33.10	2.44	58.35	3.84	3	3	0.4	95	0.38	CY,FG
	3/30/16	0.5/6221.22	61.18	4.98	66.81	1.11	3.5	3.5	0.5	90	0.45	CY,FG
	5/4/16	0.5/6221.79	69.59	11.64	108.36	21.64	3	3	0.7	90	0.63	CY
Sand Pt.	11/14/13	0.5/6222.34	21.24	0.55	32.86	1.32	2	3	0.3	60	0.18	CY
	3/4/14	0.5/6222.49	20.13	3.99	33.81	1.46	3	3	0.3	85	0.26	CY,FG
	4/11/14	0.5/6222.60	24.87	1.92	40.10	5.98	NA	2	0.3	80	0.24	CY,FG
	5/21/14	0.5/6222.75	14.25	2.28	31.49	10.90	3	3	0.7/0.1	30/80	0.26	CY,FG
	7/2/14	0.5/6222.42	13.83	1.36	20.79	3.24	3	3	0.5/0.1	30/70	0.22	CY,FG
	11/11/14	0.5/6221.05	17.86	0.58	22.75	0.31	3	3	0.2	80	0.16	CY,FG
	2/20/15	0.5/6221.20	19.95	0.97	31.46	3.22	2	3	0.3	100	0.30	CY,FG
	3/19/15	0.5/6221.19	25.19	0.59	33.06	3.88	3	3	0.6	80	0.48	CY
	5/19/15	0.5/6221.24	25.56	3.26	35.65	0.22	3	3	0.8	80	0.64	CY,FG
	6/16/15	0.5/6221.35	34.57	9.40	49.48	11.41	2	3	1.2/0.5	20/90	0.59	CY,FG
	11/19/15	0.5/6219.89	21.03	2.53	33.84	8.36	2	2	0.3	70	0.21	CY
	2/29/16	0.5/6220.60	46.90	14.48	59.18	15.98	3	3	0.4	95	0.38	CY,FG
	4/1/16	0.5/6221.23	34.51	12.05	40.89	11.47	2	3	0.3	80	0.24	CY,FG
	5/4/16	0.5/6221.79	19.24	0.36	33.33	4.95	3	3	0.5	50	0.25	CY,FG

Site	Date	Sampling Depth/Elev (m/ ft)	Chlor. *a* (mg/m²)	Std Dev (mg/m²)	AFDW (g/m²)	Std Dev (g/m²)	Above Visual Score	Below Visual Score	Avg. Fil. Length (cm)	Algal Cover (%)	Biomass Index	Algal Type
Deadman Pt.	11/14/13	0.5/6222.34	14.48	1.96	24.09	2.01	3	3	0.3	70	0.21	CY
	3/4/14	0.5/6222.49	23.17	0.76	27.96	0.41	2	3	0.3	80	0.24	CY
	4/11/14	0.5/6222.60	12.59	3.75	19.91	2.98	2	2	0.2	50	0.10	CY
	5/21/14	0.5/6222.75	19.18	6.02	28.62	7.83	2	3	0.7/0.1	30/80	0.26	CY,FG
	7/2/14	0. 5/6222.42	30.84	3.25	36.08	5.50	3	3	0.7/0.1	50/80	0.43	CY/FG
	11/11/14	0.5/6221.05	22.19	0.71	31.81	7.85	3	3	0.3	90	0.27	CY
	2/20/15	0.5/6221.20	16.02	3.85	26.72	2.13	2	2	0.2	80	0.16	CY
	3/19/15	0.5/6221.19	28.15	4.57	43.82	8.50	3	3	0.4	88	0.35	CY
	5/19/15	0.5/6221.24	24.78	2.96	39.81	3.08	3	3.5	0.5	80	0.40	CY,FG
	6/16/15	0.5/6221.35	25.72	4.04	46.10	3.44	3	3	0.6	90	0.60	CY/FG
	11/19/15	0.5/6219.89	35.59	10.48	50.62	8.79	3	3	0.4	60	0.24	CY
	2/29/16	0.5/6220.60	28.38	5.41	48.38	3.54	2	3	0.5	90	0.45	CY
	4/1/16	0.5/6221.23	46.20	15.87	69.30	9.84	2	3	0.3	95	0.29	CY
	5/4/16	0.5/6221.79	30.87	14.16	39.00	17.67	2	2	0.3	50	0.15	CY,FG
Zephyr Pt.	11/14/13	0.5/6222.34	10.38	4.85	10.74	4.73	2	2	0.2	70	0.14	SD,CY
	3/4/14	0.5/6222.49	11.01	2.14	13.62	0.09	2.5	2	0.1	80	0.08	SD,CY
	4/11/14	0.5/6222.60	3.36	0.53	NES	NES	2	2	<0.1	10	<0.01	
	5/21/14	0.5/6222.75	15.81	2.62	25.30	2.83	3	3	0.4	70	0.28	FG,CY
	7/2/14	0.5/6222.42	6.45	0.60	10.47	3.31	3	3	0.3	50	0.15	FG,CY
	11/11/14	0.5/6221.05	13.91	2.15 (n=3)	13.25	4.37 (n=3)	3	2	0.1	70	0.07	CY,FG
	2/20/15	0.5/6221.20	12.53	1.22	12.92	1.74	2	2	0.3	80	0.24	SD
	3/19/15	0.5/6221.19	12.01	3.94	13.36	6.52	2.5	2.5	0.3	60	0.18	CY,FG
	5/19/15	0.5/6221.24	10.58	1.12	14.81	0.18	3	3	0.8/0.1	50/80%	0.43	CY,FG
	6/16/15	0.5/6221.35	18.55	(n=1)	23.40	(n=1)	3	3	0.9/0.1	50/60	0.46	CY,FG
	11/19/15	0.5/6219.89	11.93	1.18	12.30	4.49	3	2	0.2	80	0.16	CY
	2/29/16	0.5/6220.60	16.12	0.56	19.54	0.99	3	3	0.3	90	0.27	SD,CY,FG
	4/1/16	0.5/6221.23	22.02	4.49	35.03	5.65	2	2	0.7	60	0.42	CY,FG
	5/4/16	0.5/6221.79	19.53	4.12	43.97	7.05	3	3	0.5	80	0.40	CY

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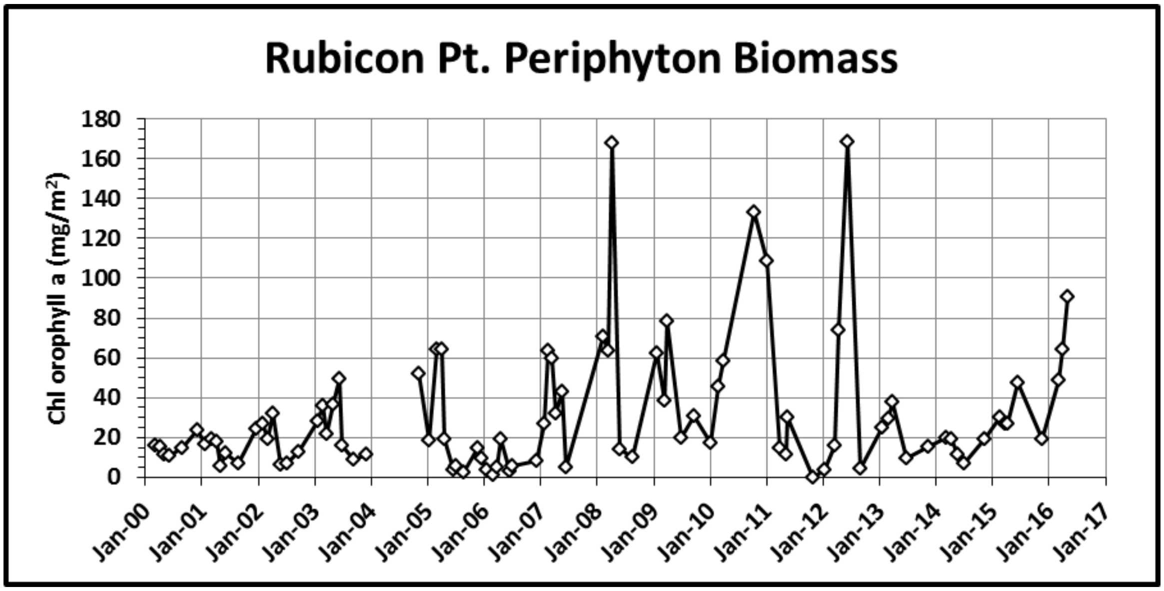

Figure 4 a. Rubicon Pt. periphyton biomass (chlorophyll *a*) 2000-2016.

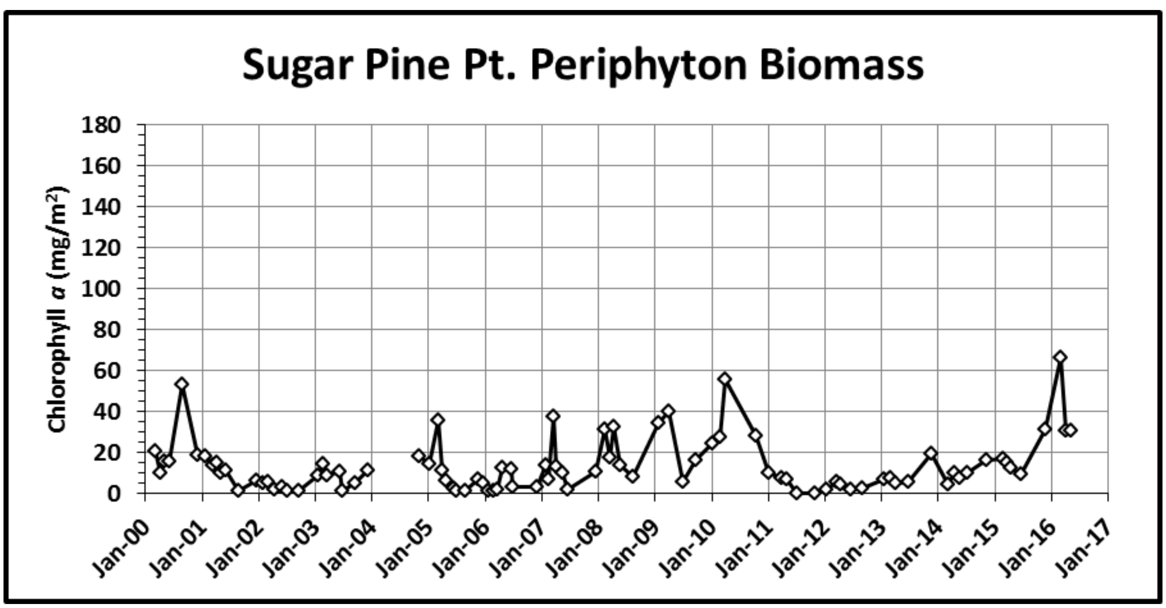

Figure 4 b. Sugar Pine Pt. periphyton biomass (chlorophyll *a*) 2000-2016.

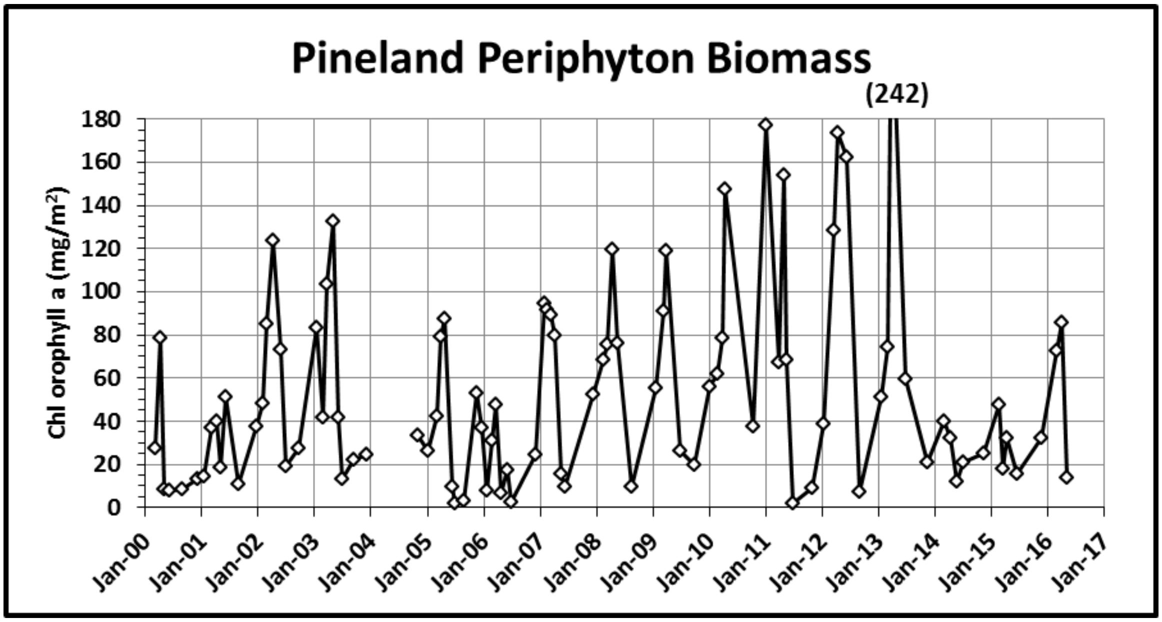

Figure 4 c. Pineland periphyton biomass (chlorophyll *a*) 2000-2016.

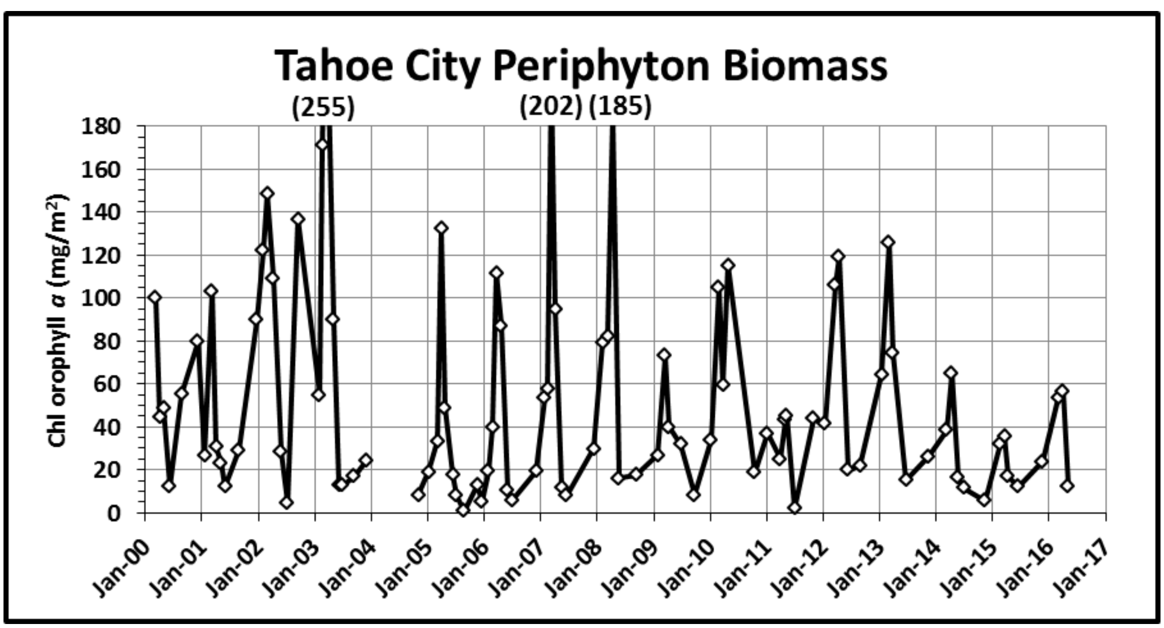

Figure 4 d. Tahoe City periphyton biomass (chlorophyll *a*) 2000-2016.

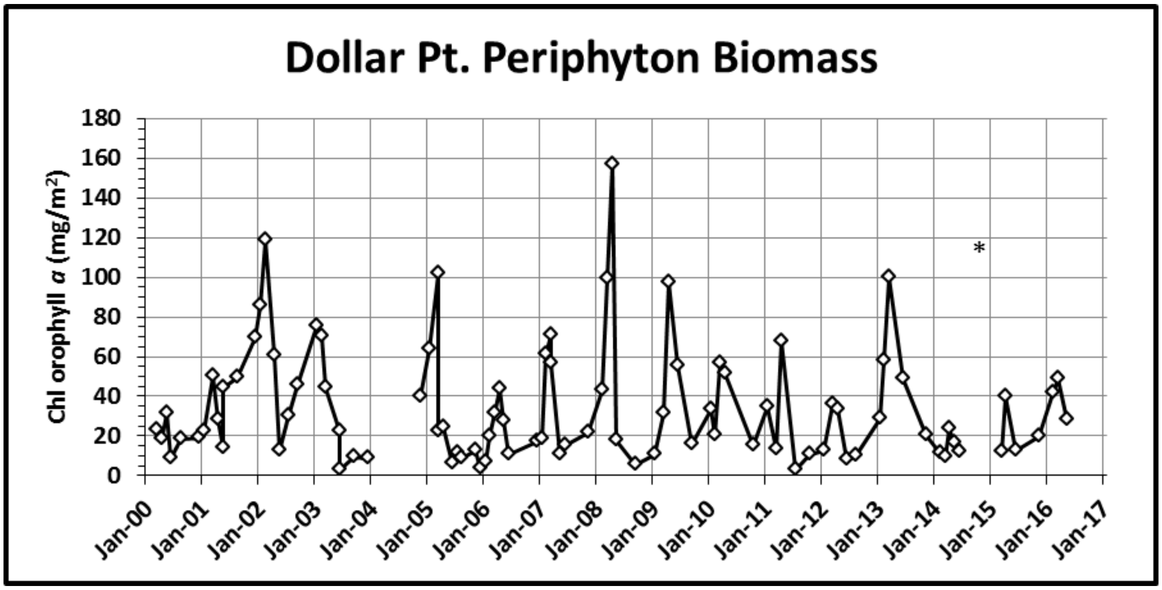

Figure 4 e. Dollar Pt. periphyton biomass (chlorophyll *a*) 2000-2016. *Note- 11/11/14 Dollar Pt. samples had much sand associated with them and the chlorophyll was high with high variation. In contrast, another biomass indicator AFDW was low and more consistent with levels before and after 11/11/14 date. The chlorophyll data for 11/11/14 was considered anomalous and not included in the long-term data (see Section IV, Quality Assurance for additional explanation).

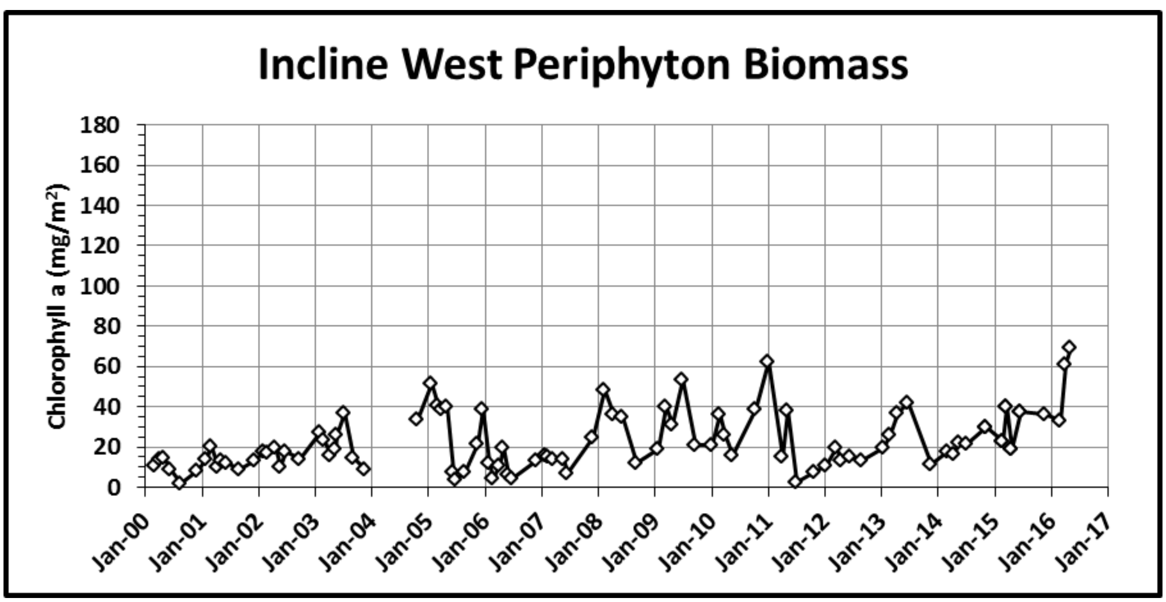

Figure 4 f. Incline West periphyton biomass (chlorophyll *a*) 2000-2016.

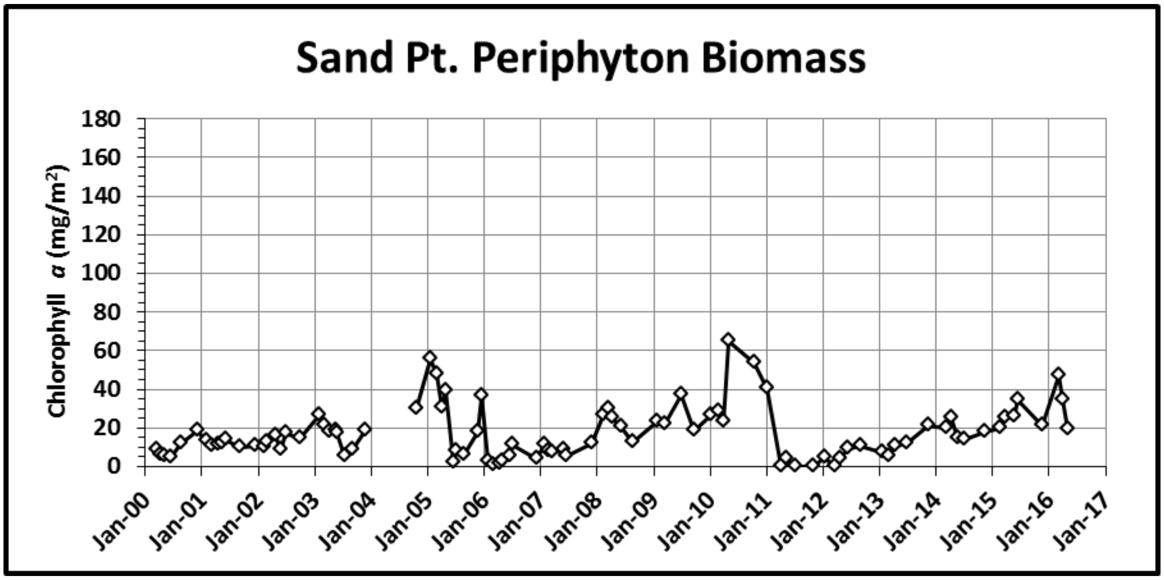

Figure 4 g. Sand Pt. periphyton biomass (chlorophyll *a*) 2000-2016.

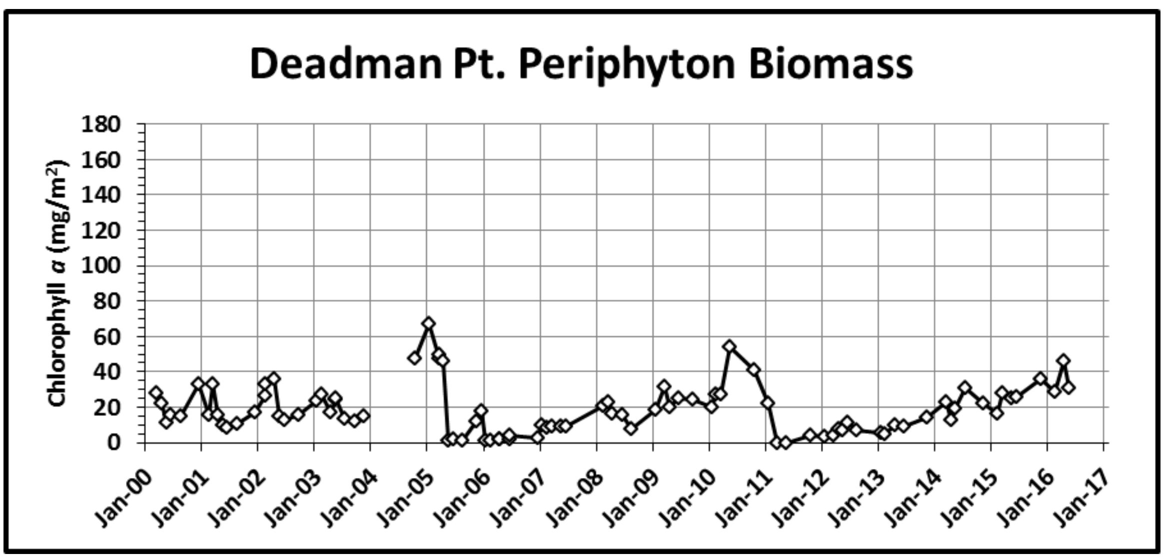

Figure 4 h. Deadman Pt. periphyton biomass (chlorophyll *a*) 2000-2016.

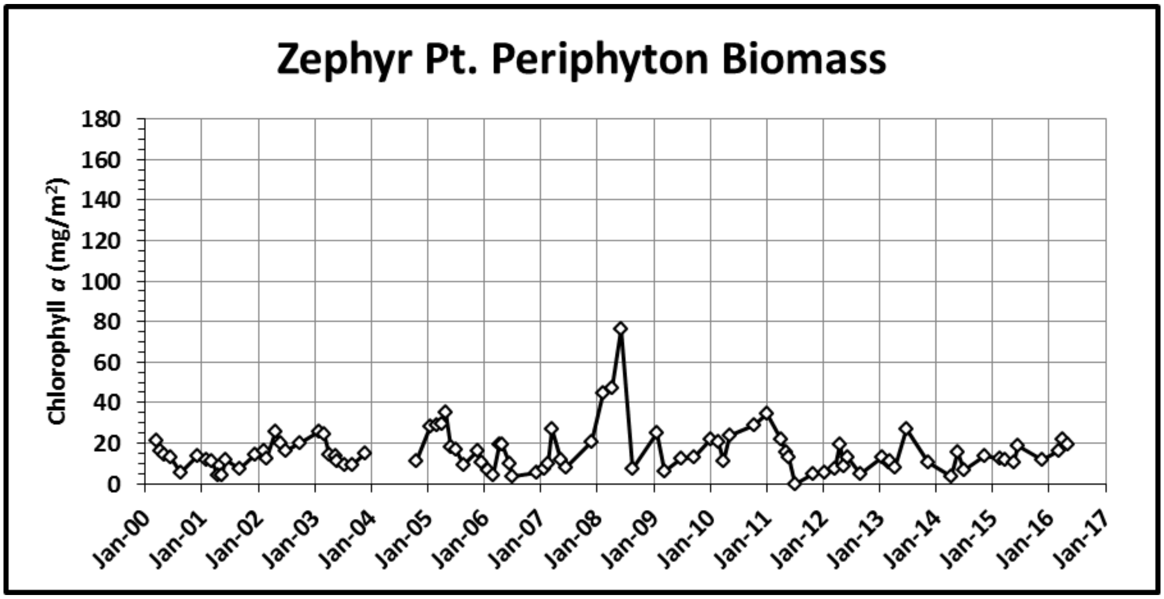

Figure 4 i. Zephyr Pt. periphyton biomass (chlorophyll *a*) 2000-2016.

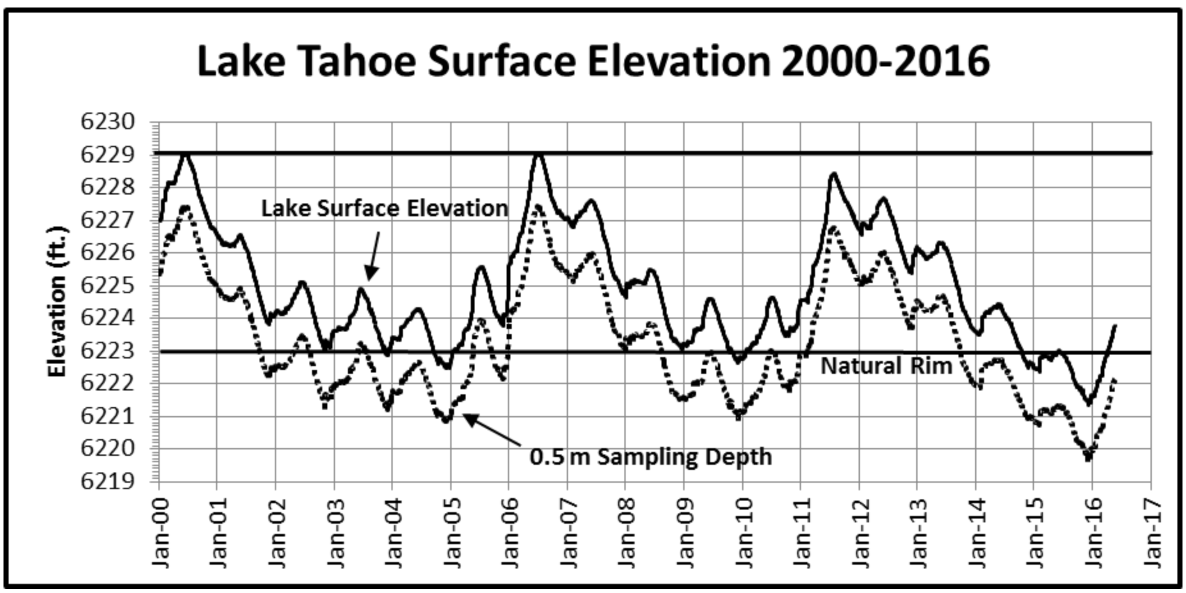

Figure 5. Fluctuation in Lake Tahoe surface elevation 1/1/00-5/25/16. Periphyton samples were typically collected during the period from natural rock substrata at a depth of 0.5m below the water surface. The 0.5m sampling depth (shown as a dotted line) fluctuates with the lake surface elevation. The elevation of the natural rim of Lake Tahoe is 6223 ft. The top 6.1 ft. of the lake above the natural rim (to 6229.1 ft.) is operated as a reservoir. Lake level data is from USGS web site (http://nwis.waterdata.usgs.gov) data and includes provisional data for part of 2016).

Annual Maximum Biomass

Figure 6 presents the maximum periphyton chlorophyll *a* biomass for water years 2013-2016. A couple of interesting observations emerge:

- Annual maximum chlorophyll *a* levels in 2016 were higher than the previous two years at a majority of sites (the exceptions being Zephyr where the maximum has remained consistently low, and Tahoe City where the 2014 maximum was slightly higher than 2016). The increases in biomass in 2016 were particularly notable for sites along the west shore (Rubicon Pt., Sugar Pine Pt. and Pineland). It is likely increased nutrient inputs contributed to higher biomass levels in 2016.

- Maximum biomasses during WY 2013-2016 occurred during WY 2013 at the three sites in the northwest portion of the lake (Pineland, Tahoe City and Dollar Pt.). This is interesting since WY 2013 was a drier than normal year. It is apparent that a "drier than normal year" doesn't necessarily always equate to a low periphyton year. WY 2012 and 2013 were years of lower precipitation, yet annual maximum biomass was quite high at Pineland and Tahoe City in both years. Rubicon Pt. was also high in 2012 and Dollar Pt. high in 2013. The timing of when precipitation occurs during a year, carryover conditions from the previous year (i.e. the degree of soil saturation and ground water levels), lake level and other factors may also play a role in addition to nutrient inputs in determining the biomass level in any year. WY 2012 followed an extremely wet year in 2011. WY 2013 started out very "wet" with much precipitation occurring in Nov. and Dec. however very dry conditions prevailed the rest of that WY. It is possible these conditions contributed to heavier periphyton growth in 2012 and 2013 despite those years being drier than usual.

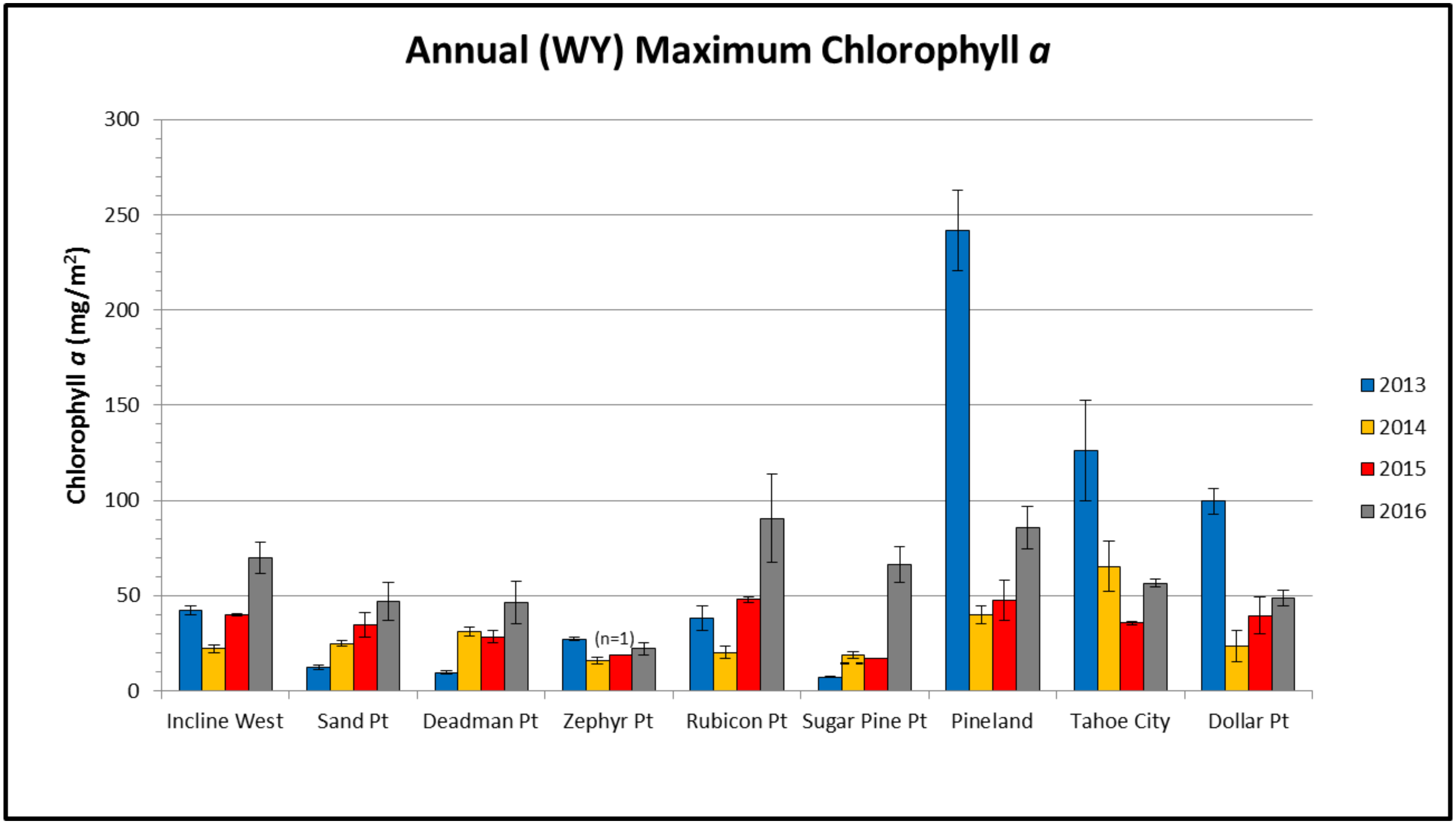

Figure 6. Maximum periphyton chlorophyll *a* for Water Years 2013-2016 at the nine routine periphyton monitoring sites at 0.5m Note: n=1 for Zephyr Pt. maximum value in 2015. Note, the 2014 WY peak at Sugar Pine Pt.occurred in Nov. 2014, the 2015 spring peak biomass for this site (which was lower) is indicated by dashed line.

Spring Synoptic Monitoring

An additional 40-45 sites (Table 9) are monitored once each spring to provide information on the distribution of biomass between the nine routine sites around the lake. Monitoring of these additional sites is timed as much as possible to occur with the peak spring biomass, the routine sites are also monitored during this period. This “spring synoptic” sampling provides essentially a “snapshot picture” of the distribution of periphyton biomass around the lake. Since peak periphyton growth does not necessarily occur at the same time at all sites around the lake, this synoptic monitoring may catch some sites prior to or following their peak biomass.

Table 9. Periphyton Spring Synoptic monitoring locations.

SITE DESIGNATION	WEST SHORE	LOCATION
A	Cascade Creek	N38 57.130; W120 04.615
B	S. of Eagle Point	N38 57.607; W120 04.660
C	E.Bay/Rubicon	N38 58.821; W120 05.606
D	Gold Coast	N39 00.789; W120 06.796
E	S. Meeks Point	N39 01.980; W120 06.882
F	N. Meeks Bay	N39 02.475; W120 07.194
G	Tahoma	N39 04.199; W120 07.771
H	S. Fleur Du Lac	N39 05.957; W120 09.774
I	Blackwood Creek	N39 06.411; W120 09.424
	Kaspian Pt.	(Point near Elizabeth Dr.)
J	Ward Creek	N39 07.719; W120 09.304
K	N. Sunnyside	N39 08.385; W120 09.135
L	Tavern Point	N39 08.806; W120 08.628
TCT	Tahoe City Tributary	(adjacent to T.C. Marina)
M	TCPUD Boat Ramp	N39 10.819; W120 07.177
	Lake Forest	
N	S. Dollar Point	N39 11.016; W120 05.888
O	S. Dollar Creek	N39 11.794; W120 05.699
P	Cedar Flat	N39 12.567; W120 05.285
Q	Garwood’s	N39 13.486; W120 04.974
R	Flick Point	N39 13.650; W120 04.155
S	Stag Avenue	N39 14.212; W120 03.710
T	Agatam Boat Launch	N39 14.250; W120 02.932
	EAST SHORE	
E1	South side of Elk Point	N38 58.965; W119 57.399
E2	North Side of Elk Point	N38 59.284; W119 57.341
E3	South Side of Zephyr Point	N38 59.956; W119 57.566
E4	North Zephyr Cove	N39 00.920; W119 57.193
E5	Logan Shoals	N39 01.525; W119 56.997
E6	Cave Rock Ramp	N39 02.696; W119 56.935
E7	South Glenbrook Bay	N39 04.896;W119 56.955
E8	South Deadman Point	N39 05.998; W119 57.087
E9	Skunk Harbor	N39 07.856; W119 56.597
E10	Chimney Beach	N39 09.044; W119 56.008
E11	Observation Point	N39 12.580; W119 55.861
	NORTH SHORE	
E12	Hidden Beach	N39 13.263; W119 55.832
E13	Burnt Cedar Beach	N39 14.680; W119 58.132
	Incline Condo	N39 14.90; W119 59.63
	Old Incline West	(100 yds No. Incline West)
E14	Stillwater Cove	N39 13.789; W120 00.020
E15	North Stateline Point	N39 13.237; W120 00.193
E16	Brockway Springs	N39 13.560; W120 00.829
E17	Kings Beach Ramp Area	N39 14.009; W120 01.401
	SOUTH SHORE	
S1	Tahoe Keys Entrance	N38 56.398; W120 00.390
S2	Kiva Point	N38 56.555; W120 03.203
	Timber Cove Rocks	Rocks west T. Cove Pier

Chlorophyll *a* to Periphyton Biomass Index Relationship

At all spring synoptic sites, a “Periphyton Biomass Index (PBI)” value was determined. PBI is useful for rapidly assessing the aesthetic condition of the nearshore with respect to periphyton growth. Periphyton chlorophyll *a* is also determined on about a third of samples from the spring synoptic sites. Comparison of PBI with chlorophyll *a* measurements has shown there is an association between the two but it is not always strong. Figures 7-9 present the relationships between PBI and chlorophyll *a* for WY2014-2016. The association between chlorophyll *a* and PBI varied for these synoptics with R^2 values of 0.57, 0.31 and 0.55 for 2014, 2015 and 2016 respectively. When the spring synoptic and WY routine sites chlorophyll a and PBI data for 2014-2016 were compared (Figure 10) the R^2 value was 0.43.

The divergence at times between PBI and chlorophyll *a* biomass does not have to be problematic as they do not necessarily measure the same thing. The PBI relies on rapidly measured physical features of the overall periphyton mat (algal length, % coverage- when multiplied the product is PBI), while chlorophyll *a* is a laboratory extraction of pigment, representing biomass primarily of the live algae. PBI relates more to the visual characteristics of the periphyton while chlorophyll *a* is a measure of live biomass. Chlorophyll *a* is a measure of biomass and directly comparable to other ecosystems while PBI is primarily an indicator of aesthetic condition, i.e. visual perception of the bottom. Overall, PBI is useful for rapidly assessing the aesthetic condition of the nearshore with respect to periphyton growth. It allows for assessment of the aesthetic conditions relative to periphyton around the lake with greater resolution, i.e. approximately 45 sites in addition to the 9-10 routine sites. However, PBI and chlorophyll *a* are not interchangeable, they measure different aspects of the periphyton biomass.

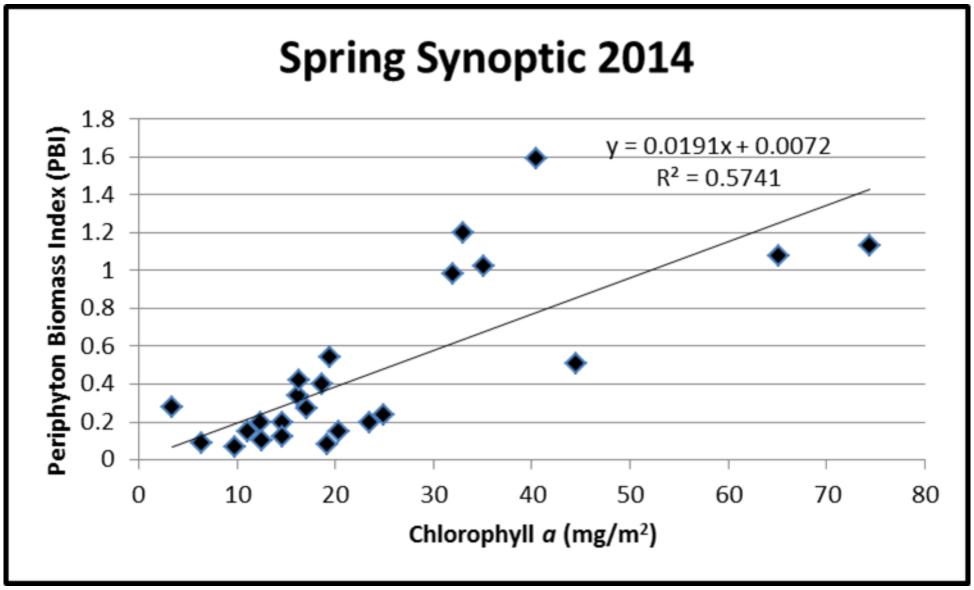

Figure 7. Relation between periphyton chlorophyll *a* and Periphyton Biomass Index for sites where both were measured during the 2014 spring synoptic survey.

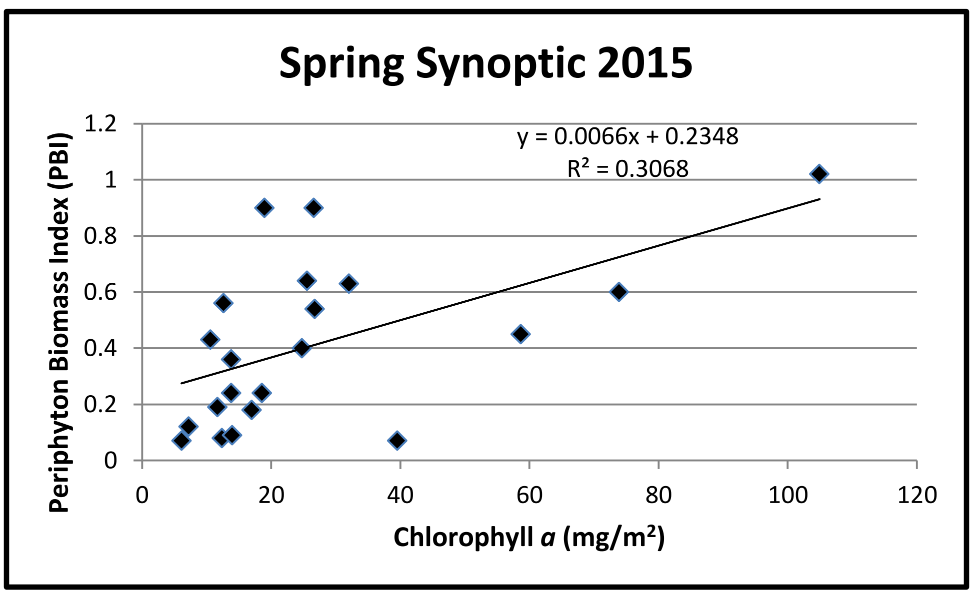

Figure 8. Relation between periphyton chlorophyll *a* and Periphyton Biomass Index for sites where both were measured during the 2015 spring synoptic survey.

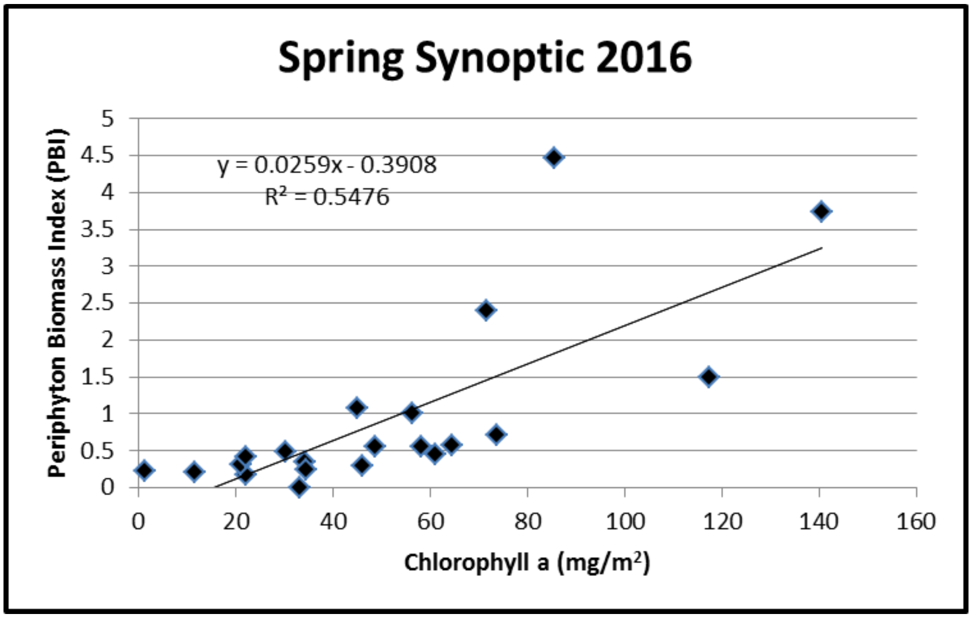

Figure 9. Relation between periphyton chlorophyll *a* and Periphyton Biomass Index for sites where both were measured during the 2016 spring synoptic survey.

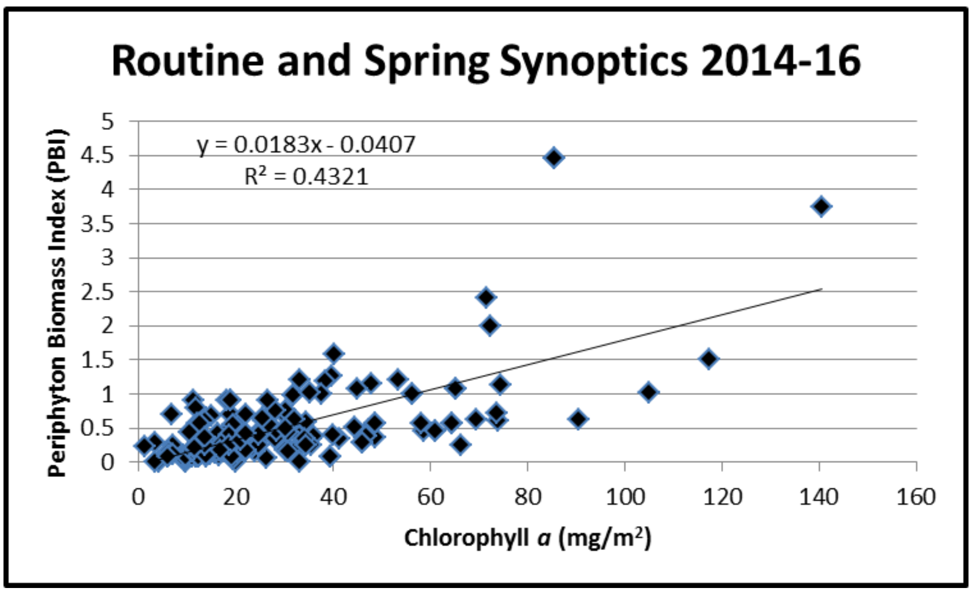

Figure 10. Relation between periphyton chlorophyll *a* and Periphyton Biomass Index for sites where both were measured WY 2014-2016 routine and synoptic site monitoring.

Results of Spring Synoptic Monitoring 2014

The PBI values were used to prepare the map of synoptic distribution of periphyton for spring 2014 (Figure 11). This map shows distribution of PBI around the lake during April 4 – April 18, 2014. 45 sites were monitored in addition to the 9 routine sites. Data collected for the 2014 spring synoptic survey are summarized in Table 10. Based on a comparison of data throughout the year at routine sites and observations in the field, it appeared the synoptic survey occurred slightly after the peak at some sites (e.g., Pineland, and South Shore sites) and slightly before the peak at some north and east shore sites (e.g., Incline West, and Deadman Pt.).

Generally light PBI (indicated by the two shades of green, in the map) was observed along much of the shoreline around the lake during the 2014 spring synoptic survey. Growth was light along much of the north, east and south shore (with the exception of Timber Cove which had relatively heavy PBI). Regions of lighter PBI were also observed along the west shore including areas from north of Rubicon Bay to Tahoma, and much of the region north of Tahoe City to Kings Beach. When compared with previous spring synoptics done 2011-2013 (Hackley et al., 2013), the extent of shoreline with relatively light growth was greater in 2014. A combination of factors may have contributed to this widespread lighter growth including: lower precipitation, lower nutrient inputs associated with runoff, less frequent storms, and possibly wind-related events that may have disrupted algal growth early on.

Sites with moderate or heavier periphyton biomass also were observed in the spring 2014 synoptic. Stretches of moderate biomass occurred along the west shore interspersed with areas of lighter or heavier growth. Areas of moderate-heavy biomass occurred in several areas where heavier biomass has been observed in past synoptics. These sites included Ward Cr. mouth, Tahoe City, Tahoe City Tributary and South Dollar Cr, on the northwest shore and Timber Cove Rocks along the south shore.

Predominant algal types in the periphyton around the lake during the spring synoptic survey showed some variation. A mix of cyanobacteria and filamentous green algae appeared to dominate the biomass along much of the north and east shore, as well as along the south west shore from Cascade Cr. to Rubicon Pt. A mix of Stalked diatoms and filamentous green algae dominated the biomass along the south shore. Stalked diatoms were predominant along the northwest shore from Blackwood to Dollar Pt.

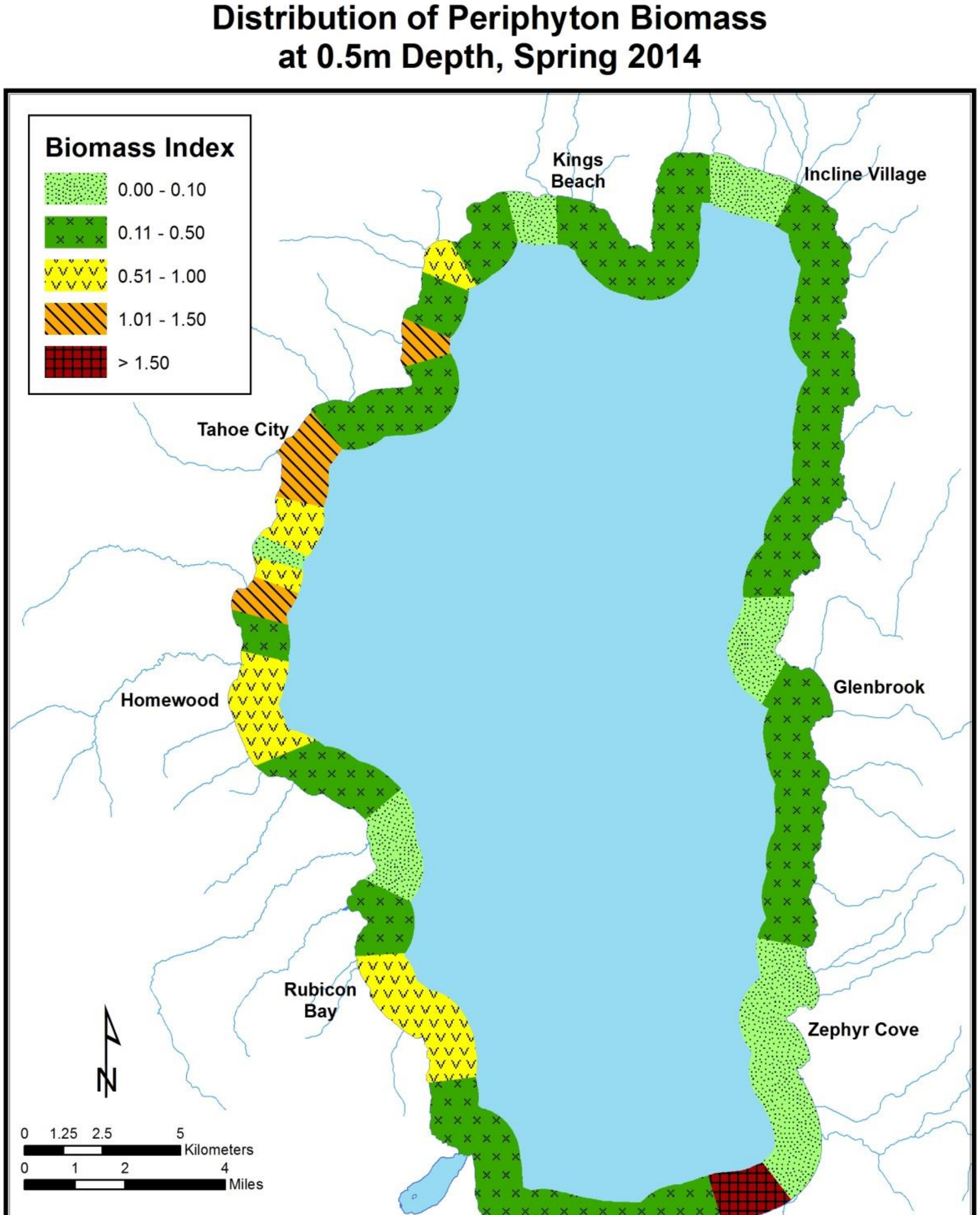

Figure 11. Extrapolated regional distribution of periphyton biomass measured as Biomass Index (Avg. Filament Length x % Area Covered with Algae) April 4-19, 2014.

Table 10. Summary of 0.5m periphyton chlorophyll *a*, Ash Free Dry Weight (AFDW), visual score, avg. filament length and percent algal coverage, predominant algae present based on visual observations while snorkeling (FG=filamentous greens; SD=stalked diatoms; CY= blue green algae), for routine sites (shaded) and Spring Synoptic survey sites during April 4-18, 2014. Note for chlorophyll *a* and AFDW, n=2 unless otherwise indicated. Visual score is a subjective ranking of the aesthetic appearance of algal growth (viewed underwater) where 1 is the least offensive and 5 is the most offensive. Biomass Index is filament length times percent algal cover. "NA" = not available or not collected; "NES" = not enough sample for analysis. Sampling depth and corresponding sampling elevation are also indicated.

Site	Site Name	Date	Sampling Depth/Elev (m/ ft)	Chl a (mg/m^2)	Std Dev (mg/m^2)	AFDW (g/m^2)	Std Dev (mg/m^2)	Above Visual Score	Below Visual Score	Fil. Length (cm)	Algal Cover. %	Biomass Index	Algal Type
A	Cascade Creek	4/14/14	0.5/6222.60	14.59	4.30	20.79	3.47	3	3	0.3	68%	0.20	CY,FG
B	S. of Eagle Point	4/14/14	0.5/6222.60					3	2.5	0.3	45%	0.14	CY,FG
C	E.Bay/Rubicon	4/14/14	0.5/6222.60					3	3	0.5	60%	0.30	CY,FG
	Rubicon Pt.	4/11/14	0.5/6222.60	19.39	0.63	21.80	6.49	3	3.5	0.8	68%	0.54	CY,FG
D	Gold Coast	4/14/14	0.5/6222.60	44.55	7.67	32.56	0.41	3	3	0.8	64%	0.51	SD,CY,FG
E	S. Meeks Point	4/14/14	0.5/6222.60					3	3	0.7	70%	0.49	SD,CY,FG
F	N. Meeks Bay	4/14/14	0.5/6222.60					3	3	0.5/0.1	50/75%	0.28	CY,FG
	Sugar Pine Pt.	4/11/14	0.5/6222.60	9.74	2.52	NES	NES	NA	2	<0.1	70%	<0.07	CY,SD
G	Tahoma	4/14/14	0.5/6222.60	20.41	3.27	21.98	4.35	3	2	0.3	50%	0.15	CY,SD
H	S. Fleur Du Lac	4/14/14	0.5/6222.60					3.5	3.5	1.2	67%	0.80	SD,CY,FG
I	Blackwood Creek	4/14/14	0.5/6222.60					2	3	1.8	30%	0.54	SD
	Kaspian Pt.	4/14/14	0.5/6222.60					NA	3	0.5	90%	0.45	SD,CY,FG
J	Ward Creek	4/14/14	0.5/6222.60	33.08	7.79(n=3)	22.53	0.80(n=3)	4	5	2.0	60%	1.20	SD
	Pineland	4/11/14	0.5/6222.60	31.96	10.70	32.26	4.44	3	4	1.5	65%	0.98	CY,SD
K	N. Sunnyside	4/14/14	0.5/6222.60					1	1	0.2	40%	0.08	SD
L	Tavern Pt.	4/14/14	0.5/6222.60					3	3	1.0	60%	0.60	SD
	Tahoe City	4/11/14	0.5/6222.60	65.18	22.92(n=3)	70.15	14.69(n=3)	4	4	1.8	60%	1.08	SD
TCT	Tahoe City Trib.	4/16/14	0.5/6222.62	74.44	4.76(n=3)	46.98	1.10(n=3)	4	4	1.5	75%	1.13	SD
M	TCPUD Boat Ramp	4/16/14	0.5/6222.62					3	3	0.7	25%	0.18	SD
	Lake Forest	4/16/14	0.5/6222.62					3	3	0.7	34%	0.24	SD,CY
N	S. Dollar Pt.	4/14/14	0.5/6222.62					2	2	0.3	60%	0.18	SD,CY
	Dollar Pt.	4/11/14	0.5/6222.60	23.52	11.45	11.64	2.77	2	2.5	0.3	65%	0.20	SD
O	S. Dollar Creek	4/16/14	0.5/6222.62	35.17	7.60(n=3)	25.87	7.58(n=3)	3	4	2.0/0.1	50/70%	1.02	SD,CY
P	Cedar Flat	4/16/14	0.5/6222.62					3	3	0.5	60%	0.30	SD,CY,FG
Q	Garwood's	4/16/14	0.5/6222.62					2	3	0.7	80%	0.56	SD,CY
R	Flick Point	4/16/14	0.5/6222.62	12.45	0.35	23.89	2.57	2	3	0.4/0.1	40/80%	0.20	CY,FG
S	Stag Avenue	4/16/14	0.5/6222.62					2	3	0.6	80%	0.48	SD,CY,FG

Site	Site Name	Date	Sampling Depth/Elev (m/ ft)	Chl a (mg/m^2)	Std Dev (mg/m^2)	AFDW (g/m^2)	Std Dev (mg/m^2)	Above Visual Score	Below Visual Score	Fil. Length (cm)	Algal Cover. %	Biomass Index	Algal Type
T	Agatam Boat R.	4/16/14	0.5/6222.62					1	2	<0.1	70%	<0.07	CY
E17	Kings Beach	4/16/14	0.5/6222.62					1	2	0.2	60%	0.12	SD
E16	Brockway Springs	4/16/14	0.5/6222.62	16.17	5.42	37.14	14.84	3	3	0.7/0.1	40/95%	0.34	SD,CY,FG
E15	No. Stateline Point	4/16/14	0.5/6222.62					2	2.5	0.3	60%	0.18	SD,CY,FG
E14	Stillwater Cove	4/16/14	0.5/6222.62					3	2.5	0.3	65%	0.20	SD,CY,FG
	Old Incline West	4/16/14	0.5/6222.62					3	3	1.0/0.1	50/75%	0.53	CY,FG
	Incline West	4/11/14	0.5/6222.60	16.31	2.66	23.30	1.99	3	3	0.6	70%	0.42	CY,FG
	Incline Condo	4/16/14	0.5/6222.62	18.72	1.87	36.46	3.60	2.5	3	0.5	80%	0.40	CY,FG
E13	Burnt Cedar Beach	4/18/14	0.5/6222.63					2	2	0.3	30%	0.09	CY,FG
E12	Hidden Beach offsh.	4/18/14	0.5/6222.63					1	2	0.2	50%	0.10	CY
	Hidden Beach insh.	4/18/14	0.5/6222.63	14.59	2.66	20.91	7.25	1	2	0.2	60%	0.12	SD,CY
E11	Observation Point	4/18/14	0.5/6222.63					3	3	0.5	50%	0.25	CY
	Sand Pt.	4/11/14	0.5/6222.60	24.87	1.92	40.10	5.98		2	0.3	80%	0.24	CY,FG
E10	Chimney Beach	4/18/14	0.5/6222.63					3	3	0.5	60%	0.30	CY,FG
E9	Skunk Harbor	4/18/14	0.5/6222.63	11.05	0.37	20.45	0.75	2	2	0.3	50%	0.15	CY,FG
	Deadman Pt.	4/11/14	0.5/6222.60	12.59	3.75	19.91	2.98	2	2	0.2	50%	0.10	CY
E8	So. Deadman Point	4/18/14	0.5/6222.63					3	3	0.6	50%	0.30	CY,FG
E7	So. Glenbrook Bay	4/18/14	0.5/6222.63					3	3	0.6	70%	0.42	CY,FG
E6	Cave Rock Ramp	4/18/14	0.5/6222.63	17.04	2.66	27.29	3.96	3	3	0.5/<0.1	50/70%	0.27	CY,FG
E5	Lincoln Park	4/18/14	0.5/6222.63					2	2	0.3	70%	0.21	CY,FG
E4	No. Zephyr Cove	4/18/14	0.5/6222.63					2.5	2	0.1	90%	0.09	CY,FG
E3	So. Zephyr Pt.	4/18/14	0.5/6222.63	19.17	6.79	16.53	7.51	2	2	<0.1	75%	<0.08	CY
	Zephyr Pt.	4/11/14	0.5/6222.60	3.36	0.53	NES	NES	2	2	<0.1	10%	0.28	CY,FG
E2	No. Elk Pt.	4/18/14	0.5/6222.63					1.5	1.5	<0.1	<1%	<0.01	CY,FG
E1	So. Elk Point	4/18/14	0.5/6222.63	6.43	1.34	NES	NES	3	3	0.1	90%	0.09	SD,FG
	Timber Cove Rock	4/4/14	0.5/6222.58	40.4	16.24(n=3)	29.40	6.80(n=3)		4	1.8	90%	1.59	SD,FG
S1	T. Keys Entrance	4/4/14	0.5/6222.58					3.5	3	0.5	60%	0.30	SD,FG
S2	Kiva Point	4/4/14	0.5/6222.58					3	3	0.5	50%	0.25	SD

Results of Spring Synoptic Monitoring 2015

Spring synoptic monitoring in 2015 was done April 6 – May 19, 2015. The PBI and chlorophyll *a* data are presented in Figure 12 and all data summarized in Table 11. 45 sites were monitored in addition to the nine routine sites (total number of sites sampled = 54). Based on a comparison of data throughout the year at routine sites and observations in the field, it appeared the synoptic survey occurred slightly after the peak at some sites (e.g., Pineland, and South Shore sites) and slightly before the peak at some east shore sites (e.g., Sand Pt. and Zephyr Pt.).

Generally light PBI (indicated by the two shades of green, in the map) with some areas of slightly heavier growth interspersed (indicated by yellow shading) was observed along the shoreline during the spring synoptic in WY 2015. Chlorophyll *a* levels were below 35 mg/m^2 at most of the sites where samples were taken. Three sites (Dollar Pt., Timber Cove and So. Fleur du lac) had moderate chlorophyll *a* ranging from 40-74 mg/m^2 and the Tahoe City Tributary site had high chlorophyll *a* (105 mg/m^2). The Tahoe City Tributary site was the only site 2015 with PBI > 1 (PBI=1.02). Stream water inputs with associated nutrients are likely contributing to the elevated spring periphyton growth at that site.

Predominant algae types at sites consisted of either blue-greens, stalked diatoms or filamentous green algae or a combination of these types. With the lowered lake level in 2015, blue-green algae were predominant in the algal community at 0.5m at a majority of sites. Stalked diatoms and/or filamentous green algae were also present at many sites.

Distribution of Periphyton Biomass at 0.5m Depth, Spring 2015

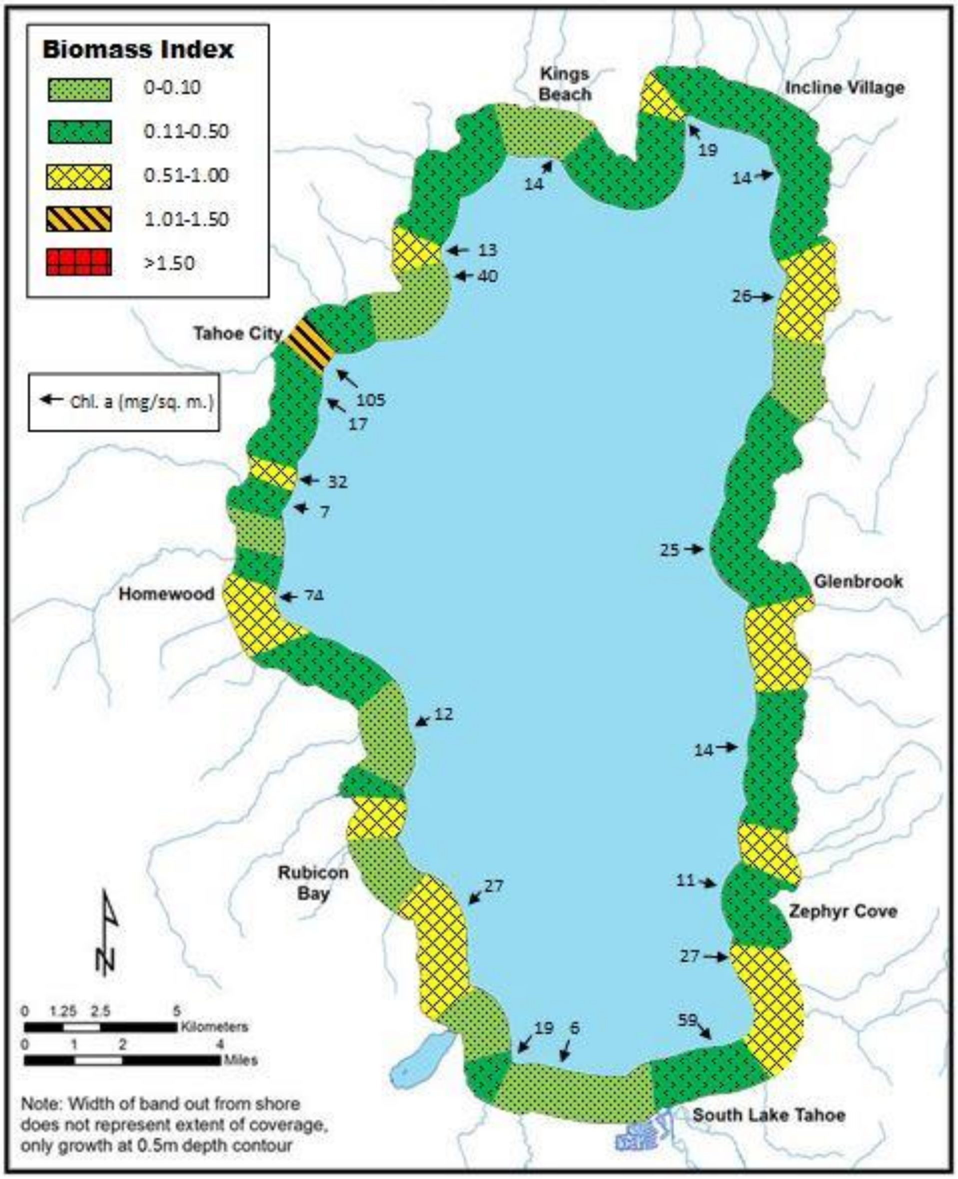

Figure 12. Distribution of periphyton biomass measured during the spring synoptic 2015 (April 6-May 19, 2015). Shading indicates levels of biomass measured using a rapid assessment method: Periphyton Biomass Index (PBI). (PBI = Avg. Filament Length x % Area Covered with Algae). Levels of periphyton chlorophyll *a* measured at selected sites are also shown (black numbers and arrows).

Table 11. Summary of 0.5m periphyton chlorophyll *a*, Ash Free Dry Weight (AFDW), visual score, avg. filament length and percent algal coverage, predominant algae present based on visual observations while snorkeling (FG=filamentous greens; SD=stalked diatoms; CY= blue green algae), for routine sites (shaded) and Spring Synoptic survey sites during April 6-May 19,2015. Note for chlorophyll *a* and AFDW, n=2 unless otherwise indicated. Visual score is a subjective ranking of the aesthetic appearance of algal growth (viewed underwater) where 1 is the least offensive and 5 is the most offensive. Biomass Index is filament length times percent algal cover. "NA" = not available or not collected; "NES" = not enough sample for analysis. Sampling depth and corresponding sampling elevation are also indicated.

Site	Site Name	Date	Sampling Depth/Elev. (m/ ft.)	Chl a (mg/m^2)	Std Dev (mg/m^2)	AFDW (g/m^2)	Std Dev (mg/m^2)	Above Visual Score	Below Visual Score	Fil. Length (cm)	Algal Cover. %	Biomass Index	Algal Type
A	Cascade Creek	4/9/15	0.5/6221.14	18.58	0.82	19.59	1.32	2	2	0.3	80%	0.24	CY,FG
B	S. of Eagle Point	4/9/15	0.5/6221.14					2	2	0.1/0.3	80/5%	0.09	CY,FG
C	E.Bay/Rubicon	4/9/15	0.5/6221.14					3	4	1.0	95%	0.95	CY,FG
	Rubicon Pt.	4/9/15	0.5/6221.14	26.76	3.36	30.71	4.37	3	3	0.6	90%	0.54	SD,CY,FG
D	Gold Coast	4/9/15	0.5/6221.14					1	2	0.4	20%	0.08	SD
E	S. Meeks Point	4/9/15	0.5/6221.14					3	3	0.8	90%	0.72	CY,FG
F	N. Meeks Bay	4/9/15	0.5/6221.14					2	3	1.5	30%	0.45	SD
	Sugar Pine Pt.	4/9/15	0.5/6221.14	12.37	6.36	15.61	9.88	NA	2	0.2	40%	0.08	SD
G	Tahoma	4/9/15	0.5/6221.14					2	2	0.2	90%	0.18	CY,SD
H	S. Fleur Du Lac	4/9/15	0.5/6221.14	73.87	31.28	53.88	12.54	3	3	0.8	75%	0.60	SD,CY
I	Blackwood Creek	4/9/15	0.5/6221.14					2	3	0.4	37%	0.15	SD
	Kaspian Pt.	4/9/15	0.5/6221.14					2	2.5	0.1	50%	0.05	CY
J	Ward Creek	4/9/15	0.5/6221.14	7.23	2.89	12.46	(n=1)	2	3	0.2	60%	0.12	SD
	Pineland	4/9/15	0.5/6221.14	32.07	14.96	31.75	9.90	2.5	3	1.4	45%	0.63	CY,SD
K	N. Sunnyside	4/9/15	0.5/6221.14					2	2.5	0.3	18%	0.05	SD
L	Tavern Pt.	4/9/15	0.5/6221.14					1.5	2	0.1	55%	0.06	CY
	Tahoe City	4/9/15	0.5/6221.14	16.98	1.54	22.00	1.01	NA	3	0.5	35%	0.18	SD
TCT	Tahoe City Trib.	4/13/15	0.5/6221.14	104.93	39.94(n=3)	59.84	18.08	4	4	1.5	68%	1.02	SD
M	TCPUD Boat Ramp	4/13/15	0.5/6221.14					2	2	0.3	38%	0.11	SD
	Lake Forest	4/13/15	0.5/6221.14	11.67	0.23	14.14	1.88	3	3	0.5	37%	0.19	SD,CY
N	S. Dollar Pt.	4/9/15	0.5/6221.14					2	2	0.1	52%	0.05	SD,CY
	Dollar Pt.	4/9/15	0.5/6221.14	39.55	13.50	18.49	5.83	3	2	0.1	70%	0.07	SD,CY
O	S. Dollar Creek	4/23/15	0.5/6221.09	12.62	1.90	22.02	3.63	2.5	3	0.7	80%	0.56	SD,CY,FG
P	Cedar Flat	4/23/15	0.5/6221.09					3	3	0.1/1.0	70/40%	0.43	CY,FG
Q	Garwood's	4/13/15	0.5/6221.14					2	2.5	0.4	60%	0.24	SD,CY
R	Flick Point	4/23/15	0.5/6221.09					2.5	2.5	0.5	50%	0.25	SD
S	Stag Avenue	4/13/15	0.5/6221.14					NA	2	0.1/0.4	90/50%	0.24	SD,CY,FG

Site	Site Name	Date	Sampling Depth/Elev. (m/ ft.)	Chl a (mg/m^2)	Std Dev (mg/m^2)	AFDW (g/m^2)	Std Dev (mg/m^2)	Above Visual Score	Below Visual Score	Fil. Length (cm)	Algal Cover. %	Biomass Index	Algal Type
T	Agatam Boat R.	4/13/15	0.5/6221.14					NA	1.5	0.1	30%	0.03	SD,CY
E17	Kings Beach	4/23/15	0.5/6221.09	13.95	2.16	22.44	1.36	1.5	2	<0.1	90%	<0.09	SD,CY
E16	Brockway Springs	423/15	0.5/6221.09					2	2	0.3	90%	0.27	SD,CY
E15	No. Stateline Point	4/23/15	0.5/6221.09					NA	2	0.4	70%	0.28	SD,CY
E14	Stillwater Cove	4/23/15	0.5/6221.09					2	3	0.6	80%	0.48	CY,FG
	Old Incline West	4/23/15	0.5/6221.09					3	3	0.7	90%	0.63	SD,CY,FG
	Incline West	4/23/15	0.5/6221.09	18.98	5.90	36.99	15.20	3	3	1.0	90%	0.90	CY,FG
	Incline Condo	4/23/15	0.5/6221.09					2	3	0.1/1.0	80/30%	0.35	CY,FG
E13	Burnt Cedar Beach	4/23/15	0.5/6221.09					2	2.5	0.1/0.5	70/30%	0.22	NA
E12	Hidden Beach offsh.	4/23/15	0.5/6221.09					2	2	0.3	60%	0.18	CY
	Hidden Beach insh.	4/23/15	0.5/6221.09	13.79	0.13	23.64	2.18	2	2	0.3	80%	0.24	CY
E11	Observation Point	5/19/15	0.5/6221.24					2.5	2.5	0.3/0.1	15/75%	0.11	CY,FG
	Sand Pt.	5/19/15	0.5/6221.24	25.56	3.26	35.65	0.22	3	3	0.8	80%	0.64	CY,FG
E10	Chimney Beach	5/19/15	0.5/6221.24					2	2.5	0.1	71%	0.07	SD,CY
E9	Skunk Harbor	5/19/15	0.5/6221.24					3	3	0.6/0.1	30/70%	0.22	CY,FG
	Deadman Pt.	5/19/15	0.5/6221.24	24.78	2.96	39.81	3.08	3	3.5	0.5	80%	0.40	CY,FG
E8	So. Deadman Point	5/19/15	0.5/6221.24					3.5	3.5	0.6	70%	0.42	CY,FG
E7	So. Glenbrook Bay	5/19/15	0.5/6221.24					3	3	0.3/1.2	80/30%	0.51	CY,FG
E6	Cave Rock Ramp	5/19/15	0.5/6221.24	13.81	1.00	17.69	3.04	2	2	0.4	90%	0.36	SD,CY,FG
E5	Lincoln Park	5/19/15	0.5/6221.24					1	2	0.3	40%	0.12	CY,FG
E4	No. Zephyr Cove	5/19/15	0.5/6221.24					2.5	3	1.4	50%	0.70	SD,FG
E3	So. Zephyr Pt.	5/19/15	0.5/6221.24					2	2	0.3	70%	0.21	SD,CY
	Zephyr Pt.	5/19/15	0.5/6221.24	10.58	1.12	14.81	0.18	3	3	0.8/0.1	50/80%	0.43	CY,FG
E2	No. Elk Pt.	5/19/15	0.5/6221.24					NA	2	0.5	90%	0.45	SD,CY
E1	So. Elk Point	5/19/15	0.5/6221.24	26.61	9.48	15.06	3.85	4	4	1	90%	0.90	SD
	Timber Cove Rock	4/6/15	0.5/6221.13	58.66	20.24(n=3)	31.47	8.21(n=3)	NA	4	1.5	30%	0.45	SD
S1	T. Keys Entrance	4/6/15	0.5/6221.13										
S2	Kiva Point	4/6/15	0.5/6221.13	6.12	0.36	7.67	0.67	2	2.5	0.35	20%	0.07	SD,FG

Observations of localized area of heavy periphyton growth in 2015

One additional area of heavier growth stood out during sampling in 2015. Although not a regular synoptic monitoring site, the growth was so heavy at this site we thought it worthy to note. Very heavy growth of stalked diatoms was observed in a localized area of shoreline a short distance west of the Garwood's site in April, 2015 (Figure 13). Heavy biomass persisted at this site through the summer of 2015, with a heavy, green filamentous algae (*Cladophora sp*) (Figure 14) dominating the biomass, but substantial stalked diatoms also persisting through the summer. Substantial dried, white old periphyton material coated a good portion of the backshore rocks in this area, which extends about 50-60 yards along the shore. Very little periphyton growth was observed on either side of the heavy growth as well as further out into the lake. This growth was quite distinct from the generally light periphyton growth observed along much of the Tahoe shoreline in 2015.

The heavy periphyton growth was located downslope of a forested ephemeral drainage and residential area and downslope of an area where subsurface water or groundwater is seeping through backshore sediments onto the beach. A sample of water seeping from the backshore 4/21/15 was analyzed and found to have slightly elevated levels of both nitrate nitrogen and phosphorus (NO_3-N= 86µg/l; NH_4-N=2µg/l) and phosphorus (SRP=29 µg/l). These levels are similar to groundwater concentrations in wells from upgradient portions of Ward Valley along the west shore in an earlier study (Loeb, 1987).

The growth of stalked diatoms (*Gomphoneis herculeana)* at this site continued throughout the summer. This was different from the typical seasonal pattern for *Gomphoneis* at other sites where it dies back or sloughs from the rocks in early summer. Continuous inputs of N and P concentrated in the nearshore may have sustained the growth of the *Gomphoneis* through the summer at this site. The presence of heavy *Cladophora* growth also is indicative of nutrient enriched conditions. The *Cladophora* appeared heaviest in spring and summer and appeared to be die back in the fall of 2015. Heavy growth of algae including *Cladophora* has been observed at this site in some previous years by TERC.

Although it appears this seepage water is groundwater, and N and P are slightly elevated the extent of anthropogenic contribution of nutrients is not known – this would be interesting to evaluate further. Whether primarily natural nutrients or a combination of natural and anthropogenically derived nutrients, this site provides a very observable example of heavy periphyton growth likely supported by nutrient inputs to the nearshore.

Figure 13. Localized area of heavy growth of stalked diatoms on 4/21/15 observed adjacent to a residential area, slightly west of the Garwood's synoptic site. The periphyton growth in this area appears to be supported by localized, and persistent seepage of subsurface water or groundwater from sediments in the backshore and along the beach, and which contains slightly elevated nitrogen and phosphorus levels.

Figure 14. Localized area of heavy growth of *Cladophora sp* with stalked diatoms also present mid-August 2015 observed adjacent to a residential area, slightly west of the Garwood's synoptic site. The periphyton growth in this area appears to be supported by localized, and persistent seepage of subsurface water or groundwater from sediments in the backshore and along the beach, and which contains slightly elevated nitrogen and phosphorus levels.

Observations of sloughed blue-green algae during spring and summer, 2015

During spring and summer TERC received reports from concerned public about unknown sediment, wood-like or algal material accumulating and washing up along shore in the Tahoe Vista, Kings Beach, and some sites along the east and west shore areas. This material (Figure 15) was crusty, cork-like small pieces of blue-green algae periphyton mat likely sloughed from the rocks nearby. Although sloughed diatom and filamentous green algae material is frequently observed along portions of the shoreline in the spring and summer, we had not observed accumulations of sloughed blue-green algae material in the nearshore before, although it has likely occurred. It may have been related to the extended exposure of the blue-green algae mat (which is typically located deeper under more "normal" lake levels) near the surface under the low lake level conditions in 2015. Near the surface these algae would be subjected to abrasion by waves and effects of UV, and potentially drying where algae remained exposed above the surface for a prolonged period, which could result in sloughing of algae from the rocks.

Figure 15. Sloughed blue-green algae along shoreline in Tahoe Vista, spring 2015, (Photo courtesy of Ann Lyman).

Results of Spring Synoptic Monitoring 2016

The distribution of PBI and chlorophyll *a* during spring 2016 are presented in Figure 16. 46 sites were monitored in addition to the nine routine sites (total number of sites sampled = 55). Data collected for the 2016 spring synoptic survey are summarized in Table 12. Based on a comparison of data available so far in 2016 for routine sites and observations in the field, it appeared the synoptic survey occurred near the peak along the west and northwest shore, likely after the peak along the south shore.

In 2016, heavier PBI tended to be found along the west side of the lake with lower PBI along the east side. Moderate PBI (indicated by yellow in the map) was observed along much of the west side of the lake. There were multiple areas of heavy PBI along the west and northwest shore (South Fleur du lac, Ward Cr., Pineland, North Sunnyside, Tahoe City Tributary, Tahoe City Boat Ramp, South Dollar Cr.). The highest measured chlorophyll *a* was 141 mg/m^2 at the Tahoe City tributary site. There were also multiple areas of light PBI (green shades) along the same stretch of shoreline. Stalked diatoms were an important contributor to biomass along much of the south west to northwest shoreline. At many sites blue-green algae and filamentous green algae also contributed to biomass.

Generally light PBI was observed along the east side of the lake, with a couple of regions of heavier PBI (Cave Rock and South Elk Pt. regions). The highest chlorophyll *a* along the east shore was at south Elk Pt. (117 mg/m^2). Unusually low periphyton chlorophyll a was measured at Timber Cove (1 mg/m^2). In collections at this site back through 2011 chlorophyll *a* has ranged between 40-82 mg/m^2. At many sites along the east shore, Cyanophytes were predominant, with also some filamentous greens and/or green filamentous algae present. Stalked diatoms contributed to the heavy biomass at the South Elk Point site.

The synoptic monitoring has shown some sites to be frequently high in PBI. Areas where heavier biomass have frequently been observed in past spring synoptics include Ward Cr. mouth, Pineland, Tahoe City, Tahoe City Tributary and South Dollar Cr, on the northwest shore and Timber Cove Rocks along the south shore. Several of these areas are near tributaries which may provide nutrient inputs. Periphyton PBI levels appeared to drop off in 2014 and 2015 at many of these sites from higher levels in 2013 (Table 13). However, biomass at Tahoe City Tributary site remained high throughout this period. The Tahoe City Tributary may provide a consistent source of nutrients. Interestingly Timber Cove PBI was very low in 2016. This may have resulted from the algae sloughing earlier in the year or from unusually low nutrient inputs to support the periphyton growth or some other cause.

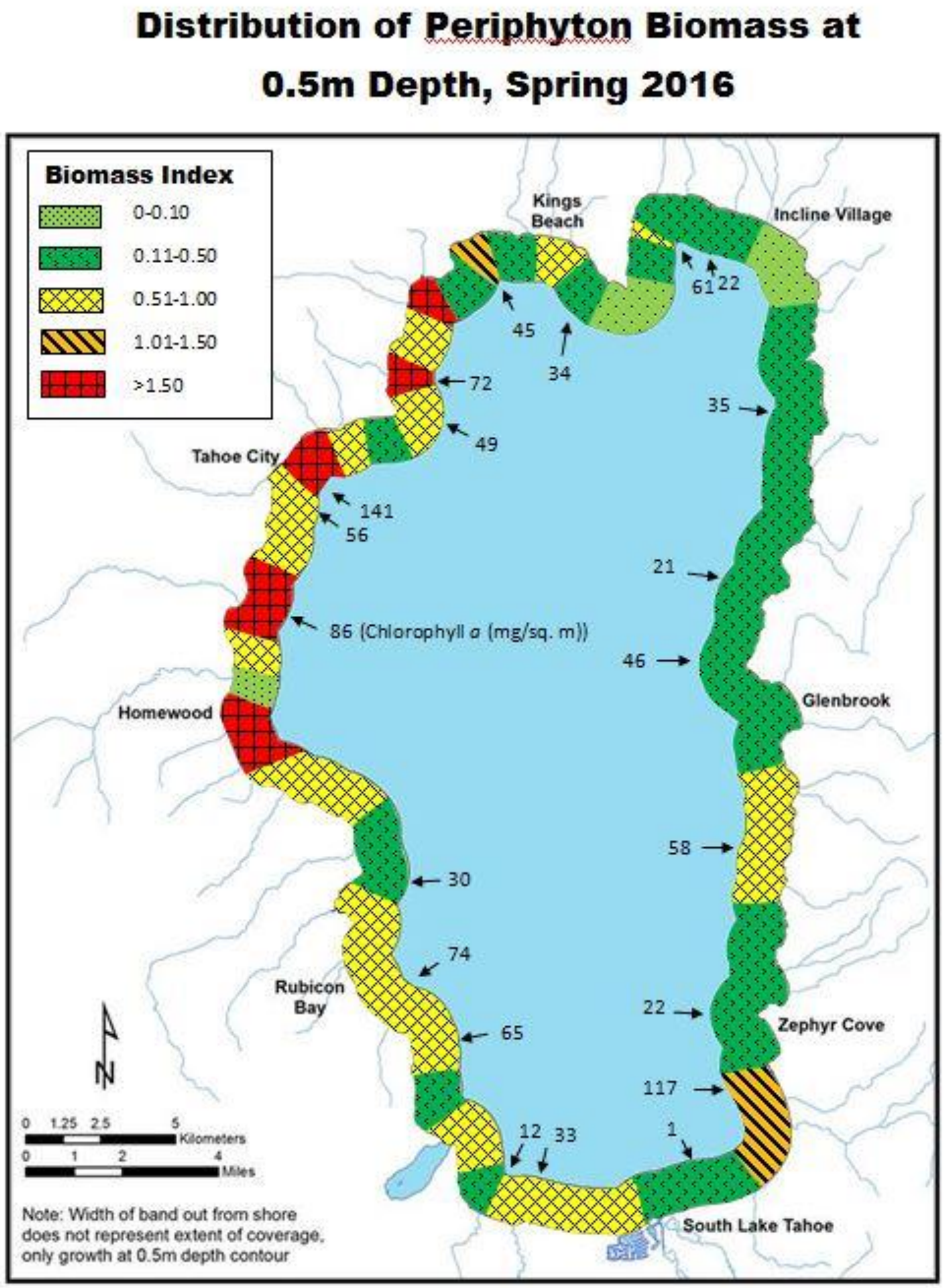

Figure 16. Distribution of periphyton biomass measured during the spring synoptic 2016 (March 30 – April 1, 2016). Shading indicates levels of biomass measured using a rapid assessment method: Periphyton Biomass Index (PBI). (PBI = Avg. Filament Length x % Area Covered with Algae). Levels of periphyton chlorophyll *a* measured at selected sites are also shown (black numbers and arrows).

Table 12. Summary of 0.5m periphyton chlorophyll *a*, Ash Free Dry Weight (AFDW), visual score, avg. filament length and percent algal coverage, predominant algae present based on visual observations while snorkeling (FG=filamentous greens; SD=stalked diatoms; CY= blue green algae), for routine sites (shaded) and Spring Synoptic survey sites during March 30-April 1, 2016. Note for chlorophyll *a* and AFDW, n=2 unless otherwise indicated. Visual score is a subjective ranking of the aesthetic appearance of algal growth (viewed underwater) where 1 is the least offensive and 5 is the most offensive. Biomass Index is filament length times percent algal cover. "NA" = not available or not collected; "NES" = not enough sample for analysis. Sampling depth and corresponding sampling elevation are also indicated.

Site	Site Name	Date	Sampling Depth/Elev. (m/ ft.)	Chl a (mg/m^2)	Std Dev (mg/m^2)	AFDW (g/m^2)	Std Dev (mg/m^2)	Above Visual Score	Below Visual Score	Fil. Length (cm)	Algal Cover. %	Biomass Index	Algal Type
A	Cascade Creek	3/31/16	0.5/6221.22	11.63	4.19	8.17	3.89	2	3	0.5	40%	0.20	FG
B	S. of Eagle Point	3/31/16	0.5/6221.22					2	3	1.3	50%	0.65	SD,FG
C	E.Bay/Rubicon	3/31/16	0.5/6221.22					3	3	0.5	90%	0.45	SD,CY,FG
	Rubicon Pt.	3/31/16	0.5/6221.22	64.54	20.52	45.85	13.40	3	3	0.6	95%	0.57	SD,CY,FG
D	Gold Coast	3/31/16	0.5/6221.22	73.85	17.12	45.61	8.05	3	4	1.2	60%	0.72	SD,CY,FG
E	S. Meeks Point	3/31/16	0.5/6221.22					3	3	0.6	100%	0.6	CY,FG
F	N. Meeks Bay	3/31/16	0.5/6221.22					3	3	1.0	70%	0.70	SD,CY,FG
	Sugar Pine Pt.	3/31/16	0.5/6221.22	30.27	7.35	27.78	6.17	2	3	0.7	70%	0.49	SD,CY,FG
G	Tahoma	3/31/16	0.5/6221.22					2	3	1.5	60%	0.09	SD,FG
H	S. Fleur Du Lac	3/31/16	0.5/6221.22					4	4	2.0	90%	1.80	SD,CY,FG
I	Blackwood Creek	3/31/16	0.5/6221.22					1	2	0.1	20%	0.02	SD
	Kaspian Pt.	3/31/16	0.5/6221.22					3	3	1	65%	0.65	SD,CY
J	Ward Creek	3/31/16	0.5/6221.22					4	5	3.5	95%	3.33	SD
	Pineland	3/31/16	0.5/6221.22	85.56	19.29	68.68	26.06	5	5	4.5	99%	4.46	SD
K	N. Sunnyside	3/31/16	0.5/6221.22					3	5	5	77%	3.85	SD
L	Tavern Pt.	3/31/16	0.5/6221.22					3	3.5	1.2	57%	0.68	SD,CY,FG
	Tahoe City	3/30/16	0.5/6221.22	56.47	2.96	70.92	6.42	4	4	2	50%	1.0	SD
TCT	Tahoe City Trib.	3/31/16	0.5/6221.22	140.60	4.64(n=3)	75.07	13.78 (n=3)	5	5	4.5	83%	3.74	SD
M	TCPUD Boat Ramp	4/1/16	0.5/6221.23					4	4	2.5	96%	2.4	SD
	Lake Forest	4/1/16	0.5/6221.23					3	3	1.0	51%	0.51	SD,CY
N	S. Dollar Pt.	3/30/16	0.5/6221.22					2	3	0.6	60%	0.36	SD
	Dollar Pt.	3/30/16	0.5/6221.22	48.69	5.63	33.24	2.93	2	3	0.8	70%	0.56	SD
O	S. Dollar Creek	3/30/16	0.5/6221.22	71.55	13.14	39.17	1.95	5	5	3	80%	2.40	SD
P	Cedar Flat	3/30/16	0.5/6221.22					3	3	1.0	90%	0.90	SD,CY,FG
Q	Garwood's	3/30/16	0.5/6221.22					4	4	2	90%	1.80	SD,CY
R	Flick Point	3/30/16	0.5/6221.22					2	3	0.5	70%	0.35	SD,CY,FG
S	Stag Avenue	3/30/16	0.5/6221.22	44.96	8.62	43.32	15.57	3	4	1.2	90%	1.08	SD,CY

Site	Site Name	Date	Sampling Depth/Elev. (m/ ft.)	Chl a (mg/m^2)	Std Dev (mg/m^2)	AFDW (g/m^2)	Std Dev (mg/m^2)	Above Visual Score	Below Visual Score	Fil. Length (cm)	Algal Cover. %	Biomass Index	Algal Type
T	Agatam Boat R.	3/30/16	0.5/6221.22					2	2	1.0	50%	0.50	SD
E17	Kings Beach	3/30/16	0.5/6221.22					3	4	1.0	60%	0.60	SD
E16	Brockway Springs	3/30/16	0.5/6221.22	34.32	14.84	48.27	16.80	3	3	0.5	70%	0.35	CY,FG
E15	No. Stateline Point	3/30/16	0.5/6221.22					2	3	0.1	66%	0.07	CY
E14	Stillwater Cove	3/30/16	0.5/6221.22					3	3	0.3	61%	0.18	CY,FG
	Old Incline West	3/30/16	0.5/6221.22					3.5	3.5	0.7	100%	0.70	SD,CY,FG
	Incline West	3/30/16	0.5/6221.22	61.18	4.98	66.81	1.11	3.5	3.5	0.5	90%	0.45	CY,FG
	Incline Condo	3/30/16	0.5/6221.22					3	3	0.5	60%	0.30	CY,FG
E13	Burnt Cedar Beach	3/30/16	0.5/6221.22	22.12	3.26	19.73	6.73	3	3	0.2	90%	0.18	SD,CY,FG
E12	Hidden Beach offsh.	3/30/16	0.5/6221.22					3	3	0.3	73%	0.22	CY
	Hidden Beach insh.	3/30/16	0.5/6221.22					2	2	<0.1	16%	<0.02	CY
E11	Observation Point	4/1/16	0.5/6221.23					2	2	0.2	75%	0.15	CY
	Sand Pt.	4/1/16	0.5/6221.23	34.51	12.05	40.89	11.47	2	3	0.3	80%	0.24	CY,FG
E10	Chimney Beach	4/1/16	0.5/6221.23					2	2	0.3	80%	0.32	SD,CY
E9	Skunk Harbor	4/1/16	0.5/6221.23	20.99	3.02	19.53	3.87	2	2	0.4	80%	0.32	CY,FG
	Deadman Pt.	4/1/16	0.5/6221.23	46.20	15.87	69.30	9.84	2	3	0.3	95%	0.29	CY
E8	So. Deadman Point	4/1/16	0.5/6221.23					2	3	0.5	90%	0.45	SD,CY,FG
E7	So. Glenbrook Bay	4/1/16	0.5/6221.23										
E6	Cave Rock Ramp	4/1/16	0.5/6221.23	58.13	15.17	28.21	11.34	2	3	0.7	80%	0.56	SD,CY,FG
E5	Lincoln Park	4/1/16	0.5/6221.23					2	2	0.5	60%	0.03	CY,FG
E4	No. Zephyr Cove	4/1/16	0.5/6221.23					2	3	0.5	70%	0.35	CY,FG
E3	So. Zephyr Pt.	4/1/16	0.5/6221.23					2	2	0.6	40%	0.24	SD,CY
	Zephyr Pt.	4/1/16	0.5/6221.23	22.02	4.49	35.03	5.65	2	2	0.7	60%	0.42	CY,FG
E2	No. Elk Pt.	4/1/16	0.5/6221.23					1	2	0.3	40%	0.12	SD,CY
E1	So. Elk Point	4/1/16	0.5/6221.23	117.32	16.89	39.72	13.21	3	3	1.5	100%	1.50	SD
	Timber Cove Rock	4/1/16	0.5/6221.23	1.29	0.49	NA	NA	3	3	0.7	33%	0.23	SD
S1	T. Keys Entrance												
S2	Kiva Point	4/1/16	0.5/6221.23	33.31	7.82	35.64	14.16	3	3	1.0	70%	0. 7	SD

Table 13. Comparison of Periphyton Biomass Index (PBI) at sites with frequently high PBI, 2013-2016.

Site	2013 PBI	2014 PBI	2015 PBI	2016 PBI
Ward Cr. Mouth	5.00	1.20	0.12	3.33
Pineland	2.00	0.98	0.63	4.46
Tahoe City	2.67	1.08	0.18	1.00
Tahoe City Trib.	2.38	1.13	1.02	3.74
South Dollar Cr.	2.70	1.02	0.56	2.40
Timber Cove	1.36	1.59	0.45	0.23

Section IV. Project Quality Assurance

This section provides details of the project quality assurance and quality control measures for the primary areas of study associated with this contract. The QA/QC is an explicit task (Task 2) as required in the original contract. QA/QC provides information on procedures for assuring quality in the research being done and the observation techniques or measures that are used to help verify quality data are being collected. The QA/QC details are presented for the three primary areas study below: (1) algal growth potential assays; (2) phytoplankton enumeration; (3) periphyton analyses.

1. Quality assurance and quality control for algal growth potential bioassays

(QA/QC) applied to the AGP bioassays was similar to methods used for QA/QC in algal nutrient bioassays, see: "Lake Tahoe Algal Bioassay Procedure" in Hackley et al., (2007). Avoidance of sources of contamination and factors that can compromise samples is a critical quality assurance concern in collection of AGP bioassay samples. Glassware and carboys are carefully cleaned in the lab with Liquinox soap, tap water, 0.1N HCl and deionized water. When sampling on the research boat, standard, clean limnological sampling techniques are employed to prevent contamination. After collection, samples are protected from direct sunlight and kept cool. The bioassays are typically initiated on the same day of collection. Similarly, avoidance of sources of contamination in bioassay set-up is of critical concern.

To distinguish differences among sites in the AGP tests, it is desirable to have low variation among treatment replicates. Treatment replicate variability can result from a various factors including: natural variability in the sample phytoplankton and nutrients, unequal distribution of phytoplankton numbers or proportions of particular algal types among replicate flasks (this is minimized by frequent mixing during distribution of lake water to flasks) and contamination which may result in either increase or decrease algae growth (this is minimized by rigorous cleaning and rinsing). To keep these tests at a manageable workload level, we used duplicate treatment flasks for all AGP tests except AGP#2 in which triplicate flasks were used.

Generally, treatment replication was good using duplicate treatments. Appendix Tables 1.a-1.k. provide the means and standard deviations for extracted chlorophyll *a* measurements and in vivo fluorescence measurements in the AGP experiments. The coefficients of variation (which is Std. Dev. ÷ Mean) for *in vivo* fluorescence were generally relatively low, with highest values often being below 15%. Figure XX shows the coefficients of variation for extracted chlorophyll a for replicate treatment flasks during various stages of the AGP experiments. The coefficients of variation for extracted chlorophyll a replicate treatment flasks generally less than about 20% (Figure 17). There were some AGP test treatments which had particularly high treatment replicate variability. Samples of Tahoe Keys water from AGP #1 and AGP #4 had high coefficients of variation for extracted chlorophyll a and these values were included in the final AGP results. These levels of variation may have been a consequence of natural variation in the sample of nutrients or particular species distributions at the start of the experiment in the replicates. The Tahoe Keys site is in relatively shallow water and may be influenced by particles in the water and potentially resuspended benthic algae or algae associated with the macrophytes in the area. Finally, for comparison, coefficients of variation for chlorophyll a samples for replicate samples of initial lake water replicates were generally less than about 15% (Figure 18).

We chose not to censor any of the AGP results for these initial AGP assays in 2014-2016. As additional data is collected for these tests, sufficient information should be acquired to make decisions on coefficients of variation considered too high for inclusion in the AGP results.

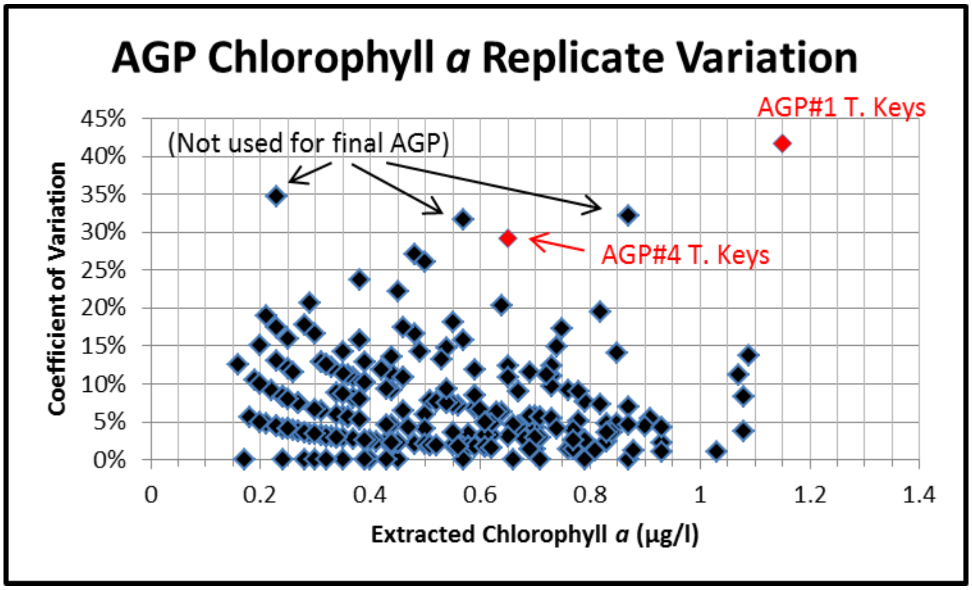

Figure 17. Coefficients of variation (Std. Dev. ÷ Mean) for extracted chlorophyll a for samples from replicate treatment flasks during the AGP experiments. This was water collected from flasks during various stages of the AGP test. There were some sample replicates which had relatively high coefficients of variation. The two high CV samples from Tahoe Keys (shown in red) were used in the final AGP levels.

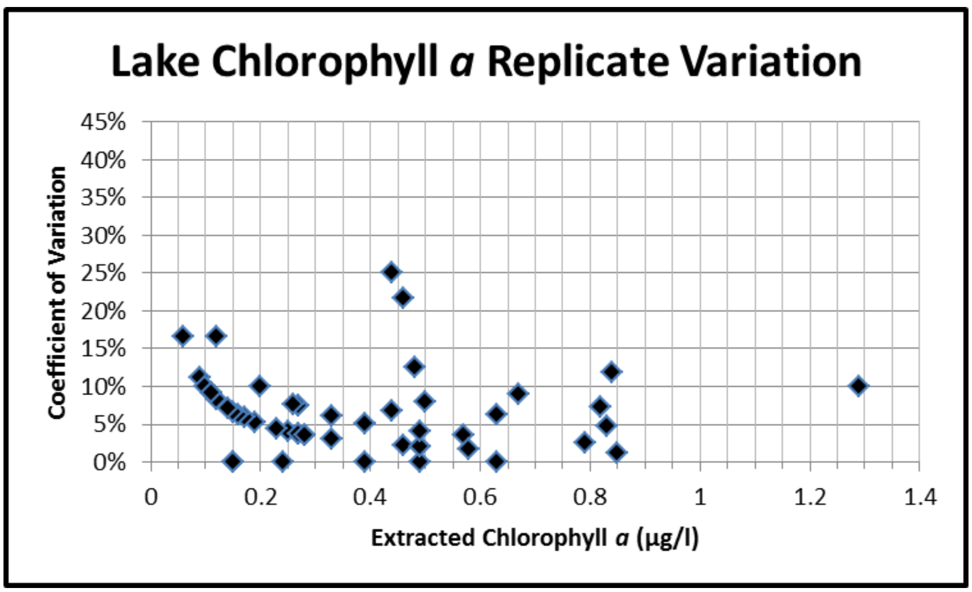

Figure 18. Coefficients of variation (Std. Dev. ÷ Mean) for extracted chlorophyll a for replicate samples of lake water from AGP monitoring sites. This was the initial lake water used to set up bioassays. Replicate samples only available for a portion of the sampling dates.

2. Quality Assurance for Phytoplankton

Appendix 2 of this report provides detailed methods for phytoplankton counting and quality assurance. Quality assurance for phytoplankton enumeration focuses on careful preparation and settling of samples and multiple counts of settled samples. Counts were made along multiple strips of view of settled samples, under the inverted microscope. The replicate strip counts are a measure of precision, much like duplicate water samples provide an estimate of precision for water chemistry. Precision measures the goodness of the procedure, i.e., did the cells settle randomly in the chamber. 1 cm^2 areas of view in the settling chamber were first counted at low magnification to quantify larger cells. Then multiple counts were made at high magnification along 1 cm long strips. The data from all counted strips are combined in computation of totals for the sample. The data from individual counts of settling chamber 1 cm strips is retained in a database if needed for further analysis.

Beginning with samples collected in August 2015, samples were counted by a new phytoplankton specialist Lidia Tanaka. The phytoplankton specialist for many years and coauthor of several of these reports, Debbie Hunter retired from this position. Both specialists worked together for a period to help ensure consistency in the counts.

3. Quality Assurance and Quality Control for Periphyton

For QA/QC applied to periphyton monitoring see "Periphyton Quality Assurance Project Plan" in Hackley et al. (2004). Periphyton monitoring is designed to reflect the amount of attached algal biomass present in specific lake locations. There is no standard growth pattern that the collected samples can be compared to; therefore, it is assumed that the collected biomass is representative of the area in which it was collected. Assurances that collected samples are representative rely on replicate samples and expertise of the sampling personnel to place sampling tubes over sections of substrate that reflect the area's growth pattern. During periods of high standing biomass, when within site variability can be high, researchers may collect triplicate samples. The additional sample increases the statistical power of the analysis and can help account for the presence of higher variability. Collection of the triplicate sample is at the discretion of the scientist. During the study period, triplicate samples were collected for 8 of 126 routine site samples and 7 of 39 spring synoptic site samples.

In 2014 one set of samples was collected which exhibited substantial variation in replicate chlorophyll *a*. This was the Dollar Pt. sample collected Nov. 14, 2014. Along with high chlorophyll *a* (mean chlorophyll *a*= 116 mg/m^2 std. dev. = 55 mg/m^2) these samples had high sand content. PBI however was very low. Figure 19 shows a comparison of chlorophyll *a* and AFDW for samples collected from routine sites on Nov. 11, 2014. The samples from Dollar Pt. had much higher chlorophyll *a* relative to AFDW compared to the other sites. We considered the chlorophyll levels from this sample anomalously high and the data were not used.

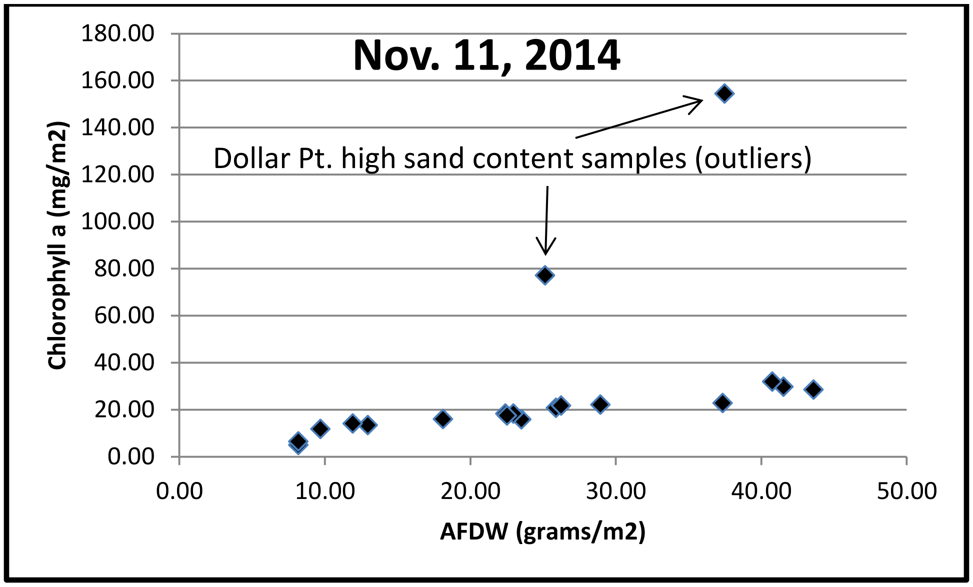

Figure 19. Dollar Pt. routine samples for November 11, 2014 had unusually high chlorophyll *a* relative to AFDW biomass compared to all other routine samples collected on this date. These samples also had very high sand content. The chlorophyll *a* levels for Dollar Pt. on this date were considered anomalous and not used.

In 2016, data from 3 sites showed substantial variation and was censored. At Tahoe City on 3/30/16 one sample replicate was much higher than two other replicates (i.e. 161.83 mg/m^2 compared to 54.38 and 58.56 mg/m^2). This sample had a large amount of sand associated with it and was censored. Spring synoptic sample replicates collected from Garwood's on 3/30/16 showed large variation (160.14 and 75.07 mg/m^2) and were censored. Spring synoptic sample replicates collected on 3/31/16 from So. Fleur du lac similarly showed large variation (127.82 and 64.28 mg/m^2) and were censored.

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Appendix 1. Summary of data for Algal Growth Potential Assays

Table 1.a. Summary of field and experimental data collected for Algal Growth Potential (AGP) experiment done on Lake Tahoe water collected from nearshore and mid-lake sites on 8/15/13. Data for date of collection from various sites is shown in upper left (Date, Time, Surface Temp., Depth collected, chlorophyll *a*, selected observations). On selected dates, extracted chlorophyll *a* was measured, these values are summarized under the heading "Extracted Chlor. *a*". Final AGP results are shown at top right of table (in bold). Initial background fluorescence (i.e. fluorescence of filtered lake water) and mean daily *in vivo* fluorescence readings during the AGP experiment are shown along the bottom of the table.

AGP #1 H_2O Collection 8/15/13	Date Collected	Time Collected	Lake Surface T (°C)	Collection Depth (m)	Lake Chl. *a* (µg/l)	Observations	**Extracted Chlor. *a*** AGP D4 8/19/13	**Extracted Chlor. *a*** AGP D6 8/21/13	**Final AGP Results Chl. *a* ± s.d. (µg/l)**
Nearshore:									
Sunnyside	8/15/13	14:24	18.5	1-1.5	.25	Mod. SW wind	.82 ± .16	.57 ± .18	**.84 ± .21**
Tahoe City	8/15/13	09:05	18.0	1-1.5	.43	Least clear site	.91 ± .05	.73 ± .07	**.99 ± .01**
Kings Beach	8/15/13	10:40	18.0	1-1.5	.28		.79 ± .06	.69 ± .08	**.85 ± .05**
Crystal Bay	8/15/13	11:00	19.5	1-1.5	.26		.64 ± .13	.48 ± .08	**.64 ± .13**
Glenbrook	8/15/13	11:40	18.5	1-1.5	.27		.62 ± .03	.58 ± .02	**.64 ± .04**
Zephyr	8/15/13	12:00	18.5	1-1.5	.22		.85 ± .12	.70 ± .01	**.89 ± .02**
Bijou	8/15/13	13:00	20.0	1-1.5	.27	NE wind	.67 ± .06	.51 ± .04	**.81 ± .08**
Tahoe Keys	8/15/13	13:20	19.5	1-1.5	.27	Mod. SW wind	1.15 ± .48	.87 ± .28	**1.15 ± .48**
CR/Taylor	8/15/13	13:30	19.0	1-1.5	.31	Light SW wind	.73 ± .08	.59 ± .04	**.85 ± .12**
Rubicon Bay	8/15/13	13:53	19.0	1-1.5	.20		.55 ± .10	.56 ± .04	**.55 ± .10**
Mid-Lake:									
Mid-lk No.	8/15/13	09:35	18.5	1.5	.20		.64 ± .04	.58 ± .01	**.64 ± .04**
Mid-lk So.	8/15/13	12:45	18.5	1.5	.18		.48 ± .13	.50 ± .13	**.50 ± .15**

Experiment Daily Fluorescence	Backgrd. Fluor. GF/F Fil.	D0 Fluor. 8/15/13 21:00	D1 Fluor. 8/16/13 12:45	D2 Fluor. 8/17/13 15:30	D3 Fluor. 8/18/13 17:45	D4 Fluor. 8/19/13 14:30	D5 Fluor. 8/20/13 15:35	D6 Fluor. 8/21/13 13:10
Nearshore:								
Sunnyside	.000	.135± .004	.196±.004	.258± .016	.308± .066	.285± .057	.268± .064	.214± .053
Tahoe City	.000	.210± .002	.247±.004	.314± .001	.356± .001	.328± .006	.306± .014	.253± .007
Kings Beach	.000	.135± .005	.179± .005	.216± .005	.301± .019	.305± .019	.311± .017	.251± .043
Crystal Bay	.000	.147± .001	.176± .008	.226± .034	.250± .047	.252± .056	.229± .037	.179± .034
Glenbrook	.000	.138± .011	.185± .013	.208± .013	.247± .013	.236± .013	.231± .007	.210± .006
Zephyr	.000	.113± .006	.172± .017	.250± .007	.324± .007	.321± .018	.312± .001	.256± .008
Bijou	.000	.161± .008	.208± .006	.254± .008	.300± .025	.288± .027	.255± .009	.204± .003
Tahoe Keys	.007	.163± .001	.213± .006	.298± .090	.390± .134	.386± .123	.358± .105	.303± .098
CR/Taylor	.004	.186± .013	.250± .000	.288± .016	.312± .036	.286± .017	.277± .014	.233± .003
Rubicon Bay	.000	.113± .002	.144± .007	.181± .025	.208± .031	.216± .039	.219± .031	.202± .032
Mid-Lake:								
Mid-lk No.	.000	.108± .007	.144± .011	.202± .002	.238± .008	.236± .006	.226± .005	.198± .020
Mid-lk So.	.000	.105± .002	.135± .023	.163± .046	.190± .057	.181± .049	.202± .047	.173± .042

Table 1.b. Summary of field and AGP experimental data collected: Lake Tahoe water collected 12/12/13. Note- This experiment was run using increased replicates per treatment (triplicates) and to accommodate the increased number of flasks, a walk-in incubator w/ High Output T5 fluorescent lighting was used; typically a Percival incubator "PI", with cool white fluorescent lighting is used; one duplicate set of flasks "Mid-lk So. PI" was also run in the Percival Incubator.

AGP #2 H_2O Collection 12/12/13	Date Collected	Time Collected	Lake Surface T (°C)	Collection Depth (m)	Lake Chl. *a** (µg/l) 12/13/13	Observations	**Extracted Chlor. *a*** AGP D0 12/13/13	**Extracted Chlor. *a*** AGP D6 12/19/13	**Final AGP Results Chl. *a* (µg/l)**
Nearshore:									
Sunnyside	12/12/13	15:12	8.0	1.5	0.44		0.44	.24 ± .02	**0.44**
Tahoe City	12/12/13	10:00	6.5	0.5	0.39		0.39	.27 ± .02	**0.39**
Kings Beach	12/12/13	10:50	6.8	0.5	0.41		0.41	.22 ± .02	**0.41**
Crystal Bay	12/12/13	11:10	7.8	1.0	0.45		0.45	.19 ± .02	**0.45**
Glenbrook	12/12/13	11:48	7.5	1.0	0.34		0.34	.23 ± .01	**0.34**
Zephyr	12/12/13	12:12	7.5	1.0	0.34		0.34	.21 ± .01	**0.34**
Timber Cove	12/12/13	12:55	6.2	1.5	0.41		0.41	.25 ± .03	**0.41**
Tahoe Keys	12/12/13	13:00	6.5	0.5	0.41		0.41	.27 ± .01	**0.41**
Camp Rich.	12/12/13	13:20	8.0	1.0	0.42		0.42	.24 ± .02	**0.42**
Emerald Bay	12/12/13	14:00	6.5	1.5	0.69		0.69	.39 ± .04	**0.69**
Rubicon Bay	12/12/13	14:40	-	1.0	0.58		0.58	.32 ± .04	**0.58**
Mid-Lake:									
Mid-lk No.	12/12/13	10:29	7.8	1.5	0.49		0.49	.23 ± .01	**0.49**
Mid-lk So.	12/12/13	12:28	8.0	1.5	0.55		0.55	.27 ± .02	**0.55**
Mid-lk So. PI							0.55	.54 ± .08	**0.55**

Experiment Daily Fluorescence	Backgrd. Fluor. GF/F Fil.	D0 Fluor. 12/13/13 ~14:30	D1 Fluor. 12/14/13 12:15	D2 Fluor. 12/15/13 12:30	D3 Fluor. 12/16/13 13:50	D4 Fluor. 12/17/13 14:00	D5 Fluor. 12/18/13 13:40	D6 Fluor. 12/19/13 14:45
Nearshore:								
Sunnyside	.057	.292± .001	.187±.009	.169± .013	.137± .007	.147± .017	.159± .012	.136± .006
Tahoe City	.065	.257± .003	.164±.015	.166± .003	.155± .006	.168± .007	.179± .011	.167± .007
Kings Beach	.056	.260± .013	.176± .001	.167± .007	.150± .021	.144± .005	.138± .002	.131± .005
Crystal Bay	.059	.262± .003	.176± .010	.169± .008	.141± .002	.153± .005	.135± .007	.136± .008
Glenbrook	.064	.276± .006	.165± .002	.156± .003	.137± .004	.142± .003	.138± .004	.139± .007
Zephyr	.061	.239± .004	.152± .005	.152± .006	.140± .005	.148± .002	.155± .011	.135± .005
Timber Cove	.042	.280± .001	.176± .014	.174± .003	.153± .009	.164± .012	.158± .015	.141± .010
Tahoe Keys	.057	.284± .001	.181± .013	.180± .008	.161± .010	.173± .002	.162± .013	.158± .010
Camp Rich.	.062	.281± .003	.174± .004	.171± .002	.154± .016	.142± .006	.144± .006	.127± .006
Emerald Bay	.078	.342± .013	.226± .018	.213± .005	.188± .004	.195± .011	.190± .008	.179± .012
Rubicon Bay	.057	.327± .008	.210± .012	.200± .009	.172± .016	.190± .013	.184± .003	.174± .016
Mid-Lake:								
Mid-lk No.	.070	.283± .005	.186± .007	.175± .003	.153± .004	.170± .003	.149± .009	.152± .007
Mid-lk So.	.063	.312± .002	.192± .001	.185± .014	.157± .011	.169± .014	.156± .010	.146± .011
Mid-lk So. PI	.063	.312± .002	.265± .006	.264± .002	.263± .003	.256± .016	.257± .025	.260± .030

Table 1.c. Summary of field and experimental data collected for Algal Growth Potential (AGP) experiment done on Lake Tahoe water collected from nearshore and mid-lake sites on 2/20/14. Experiment run in Percival incubator, two replicates per treatment. Note- “Zoopl” = zooplankton.

<u>AGP #3 H_2O Collection 2/20/14</u>	Date Collected	Time Collected	Lake Surface T (°C)	Collection Depth (m)	Lake Chl. *a** (µg/l)	Observations	**Extracted Chlor. *a*** AGP D1 2/21/14	**Extracted Chlor. *a*** AGP D6 2/26/14	**Extracted Chlor. *a*** AGP D9 3/1/14	**Final AGP Results Chl. *a* (µg/l)**
Nearshore:										
Sunnyside	2/20/14	15:00	5.5	1.0	0.63		.54 ± .04	.57 ± .09	.59 ± .05	**.63**
Tahoe City	2/20/14	09:36	5.0	0.5	0.24		.24 ± .02	.45± .00	.69± .01	**.69 ± .01**
Kings Beach	2/20/14	10:50	5.0	0.5	0.58		.55 ± .01	.68 ± .02	.87 ± .06	**.87 ± .06**
Crystal Bay	2/20/14	11:20	5.0	0.5	0.81		.65 ± .08	.67 ± .03	.71 ± .02	**.81**
Glenbrook	2/20/14	11:45	5.0	0.5	0.79		.69 ± .03	.70 ± .04	.73 ± .09	**.79**
Zephyr	2/20/14	12:09	5.0	0.5	0.96		.90 ± .04	.66 ± .03	.70 ± .02	**.96**
Timber Cove	2/20/14	12:51	5.0	0.5	0.50		.45 ± .01	.87 ± .00	1.09± .15	**1.09±.15**
Tahoe Keys	2/20/14	13:05	5.0	0.5	0.60		.55 ± .02	.93 ± .02	1.08± .04	**1.08± .04**
Camp Rich.	2/20/14	13:20	6.0	0.5	0.67		.61 ± .01	.63 ± .04	.83 ± .02	**.83 ± .02**
Emerald Bay	2/20/14	13:52	4.5	1.0	0.74	many Zoopl.	.70 ± .03	.77 ± .02	.75 ± .13	**.77 ± .02**
Rubicon Bay	2/20/14	14:20	5.2	1.0	0.41		.36 ± .02	.55 ± .04	.61 ± .01	**.61 ± .01**
Mid-Lake:										
Mid-lk No.	2/20/14	10:05	5.0	1.0	0.87		.79 ± .02	.65 ± .02	.60 ± .04	**.87**
Mid-lk So.	2/20/14	12:23	5.0	1.0	0.87		.79 ± .00	.76 ± .01	.72 ± .08	**.87**

Experiment Daily Fluorescence	Backgrd. Fluor.	D0 Fluor. 2/20/14 19:35	D1 Fluor. 2/21/14 12:25	D2 Fluor. 2/22/14 11:45	D3 Fluor. 2/23/14 11:50	D4 Fluor. 2/24/14 12:00	D5 Fluor. 2/25/14 12:05	D6 Fluor. 2/26/14 12:10	D7 Fluor. 2/27/14 12:25	D8 Fluor. 2/28/14 13:13	D9 Fluor. 3/1/14 14:15
Nearshore:											
Sunnyside	.064	.371± .008	.317±.004	.314± .016	.313± .014	.322± .002	.325± .000	.354± .015	.330± .016*	.324± .020*	.385± .012
Tahoe City	.074	.218± .004	.188±.001	.196± .003	.200± .004	.219± .001	.251± .001	.280± .001	.346± .022*	.352± .010*	.418± .001
Kings Beach	.062	.403± .001	.347± .008	.331± .008	.329± .003	.331± .009	.348± .006	.364± .016	.389± .018*	.364± .020*	.441± .023
Crystal Bay	.075	.490± .001	.383± .007	.374± .010	.368± .011	.355± .001	.380± .018	.357± .005	.353± .016*	.347± .004*	.381± .011
Glenbrook	.074	.483± .010	.378± .013	.380± .015	.372± .009	.359± .004	.380± .008	.365± .004	.373± .012*	.356± .020*	.406± .007
Zephyr	.068	.527± .018	.410± .012	.395± .001	.392± .001	.364± .022	.370± .027	.363± .008	.362± .020*	.337± .018*	.401± .025
Timber Cove	.118	.402± .017	.371± .005	.415± .002	.434± .018	.473± .004	.507± .002	.549± .006	.544± .000*	.572± .004*	.623± .030
Tahoe Keys	.105	.425± .008	.381± .002	.425± .008	.457± .004	.490± .000	.513± .013	.547± .004	.538± .008*	.555± .016*	.621± .014
Camp Rich.	.071	.416± .001	.372± .011	.378± .016	.387± .016	.379± .003	.390± .004	.418± .002	.421± .000*	.384± .024*	.476± .010
Emerald Bay	.126	.361± .004	.316± .006	.330± .006	.337± .001	.338± .002	.333± .001	.356± .006	.332± .006*	.313± .004*	.378± .029
Rubicon Bay	.062	.292± .000	.257± .020	.268± .007	.274± .001	.298± .001	.315± .007	.345± .012	.327± .008*	.333± .004*	.420± .008
Mid-Lake:											
Mid-lk No.	.070	.484± .019	.364± .008	.358± .014	.347± .005	.339± .006	.320± .004	.332± .003	.333± .024*	.320± .002*	.357
Mid-lk So.	.066	.486± .008	.382± .006	.375± .004	.379± .016	.359± .001	.368± .016	.366± .006	.376± .021*	.364± .024*	.401± .001

Table 1.d. Summary of field and experimental data collected for Algal Growth Potential (AGP) experiment done on Lake Tahoe water collected from nearshore and mid-lake sites on 6/9/14. Experiment run in Percival incubator, two replicates per treatment. Notes- "Meta."= metaphyton present; Surface oil sheen observed at surface at Tahoe City; metaphyton and plants observed along bottom at sites indicated (not in samples).

AGP #4 H_2O Collection 6/9/14	Date Collected	Time Collected	Lake Surface T (°C)	Collection Depth (m)	Lake Chl. *a** (µg/l)	Observations	**Extracted Chlor. *a*** AGP D4 6/13/14	**Extracted Chlor. *a*** AGP D6 6/15/14	**Extracted Chlor. *a*** AGP D9 6/18/14		**Final AGP Results Chl. *a* (µg/l)**
Nearshore:											
Sunnyside	6/9/14	13:45	16.0	1.5	0.14		.52 ± .04	.58 ± .01			**.69 ± .06**
Tahoe City	6/9/14	09:00	14.0	1.5	0.31	Surf. Oil sheen	.61 ± .01	.39(n=1)			**.61 ± .01**
Kings Beach	6/9/14	09:45	14.5	0.75	0.17		.32 ± .01	.37 ± .04			**.37 ± .04**
Crystal Bay	6/9/14	10:10	15.0	1.5	0.18		.35 ± .02	.36 ± .04	.39 ± .04		**.39 ± .04**
Glenbrook	6/9/14	10:40	15.0	1.0	0.11		.31 ± .04	.35 ± .04	.33 ± .04		**.44 ± .06**
Zephyr	6/9/14	11:05	15.5	0.75	0.21		.44 ± .05	.48 ± .01			**.50 ± .03**
Timber Cove	6/9/14	11:35	16.0	0.5	0.13	Metaphyton	.43 ± .01	.50 ± .03			**.50 ± .03**
Tahoe Keys	6/9/14	11:50	16.5	0.5	0.30	Plants & Meta.	.46 ± .08	.41 ± .01	.65 ± .19		**.65 ± .19**
Camp Rich.	6/9/14	12:00	16.5	1.5	0.24		.51 ± .01	.57 ± .01	.83 ± .04		**.83 ± .04**
Emerald Bay	6/9/14	12:32	17.0	1.5	0.42		.69 ± .04	.61 ± .03			**.69 ± .04**
Rubicon Bay	6/9/14	13:00	17.0	1.0	0.12		.26 ± .01	.18 ± .01			**.26 ± .02**
Mid-Lake:											
Mid-lk No.	6/9/14	09:25	15.0	1.5	0.12		.26 ± .03	.20 ± .01	.23 ± .08		**.26 ± .03**
Mid-lk So.	6/9/14	11:20	15.5	1.5	0.17		.31 ± .01	.34 ± .01	.58 ± .01		**.58 ± .01**

Experiment Daily Fluorescence	Backgrd. Fluor.	D0 Fluor. 6/9/14 19:30	D1 Fluor. 6/10/14 14:40	D2 Fluor. 6/11/14 15:34	D3 Fluor. 6/12/14 15:20	D4 Fluor. 6/13/14 16:00	D5 Fluor. 6/14/14	D6 Fluor. 6/15/14 10:30	D7 Fluor. 6/16/14 14:50	D8 Fluor. 6/17/14	D9 Fluor. 6/18/14 15:20
Nearshore:											
Sunnyside	.024	.183± .006	.209±.005	.261± .006	.340± .008	.397± .011		.421± .016	.436± .035		.252± .018
Tahoe City	.049	.256± .007	.356±.021	.361± .012	.387± .011	.395± .022		.305± .026	.262± .008		.202± .037
Kings Beach	.037	.178± .001	.208± .001	.215± .007	.244± .005	.242± .001		.228± .002	.249± .013		.242± .012
Crystal Bay	.051	.201± .001	.235± .001	.254± .003	.262± .004	.256± .005		.243± .021	.255± .007		.258± .008
Glenbrook	.036	.176± .005	.210± .002	.223± .004	.258± .002	.270± .012		.263± .015	.293± .037		.241± .022
Zephyr	.031	.212± .011	.235± .003	.258± .001	.299± .003	.330± .001		.323± .001	.327± .014		.262± .006
Timber Cove	.050	.190± .006	.205± .019	.232± .001	.277± .010	.295± .006		.289± .008	.265(n=1)		.223(n=1)
Tahoe Keys	.076	.260± .013	.281± .008	.281± .006	.287± .004	.296± .010		.289± .006	.323± .001		.352± .058
Camp Rich.	.043	.290± .005	.283± .004	.269± .011	.277± .001	.291± .002		.277± .003	.330± .004		.413± .005
Emerald Bay	.057	.327± .009	.322± .025	.351± .010	.391± .018	.394± .005		.360± .000	.356± .014		.307± .004
Rubicon Bay	.030	.169± .001	.170± .011	.195± .004	.210± .011	.211± .013		.172± .003	.185± .003		.215± .008
Mid-Lake:											
Mid-lk No.	.036	.157± .001	.195± .001	.175± .007	.218± .009	.224± .007		.180± .008	.180± .003		.203± .021
Mid-lk So.	.037	.212± .005	.220± .001	.198± .004	.203± .014	.220± .004		.226± .001	.265± .011		.313± .029

Appendix 1.e. Summary of field and experimental data collected for Algal Growth Potential (AGP) experiment done on Lake Tahoe water collected from nearshore and mid-lake sites on 8/29/14. Data for date of collection from various sites is shown in upper left (Date, Time, Surface Temp., Depth collected, chlorophyll *a*, selected observations). On selected dates, extracted chlorophyll *a* was measured, these values are summarized under heading "Extracted Chlor. a". Final AGP results are shown at top right of table (in bold). Initial background fluorescence (i.e. fluorescence of filtered lake water) and mean daily *in vivo* fluorescence readings during the AGP experiment are shown along bottom of table.

AGP #5 H_2O Collection 8/29/14	Date Collected	Time Collected	Lake Surface T (°C)	Collection Depth (m)	Lake Chl. *a* (µg/l)	Observations	**Extracted Chlor. *a*** AGP D4 9/2/14	**Extracted Chlor. *a*** AGP D11 9/9/14	**Final AGP Results Chl. *a* ± s.d. (µg/l)**
Nearshore:									
Sunnyside	8/29/14	13:10	NA	1	.19		.34 ± .02		**.42 ± .07**
Tahoe City	8/29/14	08:30	17.0	1	.41	Surf. Oil sheen	.74 ± .11	.36 ± .02	**.82 ± .05**
Kings Beach	8/29/14	09:30	17.5	0.5	.40		.40 ± .00		**.48 ± .03**
Crystal Bay	8/29/14	10:00	18.0	1	.17		.35 ± .01		**.43 ± .02**
Glenbrook	8/29/14	10:24	17.5	1	.23		.40 ± .01		**.40 ± .01**
Zephyr	8/29/14	10:46	17.5	0.5	.18		.62 ± .02		**.61 ± .02**
Timber Cove	8/29/14	11:15	18.5	0.5	.11	Metaphyton	.50 ± .02	.38 ± .06	**.65 ± .01**
Tahoe Keys	8/29/14	11:30	19.0	0.25	.20	Aquatic plants	.38 ± .06		**.56 ± .03**
Camp Rich.	8/29/14	11:42	18.5	1	.18		.50 ± .01		**.45 ± .01**
Emerald Bay	8/29/14	12:14	19.0	1	.23		.28 ± .00		**.39 ± .02**
Rubicon Bay	8/29/14	12:45	18.0	1	.16		.38 ± .09	.17 ± .00	**.44 ± .08**
Mid-Lake:									
Mid-lk No.	8/29/14	08:56	17.5	1	.15		.30 ± .00		**.44 ± .002**
Mid-lk So.	8/29/14	11:00	18.0	1	.17		.33 ± .01		**.37 ± .04**

Experiment Daily Fluor.	Backgrd. Fluor. GF/F Fil.	D0 Fluor. 8/29/14 17:30	D2 Fluor. 8/31/14 11:00	D3 Fluor. 9/1/14 17:05	D4 Fluor. 9/2/14 10:25	D5 Fluor. 9/3/14 14:15	D6 Fluor. 9/4/14 11:15	D8 Fluor. 9/6/14 17:50	D11 Fluor. 9/9/14 13:15
Nearshore:									
Sunnyside	.042	.188± .001	.207±.002	.231± .001	.224± .002	.245± .016	.244± .019	.261± .033	.247± .035
Tahoe City	.046	.295± .006	.379±.005	.443± .021	.395± .010	.419± .024	.391± .037	.359± .003	.313± .019
Kings Beach	.049	.270± .003	.255± .009	.275± .024	.244± .026	.286± .016	.269± .002	.286± .023	.264± .016
Crystal Bay	.034	.195± .031	.226± .019	.263± .008	.247± .015	.266± .011	.251± .009	.224± .004	.202± .002
Glenbrook	.042	.192± .002	.210± .003	.239± .006	.221± .007	.252± .003	.247± .001	.230± .018	.208± .046
Zephyr	.050	.160± .001	.236± .002	.319± .001	.318± .007	.347± .008	.331± .019	.310± .006	.307± .052
Timber Cove	.040	.151± .009	.203± .001	.299± .018	.320± .021	.365± .002	.347± .009	.345± .004	.307± .023
Tahoe Keys	.051	.209± .003	.231± .019	.282± .004	.277± .011	.323± .014	.313± .008	.275± .000	.202± .004
Camp Rich.	.038	.201± .002	.222± .004	.255± .006	.254± .004	.273± .005	.265± .000	.250± .006	.225± .016
Emerald Bay	.045	.190± .001	.228± .004	.244± .007	.232± .001	.230± .011	.218± .020	.206± .021	.182± .016
Rubicon Bay	.044	.169± .004	.211± .016	.247± .023	.242± .025	.271± .038	.250± .001	.222± .002	.171± .001
Mid-Lake:									
Mid-lk No.	.044	.169± .004	.193± .003	.227± .011	.218± .004	.231± .021	.237± .001	.267± .001	.245± .018
Mid-lk So.	.034	.178± .001	.192± .005	.204± .012	.200± .016	.223± .002	.232± .005	.237± .018	.208± .015

Appendix 1.f. Summary of field and experimental data collected for Algal Growth Potential (AGP) experiment done on Lake Tahoe water collected from nearshore and mid-lake sites on 12/9/14.

AGP #6 H_2O Collection 12/9/14	Date Collected	Time Collected	Lake Surface T (°C)	Collection Depth (m)	Lake Chl. *a* (µg/l)	Observations	**Extracted Chlor. *a*** AGP D10 12/19/14	**Extracted Chlor. *a*** AGP D14 12/23/14	**Final AGP Results Chl. *a* ± s.d. (µg/l)**
Nearshore:									
Sunnyside	12/9/14	14:55	9.5	0.5	.52		.31 ± .02		**.52**
Tahoe City	12/9/14	09:10	8.0	0.5	.46	Dredging Ramp	.45 ± .10	.39 ± .05	**.46**
Kings Beach	12/9/14	10:15	9.0	0.5	.45		.34 ± .01		**.45**
Crystal Bay	12/9/14	10:40	9.5	0.5	.61		.30 ± .02		**.61**
Glenbrook	12/9/14	11:15	9.5	0.5	.46		.30 ± .05		**.46**
Zephyr Cove	12/9/14	11:35	9.0	0.5	.34		.37 ± .03		**.39 ± .02**
Timber Cove	12/9/14	12:15	9.0	0.5	.31	Macrophytes	.39 ± .04		**.39 ± .04**
Tahoe Keys	12/9/14	12:30	9.0	0.5	.53	Macrophytes	.42 ± .05	0.43 ± .04	**.53**
Camp Rich.	12/9/14	12:45	9.0	0.5	.43		.31 ± .01		**.43**
Emerald Bay	12/9/14	13:15	9.0	0.5	.52		.44 ± .04	.32 ± .01	**.52**
Rubicon Bay	12/9/14	13:50	9.5	0.5	.38		.27 ± .01		**.38**
Mid-Lake:									
Mid-lk No.	12/9/14	09:40	9.0	0.5	.53		.27 ± .02		**.53**
Mid-lk So.	12/9/14	11:55	9.5	0.5	.43		.31 ± .04		**.43**

Experiment Daily Fluorescence	Backgrd. Fluor. GF/F Fil.	D0 Fluor. 8/29/14 17:30	D1 Fluor. 12/10/14 16:00	D3 Fluor. 12/12/14 12:10	D4 Fluor. 12/13/14 12:50	D6 Fluor. 12/15/14 15:35	D8 Fluor. 12/17/14 13:45	D10 Fluor. 12/19/14 15:00	D12 Fluor. 12/21/14 14:05	D14 Fluor. 12/23/14 17:15
Nearshore:										
Sunnyside	.057	.293	.227±.008	.211± .000	.192± .005	.213± .001	.219± .009	.239± .001	.255± .004	.264± .025
Tahoe City	.063	.263	.223±.007	.197± .013	.220± .010	.245± .007	.280± .010	.292± .010	.288± .011	.311± .015
Kings Beach	.045	.243	.216± .009	.186± .013	.193± .004	.196± .004	.216± .005	.233± .001	.244± .005	.264± .002
Crystal Bay	.059	.279	.223± .008	.197± .006	.197± .004	.205± .002	.209± .020	.220± .011	.234± .006	.237± .005
Glenbrook	.056	.249	.210± .008	.186± .005	.185± .005	.189± .001	.202± .009	.220± .001	.237± .004	.257± .010
Zephyr	.054	.208	.182± .001	.174± .001	.187± .001	.209± .000	.223± .007	.248± .001	.264± .007	.274± .019
Timber Cove	.058	.209	.181± .009	.187± .001	.201± .006	.238± .006	.264± .012	.279± .013	.276± .006	.261± .007
Tahoe Keys	.067	.307	.246± .009	.226± .015	.215± .009	.222± .017	.254± .012	.279± .013	.288± .028	.286± .016
Camp Rich.	.055	.252	.212± .002	.198± .007	.198± .009	.210± .001	.215± .004	.241± .004	.247± .004	.249± .011
Emerald Bay	.093	.322	.300± .000	.303± .008	.316± .006	.336± .001	.322± .000	.330± .006	.292± .001	.255± .004
Rubicon Bay	.057	.225	.193± .003	.176± .004	.192± .009	.198± .010	.206± .001	.222± .004	.240± .015	.252± .040
Mid-Lake:										
Mid-lk No.	.056	.252	.211± .013	.176± .004	.182± .001	.182± .002	.187± .002	.207± .006	.225± .007	.244± .005
Mid-lk So.	.051	.265	.208± .006	.198± .010	.192± .001	.202± .006	.209± .006	.227± .003	.233± .004	.244± .003

Note- Used association between Corrected *In Vivo* Fluorescence (Uncorrected – Day 0 Blank) and Chlorophyll *a* to calculate Day 14 chlorophyll *a* for Zephyr Cove.

Appendix 1.g. Summary of field and experimental data collected for Algal Growth Potential (AGP) experiment done on Lake Tahoe water collected from nearshore and mid-lake sites on 2/26/15.

AGP #7 H_2O Collection 2/26/15	Date Collected	Time Collected	Lake Surface T (°C)	Collection Depth (m)	Lake Chl. *a* (µg/l)	Observations	**Extracted Chlor. *a*** AGP D6 3/4/15	**Extracted Chlor. *a*** AGP D14 3/12/15	**Final AGP Results Chl. *a* ± s.d. (µg/l)**
Nearshore:									
Sunnyside	2/26/15	10:10	6.5	1.0	.52		.71 ± .04	.65 ± .07	**.71 ± .04**
Tahoe City	2/26/15	09:05	6.0	0.5-1.0	.35		.45 ± .01	.62 ± .01	**.62 ± .01**
Kings Beach	2/26/15	14:15	7.0	0.5	.43	Bottom Detritus	.62 ± .03	.77 ± .01	**.83 ± .03**
Crystal Bay	2/26/15	13:50	7.0	0.5	.59		.71 ± .00	.73 ± .04	**.84 ± .02**
Glenbrook	2/26/15	13:15	7.0	0.5	.42		.57 ± .00	.85 ± .04	**.97 ± .04**
Zephyr Cove	2/26/15	12:55	6.5	0.5	.33		.54 ± .04	.87 ± .04	**.94 ± .01**
Timber Cove	2/26/15	12:15	6.0	0.5	.17		.37 ± .01	1.08± .09	**1.08 ± .09**
Tahoe Keys	2/26/15	12:00	7.0	0.5	.37		.59 ± .01	.69 ± .01	**.90 ± .02**
Camp Rich.	2/26/15	11:45	6.5	0.5	.48		.61 ± .02	.62 ± .01	**.75 ± .01**
Emerald Bay	2/26/15	11:20	6.0	0.5	.98		.93 ± .04	.51 ± .01	**.98**
Rubicon Bay	2/26/15	10:45	6.5	0.5	.76		.71 ± .04	.59 ± .07	**.76**
Mid-Lake:									
Mid-lk No.	2/26/15	09:30	6.5	1.0	.63		.56 ± .01	.61 ± .03	**.67 ± .03**
Mid-lk So.	2/26/15	12:35	7.0	0.5	.62		.61 ± .01	.67 ± .06	**.76 ± .02**

Experiment Daily Fluorescence	Backgrd. Fluor. GF/F Fil.	D0 Fluor. 2/26/15 19:35	D1 Fluor. 2/27/15 14:05	D2 Fluor. 2/28/15 15:00	D4 Fluor. 3/2/15 13:15	D6 Fluor. 3/4/15 14:20	D8 Fluor. 3/6/15 14:30	D10 Fluor. 3/8/15 11:20	D12 Fluor. 3/10/15 13:00	D14 Fluor. 3/12/15 12:50
Nearshore:										
Sunnyside	.074	.389	.345±.004	.332± .006	.361± .002	.368± .002	.390± .012	.390± .013	.384± .018	.350± .004
Tahoe City	.079	.285	.254±.004	.289± .001	.301± .005	.295± .000	.302± .002	.292± .009	.316± .012	.307± .012
Kings Beach	.067	.298	.297± .007	.309± .005	.362± .007	.386± .015	.417± .000	.422± .012	.435± .015	.391± .008
Crystal Bay	.071	.344	.306± .006	.333± .002	.352± .009	.408± .014	.459± .012	.449± .007	.438± .004	.387± .004
Glenbrook	.080	.293	.271± .001	.292± .003	.331± .002	.388± .006	.453± .012	.474± .004	.499± .019	.445± .018
Zephyr	.080	.283	.266± .003	.283± .003	.324± .002	.368± .009	.434± .004	.471± .015	.486± .004	.456± .014
Timber Cove	.077	.171	.157± .002	.184± .000	.218± .003	.272± .004	.357± .004	.420± .016	.515± .004	.521± .027
Tahoe Keys	.084	.270	.260± .001	.278± .016	.313± .001	.368± .001	.429± .006	.441± .001	.468± .009	.407± .010
Camp Rich.	.078	.326	.312± .006	.333± .008	.362± .011	.365± .008	.407± .017	.397± .008	.400± .005	.366± .001
Emerald Bay	.112	.464	.468± .002	.474± .027	.489± .015	.462± .005	.424± .006	.363± .021	.353± .004	.307± .013
Rubicon Bay	.079	.408	.356± .011	.371± .001	.378± .006	.390± .004	.411± .002	.411± .044	.379± .016	.341± .025
Mid-Lake:										
Mid-lk No.	.074	.370	.307± .011	.304± .005	.339± .001	.356± .005	.364± .019	.342± .026	.364± .015	.325± .011
Mid-lk So.	.068	.408	.356± .006	.359± .004	.377± .011	.394± .003	.406± .004	.389± .013	.407± .011	.390± .019

Appendix 1.h. Summary of field and experimental data collected for Algal Growth Potential (AGP) experiment done on Lake Tahoe water collected from nearshore and mid-lake sites on 5/26/15

AGP #8 H_2O Collection 5/26/15	Date Collected	Time Collected	Lake Surface T (°C)	Collection Depth (m)	Lake Chl. *a* (µg/l)	Observations	**Extracted Chlor. *a*** AGP D6 6/1/15	**Extracted Chlor. *a*** AGP D11 6/6/15	**Final AGP Results Chl. *a* ± s.d. (µg/l)**
Nearshore:									
Sunnyside	5/26/15	13:35	14.0	0.5	.28±.01		.44 ± .02	.32 ± .01	**.44 ± .02**
Tahoe City	5/26/15	09:10	11.0	0.5	.63±.00	5/24 T-storm, mod. turbidity	.78 ± .04	.46 ± .03	**.78 ± .04**
Kings Beach	5/26/15	09:55	11.0	0.5	.29	Slight turbidity	.44 ± .01	.29 ± .01	**.44 ± .01**
Crystal Bay	5/26/15	10:20	11.5	0.5	.27±.01		.43 ± .02	.27 ± .02	**.43 ± .02**
Glenbrook	5/26/15	10:50	11.5	0.5	.25±.01		.35 ± .00	.38 ± .03	**.35 ± .00**
Zephyr Cove	5/26/15	11:15	12.0	0.5	.27±.01		.46 ± .05	.28 ± .01	**.46 ± .05**
Timber Cove	5/26/15	11:40	13.5	0.25	.09±.01		.88 ± .01	.32 ± .04	**.88 ± .01**
Tahoe Keys	5/26/15	11:50	13.0	0.5	.23±.01		.39 ± .01	.34 ± .03	**.39 ± .01**
Camp Rich.	5/26/15	12:10	13.0	0.5	.27±.02		.43 ± .00	.39 ± .01	**.43 ± .00**
Emerald Bay	5/26/15	12:35	15.0	0.5	.49±.00		.52 ± .01	.44 ± .01	**.52 ± .01**
Rubicon Bay	5/26/15	13:05	12.5	0.5	.33±.02		.38 ± .02	.35 ± .05	**.38 ± .02**
Mid-Lake:									
Mid-lk No.	5/26/15	09:30	11.0	0.5	.22		.32 ± .00	.25 ± .01	**.33 ± .02**
Mid-lk So.	5/26/15	11:30	11.0	0.5	.19±.01		.24 ± .01	.25 ± .02	**.24 ± .01**

Experiment Daily Fluorescence	Backgrd. Fluor. GF/F Fil.	D0 Fluor. 5/26/15 17:35	D1 Fluor. 5/27/15 14:30	D3 Fluor. 5/29/15 13:15	D4 Fluor. 5/30/15 14:15	D6 Fluor. 6/1/15 14:20	D8 Fluor. 6/3/15 15:40	D11 Fluor. 6/6/15 14:40	D14 Fluor. 6/9/15 16:15
Nearshore:									
Sunnyside	.046	.289	.242±.000	.219± .001	.216± .001	.224± .002	.193± .008	.171± .004	.164± .008
Tahoe City	.053	.412	.404±.004	.357± .010	.359± .018	.346± .001	.306± .035	.267± .005	.236± .003
Kings Beach	.058	.253	.243± .014	.221± .001	.218± .004	.231± .006	.221± .004	.178± .005	.149± .013
Crystal Bay	.064	.255	.270± .004	.257± .000	.249± .001	.253± .009	.224± .002	.183± .000	.169± .004
Glenbrook	.048	.225	.213± .000	.200± .000	.203± .004	.202± .006	.195± .005	.201± .008	.223± .046
Zephyr	.053	.249	.247± .004	.237± .010	.245± .001	.247± .022	.228± .007	.177± .001	.163± .004
Timber Cove	.053	.131	.140± .009	.216± .006	.301± .003	.454± .008	.455± .004	.232± .014	.141± .001
Tahoe Keys	.054	.239	.234± .003	.232± .006	.227± .013	.242± .006	.240± .004	.213± .010	.194± .008
Camp Rich.	.047	.251	.259± .007	.237± .001	.233± .004	.244± .011	.237± .002	.219± .005	.238± .003
Emerald Bay	.069	.341	.331± .011	.308± .005	.311± .001	.321± .008	.310± .006	.316± .001	.274± .002
Rubicon Bay	.048	.243	.244± .005	.211± .004	.208± .008	.204± .010	.198± .008	.180± .008	.161± .007
Mid-Lake:									
Mid-lk No.	.048	.205	.212± .010	.196± .004	.195± .008	.183± .001	.173± .004	.155± .004	.138± .017
Mid-lk So.	.044	.196	.184± .001	.172± .003	.176± .008	.184± .008	.178± .006	.180± .009	.141± .001

Appendix 1.i. Summary of field and experimental data collected for Algal Growth Potential (AGP) experiment done on Lake Tahoe water collected from nearshore and mid-lake sites on 9/1/15

AGP #9 H_2O Collection 9/1/15	Date Collected	Time Collected	Lake Surface T (°C)	Collection Depth (m)	Lake Chl. *a* (µg/l)	**Extracted Chlor. *a* GF/C** AGP D4 9/5/15	**Extracted Chlor. *a* GF/F** AGP D4 9/5/15	**Extracted Chlor. *a* GF/C** AGP D9 9/10/15	**Extracted Chlor. *a* GF/F** AGP D9 9/10/15	**Final AGP Results Chl. *a* ± s.d. (µg/l)**
Nearshore:										
Sunnyside	9/1/15	12:50	18.5	0.5	.11±.01	.23 ± .04	0.15	NA	.20	**.23 ± .04**
Tahoe City	9/1/15	08:20	16.5	0.5	.17±.01	.49 ± .07	0.45	.43	.36	**.49 ± .07**
Kings Beach	9/1/15	09:15	18.0	0.5	.16±.01	.28 ± .05	0.28	.26	.21	**.28 ± .05**
Crystal Bay	9/1/15	09:35	18.0	0.5	.15±.01	.24 ± .00	0.21	.19	.17	**.24 ± .00**
Glenbrook	9/1/15	10:10	17.5	0.5	.14±.01	.20 ± .03	0.18	.21	.22	**.21**
Zephyr Cove	9/1/15	10:30	17.5	0.5	.15±.00	.21 ± .04	0.24	.22	.22	**.22**
Timber Cove	9/1/15	10:55	18.0	0.25	.06±.01	.46 ± .05	0.49	.35	.31	**.46 ± .05**
Tahoe Keys	9/1/15	11:10	17.5	0.5	.12±.02	.35 ± .03	0.31	.24	.22	**.35 ± .03**
Camp Rich.	9/1/15	11:25	18.0	0.5	.10±.01	.20 ± .02	0.22	.20	.18	**.20 ± .02**
Emerald Bay	9/1/15	11:50	18.5	0.5	.20±.02	.23 ± .01	0.20	.29	.28	**.29**
Rubicon Bay	9/1/15	12:20	18.5	0.5	.12±.01	.25 ± .04	0.19	.21	.16	**.25 ± .04**
Mid-Lake:										
Mid-lk No.	9/1/15	08:40	17.5	1.0	.15±.00	.16 ± .02	0.19	.21	.15	**.21**
Mid-lk So.	9/1/15	10:45	18.0	0.5	.11±.01	.23 ± .03	0.21	.19	.20	**.23 ± .03**

Experiment Daily Fluorescence	Backgrd. Fluor. GF/C Fil.	D0 Fluor. 9/1/15 17:15	D2 Fluor. 9/3/15 15:30	D3 Fluor. 9/4/15 15:15	D4 Fluor. 9/5/15 16:25	D6 Fluor. 9/7/15 16:20	D9 Fluor. 9/10/15 13:45
Nearshore:							
Sunnyside	.028	.124±.002	.177±.007	.181± .001	.185± .001	.163± .001	.141± .008
Tahoe City	.042	.173±.003	.259±.008	.312± .001	.357± .019	.340± .009	.266± .001
Kings Beach	.031	.160±0	.180± .002	.197± .005	.201± .014	.196± .001	.184± .005
Crystal Bay	.032	.155±.006	.181± .004	.183± .009	.185± .006	.168± .013	.140± .015
Glenbrook	.027	.150±.010	.174± .003	.166± .008	.172± .002	.162± .001	.152± .003
Zephyr	.029	.156±.006	.190± .003	.190± .006	.189± .002	.180± .002	.159± .001
Timber Cove	.033	.105±.002	.195± .001	.259± .011	.348± .032	.315± .035	.252± .040
Tahoe Keys	.032	.153±.004	.204± .003	.215± .005	.238± .001	.219± .003	.190± .012
Camp Rich.	.025	.152±.001	.170± .001	.175± .001	.186± .001	.172± .001	.156± .020
Emerald Bay	.042	.193±.001	.189± .001	.197± .008	.202± .001	.210± .011	.243± .013
Rubicon Bay	.025	.138±.002	.185± .003	.191± .018	.203± .016	.178± .013	.154± .002
Mid-Lake:							
Mid-lk No.	.034	.151±.001	.175± .008	.163± .006	.166± .006	.143± .001	.126± .016
Mid-lk So.	.027	.148±.004	.173± .012	.179± .000	.184± .005	.163± .002	.150± .003

Appendix 1.j. Summary of field and experimental data collected for Algal Growth Potential (AGP) experiment done on Lake Tahoe water collected from nearshore and mid-lake sites on 12/16/15. Peak chlorophyll a was the same as the initial lake chlorophyll a at all sites.

AGP #10 H_2O Collection 12/16/15	Date Collected	Time Collected	Lake Surface T (°C)	Collection Depth (m)	Lake Chl. *a* (µg/l)	Observations	**Extracted Chlor. *a*** AGP D12 12/28/15	**Final AGP Results Chl. *a* ± s.d. (µg/l)**
Nearshore:								
Sunnyside	12/16/15	14:50	6.5	0.5	.44±.11		.25 ± .01	**.44±.11**
Tahoe City	12/16/15	09:30	2.5	0.5	.50±.04		.29 ± .06	**.50±.04**
Kings Beach	12/16/15	10:45	5.5	0.5	.49±.01			**.49±.01**
Crystal Bay	12/16/15	11:05	6.5-7.0	0.5	.46±.10			**.46±.10**
Glenbrook	12/16/15	11:40	6.5	0.5	.46±.01			**.46±.01**
Zephyr Cove	12/16/15	12:05	7.5	0.5	.49±.01			**.49±.01**
Timber Cove	12/16/15	12:40	2.0-2.5	0.5	.44±.03	Thin ice		**.44±.03**
Tahoe Keys	12/16/15	13:00	5.0-5.5	0.5	.48±.06			**.48±.06**
Camp Rich.	12/16/15	13:15	6.0-6.5	0.5	.49±.02			**.49±.02**
Emerald Bay	12/16/15	13:40	5.0	0.5	1.29±.13		.47 ± .02	**1.29±.13**
Rubicon Bay	12/16/15	14:20	6.5	0.5	.39±.00			**.39±.00**
Mid-Lake:								
Mid-lk No.	12/16/15	10:20	6.5	0.5	.63±.04		.25 ± .01	**.63±.04**
Mid-lk So.	12/16/15	12:20	7.0	0.5	.57±.02			**.57±.02**

Experiment Daily Fluorescence	Backgrd. Fluor. GF/C Fil.	D0 Fluor. 12/16/15 19:15	D1 Fluor. 12/17/15 13:45	D2 Fluor. 12/18/15 13:40	D4 Fluor. 12/20/15 13:45	D7 Fluor. 12/23/15 14:45	D9 Fluor. 12/25/15 14:15	D12 Fluor. 12/28/15 12:40
Nearshore:								
Sunnyside	.059	.335	.316±.013	.279± .002	.268± .003	.276± .006	.197± .005	.243± .008
Tahoe City	.077	.336	.292±.004	.267± .007	.266± .003	.253± .007	.243± .021	.237± .008
Kings Beach	.057	.311	.288± .001	.255± .013	.240± .001	.223± .004	.177± .006	.204± .013
Crystal Bay	.061	.316	.273± .009	.245± .003	.239± .001	.232± .001	.182± .013	.210± .007
Glenbrook	.055	.325	.265± .013	.248± .001	.245± .006	.238± .006	.175± .034	.216± .017
Zephyr	.049	.312	.276± .005	.260± .007	.235± .001	.226± .006	.192± .012	.212± .003
Timber Cove	.055	.326	.277± .011	.263± .011	.254± .004	.247± .010	.178± .008	.235± .004
Tahoe Keys	.063	.343	.305± .005	.270± .011	.252± .001	.252± .001	.181± .003	.232± .005
Camp Rich.	.057	.337	.302± .016	.284± .002	.252± .001	.245± .008	.179± .009	.231± .004
Emerald Bay	.082	.644	.519± .020	.501± .002	.460± .029	.415± .001	.317± .026	.372± .006
Rubicon Bay	.041	.343	.291± .004	.260± .002	.242± .008	.235± .004	.166± .013	.227± .011
Mid-Lake:								
Mid-lk No.	.063	.326	.278± .003	.255± .004	.220± .009	.220± .001	.187± .000	.190± .000
Mid-lk So.	.053	.325	.294± .016	.264± .008	.251± .006	.242± .007	.161± .008	.208± .004

Appendix 1.k. Summary of field and experimental data collected for Algal Growth Potential (AGP) experiment done on Lake Tahoe water collected from nearshore and mid-lake sites on 3/23/16. *(Used Day 6 Fluor. (corrected for background fluor): chlorophyll association to estimate chl at peak.)

AGP #11 H_2O Collection 3/23/16	Date Collected	Time Collected	Lake Surface T (°C)	Collection Depth (m)	Lake Chl. *a* (µg/l)	Observations	**Extracted Chlor. *a*** AGP D6 3/29/16	**Extracted Chlor. *a*** AGP D13 4/5/16	**Final AGP Results Chl. *a* ± s.d. (µg/l)**
Nearshore:									
Sunnyside	3/23/16	13:50	6.3	0.5	.27±.02		.39 ± .00	.79 ± .02	**.79 ± .02**
Tahoe City	3/23/16	09:25	3.9	0.5	.26±.02	Slight green/ tannin color	.53 ± .07	.78 ± .07	**.78 ± .07**
Kings Beach	3/23/16	10:05	5.8	0.5	.24±.00		.34 ± .01	.82 ± .06	**.82 ± .06**
Crystal Bay	3/23/16	10:30	6.5	0.5	.82±.06		.93 ± .01	.44 ± .06	**.93 ± .01**
Glenbrook	3/23/16	11:00	6.4	0.5	.58±.01		.84 ± .03		**.95 ± .03***
Zephyr Cove	3/23/16	11:23	6.7	0.5	.67±.06		.81 ± .01		**.98 ± .01***
Timber Cove	3/23/16	11:50	5.8	0.25	.39±.02		.76 ± .07	.74 ± .03	**1.04 ± .01***
Tahoe Keys	3/23/16	12:10	4.6	0.5	.85±.01	Brown tannin color, Upper Truckee plume	1.03 ± .01	1.07 ± .12	**1.07 ± .12**
Camp Rich.	3/23/16	12:26	6.1	0.5	.33±.01	Slight green & med. turbidity	.54 ± .05	.77 ± .02	**.77 ± .02**
Emerald Bay	3/23/16	12:50	5.7	0.5	.84±.10		.66 ± .00		**.84 ± .10**
Rubicon Bay	3/23/16	13:20	6.4	0.5	.28±.01		.30 ± .01	.56	**.56**
Mid-Lake:									
Mid-lk No.	3/23/16	09:45	6.0	0.5	.79±.02		.77 ± .03	.59 ± .05	**.79 ± .02**
Mid-lk So.	3/23/16	11:35	6.9	0.5	.83±.04		.83 ± .03		**.83 ± .04**

Experiment Daily Fluorescence	Backgrd. Fluor. GF/F Fil.	D0 Fluor. 3/23/16 18:45	D1 Fluor. 3/24/16 15:15	D3 Fluor. 3/26/16 14:30	D5 Fluor. 3/28/16 16:15	D6 Fluor. 3/29/16 14:00	D8 Fluor. 3/31/16 17:45	D10 Fluor. 4/2/16 11:45	D13 Fluor. 4/5/16 14:15
Nearshore:									
Sunnyside	.063	.249	.227±.006	.252± .011	.301± .001	.298± .014	.386± .005	.420± .010	.507± .031
Tahoe City	.449	.583	.520±.024	.510± .008	.595± .011	.625± .025	.629± .003	.685± .002	.742± .027
Kings Beach	.120	.312	.291± .001	.268± .009	.333± .008	.307± .005	.388± .008	.465± .012	.573± .004
Crystal Bay	.128	.560	.514± .023	.541± .008	.568± .001	.493± .004	.496± .017	.436± .007	.382± .018
Glenbrook	.085	.517	.481± .000	.514± .005	.581± .000	.537± .001	.545± .006	.499± .008	.429± .018
Zephyr	.068	.570	.514± .024	.532± .016	.577± .005	.529± .005	.533± .017	.492± .011	.447± .017
Timber Cove	.081	.390	.370± .008	.417± .001	.521± .011	.523± .021	.622± .006	.608± .014	.520± .023
Tahoe Keys	.573	.976	.885± .015	.901± .008	1.015± .007	1.006± .034	1.125± .007	1.13± .042	1.024± .051
Camp Rich.	.113	.358	.329± .003	.376± .002	.461± .011	.436± .018	.548± .013	.572± .033	.583± .008
Emerald Bay	.120	.672	.586± .007	.529± .005	.514± .010	.468± .001	.432± .003	.392± .001	.333± .001
Rubicon Bay	.058	.292	.256± .004	.260± .008	.286± .008	.286± .002	.345± .001	.370± .008	.448± .011
Mid-Lake:									
Mid-lk No.	.084	.513	.448± .001	.405± .004	.465± .008	.443± .012	.457± .014	.447± .031	.436± .017
Mid-lk So.	.061	.590	.518± .001	.511± .004	.569± .011	.518± .006	.517± .011	.472± .004	.424± .016

Appendix 2. Phytoplankton Enumeration Standard Operation Procedure

Appendix 2. Tahoe Environmental Research Center
Standard Operating Procedure

Freshwater Phytoplankton Analysis

Introduction:

Phytoplankton are unicellular microscopic plants that live suspended in natural waters. The abundance and growth of these cells are important to the biological systems in lakes and oceans. While other methods can quantify phytoplankton cells based on physiological components, enumeration, using the microscope, is the only method to reliably identify cells.

This method is called the inverted-microscope method (Utermöhl method) which is based on the gravity sedimentation of lake samples. In a series of steps, particles are concentrated and the surrounding sample water is removed. Phytoplankton cells can then be viewed and quantitatively counted. Taxonomic identification of cells can be accomplished because cells are concentrated gently. Very little disturbance to the cell morphology has occurred due to sample handling. This method does not require expensive specialized equipment for sample concentration.

Procedures described in this document summarize the treatment of samples prior to microscopic examination, including sample preservation, storage, chamber preparation, sedimentation, counting methods and sample disposal.

Particles ranging in size from 1-300 µm can clearly be seen during microscope observation. Often it is difficult to identify cells less than 4 µm and so the method yields the best results on cells larger than this size.

Pre-treatment of Water Samples:

Analysis is run on unfiltered lake water samples. Water is drained into the sample bottles directly from the collection vessels (Van Dorn Bottles). For Lake Tahoe, 100 ml of water from each discrete depth is placed in a clean glass bottle fitted with a lid containing a Teflon liner. Approximately 1 ml of Lugol's solution is added to the bottle, as a preservative, and the samples are tightly capped. Samples can be stored at room temperature for several years, but the best counting results come from samples less than one year old. The acidic Lugol's solution will contribute to degradation over time.

Reagents:

Lugol's Solution - Store in a glass stopcock bottle, room temperature

Iodine crystals (I_2) Potassium Iodide (KI)	25g
50 ml Acetic Acid	50g
Distilled De-ionized Water	50ml
	bring to 500 ml

Instruments:
Phase-Contrast Inverted Compound Microscope
Utermöhl Counting Chambers and Settling Towers

Chamber Preparation:

The sedimentation apparatus has two components, the chamber and the settling tower. Once both parts are cleaned and prepared, they are 'adhered' together to form the complete unit. Each chamber is marked with an identification tag which is unique. The towers are also marked, but it is not necessary to match the towers to the chambers.

Sedimentation chambers must be exceptionally clean. The cover glass in the base of the chamber is very fragile. It is essential that the cover glass be free of grease streaks and particulates which interfere with high magnification viewing. Extreme care must be taken when cleaning the cover glass. Wiping the glass with dish soap on a Q-tip®, rinsing with water and drying with a tissue is one option. It is sometimes helpful to use a glass cleaner, such as Windex®, and a tissue for drying, to clean the cover glass.

When the chamber is clean, it is ready for assembly. The topside Plexiglas, forming the outer collar of the settling chamber, should be thinly coated with Dow Corning® high vacuum grease. Set this component to one side and prepare the settling towers.

The settling towers must be wiped down between uses. Sometimes cells and particulates adhere to the towers and can lead to contamination of the next sample. It is helpful to use a small nylon bottle brush soaked in dish soap and water to gently cleanse the towers. Rinse with distilled water. The towers can be air dried or the water can be shaken loose from the towers before assembly. The bottom side of the Plexiglas, forming the outer collar of the tower base, should be thinly coated with Dow Corning® vacuum grease.

The tower and chamber can now be placed together. Set the settling tower on top of the chamber, moving the two pieces slightly back and forth to adhere the two layers of vacuum grease. Wipe away excess grease from the union of the two components.

Procedure:

Sedimentation

-Record the tower *I* chamber identification numbers as well as the sample information data.

-The sample bottle should be at room temperature. Gently invert the bottle back and forth several times to dislodge cells from the bottom. After sufficient mixing, pour 100 ml (or less) of the sample water into the sedimentation unit. Cover the top of the cylindrical tower with a rubber stopper or glass cover slip. Measure the **height** (cm) of the water column from the base to the meniscus line. **Record this number for each sample.**

-The selection of an 'area' where sedimentation of particles from the sample water can occur is critical to the success of this method. The sedimentation units should be placed on a level surface. The area should be shielded from temperature changes and vibration to discourage convection currents in the towers which will adversely affect the random settling. Depending on the height of the tower, the units should be left undisturbed for at least 48 hours. If 100 ml of sample was settled, it is recommended that a full 72 hours of settling be used.

Un-settling Chambers

-After the required waiting period, the sedimentation units can now be prepared for microscope viewing. The tower (and the remaining sample water) must be removed from the chamber section. This is accomplished by sliding the tower (and water) onto an adjacent sliding plate. A cover plate of glass is used on the right side of the tower to help push the tower onto the sliding plate (to the left). The goal is to move the tower without spilling any water while simultaneously sliding a cover plate on top of the sedimentation chamber. It is important that this process be accomplished with very little disturbance to the sample in the sedimentation chamber. This skill should be practiced numerous times before 'real time' performance.

Counting Methods

-The best microscopic viewing requires that cells are visible with as much definition and resolution as possible. An inverted microscope is necessary, where viewing of the chamber is from the bottom, through the cover glass. The best optical systems for cell identification are with either phase contrast microscopy or differential interference contrast systems (DIC). The microscope should have a full range of objective powers available for use. The oculars should have a micrometer for measuring cells. It is also very helpful to have stage stops where viewing of the chamber is confined to $1cm^2$.

-If quantitative counts of the cells are needed, you must track the area of the chamber that is viewed and the magnification used.

-Select a chamber and record the identification tag which links it back to the sample identification. Begin by placing the chamber on the stage, using the 10x objective (low magnification), bring the chamber bottom into focus. View the entire square centimeter of the chamber bottom as follows. Looking through the eyepieces of the microscope, move the stage so that the chamber position is in the upper right corner. Begin moving the chamber directly to the left until the stage stops. Move the chamber down one field of view and go back to the right. Continue this consecutive strip viewing until the entire area is viewed. Make sample notations about particulate concentration and size, zooplankton presence, and the relative health of the phytoplankton community. Count and identify all cells that are large and relatively rare.

-Change the objectives to higher magnification. Typically we use the 40x objective with 10x oculars. There is a 1.5x tube magnifier so the total magnification using this power is: 40 • 10 • 1.5 = 600X

-At this magnification only a portion of the chamber bottom will be viewed. Counts will be done in strips (transects), where the width of the strip is the field of view and the length of the strip is 1cm. The chamber bottom is round, so the goal is to count 2-4 transects of the chamber. Transects should cross over one another at the center of the chamber. **Note the number of transects counted at this magnification.**

- Identification of cells generally requires the use of taxonomic keys.
Record phytoplankton name identification, counts, and measurements of the cells (when needed). Counting can cease when an arbitrary number of 400 cells has been recorded.

-When doubtful about the cellular identification, it is often useful to make sketches, measurements and photographs to assist colleagues who might assist at a later date.

Calculations:

-The information from the sample counts needs to be entered into the **Phytoplankton Manager** Database. This program has several modules which require information input.

-Sample module: Enter sample identification such as sample name, sample date, depth, id number, group id, sampler name, counter name and the height of the tower chamber. Sample notes can also be entered on this screen.

-Countmetrics: Enter the objectives used and the area of the chamber viewed at each magnification.

-Counts: Enter the phytoplankton identification name, number of cells counted, and the magnification used to make those counts. The program will verify eligible counts by checking against the species dictionary and the biometrics database. Problems arise when new species (previously unrecorded) are being entered or when no measurements exist for cells. The respective modules require additional information before the counts can be validated and entered.

-Sample sets: Samples can be grouped in several ways. Using the sample set module you can define an individual sample or a group of samples. Reports can be issued based on this designation.

-Reports: Various report formats are available and can either be printed or exported to other database management programs.

QA/QC Procedures:

Field Replicate samples are sometimes counted and compared for an estimate of counting precision.

References:

Phytoplankton Manual, 1978, Monographs on Oceanographic Methodology. United Nations Educational, Scientific and Cultural Org. (UNESCO), Page Brothers (Norwich) Ltd. 337pp, ISBN 92-3-101572-9

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