APPENDIX J-3:

Evaluation of Trends in Nearshore Attached Algae: 2015 TRPA Threshold Evaluation Report

Final Report

Submitted to:

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March 9, 2016

UC DAVIS TAHOE ENVIRONMENTAL RESEARCH CENTER

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Acknowledgments

We are extremely grateful for the efforts of several individuals with the U.C. Davis Tahoe Environmental Research Center who assisted with this work. We are very grateful to Brant Allen for his many hours underwater and in the lab working with the periphyton, for discussion of the data, and for his review of this report. Thanks to former TERC member Andrea Parra Buxton who performed the 2011 analysis of coverages in intervening zones. Thanks to George Malyj for ongoing administrative help. We are very grateful for ongoing support of periphyton monitoring program provided by the State Water Resources Control Board, Lahontan Regional Water Quality Control Board. Finally we are very grateful to TRPA for the opportunity to perform this data analysis.

1. Introduction

An analysis of existing data was prepared by the U.C. Davis Tahoe Environmental Research Center (TERC) to inform the Tahoe Regional Planning Agency (TRPA) staff in the 2016 evaluation of the threshold standard related to nearshore attached algae (hereafter referred to as periphyton). The current TRPA periphyton standard: "support actions to reduce the extent and distribution of excessive periphyton (attached) algae in the nearshore (littoral zone) of Lake Tahoe" does not provide a quantitative threshold. The results provided in this report, however, are based on extensive quantitative analyses.

TERC has conducted periphyton monitoring in Lake Tahoe since 1982. Monitoring occurred for select periods in the 1980s (1982-85) and 1990s (1989-93). Near-continuous monitoring has occurred since 2000 with a one-year gap in 2004. Periphyton monitoring has primarily focused on measuring levels of algal biomass (as chlorophyll *a*) at six to ten "routine" monitoring sites around the lake. Samples of attached algae for measurement of biomass have been collected from natural rock surfaces at 0.5 m below the water level at the time of sampling. The monitoring frequency has varied from as few as three samples per year to as many as fifteen in a year (see Heyvaert et al. (2013) for more background on the history of the periphyton metric monitoring).

It is important to note that unlike the accepted indicator of ecological health of the pelagic zone, the Secchi depth, there exists no baseline for periphyton that be considered as "pre-disturbance". For example when the first period of periphyton sampling occurred, Secchi depth had decreased from over 30 m to approximately 22 m, a value similar to what exists today. Thus it is possible that the largest changes in periphyton growth may have already occurred prior to the monitoring program commencing. The current monitoring entails collection of biomass samples five times per year from nine sites with three of the five samplings done during the spring when periphyton biomass typically exhibits a peak. This monitoring provides information on levels of periphyton around the lake. In addition, once each spring an intensive synoptic sampling of approximately 40 additional sites is completed. This synoptic sampling is timed to occur when periphyton biomass is believed to be at its spring peak. This spring synoptic monitoring includes collection of biomass samples (chlorophyll *a*) at a sub-set of the sites, as well as a rapid assessment method referred to as the periphyton biomass index (PBI). The synoptic monitoring essentially provides a "snapshot" of periphyton distribution at a large number of sites around the lake close to the time of peak annual biomass.

The goal of this data analysis was to look for trends in periphyton biomass using the available data set. Specifically, the periphyton biomass data for (1) routine sites and (2) spring synoptic sites were evaluated with respect to:

a) Site-based trends;
b) Regional trends

c) Trends related to upland development
d) Overall trend, all sites

These trends were also evaluated to assess the influence of two independent variables: (1) lake level, and (2) length of time the site was submerged. Both variables are believed to have an impact on periphyton biomass and its variability through time.

In this report, we first provide background information on algal types, depth distribution, and seasonal patterns. We then briefly describe the field and lab procedures and data analysis methods. The results for routine site trends, (site-based, regional, in relation to urban development, and overall) are then presented along with an assessment of the same trends when taking into account lake level and time submerged. The results of analysis of trends for the synoptic data are then presented.

1.a. Background: Periphyton Algal Types, Depth Distribution and Seasonal Growth

In this data analysis, we refer to three primary algal types: (1) stalked diatoms, (2) filamentous green algae, and (3) Cyanophytes. These are the basic algal groups that are most common in the periphyton community of Lake Tahoe. Observations of the main algal groups present at the time of sampling have been recorded by Tahoe Research Group (TRG) and TERC divers since the 1990's. Complete taxonomic analysis and enumeration of periphyton in samples was not done as part of this monitoring. However, occasional samples are examined under the microscope to check predominant species of periphyton. These algae types tend to have characteristic distributions related to depth and environmental conditions. In the eulittoral zone (the shallow area between the low and high lake level) the algal community is typically comprised of filamentous green algae (i.e., *Ulothrix sp.*, *Zygnema sp.*, *Mougeotia sp.*) and stalked diatom species (i.e., *Gomphoneis herculeana*). The eulittoral zone is affected by wave activity and substrata within this region desiccate as the lake level declines. Periphyton must recolonize desiccated areas when lake level rises. Periphyton in the eulittoral zone is characterized by consistent seasonal growth patterns each year. Eulittoral zone periphyton have substantial growth rates resulting in rapid colonization of suitable areas in mid- to late-winter and spring. 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 (Figure 1). Similarly, this community rapidly dies back as nutrient concentrations diminish, as shallow nearshore water temperatures warm with the onset of summer, and as lake level recedes. The algae can slough from the substrate, particularly in late spring and early summer. Once liberated, the periphyton may be transported onshore by waves and prevailing currents, creating an unsightly, odorous accumulation of sloughed algae (Figure 2). The eulittoral zone periphyton can have a tangible effect on aesthetic conditions in the shorezone, they are most commonly associated with poor aesthetic quality associated with periphyton in the nearshore.

Figure 1. Example of thick spring periphyton biomass (white furry-appearing algae are stalked diatoms *Gomphoneis heruculeana*). Diver is sampling periphyton biomass on rocks at a depth of 0.5 m in the eulittoral zone at the Pineland site.

Figure 2. Sloughed periphyton washing up along shoreline at Lake Forest beach, spring 2011.

The sublittoral zone extends from the bottom of the eulittoral to the maximum depth of photoautotrophic growth. The upper portion of the sublittoral zone is dominated by cyanobacteria (blue-green algae) capable of fixing nitrogen. These include *Tolypothrix*, *Calothrix*, *Nostoc*, and *Scytonema,* which are heterocystous filamentous genera (Reuter et al., 1986). These algae firmly attach to the rock surfaces to form stable communities that are slower growing than the filamentous green and diatom species in the eulittoral zone. Typically these algae create a coating on the rocks which is either a slimy, crusty coating or a slightly furry, coating, which is less thick than the species in the eulittoral zone. The cyanophyte growth persists on the rocks throughout the year. As lake level declines, these algae are closer to the water surface and consequently become part of the biomass sample collected during periphyton monitoring. For some sites the chlorophyll contributed by cyanophytes during low lake surface elevations can be substantially higher than the chlorophyll concentration normally associated with the eulittoral species. Since this is an affect caused by lake level fluctuation, and not environmental factors such as nutrient inputs, it is desirable to know if a trend in biomass exists for shorezone periphyton, after factoring out the effect of lake level and the cyanophytes. During extremely low lake levels (such as occurred during the early 1990s and in summer of 2015), the blue green algae in some areas of heavy growth become exposed above the water surface, creating a slimy, thick, aesthetically displeasing coating of algae above water.

Figure 3. Cyanobacteria exposed above water at Rubicon Pt. during low lake level, November, 2015.

2. Methods

2.a. Field and Laboratory Methods

Routine and synoptic sampling locations are shown in Fig. 4 and site numbers and names are listed in Table 1. 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 0.5 m, using a syringe and brush sampler. Alterations in sampling depth (0.34-0.77 m) were occasionally made during periods of rapidly changing lake level, in an effort to sample a site consistently. Such occasions are noted in the database and are believed to have minimum impact on subsequent analyses. The samples are transported to the laboratory where they are processed, with one portion of the sample analyzed for Ash Free Dry Weight (AFDW) and the other portion frozen for later analysis of chlorophyll *a* (Chl *a*) concentration (both AFDW and Chl *a* are used as measures of algal biomass). Observations are made of the general algal types (Cyanophytes, stalked diatoms, filamentous green algae) at the sites.

Measurements are also taken of filament length and percent algal coverage, and a score is calculated based on these field observations. This visual-based score is referred to the Periphyton Biomass Index (PBI) and is an example of a rapid assessment methodology or RAM. PBI is calculated by multiplying the filament length (cm) by the percent of substrate area covered with algae. For example, if 80 percent of the area is covered with periphyton one cm in thickness the PBI would be 0.80*1.0 = 0.80 PBI units. The lower the PBI score the lower the overall periphyton accumulation. The use of field-based rapid periphyton surveys is found in the scientific literature (e.g. Stevenson and Bahls 1999; Lambert and Cattaneo 2008; Rost 2008). While PBI scores are not absolute values of biomass per se, they are good for assessing relative abundance, and most important they can be directly used determination of nearshore aesthetic condition (Hackley et al. 2004, Heyvaert et al. 2013).

An additional 40-45 sites 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. 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 just prior to or just following their actual peak biomass. This “spring synoptic” sampling provides a “snapshot” of the distribution of periphyton biomass around the lake.

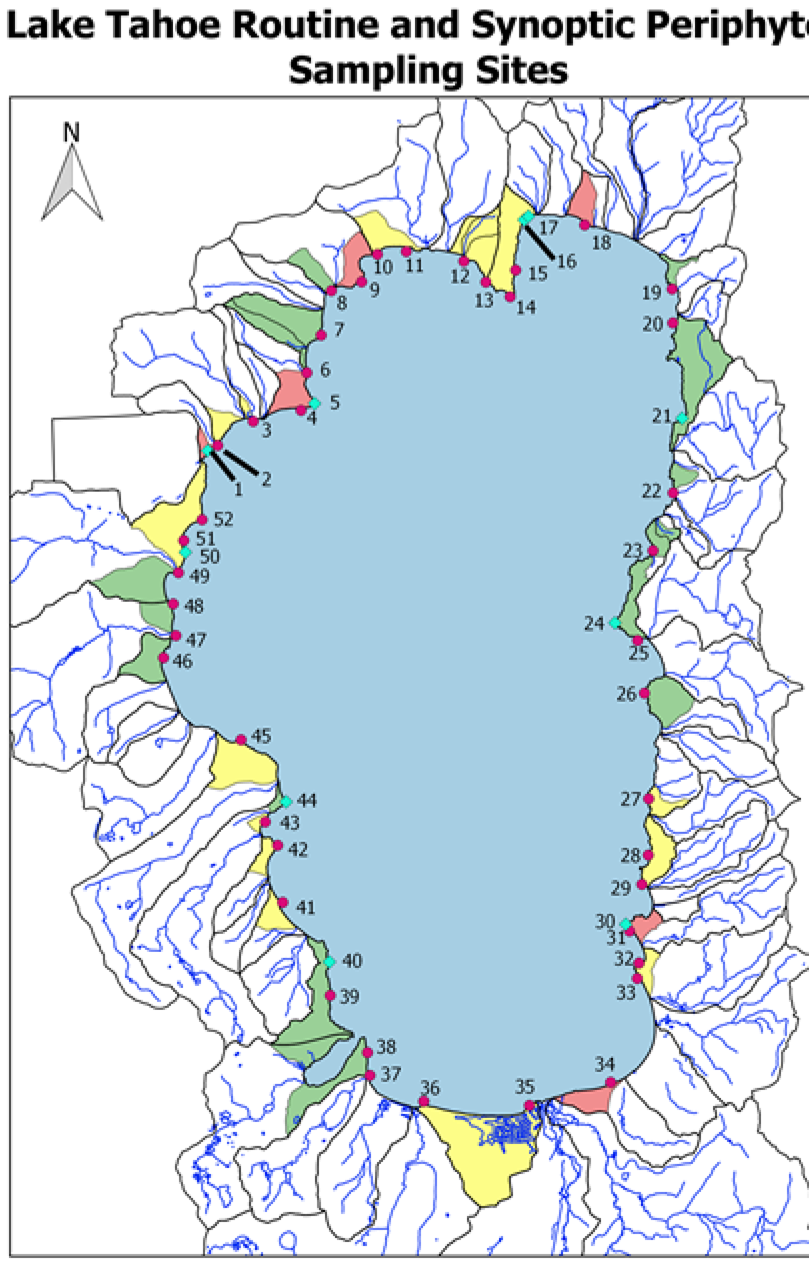


Figure 4. Map showing locations of routine (blue diamonds) and synoptic (red dots) periphyton monitoring sites around Lake Tahoe. Site names are listed in Table 1 on the following page. Intervening zones adjacent to sites are also shown (shaded areas- note significance of coloration is discussed later in report) along with tributaries.

Table 1. List of Routine (indicated with "*") and Synoptic Periphyton Monitoring Sites

Site #	Site Name	Site #	Site Name
1	Tahoe City*	27	Cave Rock Boat Ramp
2	Tahoe City Tributary	28	Logan Shoals
3	TCPUD Boat Ramp	29	No. Zephyr Cove
4	So. Dollar Pt.	30	Zephyr Pt.*
5	Dollar Pt.*	31	So. side Zephyr Pt.
6	So. Dollar Cr.	32	No. side Elk Pt.
7	Cedar Flat	33	So. side Elk Pt.
8	Garwoods	34	Timber Cove
9	Flick Pt.	35	Tahoe Keys E. Entrance
10	Stag Ave.	36	Kiva Pt.
11	Agatam Boat Launch	37	Cascade Cr.
12	Kings Beach Ramp Area	38	So. of Eagle Pt.
13	Brockway Springs	39	E. Bay/Rubicon
14	No. Stateline Pt.	40	Rubicon Pt.*
15	Stillwater Cove	41	Gold Coast
16	Incline West*	42	So. Meeks Bay
17	Incline Condo*	43	No. Meeks Bay
18	Burnt Cedar Beach	44	Sugar Pine Pt.*
19	Hidden Beach	45	Tahoma
20	Observation Pt.	46	So. Fleur du lac
21	Sand Pt.*	47	Blackwood Cr.
22	Chimney Beach	48	Kaspian
23	Skunk Harbor	49	Ward Cr.
24	Deadman Pt.*	50	Pineland*
25	So. Deadman Pt.	51	No. Sunnyside
26	So. Glenbrook	52	Tavern Pt.

2.b. Data Analysis Methods

All available periphyton monitoring data, (Chl *a*, AFDW, and PBI), for both routine and synoptic sites were compiled. Lake surface elevations were obtained from the USGS database (http://waterdata.usgs.gov/nwis/dv?referred_module=sw&site_no=10337000) as the gauge height at the Tahoe City Coast Guard dock, and elevation of sampled site are determined by subtracting 0.5 m (1.64 ft.) from the lake surface elevation on the day sampling was conducted. Time of submergence of each sampling site was calculated as the time (in days) between the date of sampling and the last date on which the sampling site was last exposed above the lake water surface.

2.b.1. Routine Sites

The time series trend in periphyton biomass at the routine sites was evaluated by the Mann-Kendall trend test (Mann, 1945 and Kendall, 1975) on Chl *a*. This test is a non-parametric test for identifying monotonic trends in time series data, and widely used for natural resource monitoring data (Gilbert, 1987). The test provides Kendall's tau, which denotes the strength of association, the S-statistic which compares each point with subsequent values (higher or lower), the normalized test statistic denoted by the z-score, and p, the level of significance. We considered a $p \leq 0.05$ in the Mann-Kendall trend test to be statistically significant. A positive value of S is an indicator of an increasing trend, and a negative value indicates a decreasing trend. Very small or very large samples sizes can affect interpretation of the Mann-Kendall trend test results. Results for very small samples sizes can be affected by outliers and very large samples sizes in a statistically significant p value for a negligible or very small trend. A large number (i.e. approximately 20) of Mann-Kendall tests were done on subsets of the data from each routine site. At the significance level of $p \leq 0.05$ there is a 95% chance that the interpretation of the results of the trend test is correct and a 5% chance that the significance is declared incorrectly (a type 1 error). Therefore out of 20 Mann-Kendall tests for a site, there is a chance that at least one of the tests will have significance declared incorrectly.

The trends for mean values for each sampling date at a site and maximum values in each water year were tested for routine sites as well as routine sites grouped by geographical regions: West (Pineland, Rubicon Pt., Sugar Pine Pt.), North (Dollar Pt., Incline Condo, Incline West, Tahoe City), and East (Deadman Pt., Sand Pt., Zephyr Pt.). Due to the data gap between 1993 and 1999, the trend in observations taken after 2000 was also tested. We also evaluated temporal trends for data separated based on lake surface elevation (<, ≥ 6225 ft.) and time submerged (≤, >1000 days) for the sites and regions. Justification for separating the data at each site based on 6225ft and 1000 days submerged is provided in sections 3.a.1 and 3.a.2. The test results for overall data set and subsets of data are presented in separate tables for each site, region and the whole lake.

To test the influence of lake surface elevation and time submerged on periphyton biomass and algal type associations, we have plotted Chl *a* against each of these physical variables for each routine site and geographical region as above. Six different algal type associations were denoted as color filled circles based on field observations at the time of sampling. Pearson product moment correlation analysis was conducted to test the association of algal biomass and physical properties. The correlation analysis was also conducted on subsets of data distinguished by lake surface elevation or days submerged, where a stronger association was found for a few sites by visual inspections of data plots. All statistical analyses were conducted using the statistical package R (R Core Team 2015), and the package rkt (Marchetto, 2015) was applied for the Mann-Kendall test. The rkt package performs an equivalent test to the type 4 test of the widely used software distributed by USGS (http://pubs.usgs.gov/sir/2005/5275/).

2.b.2. Synoptic Sites

Evaluation of time series trends of periphyton biomass at individual synoptic sites is difficult. Chl *a* observations at most sites were not as frequent as would be required for robust trend analysis. PBI has been constantly measured since 2001 though the measurement, which is conducted one time at the estimated peak of the bloom in spring, may not fully capture the seasonal maximum at any single site. Thus the interannual variation observed could be influenced somewhat by the date of sampling. Therefore, general trends for synoptic sites Chl *a* and PBI grouped by four geographical regions (North, West, South, East) classified in the same way as in Heyvaert et al. (2013) were tested. The time series trend was tested by the Mann-Kendall test in the same manner as has been done for routine sites. Transitions in algal type were visually inspected on the plots. The correlation analysis was also conducted to test the relationship between periphyton biomass (Chl *a* and PBI) and physical properties (lake surface elevation and days submerged).

The association between periphyton biomass and level of development was also determined for routine and synoptic sites. QGIS software and data from the National Land Cover Database 2011 survey were used to calculate impervious coverage for intervening zones (IVZ) immediately adjacent to routine and synoptic periphyton sampling sites. The presence of various types of hard cover (i.e. residential structures, commercial/industrial structures and primary/secondary roads) were classified and quantified in order to estimate total impervious cover in each IVZ.
The resulting percent impervious cover estimate for each IVZ was calculated using the following formula:

(Total impervious cover/Total IVZ area)*100

The impervious cover estimates were compiled into a summary sheet. Ranges were then determined for low, medium and high percent impervious cover by dividing the data into 33rd percentiles.

The relationship between periphyton biomass at individual sites and the level of development was then determined using a Kruskal-Wallis test. This non-parametric method tests whether samples originate from the same distribution. It is used for comparing two or more independent samples of equal or different sample sizes. Routine periphyton sampling sites were assigned levels of development (low, medium or high) based on the impervious cover estimates. All Chl *a* data from the routine sampling sites collected from 2002 through 2015 were parsed according to the site assignment. The resulting data sets were used to perform the Kruskal-Wallis test.

3. Results and Discussion

3.a.1. Distribution of Algal Types and Biomass: Effects of Sampling Elevation

Observations of the basic algal groups (cyanophytes, stalked diatoms, filamentous green algae) have been recorded by TRG/TERC divers since the 1990s. These observations combined with Chl *a* data and lake surface elevation on the sampling date are presented for all routine sites (Fig. 5) and correlation analysis results for association between Chl *a* and lake level are shown in Table 2. Inspection of these plots shows differences in the general distribution of algal types. Cyanobacteria or blue-green algae tend to be more prevalent at the 0.5 m deep sites when lake surface elevation is below approximately 6225 ft. (for reference the natural rim is at 6223.0 ft.). At the 0.5 m sampling depth, this corresponds to a sampled substrate elevation of <6223.4 ft. Blue-greens were present at all sites except Tahoe City at this elevation. Table 2 shows the association between Chl *a* and lake level at the routine sites. A negative r value indicates a negative correlation, i.e. increasing Chl *a* with decreasing lake elevations; conversely a positive r value indicates a positive correlation, i.e. increasing Chl *a* with increasing lake elevations. The closer to 1 or -1, the stronger the association. Statistically significant correlations were indicated by p values <0.05. Several sites show a significant trend of increasing Chl *a* with decreasing surface elevation below 6225 ft. (i.e. statistically significant negative r values). These included Deadman Pt., Sand Pt., Rubicon Pt. and Sugar Pine Pt. When samples are collected with lake levels <6225 ft. at these sites, Chl *a* associated with the blue-green algae can significantly contribute to the Chl *a* level. The blue-green algae biomass at some sites such as Deadman Pt. and Sand Pt. during low lake levels can be quite elevated compared with higher lake level years in which there is little or no contribution of blue greens to the Chl *a* biomass and little biomass associated with other algal types.[1] The blue green algae biomass is relatively consistent throughout the year. The presence of blue greens can confound the determination of trends. For instance when lake level drops, elevated biomass at some sites is due largely to the presence of blue greens and not reflective of increased seasonal growth of diatoms and filamentous greens. As presented above, we used 6225 ft. as a demarcation point for the potential influence of blue-green algae Chl *a* on sample Chl *a*. In the data analysis we separated sample data into groups based on lake elevation and time submerged as a potential way to separate out trends associated with stalked diatoms and filamentous green algae (samples collected from 0.5 m when lake level was ≥ 6225 ft.), those algal groups that are most commonly associated with poor aesthetic quality (TERC, 2012).

[1] During low lake-level years it is important to recognize that blue-green algae may also be located near the surface, resulting in algae-coated rocks near or above the surface (in some places where there is usually little algae at the surface). This is a lake level effect not necessarily associated with nutrient inputs. It is different from the thick spring growth of stalked diatoms and filamentous green algae that may develop in response to nutrient inputs.

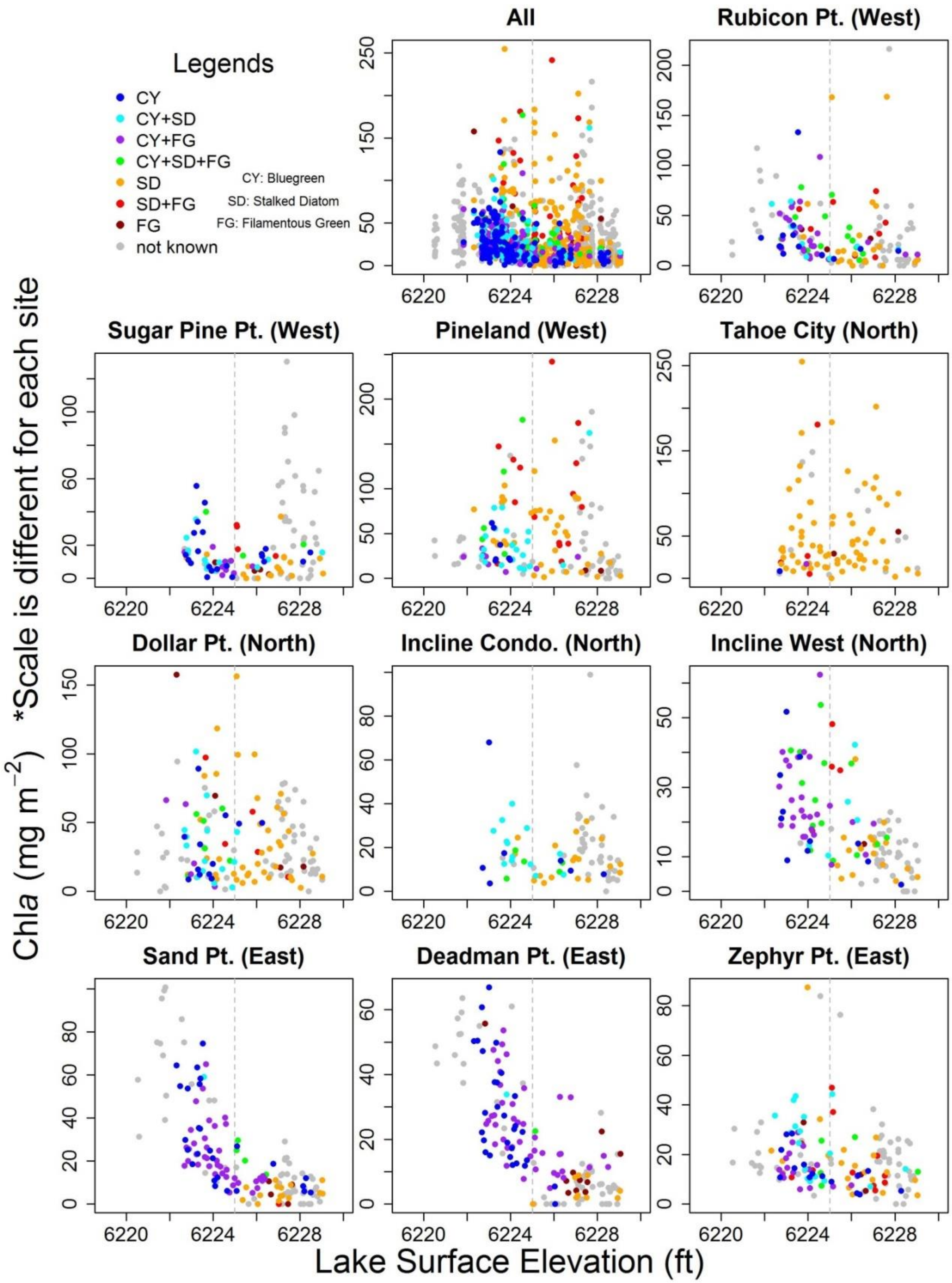


Fig. 5. Comparison of primary algal types determined by visual characterization of community in field, biomass as Chl *a* and lake surface elevation.

Table 2. Correlation analysis of Chl *a* (0.5m below surface) and lake surface elevation for routine sites and all observations together. A negative r value indicates a negative correlation, i.e. increasing Chl *a* with decreasing lake elevations; conversely a positive r value indicates a positive correlation, i.e. increasing Chl *a* with increasing lake elevations. The significant p values are shaded.

	All observation			Lake level ≤ 6225 ft.		
Site	#	r	p	#	r	p
All observation	1292	-0.21	<0.01	572	-0.12	<0.01
Rubicon Pt.	146	-0.23	<0.01	68	-0.23	0.05
Sugar Pine Pt.	115	0.22	0.02	41	-0.45	<0.01
Pineland	150	-0.02	0.79	70	0.22	0.06
Tahoe City	90	-0.04	0.74	44	0.07	0.63
Dollar Pt.	143	-0.10	0.22	69	-0.03	0.80
Incline Condo.	83	-0.06	0.58	20	-0.17	0.47
Incline West	119	-0.60	<0.01	43	-0.11	0.47
Sand Pt.	144	-0.72	<0.01	69	-0.64	<0.01
Deadman Pt.	148	-0.77	<0.01	70	-0.58	<0.01
Zephyr Pt.	145	-0.22	<0.01	69	0.02	0.86

Regional data for Chl *a*, algae type associated with Chl *a* and lake surface elevation were also plotted in Fig. 6. The results for correlation analysis for this data are in Table 3 below. The following groups were used: West Region (Rubicon Pt., Sugar Pine Pt., Pineland); North Region (Tahoe City, Dollar Pt., Incline Condo, Incline West); East Region (Sand Pt., Deadman Pt., Zephyr Pt.). This plot shows that Chl *a* tends to increase with depth, associated largely with blue green algae biomass along the east shore. There was not a similar relationship for Chl *a* with lake level along the north and west shores.

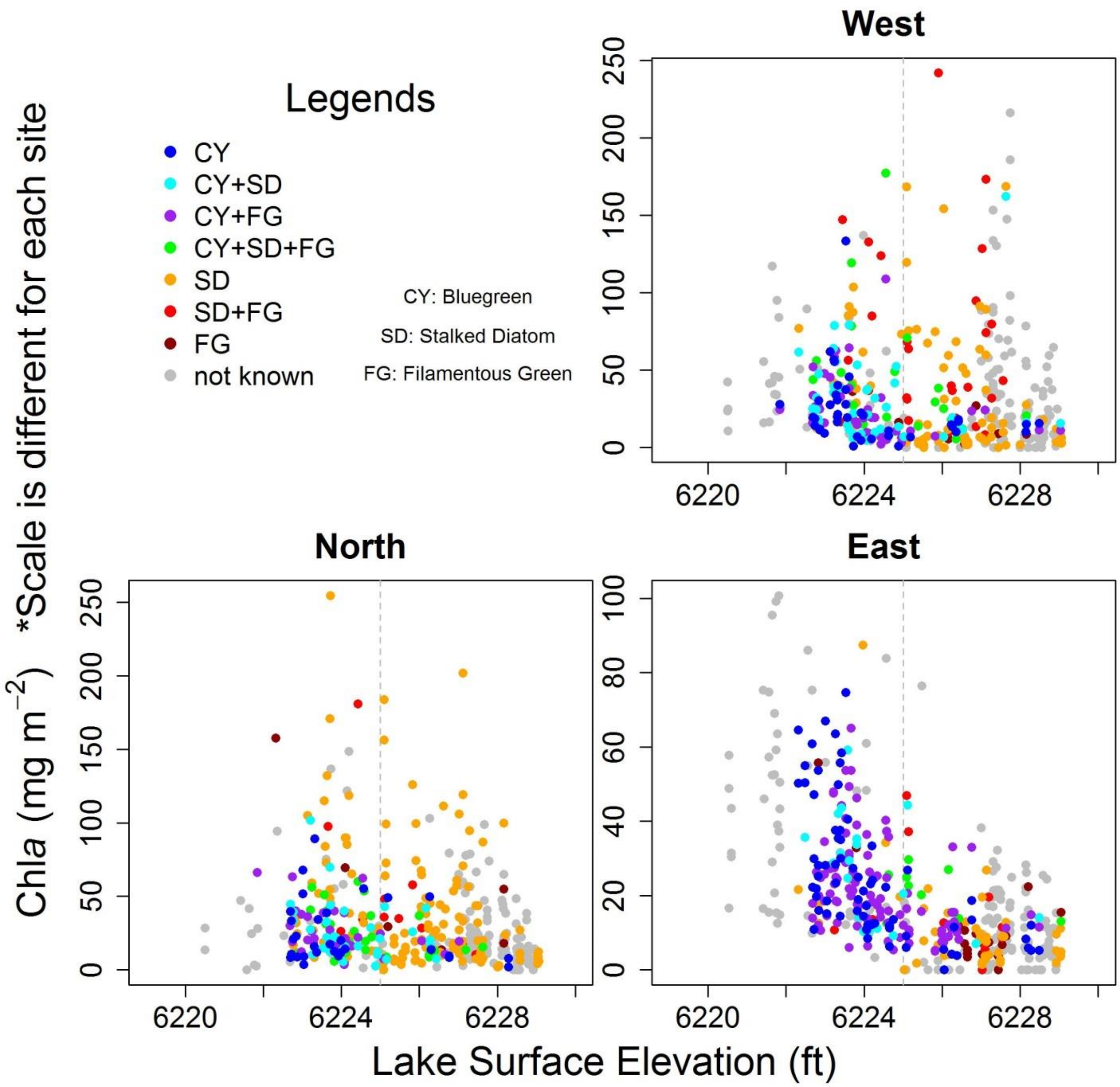


Fig. 6. Plots of mean Chl *a*, algal type and lake level for routine sites data in west, north and east regions.

Table 3. Results of correlation analysis for routine site Chl *a* and lake level data grouped by regions, including all observations and then only observations taken when lake surface elevation was <6225 ft.

	All observations			Lake level ≤ 6225 ft.		
Site	#	r	p	#	r	p
West	413	-0.08	0.11	181	-0.07	0.33
North	438	-0.19	<0.01	179	-0.01	0.91
East	439	-0.60	<0.01	210	-0.41	<0.01

3.a.2. Distribution of Algal Types: Effect of Time Submerged

Occasionally blue greens may be found at the 0.5m sampling depth when lake surface elevation is greater than 6225 ft. We believe this occurs when the blue greens had time to establish and colonize on the substrate. For instance in 2000 blue greens were observed on substrate when lake level was above 6225 ft. This followed a prolonged period of elevated lake level in the late 1990's. We looked at the relationship between blue green algae and time submerged to see if time submerged was an additional way to identify samples with potential blue-green algae present. To determine a time period which might be characterized as sufficient for blue green biomass to establish on rocks, the algal type and Chl *a* data were plotted vs. log10 of length of time submerged (Figure 7) and correlation analysis done. Correlation results for association between chlorophyll and time submerged are shown in Table 4. Blue greens were found to develop on rocks at many sites after a time of submergence of about1000 days or nearly 3 years. In addition, Chl *a* level was positively associated with length of time submerged, when time submerged was > 1000 days at four sites (Deadman Pt., Sand Pt., Incline West and Sugar Pine Pt. (Table 4). Higher levels of Chl *a* were found at these sites the longer the time period submerged beyond 1000 days. Separation of data for sites based on time submerged > 1000 days provides another potential way to separate out blue-green associated trends from those due to other factors including nutrient inputs. Algal associations found on rocks submerged <1000 days tend to be the rapid colonizers (stalked diatoms and filamentous green algae), with typically little or no of the slow-growing blue greens present.

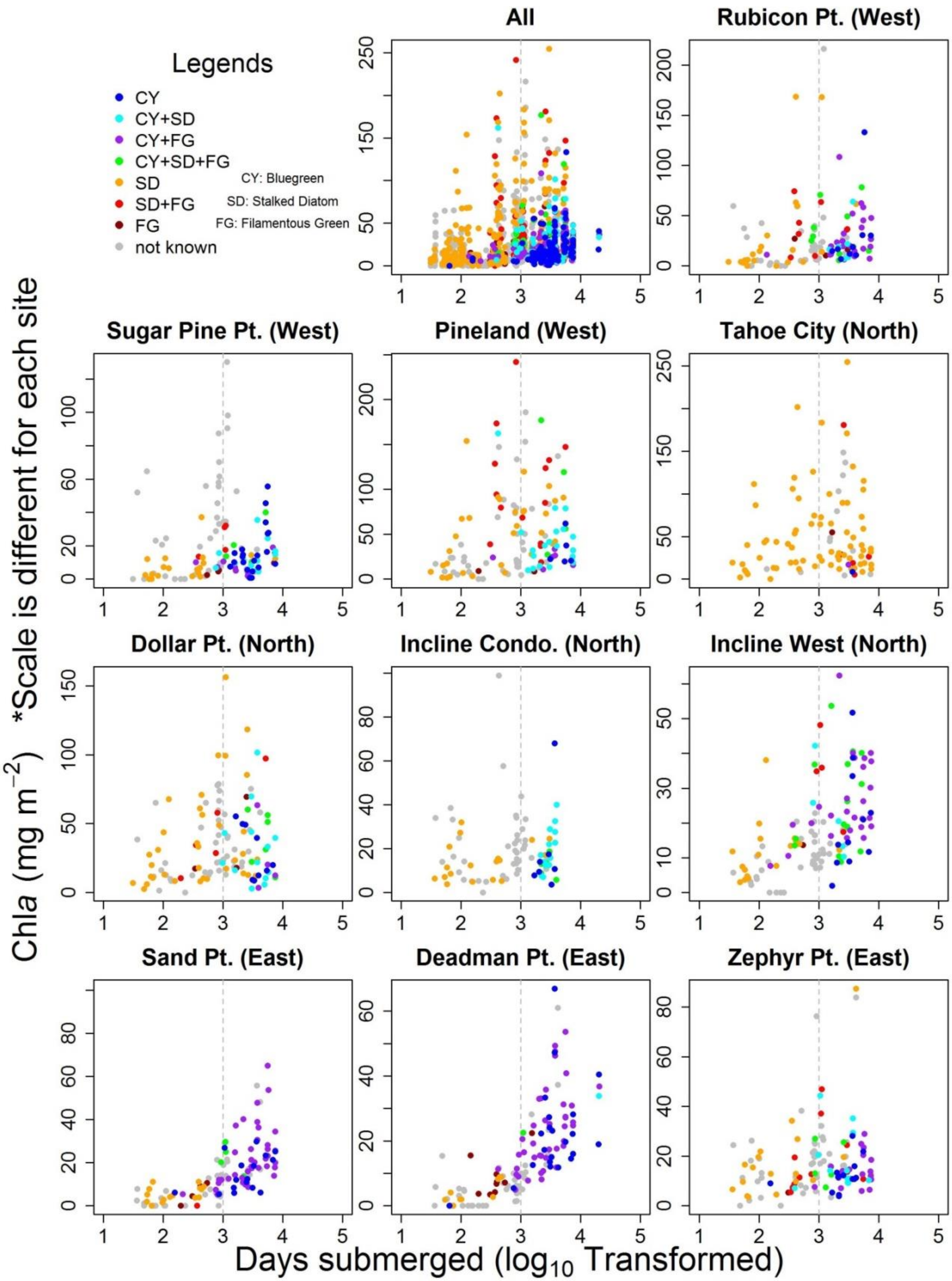


Fig. 7. Comparison of primary algal types determined by visual characterization of community in field, biomass as Chl *a* and length of time (days) site was submerged.

Table 4. Correlation analysis of Chl *a* (0.5 m below surface) and length of time substrate was submerged, for routine sites and all observations together. The significant p values are shaded.

Correlation analysis Chl vs Days submerged						
	All observation			Submerged ≥ 1000 days		
Site	#	r	p	#	r	p
All observation	1151	0.19	<0.01	614	-0.04	0.32
Rubicon Pt.	122	0.20	0.02	65	-0.07	0.58
Sugar Pine Pt.	115	0.09	0.36	61	-0.25	0.05
Pineland	126	0.20	0.03	66	-0.07	0.58
Tahoe City	90	0.12	0.27	56	-0.21	0.12
Dollar Pt.	119	0.17	0.06	62	-0.20	0.12
Incline Condo.	83	0.08	0.47	37	-0.05	0.75
Incline West	119	0.52	<0.01	62	0.25	0.05
Sand Pt.	120	0.65	<0.01	63	0.29	0.02
Deadman Pt.	127	0.70	<0.01	69	0.40	<0.01
Zephyr Pt.	121	0.20	0.03	64	-0.06	0.62

3.b.1. Trends for Routine Sites, by Site

To see patterns for Chl *a* through time and relative to lake surface elevation, site mean Chl *a* values for each sampling date were plotted against time for routine sites. The data were also separated based on surface elevation (<6225 ft., ≥6225 ft.) and time submerged (<1000 days submerged, ≥1000 days submerged) and plotted in Figures 8-20 and Fig. 26. This was to see if trends for periphyton growth could be distinguished apart from the confounding effects of blue-green algae biomass.

Trend analysis of the Chl *a* data for each site was done using the Mann Kendall test for data covering the whole period of record, and for the recent period 2000-2015 using the whole data set, and also using data separated based on surface elevation (less than or greater than 6225 ft.) and time submerged (less than or greater than 1000 days submerged). The results for the Mann Kendall test along with sample number, mean and median values are presented along with graphs for each data set for each site in this section. In assessing trends we believe particular emphasis should be placed on results for the stalked diatom and green filamentous algae, since these types of algae can develop very heavy growth in the nearshore and are most commonly associated with poor aesthetic quality. Availability of nutrients is thought to play a significant role in development of this heavy biomass. In addition, we recommend emphasis should also be placed on recent trends (i.e. 2000-2015). The severe drought in the early 1990’s resulted in extreme low lake levels and unusually high blue-green algae biomass some sampling sites which affected trends. The data 1982-2000 also had significant gaps creating less certainty about patterns for biomass throughout that period.

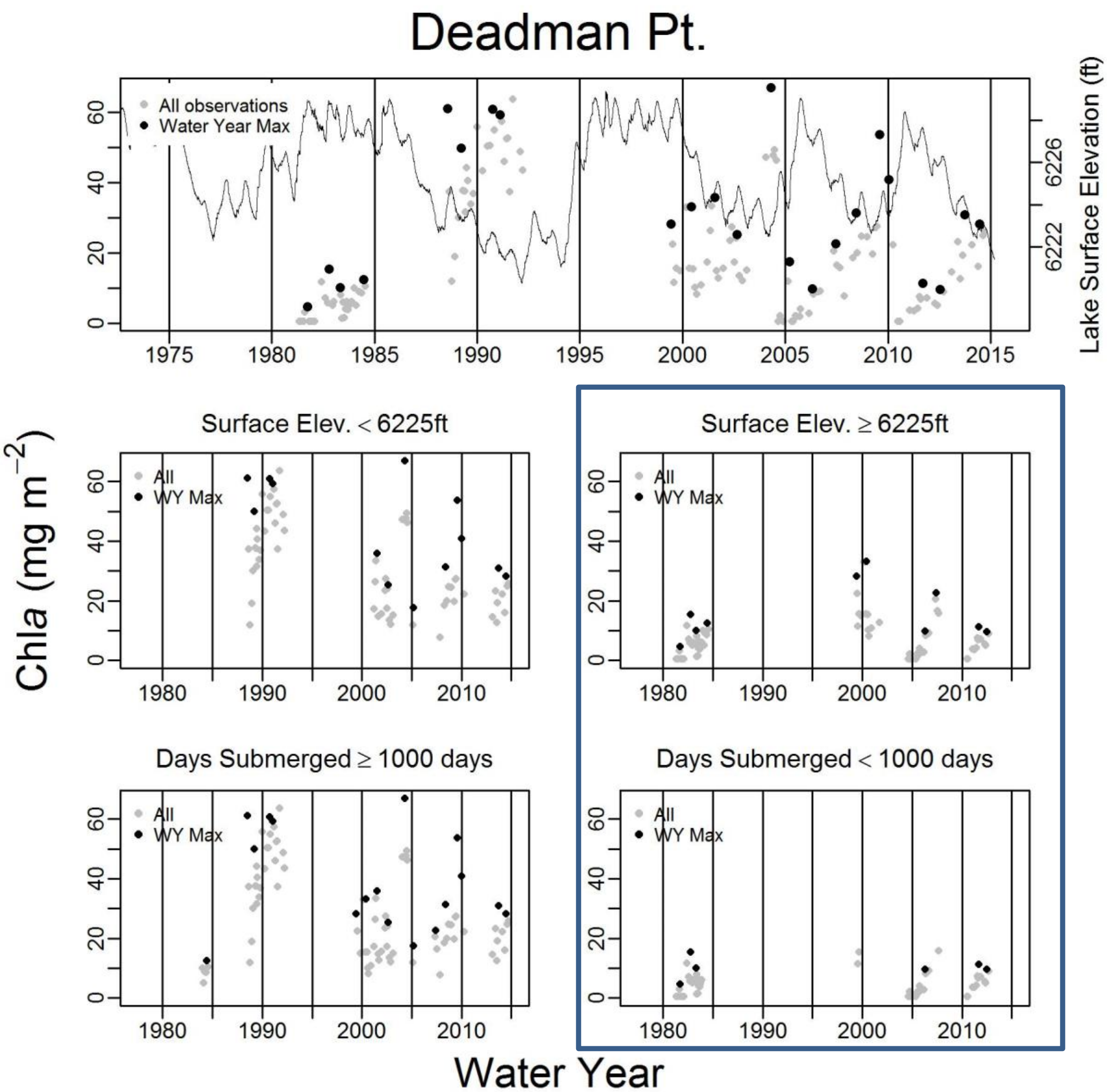


Fig. 8. Patterns for periphyton Chl *a* biomass at Deadman Pt. The top graph shows a plot of periphyton mean Chl *a* on each sampling date (gray dots), water year maximum Chl *a* (black dots) and lake surface elevation (fluctuating line). The middle row graphs present data separated based on lake surface elevation at the time of sampling i.e. ≥ 6225 ft. or <6225 ft. The bottom row graphs present data grouped according to amount of time the 0.5 m sampling site had been continuously submerged since last exposure at surface i.e. ≥1000 days or <1000 days. The two graphs enclosed by the blue rectangle represent biomass which is predominantly associated with stalked diatoms and filamentous green algae those algal groups that are most commonly associated with poor aesthetic quality.[2]

[2] In some cases blue-green algae are found when lake surface elevation is greater than 6225ft. However, they may not similarly show up in data separated based on time submerged of <1000 days. We believe this pattern occurred at Deadman Pt. in WY 2000 resulting in elevated biomass when surface elevation was ≥6225ft. but biomass was not similarly elevated in samples with time submerged less than 1000 days.

Table 5. Summary statistics (mean, median, std. dev.) and Mann-Kendall trend test statistics results for periphyton Chlorophyll *a* monitoring data collected at Deadman Point.

	All									Water Year Max							
	#	Mean	SD	Med	*Tau*	*S*	*z*	*p*		#	Mean	SD	Med	*Tau*	*S*	*z*	*p*
Entire period																	
All obs.	149	20.0	17.5	15.1	0.08	879	1.44	0.15		23	31.2	19.3	28.2	-0.03	-7	-0.16	0.87
SD./Green Fil.																	
>= 6225ft	78	7.9	7.3	6.1	0.16	494	2.13	0.03	+	10	15.7	9.2	11.9	0.02	1	0.00	1.00
< 1000 days	58	5.1	4.3	4.9	0.21	343	2.31	0.02	+	6	10.1	3.5	9.9	-0.07	-1	0.00	1.00
+ Blue-greens																	
< 6225ft	71	33.4	15.5	30.8	-0.27	-675	-3.35	<0.01	-	13	43.2	16.2	40.8	-0.41	-32	-1.89	0.06
>= 1000 days	91	29.6	15.9	25.7	-0.09	-385	-1.32	0.19		17	38.7	16.8	33.1	-0.18	-24	-0.95	0.34
After 2000																	
All obs.	88	17.8	13.5	15.5	-0.05	-185	-0.66	0.51		15	29.7	15.8	28.2	-0.16	-17	-0.79	0.43
SD./Green Fil.																	
>= 6225ft	45	9.8	8.5	8.8	-0.18	-179	-1.74	0.08		6	19.1	10.3	16.9	-0.60	-9	-1.50	0.13
< 1000 days	31	5.7	4.6	5.0	0.25	118	2.00	0.05	+	3							
+ Blue-greens																	
< 6225ft	43	26.1	12.8	24.1	0.03	23	0.23	0.82		9	36.7	15.2	31.3	-0.11	-4	-0.31	0.75
>= 1000 days	57	24.3	12.1	22.4	0.11	180	1.23	0.22		12	34.5	13.8	31.1	0.00	0	0.00	1.00

Table legend (apply to all similar tables)-"All" indicates data for all sampling dates (mean Chl *a* per date) used; "Water Year Max" indicates only Water Year maximum values used; "Entire Period" includes all data collected since the 1980s; "After 2000" includes only data collected after 2000; "All obs" indicates inclusion of all samples (not separated on the basis of lake level or time submerged). Statistics were also performed on data separated based on lake level and time submerged. Statistical results for samples collected when lake elevation was "≥ 6225 ft." or time submerged was "<1000 days" are included under the heading "SD/Green Fil." ,(stalked diatoms and/or filamentous green algae). Data collected when lake elevation was "< 6225 ft." or time submerged was "≥1000 days" were analyzed and statistical results included under the heading "+ Blue-greens" indicating some level of persistent blue-green algae is likely present at the 0.5 m sampling depth, potentially in combination with stalked diatoms and filamentous greens. The Mann-Kendall Trend Test statistics (Tau, S, z, *p*) are also shown. We consider a $p \leq 0.05$ in the Mann-Kendall trend test to be statistically significant. A positive value of *S* is an indicator of an increasing trend, and a negative value indicates a decreasing trend. Significant increase and decreasing trends are denoted in the table as + and – signs respectively and significant p values are shaded.

DEADMAN PT. TREND: (Focusing on Stalked Diatoms/Filamentous Green Algae)

NONE (2000-2015; 1982-2015)

Discussion: Deadman Pt. results

Chl *a* data, and Chl *a* data separated based on lake elevation and time submerged are plotted in Fig. 8 for Deadman Pt. Statistical results of the Mann-Kendall trend test along with values for mean, median and Std. Dev. are presented in Table 5. The Mann-Kendall trend test results for Deadman Pt. indicate there was no significant trend for periphyton Chl *a* for all data (data not separated based on lake elevation or time submerged) during the recent period 2000-2015 (see upper graph in Figure 8). When the data for 2000-2015 was separated based on lake level (≥ 6225 ft.) there similarly was no significant trend for Chl *a* biomass. The data for samples collected with a submergence time of <1000 days showed a statistically significant positive trend. Since the data for (≥6225 ft.) and (<1000 days) did not both indicate a significant trend, and since there was no trend for data not separated based on elevation and time submerged, we concluded there was no overall significant trend for the stalked diatoms and or filamentous green algae at Deadman Pt. during 2000-2015. There was similarly no trend when all data (data not separated based on lake elevation or time submerged) 1982-2015 were used. However, when this data was separated based on lake elevation (≥6225 ft.) and time submerged (<1000 days) there was a significant positive trend. However examination of the plot of this data shows little if any visually perceptible trend and similar levels of Chl *a* for samples collected when lake level≥6225 ft. both during the early 1980's and since 2010. We concluded there was no significant trend for the stalked diatoms and green filamentous algae 1982-2015. This site is located along the east shore adjacent to land with low development

It is interesting to note, there was a substantial difference in periphyton biomass at this site during periods of high and low lake level. This difference was due primarily to the contribution of the blue-green algae to the biomass. When lake surface elevation was ≥ 6225ft., mean Chl *a* was 10 mg/m^2 (2000-2015); when surface elevation was <6225 ft., mean Chl *a* was higher 26 mg/m^2 (2000-2015). Under conditions of low lake level, higher levels of biomass are encountered at the sampling depth than under high lake levels.

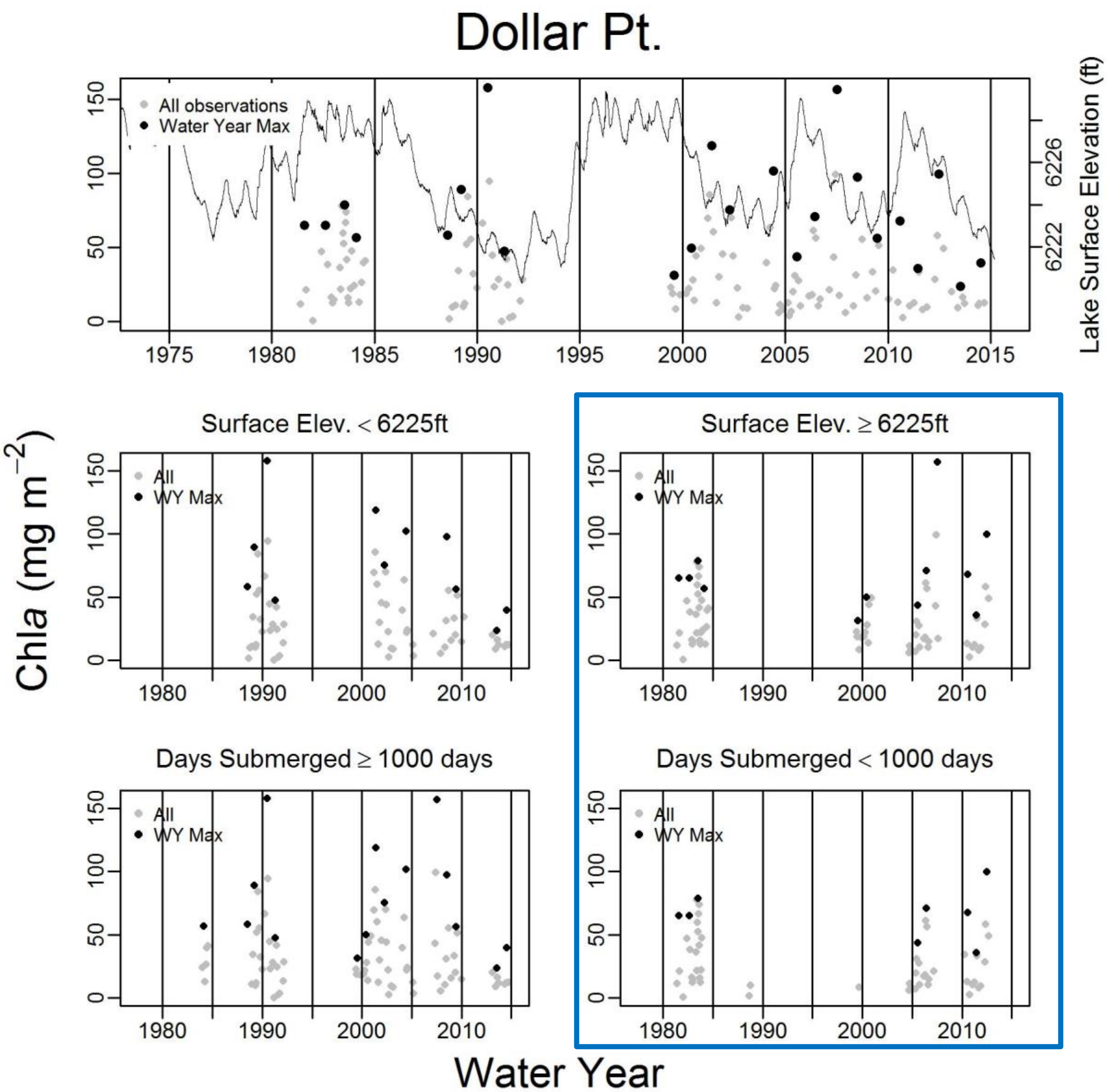


Fig. 9. Patterns for periphyton Chl *a* biomass at Dollar Pt. The top graph shows a plot of periphyton mean Chl *a* on each sampling date (gray dots), water year maximum Chl *a* (black dots) and lake surface elevation (fluctuating line). The middle row graphs present data separated based on lake surface elevation at the time of sampling i.e. ≥ 6225 ft. or<6225 ft. The bottom row graphs present data grouped according to amount of time the 0.5m sampling site had been continuously submerged since last exposure at surface i.e. ≥1000 days or <1000 days. The two graphs enclosed by the blue rectangle represent biomass which is predominantly associated with stalked diatoms and filamentous green algae those algal groups that are most commonly associated with poor aesthetic quality.

Table 6. Summary statistics (mean, median, std. dev.) and Mann-Kendall trend test statistics results for periphyton chlorophyll *a* monitoring data collected at Dollar Point.

(a) Dollar Pt.

	All									Water Year Max								
	#	Mean	SD	Med	*Tau*	*S*	*z*	*p*		#	Mean	SD	Med	*Tau*	*S*	*z*	*p*	
Entire period																		
All obs.	144	35.8	29.6	26.8	-0.09	-950	-1.64	0.10		23	73.3	35.9	65.2	-0.13	-33	-0.85	0.40	
SD./Green Fil.																		
>= 6225ft	74	34.9	27.5	26.8	-0.06	-151	-0.70	0.48		12	68.4	33.6	65.1	0.06	4	0.21	0.84	
< 1000 days	57	31.9	24.6	21.7	-0.05	-74	-0.50	0.62		8	65.9	19.8	66.4	0.07	2	0.12	0.90	
+ Blue-greens																		
< 6225ft	70	36.7	31.8	26.3	-0.12	-281	-1.42	0.16		11	78.6	39.2	75.4	-0.35	-19	-1.40	0.16	
>= 1000 days	87	38.4	32.3	28.2	-0.11	-405	-1.48	0.14		15	77.3	42.2	58.1	-0.10	-11	-0.49	0.62	
After 2000																		
All obs.	88	34.2	29.5	22.5	-0.08	-318	-1.14	0.25		15	71.2	37.4	67.7	-0.16	-17	-0.79	0.43	
SD./Green Fil.																		
>= 6225ft	45	33.0	30.1	21.9	0.09	88	0.85	0.39		8	69.4	41.6	58.7	0.36	10	1.11	0.27	
< 1000 days	32	28.3	23.7	18.9	0.23	114	1.83	0.07		5	63.6	25.2	67.7	0.20	2	0.24	0.81	
+ Blue-greens																		
< 6225ft	43	35.4	29.2	23.5	-0.27	-241	-2.51	0.01	-	7	73.2	35.0	75.4	-0.71	-15	-2.10	0.04	-
>= 1000 days	56	37.5	32.1	23.7	-0.15	-224	-1.58	0.12		10	75.0	42.9	65.8	-0.11	-5	-0.36	0.72	

Note- for explanation of various terms above, refer to notes in Table 5.

TREND: (Focusing on Stalked Diatoms/Filamentous Green Algae)

NONE (2000-2015; 1982-2015)

Discussion: Dollar Pt. results

Chl *a* data, and Chl *a* data separated based on lake elevation and time submerged are plotted in Fig. 9 for Dollar Pt. Statistical results of the Mann-Kendall trend test along with values for mean, median and Std. Dev. are presented in Table 6. The Mann-Kendall trend test results for Dollar Pt. indicate there was no significant trend for periphyton Chl *a* for all data (data not separated based on lake elevation or time submerged) during the recent period 2000-2015 (see upper graph in Figure 9). When the data for 2000-2015 was separated based on lake level (≥6225 ft.) and length of time site was submerged (<1000 days), there similarly was no significant trend for Chl *a* biomass. We conclude there was no trend upwards or downwards for Chl *a* biomass associated with the stalked diatoms and or filamentous green algae at Dollar Pt. during 2000-2015. Similarly, there was no statistically significant trend for biomass 1982-2015. This site is located along land characterized as high development in the north-west portion of the lake.

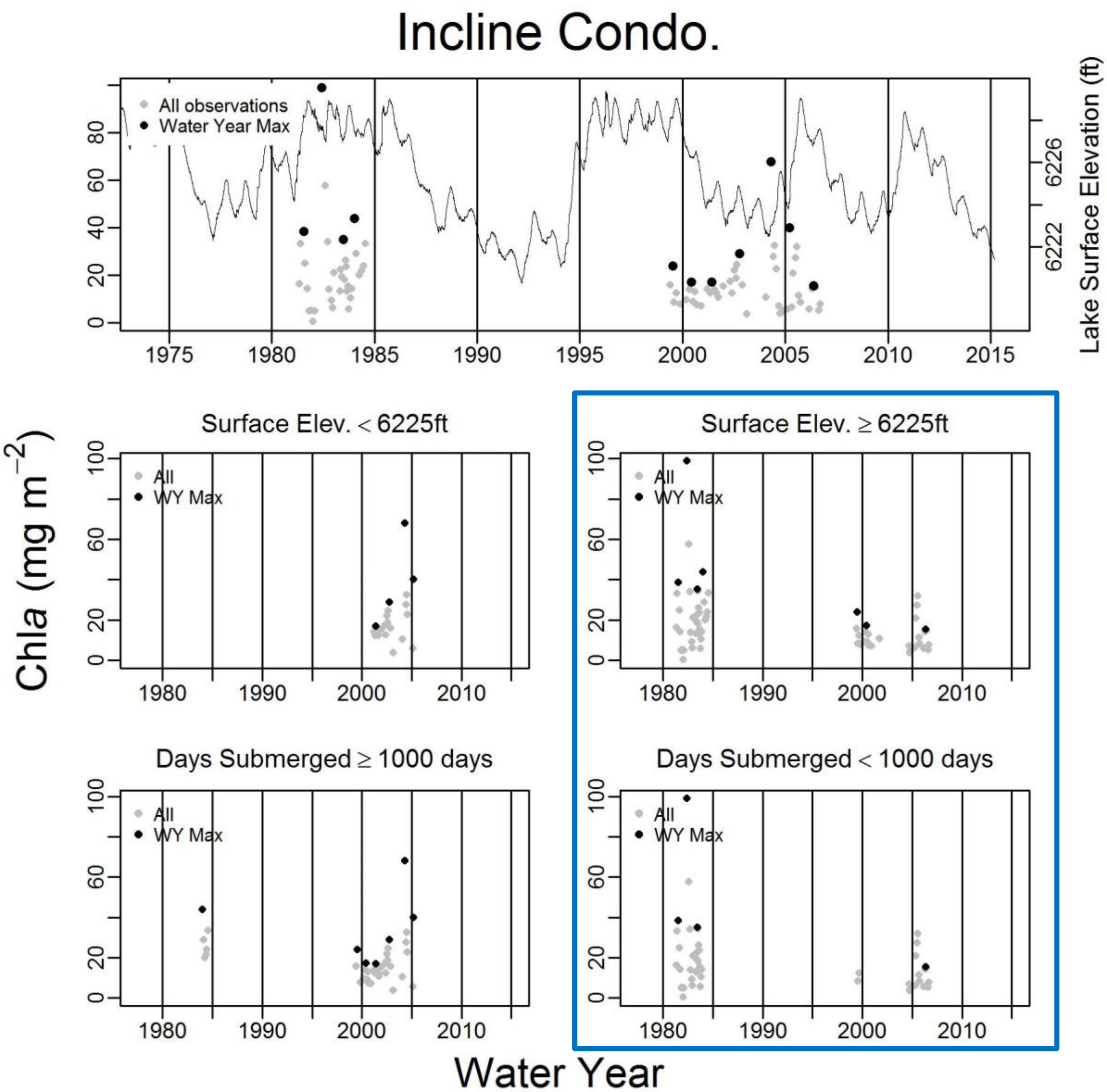


Fig. 10. Patterns for periphyton Chl *a* biomass at Incline Condo. The top graph shows a plot of periphyton mean Chl *a* on each sampling date (gray dots), water year maximum Chl *a* (black dots) and lake surface elevation (fluctuating line). The middle row graphs present data separated based on lake surface elevation at the time of sampling i.e. ≥ 6225ft. or <6225 ft. The bottom row graphs present data grouped according to amount of time the 0.5m sampling site had been continuously submerged since last exposure at surface i.e. ≥1000 days or <1000 days. The two graphs enclosed by the blue rectangle represent biomass which is predominantly associated with stalked diatoms and filamentous green algae those algal groups that are most commonly associated with poor aesthetic quality.

Table 7. Summary statistics (mean, median, std. dev.) and Mann-Kendall trend test statistics results for periphyton Chlorophyll *a* monitoring data collected at Incline Condo.

(a) Incline Condo

	All									Water Year Max								
	#	Mean	SD	Med	*Tau*	*S*	*z*	*p*		#	Mean	SD	Med	*Tau*	*S*	*z*	*p*	
Entire period																		
All obs.	84	18.8	14.9	15.0	-0.12	-417	-1.61	0.11		11	38.8	25.1	35.1	-0.31	-17	-1.25	0.21	
SD./Green Fil.																		
>= 6225ft	63	18.2	15.3	14.2	-0.22	-420	-2.49	0.01	-	7	39.0	28.5	35.1	-0.71	-15	-2.10	0.04	-
< 1000 days	46	18.2	16.8	14.2	-0.19	-192	-1.81	0.07		4	47.0	36.1	36.8	-0.67	-4	-1.02	0.31	
+ Blue-greens																		
< 6225ft	21	20.7	13.9	17.0	0.30	64	1.90	0.06		4	38.5	21.8	34.5	0.67	4	1.02	0.31	
>= 1000 days	38	19.5	12.4	16.4	0.02	12	0.14	0.89		7	34.1	18.2	28.9	0.14	3	0.30	0.76	
After 2000																		
All obs.	49	15.8	11.2	13.7	0.01	15	0.12	0.90		7	30.1	18.8	24.0	0.05	1	0.00	1.00	
SD./Green Fil.																		
>= 6225ft	28	12.2	7.0	10.1	-0.12	-45	-0.87	0.38		3								
< 1000 days	17	12.1	8.1	8.4	0.08	11	0.41	0.68		1								
+ Blue-greens																		
< 6225ft	21	20.7	13.9	17.0	0.30	64	1.90	0.06		4	38.5	21.8	34.5	0.67	4	1.02	0.31	
>= 1000 days	32	17.8	12.3	14.7	0.29	142	2.29	0.02	+	6	32.5	19.4	26.5	0.47	7	1.13	0.26	

Note- for explanation of various terms above, refer to notes in Table 5.

INCLINE CONDO TREND: (Focusing on Stalked Diatoms/Filamentous Green Algae) :

↔ NONE (2000-2007; 1982-2007)

Discussion: Incline Condo results

Chl *a* data, and Chl *a* data separated based on lake elevation and time submerged are plotted in Fig. 10 for Incline Condo. Statistical results of the Mann-Kendall trend test along with values for mean, median and Std. Dev. are presented in Table 7. Data collection from Incline Condo ended in 2007, so there is a shorter period of record at this site since 2000 than for other sites. The Mann-Kendall trend test results for Incline Condo indicate there was no significant trend for periphyton Chl *a* for all data (data not separated based on lake elevation or time submerged) during the recent period 2000-2007 (see upper graph in Figure 10). When the data for 2000-2007 was separated based on lake level (≥6225 ft.) and length of time site was submerged (<1000 days), there similarly was no significant trend for Chl *a* biomass. Therefore we conclude there was no significant trend for Chl *a* biomass associated with the stalked diatoms and or filamentous green algae at Incline Condo during 2000-2015. Similarly, there was no temporal trend for Chl *a* at Incline Condo when either all the data or WY data was analyzed 1982-2007. When (1982-2007) data were separated based on time submerged, there was a negative trend for all data and WY data, for samples collected when surface lake elevation was ≥6225 ft. (stalked diatoms and green filamentous algae) but not for samples (<1000 days submerged). Since a significant trend was not indicated using both (≥ 6225 ft. and <1000 days submerged) and no significant trend for all data was observed, we conclude there was no overall trend 1982-2007 at Incline Condo. This site is located downslope of an adjacent condominium development.

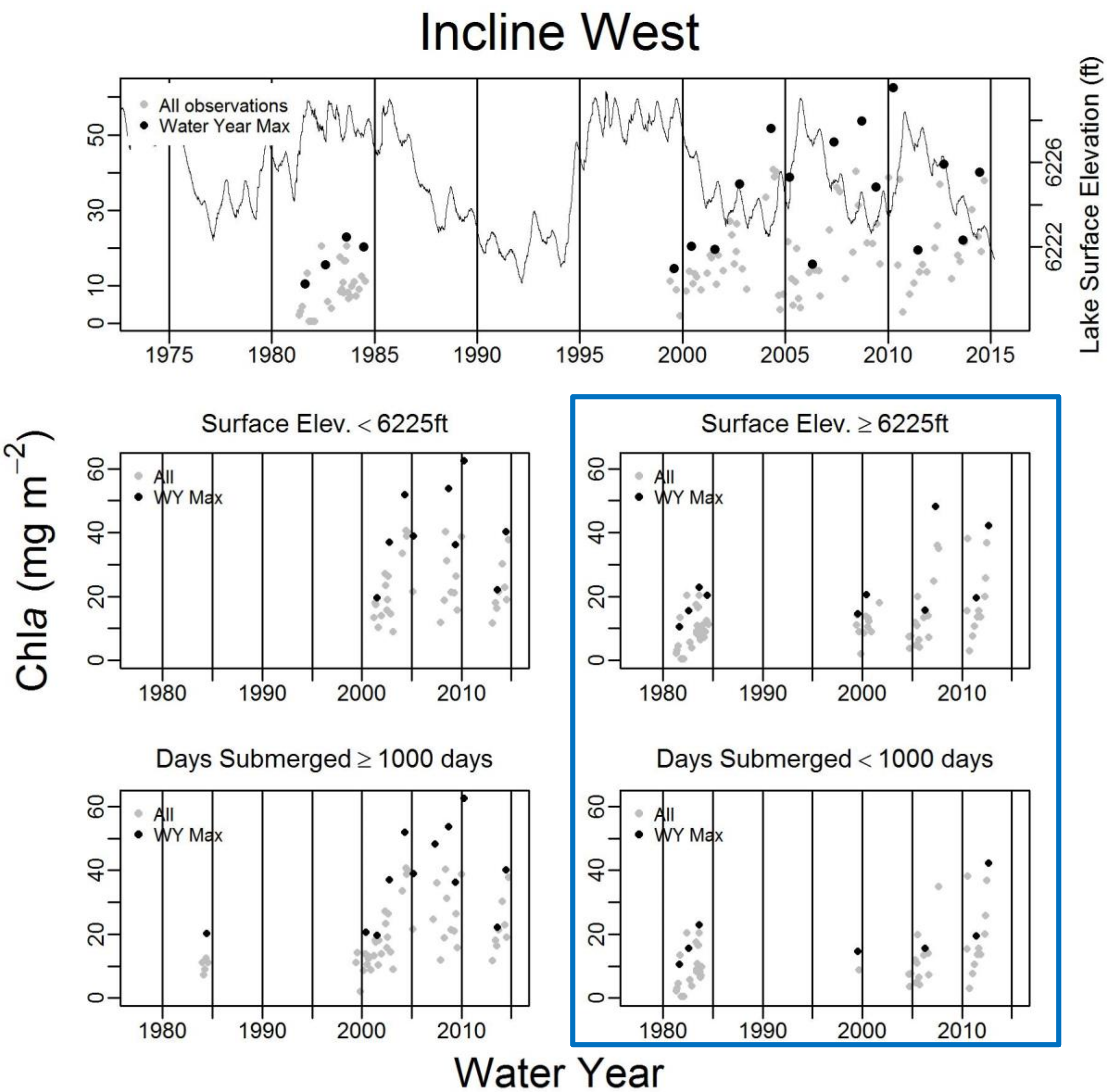


Fig. 11. Patterns for periphyton Chl *a* biomass at Incline West. The top graph shows a plot of periphyton mean Chl *a* on each sampling date (gray dots), water year maximum Chl *a* (black dots) and lake surface elevation (fluctuating line). The middle row graphs present data separated based on lake surface elevation at the time of sampling i.e. ≥ 6225ft or<6225 ft. The bottom row graphs present data grouped according to amount of time the 0.5m sampling site had been continuously submerged since last exposure at surface i.e. ≥1000 days or <1000 days. The two graphs enclosed by the blue rectangle represent biomass which is predominantly associated with stalked diatoms and filamentous green algae those algal groups that are most commonly associated with poor aesthetic quality.

Table 8. Summary statistics (mean, median, std. dev.) and Mann-Kendall trend test statistics results for periphyton Chlorophyll *a* monitoring data collected at Incline West.

(a) Incline West

	All									Water Year Max								
	#	Mean	SD	Med	*Tau*	*S*	*z*	*p*		#	Mean	SD	Med	*Tau*	*S*	*z*	*p*	
Entire period																		
All obs.	120	18.1	12.6	15.2	0.37	2618	5.94	<0.01	+	19	31.1	15.6	22.9	0.40	69	2.38	0.02	+
SD./Green Fil.																		
>= 6225ft	77	13.3	9.7	11.2	0.32	937	4.12	<0.01	+	10	23.0	12.3	19.9	0.42	19	1.61	0.11	
< 1000 days	57	12.6	9.4	10.8	0.35	553	3.80	<0.01	+	7	20.1	10.5	15.6	0.62	13	1.80	0.07	
+ Blue-greens																		
< 6225ft	43	26.7	12.6	22.1	0.18	165	1.72	0.09		9	40.2	14.1	38.8	0.22	8	0.73	0.47	
>= 1000 days	63	23.1	13.0	19.6	0.42	822	4.87	<0.01	+	12	37.6	14.6	37.9	0.39	26	1.71	0.09	
After 2000																		
All obs.	88	21.2	12.9	18.0	0.22	853	3.07	<0.01	+	15	34.8	15.4	37.0	0.26	27	1.29	0.20	
SD./Green Fil.																		
>= 6225ft	45	15.9	10.8	13.6	0.29	288	2.81	<0.01	+	6	26.8	14.6	20.0	0.47	7	1.13	0.26	
< 1000 days	31	15.3	10.4	13.6	0.39	183	3.09	<0.01	+	4	23.0	13.0	17.6	1.00	6	1.70	0.09	
+ Blue-greens																		
< 6225ft	43	26.7	12.6	22.1	0.18	165	1.72	0.09		9	40.2	14.1	38.8	0.22	8	0.73	0.47	
>= 1000 days	57	24.3	13.1	21.0	0.36	581	3.99	<0.01	+	11	39.1	14.3	38.8	0.31	17	1.25	0.21	

Note- for explanation of various terms above, refer to notes in Table 5.

INCLINE WEST TREND: (Focusing on Stalked Diatoms/Filamentous Green Algae):

POSITIVE (2000-2015; 1982-2015);

Discussion: Incline West results

Chl *a* data, and Chl *a* data separated based on lake elevation and time submerged are plotted in Fig. 11 for Incline West. Statistical results of the Mann-Kendall trend test along with values for mean, median and Std. Dev. are presented in Table 8. The Mann-Kendall trend test results for Incline West indicate there was statistically significant positive trend for periphyton Chl *a* for all data (data not separated based on lake elevation or time submerged) during the recent period 2000-2015 (see upper graph in Figure 11). When the data for 2000-2015 was separated based on lake level (≥6225ft) and length of time site was submerged (<1000 days), there similarly was a significant positive trend for Chl *a* biomass. These results taken together suggest there was a positive (upward) trend for Chl *a* biomass associated with the stalked diatoms and or filamentous green algae at Incline West during 2000-2015. A similar pattern was observed in the 1982-2015 data indicating a statistically significant positive trend for Chl *a* biomass associated with the stalked diatoms and or filamentous green algae. When the plot of all data 1982-2015 with time is reviewed (upper graph in Figure 11), general levels of Chl *a* appear fairly similar in the early 1980's and in the early 2000's. However, after about 2004 there appears to be greater range for the data with higher Chl *a* levels. This site was shifted approximately 100m north beginning with samples collected in year 2000, so the positive trend observed 2000-2015 was not a consequence of this relocation. Although there appears to be an overall positive trend for periphyton biomass at this site, the magnitude of change in mean Chl *a* has been relatively small. For 1982 -2015 the mean Chl *a* was 18 mg/m^2 and for 2000-2015 the mean was 21 mg/m^2. This site is downslope of forested land with little development immediately upslope, but it is associated with an intervening zone with medium levels of development.

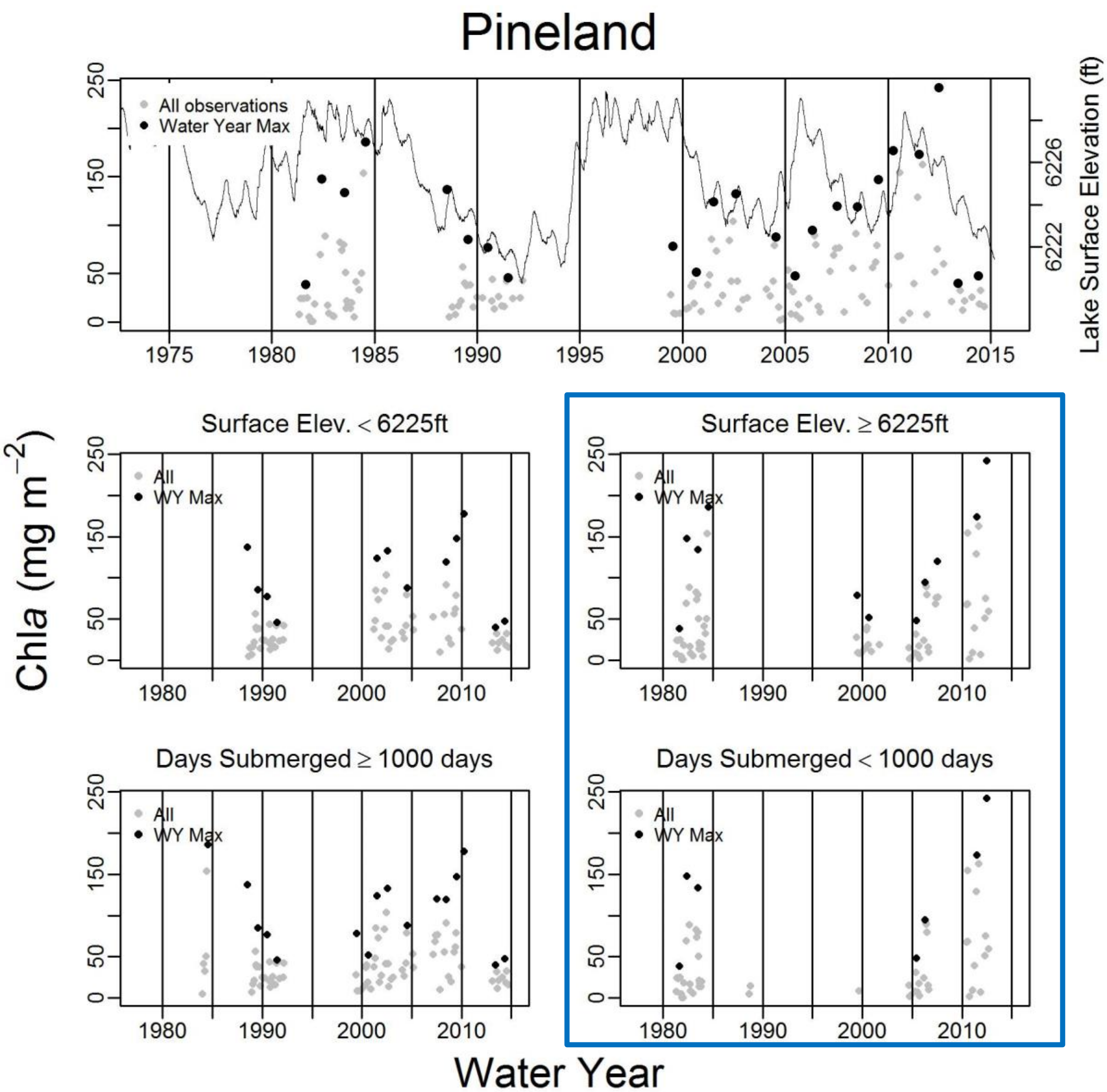


Fig. 12. Patterns for periphyton Chl *a* biomass at Pineland. The top graph shows a plot of periphyton mean Chl *a* on each sampling date (gray dots), water year maximum Chl *a* (black dots) and lake surface elevation (fluctuating line). The middle row graphs present data separated based on lake surface elevation at the time of sampling i.e. ≥ 6225 ft. or <6225 ft. The bottom row graphs present data grouped according to amount of time the 0.5m sampling site had been continuously submerged since last exposure at surface i.e. ≥1000 days or <1000 days. The two graphs enclosed by the blue rectangle represent biomass which is predominantly associated with stalked diatoms and filamentous green algae those algal groups that are most commonly associated with poor aesthetic quality.

Table 9. Summary statistics (mean, median, std. dev.) and Mann-Kendall trend test statistics results for periphyton Chlorophyll *a* monitoring data collected at Pineland.

(a) Pineland

	All									Water Year Max								
	#	Mean	SD	Med	*Tau*	*S*	*z*	*p*		#	Mean	SD	Med	*Tau*	*S*	*z*	*p*	
Entire period																		
All obs.	151	48.4	44.9	36.8	0.14	1629	2.62	<0.01	+	23	110.1	54.5	119.2	0.07	17	0.42	0.67	
SD./Green Fil.																		
>= 6225ft	80	49.1	51.3	26.1	0.17	546	2.26	0.02	+	11	119.3	64.7	119.7	0.27	15	1.09	0.28	
< 1000 days	60	46.9	52.4	22.5	0.18	311	1.98	0.05	+	7	125.3	71.8	133.6	0.52	11	1.50	0.13	
+ Blue-greens																		
< 6225ft	71	47.5	36.6	37.7	0.10	247	1.22	0.22		12	101.6	44.4	103.3	0.00	0	0.00	1.00	
>= 1000 days	91	49.3	39.4	38.0	0.08	321	1.10	0.27		16	103.4	46.3	103.3	-0.07	-8	-0.32	0.75	
After 2000																		
All obs.	91	53.5	46.9	39.9	0.11	437	1.49	0.13		15	112.1	57.3	119.2	0.20	21	0.99	0.32	
SD./Green Fil.																		
>= 6225ft	47	52.2	53.3	36.8	0.30	325	2.97	<0.01	+	7	115.3	70.5	94.6	0.71	15	2.10	0.04	+
< 1000 days	31	57.6	61.0	39.0	0.35	165	2.79	<0.01	+	4	139.4	85.7	134.0	1.00	6	1.70	0.09	
+ Blue-greens																		
< 6225ft	44	54.8	39.5	41.5	-0.19	-178	-1.79	0.07		8	109.3	47.8	121.5	-0.14	-4	-0.37	0.71	
>= 1000 days	60	51.3	38.1	39.9	0.07	128	0.81	0.42		11	102.2	44.6	119.2	0.05	3	0.16	0.88	

Note- for explanation of various terms above, refer to notes in Table 5.

PINELAND TREND: (Focusing on Stalked Diatoms/Filamentous Green Algae)

POSITIVE (2000-2015; 1982-2015)

Discussion: Pineland results

Chl *a* data, and Chl *a* data separated based on lake elevation and time submerged are plotted in Fig. 12 for Pineland. Statistical results of the Mann-Kendall trend test along with values for mean, median and Std. Dev. are presented in Table 9. The Mann-Kendall trend test results for Pineland indicates there was no statistically significant positive trend for periphyton for all data (data not separated based on lake elevation or time submerged) during the recent period 2000-2015 (see upper graph in Figure 12). However, when the data for 2000-2015 was separated based on lake level (≥6225ft) and length of time site was submerged (<1000 days), there was a significant positive trend for Chl *a* biomass. The WY max data for samples collected when lake level was ≥ 6225 ft. during 2000-2015 also shows a significant positive trend. Since the data for (≥6225 ft.) and (<1000 days) and WY Max data (≥6225 ft.) all indicate a significant trend we concluded there was a significant positive trend for the stalked diatoms and or filamentous green algae for Pineland during 2000-2015. There was also a statistically significant positive temporal trend for Chl *a* at Pineland for all data collected 1982-2015. Although there appears to be an overall positive trend for periphyton biomass at this site, the magnitude of change in mean Chl *a* has been relatively small. For 1982 -2015 the mean Chl *a* using all data was 48 mg/m^2 and for 2000-2015 the mean was 54 mg/m^2. In the middle and lower left panels of Fig. 12 there was a large drop in Chl *a* in WY 2014, 2015 possibly associated with the prolonged drought and reduced nutrient inputs to the lake. It is interesting to note periphyton Chl *a* levels were similarly very low during the prolonged drought and extremely low lake levels in the early 1990's. This site is located adjacent to land with a medium level of development. observed was due to generally low levels of Chl *a*, associated with lowered nutrient inputs, during the recent prolonged drought and lowered lake level

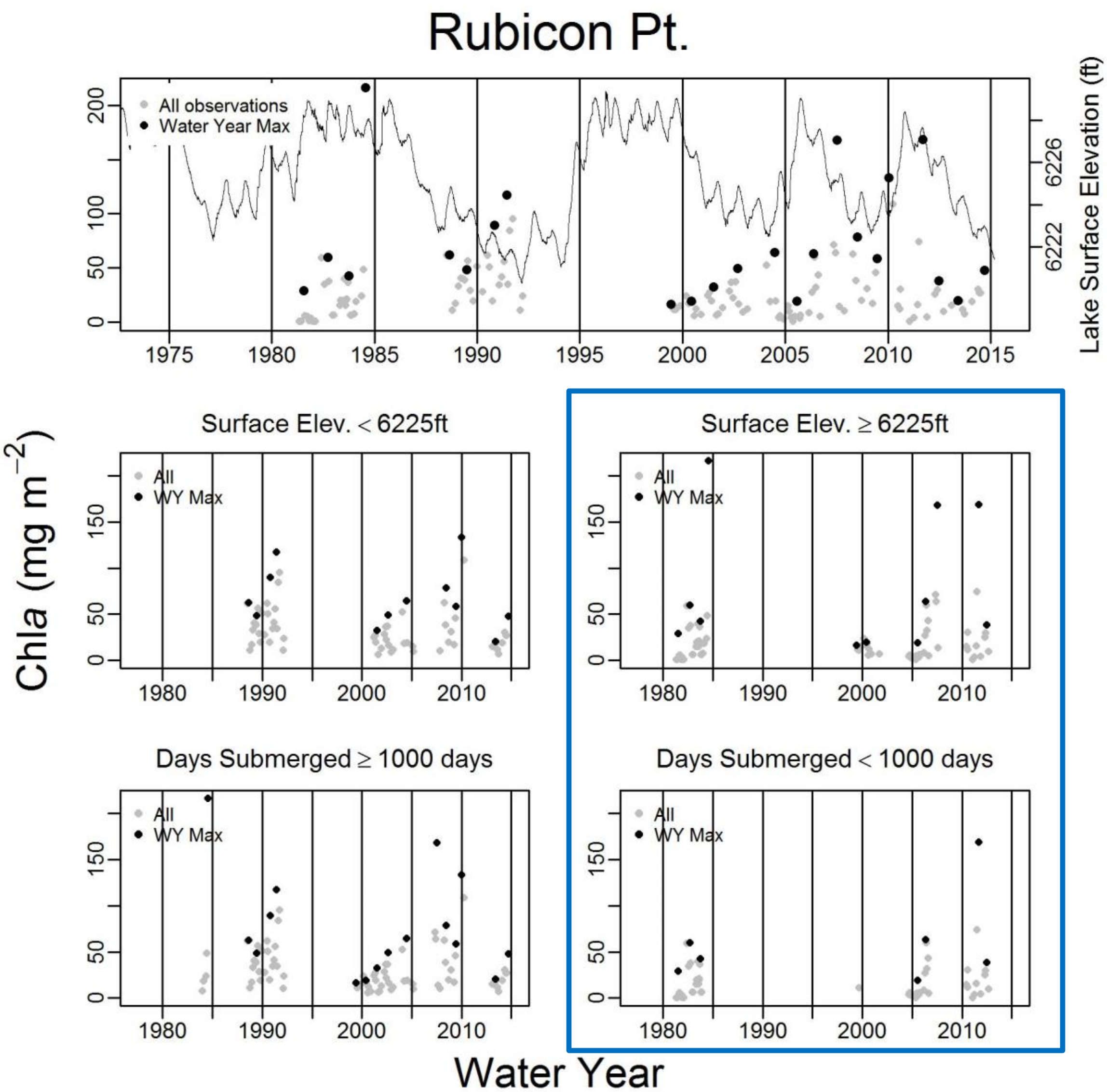


Fig. 13. Patterns for periphyton Chl *a* biomass at Rubicon Pt. The top graph shows a plot of periphyton mean Chl *a* on each sampling date (gray dots), water year maximum Chl *a* (black dots) and lake surface elevation (fluctuating line). The middle row graphs present data separated based on lake surface elevation at the time of sampling i.e. ≥ 6225ft or<6225 ft. The bottom row graphs present data grouped according to amount of time the 0.5m sampling site had been continuously submerged since last exposure at surface i.e. ≥1000 days or <1000 days. The two graphs enclosed by the blue rectangle represent biomass which is predominantly associated with stalked diatoms and filamentous green algae those algal groups that are most commonly associated with poor aesthetic quality.

Table 10. Summary statistics (mean, median, std. dev.) and Mann-Kendall trend test statistics results for periphyton Chlorophyll *a* monitoring data collected at Rubicon Pt.

(a) Rubicon Pt.

	All									Water Year Max							
	#	Mean	SD	Med	*Tau*	*S*	*z*	*p*		#	Mean	SD	Med	*Tau*	*S*	*z*	*p*
Entire period																	
All obs.	147	31.8	33.3	20.0	0.05	490	0.82	0.41		23	71.3	54.2	58.5	0.07	17	0.42	0.67
SD./Green Fil.																	
>= 6225ft	78	26.0	37.1	15.3	0.11	323	1.39	0.16		11	76.4	72.1	42.4	0.16	9	0.62	0.53
< 1000 days	57	21.6	27.3	14.6	0.16	252	1.73	0.08		7	60.0	50.4	42.4	0.24	5	0.60	0.55
+ Blue-greens																	
< 6225ft	69	38.4	27.3	30.6	-0.13	-296	-1.53	0.13		12	66.7	33.2	60.3	-0.09	-6	-0.34	0.73
>= 1000 days	90	38.3	35.3	26.9	-0.05	-209	-0.72	0.47		16	76.3	56.6	60.3	-0.07	-8	-0.32	0.75
After 2000																	
All obs.	88	29.6	32.1	19.1	0.13	491	1.77	0.08		15	65.1	51.6	49.2	0.30	31	1.48	0.14
SD./Green Fil.																	
>= 6225ft	46	26.2	36.2	14.7	0.15	154	1.45	0.15		7	70.4	68.9	38.2	0.62	13	1.80	0.07
< 1000 days	30	24.1	33.7	11.3	0.29	128	2.27	0.02	+	4	72.3	66.7	50.8	0.33	2	0.34	0.73
+ Blue-greens																	
< 6225ft	42	33.3	26.9	25.6	0.08	69	0.74	0.46		8	60.4	34.6	53.8	0.07	2	0.12	0.90
>= 1000 days	58	32.5	31.1	19.5	0.23	387	2.59	<0.01	+	11	62.5	48.6	49.2	0.35	19	1.40	0.16

Note- for explanation of various terms above, refer to notes in Table 5.

RUBICON PT. TREND: (Focusing on Stalked Diatoms/Filamentous Green Algae)

NONE (1982-2015; 2000-2015)

Discussion: Rubicon results

Chl *a* data, and Chl *a* data separated based on lake elevation and time submerged are plotted in Fig. 13 for Rubicon Pt. Statistical results of the Mann-Kendall trend test along with values for mean, median and Std. Dev. are presented in Table 10. The Mann-Kendall trend test results for Rubicon Pt. indicate there was no significant trend for periphyton Chl *a* for all data (data not separated based on lake elevation or time submerged) during the recent period 2000-2015 (see upper graph in Fig. 13). When the data for 2000-2015 were separated based on lake level (≥ 6225 ft.) there similarly was no significant trend for Chl *a* biomass. The data for samples collected with a submergence time of <1000 days showed a statistically significant positive trend. Since the data for (≥6225 ft.) and (<1000 days) did not both indicate a significant trend, and since there was no trend for data not separated based on elevation and time submerged, we conclude there was no overall significant trend for the stalked diatoms and or filamentous green algae for Rubicon Pt. during 2000-2015. There was no temporal trend for Chl *a* for the 1982-2015 period for Rubicon Pt. when all the data were analyzed. This site is located adjacent to a State Park land with low development.

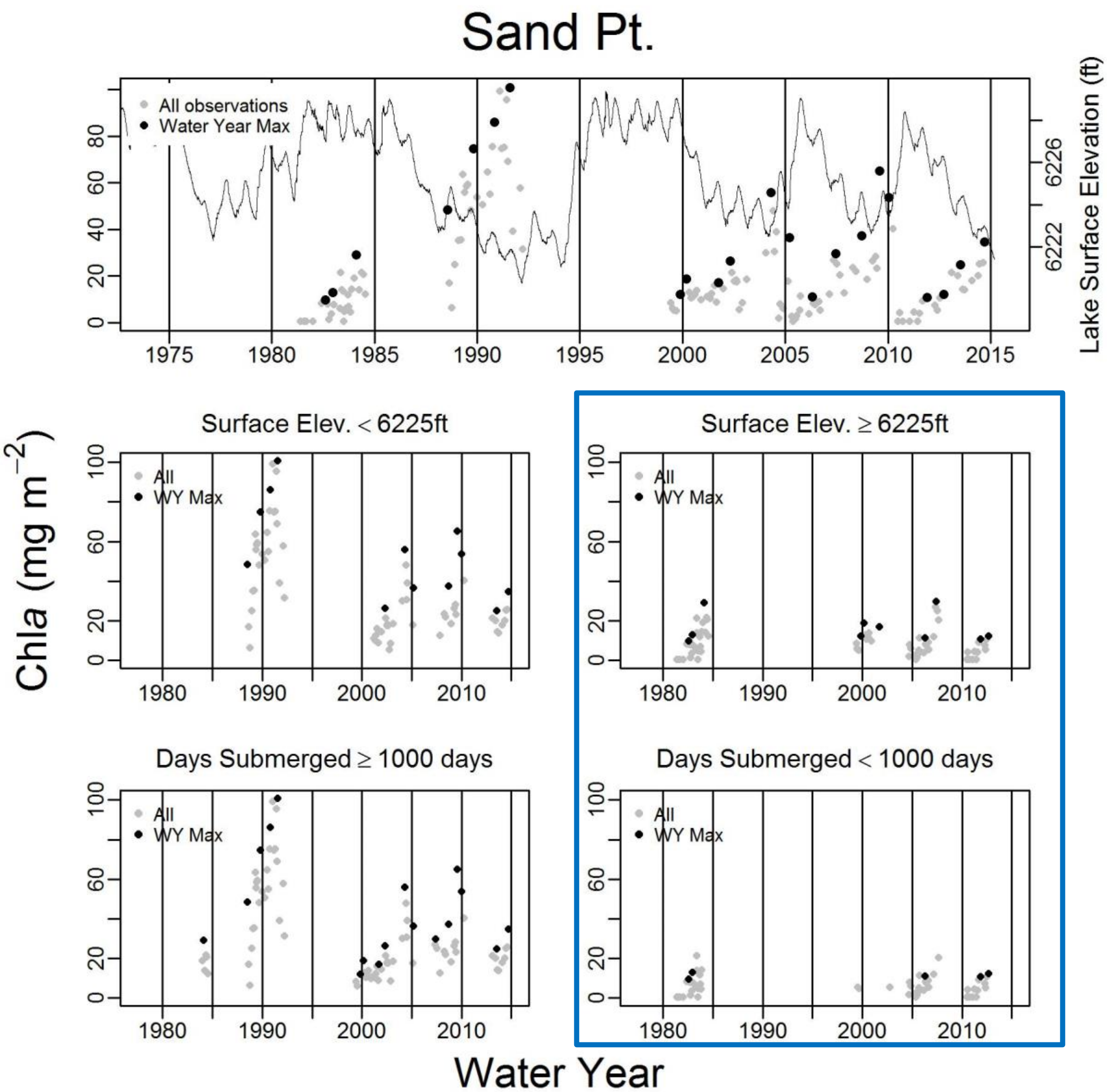


Fig. 14. Patterns for periphyton Chl *a* biomass at Sand Pt. The top graph shows a plot of periphyton mean Chl *a* on each sampling date (gray dots), water year maximum Chl *a* (black dots) and lake surface elevation (fluctuating line). The middle row graphs present data separated based on lake surface elevation at the time of sampling i.e. ≥ 6225ft or < 6225 ft. The bottom row graphs present data grouped according to amount of time the 0.5m sampling site had been continuously submerged since last exposure at surface i.e. ≥1000 days or <1000 days. The two graphs enclosed by the blue rectangle represent biomass which is predominantly associated with stalked diatoms and filamentous green algae those algal groups that are most commonly associated with poor aesthetic quality.

Table 11. Summary statistics (mean, median, std. dev.) and Mann-Kendall trend test statistics results for periphyton Chlorophyll *a* monitoring data collected at Sand Pt.

(a) Sand Pt.

	All									Water Year Max							
	#	Mean	SD	Med	*Tau*	*S*	*z*	*p*		#	Mean	SD	Med	*Tau*	*S*	*z*	*p*
Entire period																	
All obs.	145	22.6	22.5	13.9	0.03	325	0.55	0.58		22	36.7	26.3	29.4	0.01	3	0.06	0.96
SD./Green Fil.																	
>= 6225ft	76	9.0	7.2	7.8	0.02	50	0.22	0.83		10	16.3	7.5	12.5	0.02	1	0.00	1.00
< 1000 days	57	6.4	5.0	5.5	0.05	86	0.59	0.56		5	11.3	1.3	11.2	0.20	2	0.24	0.81
+ Blue-greens																	
< 6225ft	69	37.5	24.3	29.9	-0.20	-476	-2.46	0.01	-	12	53.6	24.1	51.0	-0.33	-22	-1.44	0.15
>= 1000 days	88	33.1	23.3	24.9	-0.07	-264	-0.95	0.34		17	44.1	25.4	36.4	-0.01	-2	-0.04	0.97
After 2000																	
All obs.	88	16.3	13.1	12.5	0.10	392	1.41	0.16		15	29.7	17.5	26.3	0.14	15	0.69	0.49
SD./Green Fil.																	
>= 6225ft	46	8.8	7.0	8.0	-0.08	-79	-0.74	0.46		7	15.9	6.8	12.1	-0.14	-3	-0.30	0.76
< 1000 days	33	6.0	4.6	5.3	0.14	76	1.16	0.24		3							
+ Blue-greens																	
< 6225ft	42	24.5	13.3	21.3	0.27	231	2.49	0.01	+	8	41.8	14.7	36.9	-0.07	-2	-0.12	0.90
>= 1000 days	55	22.5	12.6	18.7	0.41	607	4.40	<0.01	+	12	34.3	16.5	32.1	0.42	28	1.85	0.06

Note- for explanation of various terms above, refer to notes in Table 5.

SAND PT. TREND: (Focusing on Stalked Diatoms/Filamentous Green Algae)

NONE (2000-2015; 1982-2015)

Discussion: Sand Pt. results

Chl *a* data, and Chl *a* data separated based on lake elevation and time submerged are plotted in Fig. 14 for Sand Pt. Statistical results of the Mann-Kendall trend test along with values for mean, median and Std. Dev. are presented in Table 11. The Mann-Kendall trend test results for Sand Pt. indicate there was no significant trend for periphyton Chl *a* for all data (data not separated based on lake elevation or time submerged) during the recent period 2000-2015 (see upper graph in Fig. 14). When the data for 2000-2015 was separated based on lake level (≥6225 ft.) and length of time site was submerged (<1000 days), there similarly was no significant trend for Chl *a* biomass. Therefore, there was no significant trend for Chl *a* biomass associated with the stalked diatoms and or filamentous green algae at Sand Pt. during 2000-2015. A significant positive trend was however observed 2000-2015 for the periphyton containing blue-green algae (i.e. <6225 ft., >1000 days submerged). There was no trend when all data 1982-2015 were used. This site is located along the east shore adjacent to land with low development.

It is interesting to note that algal biomass at 0.5m depth at Sand Pt. showed a substantial difference based on surface elevation. When lake surface elevation was ≥ 6225ft., mean Chl *a* was 9 mg/m^2 (1982-2015) and 9 mg/m^2 (2000-2015); when surface elevation was <6225 ft., mean Chl *a* was higher 38 mg/m^2 (1982-2015) and 25 mg/m^2 (2000-2015). The elevated Chl *a* when surface elevation was low (below 6225 ft.) was largely due to contribution of biomass from the stable, persistent sublittoral blue-green algae to samples. When surface elevation is above 6225 ft. biomass at the sampling depth was very low at Sand Pt.

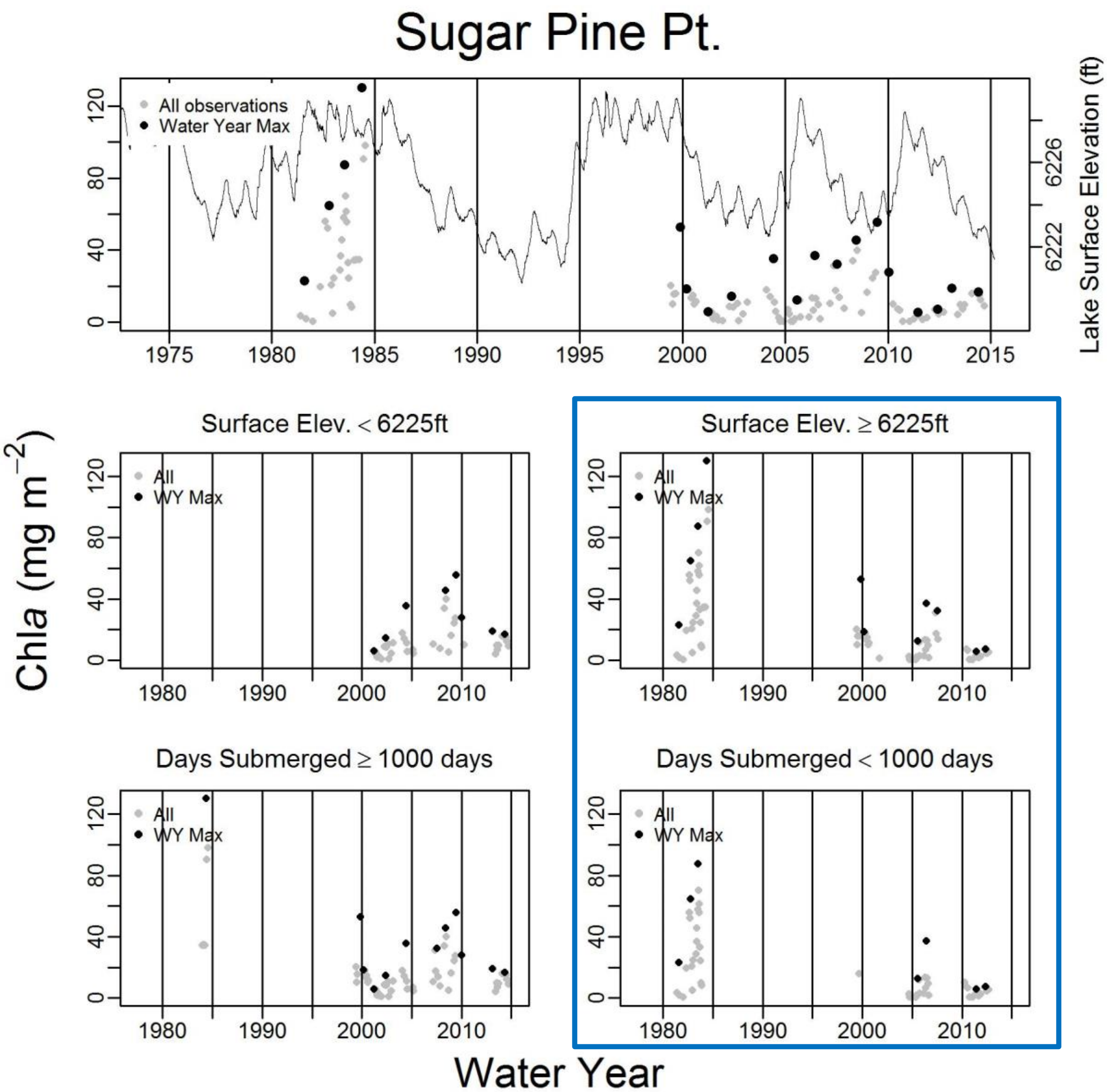


Fig. 15. Patterns for periphyton Chl *a* biomass at Sugar Pine Pt. The top graph shows a plot of periphyton mean Chl *a* on each sampling date (gray dots), water year maximum Chl *a* (black dots) and lake surface elevation (fluctuating line). The middle row graphs present data separated based on lake surface elevation at the time of sampling i.e. ≥ 6225ft or < 6225 ft. The bottom row graphs present data grouped according to amount of time the 0.5m sampling site had been continuously submerged since last exposure at surface i.e. ≥1000 days or <1000 days. The two graphs enclosed by the blue rectangle represent biomass which is predominantly associated with stalked diatoms and filamentous green algae those algal groups that are most commonly associated with poor aesthetic quality.

Table 12. Summary statistics (mean, median, std. dev.) and Mann-Kendall trend test statistics results for periphyton Chlorophyll *a* monitoring data collected at Sugar Pine Pt.

(a) Sugar Pine Pt.

	All									Water Year Max								
	#	Mean	SD	Med	*Tau*	*S*	*z*	*p*		#	Mean	SD	Med	*Tau*	*S*	*z*	*p*	
Entire period																		
All obs.	116	19.6	22.8	11.2	-0.22	-1500	-3.58	<0.01	-	19	36.4	31.6	27.9	-0.30	-51	-1.75	0.08	
SD./Green Fil.																		
>= 6225ft	74	22.7	26.5	13.2	-0.35	-954	-4.45	<0.01	-	11	42.9	38.6	32.2	-0.49	-27	-2.02	0.04	-
< 1000 days	54	18.2	22.1	7.8	-0.30	-436	-3.25	<0.01	-	7	34.0	31.4	23.1	-0.43	-9	-1.20	0.23	
+ Blue-greens																		
< 6225ft	42	14.3	12.4	10.3	0.27	235	2.54	0.01	+	8	27.6	16.9	23.4	0.14	4	0.37	0.71	
>= 1000 days	62	20.8	23.4	13.9	-0.08	-153	-0.92	0.36		12	37.8	33.0	30.0	-0.18	-12	-0.75	0.45	
After 2000																		
All obs.	87	12.2	11.8	9.6	-0.02	-88	-0.32	0.75		15	25.8	16.7	19.0	-0.10	-11	-0.49	0.62	
SD./Green Fil.																		
>= 6225ft	45	10.3	10.9	7.3	-0.23	-223	-2.17	0.03	-	7	23.7	17.5	18.5	-0.52	-11	-1.50	0.13	
< 1000 days	31	6.3	7.4	4.6	0.01	6	0.09	0.93		4	15.7	14.6	9.9	-0.33	-2	-0.34	0.73	
+ Blue-greens																		
< 6225ft	42	14.3	12.4	10.3	0.27	235	2.54	0.01	+	8	27.6	16.9	23.4	0.14	4	0.37	0.71	
>= 1000 days	56	15.5	12.5	11.8	0.09	144	1.01	0.31		11	29.4	16.4	27.9	-0.02	-1	0.00	1.00	

Note- for explanation of various terms above, refer to notes in Table 5.

SUGAR PINE PT. TREND: (Focusing on Stalked Diatoms/Filamentous Green Algae)

 NONE (2000-2015)

 NEGATIVE (1982-2015);

Discussion: Sugar Pine Pt. results

Chl *a* data, and Chl *a* data separated based on lake elevation and time submerged are plotted in Fig. 15 for Sugar Pine Pt. Statistical results of the Mann-Kendall trend test along with values for mean, median and Std. Dev. are presented in Table 12. The Mann-Kendall trend test results for Sugar Pine Pt. indicate there was no significant trend for periphyton Chl *a* for all data (data not separated based on lake elevation or time submerged) during the recent period 2000-2015 (see upper graph in Figure 15). When the data for 2000-2015 was separated based on lake level (≥ 6225 ft.) there was a statistically significant negative trend for Chl *a* biomass. However the data for samples collected with a submergence time of <1000 days showed no trend. Since the data for (≥6225 ft.) and (<1000 days) did not both indicate a significant trend, and since there was no trend for all the data (not separated based on elevation and time submerged), we conclude there was no overall significant trend for the stalked diatoms and or filamentous green algae for the west region during 2000-2015. Interestingly, there was a significant negative trend for Chl *a* biomass at Sugar Pine Pt. 1982-2015 using all data (data not separated based on lake elevation or time submerged) as well as data separated both based on lake level (≥ 6225 ft.) and time submerged (<1000 days). Chl *a* at this site was noted to be unusually high for a period in the mid-1980's (Loeb et al., 1986), while relatively low levels have been observed through much of the period 2000-2015. The cause of the elevated Chl *a* in the mid-1980's was not readily apparent. This site is adjacent to State Park land and an intervening zone characterized as medium development.

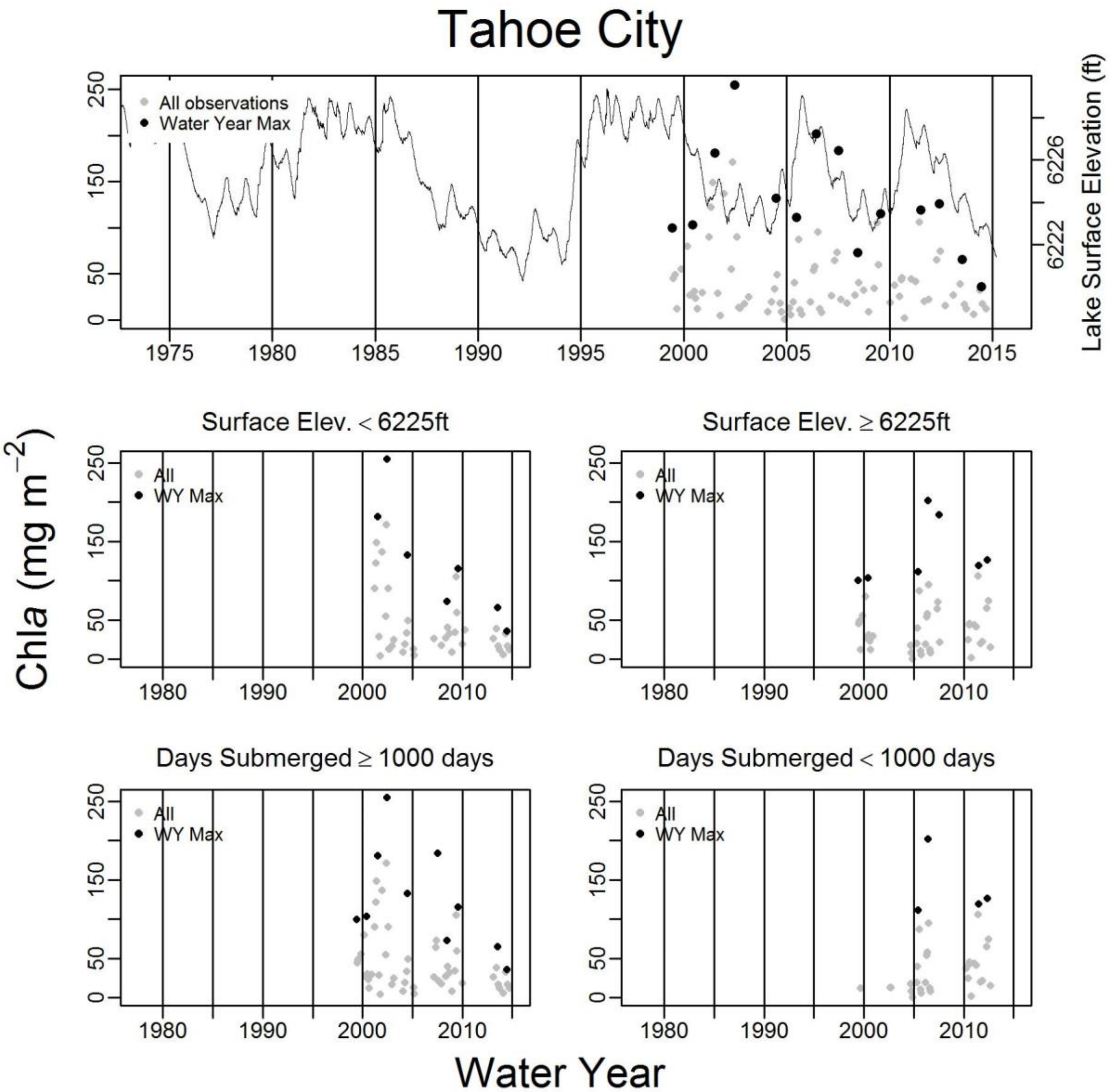


Fig. 16. Patterns for periphyton Chl *a* biomass at Tahoe City. The top graph shows a plot of periphyton mean Chl *a* on each sampling date (gray dots), water year maximum Chl *a* (black dots) and lake surface elevation (fluctuating line). The middle row graphs present data separated based on lake surface elevation at the time of sampling i.e. ≥ 6225 ft. or < 6225 ft. The bottom row graphs present data grouped according to amount of time the 0.5m sampling site had been continuously submerged since last exposure at surface i.e. ≥1000 days or <1000 days. Note there is typically little biomass associated with blue-green algae in all the samples at this site. The algae is predominantly stalked diatoms at all the sampling depths.

Table 13. Summary statistics (mean, median, std. dev.) and Mann-Kendall trend test statistics results for periphyton Chlorophyll *a* monitoring data collected at Tahoe City.

(a) Tahoe City

	All									Water Year Max								
	#	Mean	SD	Med	*Tau*	*S*	*z*	*p*		#	Mean	SD	Med	*Tau*	*S*	*z*	*p*	
After 2000																		
All obs.	91	53.4	51.2	34.0	-0.07	-284	-0.97	0.33		14	128.8	58.8	117.2	-0.23	-21	-1.09	0.27	
SD./Green Fil.																		
>= 6225ft	46	52.2	46.0	42.3	0.07	73	0.68	0.50		7	135.1	40.8	119.3	0.52	11	1.50	0.13	
< 1000 days	34	46.2	45.7	31.0	0.28	155	2.28	0.02	+	4	139.7	42.0	122.7	0.33	2	0.34	0.73	
SD./Green Fil.																		
< 6225ft	45	54.7	56.5	32.2	-0.20	-198	-1.93	0.05	-	7	122.4	75.6	115.2	-0.81	-17	-2.40	0.02	-
>= 1000 days	57	57.8	54.2	34.0	-0.18	-294	-2.02	0.04	-	10	124.4	65.8	109.2	-0.33	-15	-1.25	0.21	

Note- for explanation of various terms above, refer to notes in Table 5.

TAHOE CITY TREND: (Focusing on Stalked Diatoms/Filamentous Green Algae)

NONE (2000-2015)

Discussion: Tahoe City results

Chl *a* data, and Chl *a* data separated based on lake elevation and time submerged are plotted in Fig. 16 for Tahoe City. Statistical results of the Mann-Kendall trend test along with values for mean, median and Std. Dev. are presented in Table 13. Tahoe City is different from the other sites in that there is typically only one type of algae predominant (stalked diatoms) at the sampling site. There are typically no blue-green algae in samples. Therefore separation of data based on lake elevation and time submerged, should not be needed to isolate trends specific to the stalked diatoms and filamentous green algae. The Mann-Kendall trend test results for Tahoe City indicated there was no significant trend for Chl *a* associated with stalked diatoms for all data (data not separated based on lake elevation or time submerged) during the recent period 2000-2015 (see upper graph in Figure 16). Data separated based on lake level (<6225 ft.) and time submerged (≥1000 days submerged) indicated a significant negative trend. Since this trend was not related to blue-green algae presence, one explanation is that the downward trend observed was due to generally low levels of Chl *a*, associated with lowered nutrient inputs, during the recent prolonged drought and lowered lake level. Looking at the overall trend for Tahoe City site (considering all data) however, we conclude there has been no statistically significant trend for the stalked diatoms and filamentous green algae.

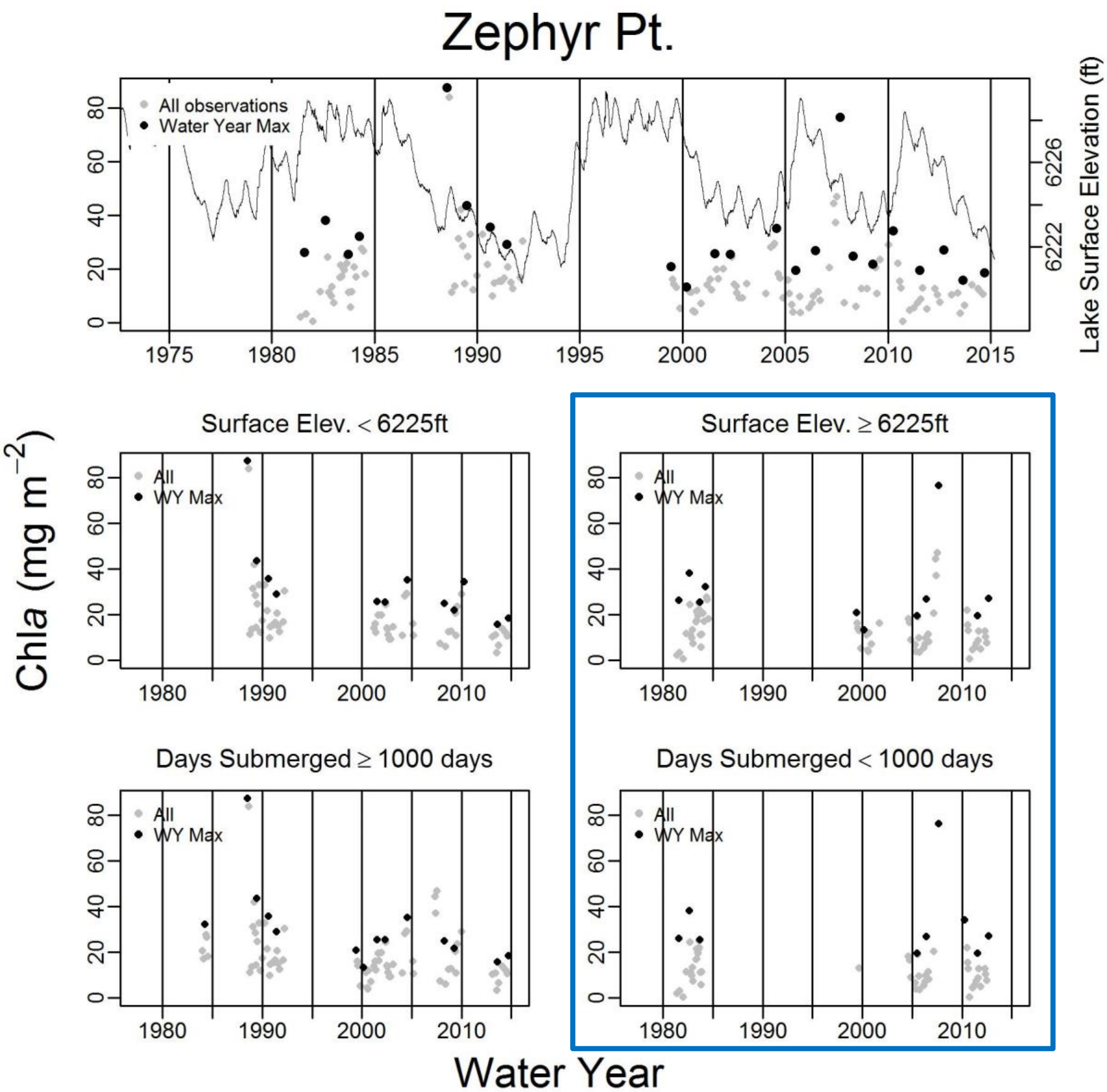


Fig. 17. Patterns for periphyton Chl *a* biomass at Zephyr Pt. The top graph shows a plot of periphyton mean Chl *a* on each sampling date (gray dots), water year maximum Chl *a* (black dots) and lake surface elevation (fluctuating line). The middle row graphs present data separated based on lake surface elevation at the time of sampling i.e. ≥ 6225 ft. or < 6225 ft. The bottom row graphs present data grouped according to amount of time the 0.5 m sampling site had been continuously submerged since last exposure at surface i.e. ≥1000 days or <1000 days. The two graphs enclosed by the blue rectangle represent biomass which is predominantly associated with stalked diatoms and filamentous green algae those algal groups that are most commonly associated with poor aesthetic quality.

Table 14. Summary statistics (mean, median, std. dev.) and Mann-Kendall trend test statistics results for periphyton Chlorophyll *a* monitoring data collected at Zephyr Pt.

(a) Zephyr Pt.

	All									Water Year Max								
	#	Mean	SD	Med	*Tau*	*S*	*z*	*p*		#	Mean	SD	Med	*Tau*	*S*	*z*	*p*	
Entire period																		
All obs.	146	18.2	13.4	15.1	-0.15	-1590	-2.69	<0.01	-	23	31.5	17.6	26.2	-0.33	-83	-2.17	0.03	-
SD./Green Fil.																		
>= 6225ft	77	15.9	12.0	13.0	-0.08	-246	-1.08	0.28		11	29.6	16.9	26.2	-0.09	-5	-0.31	0.76	
< 1000 days	57	15.0	11.8	12.7	-0.07	-115	-0.78	0.43		9	32.6	17.5	26.8	0.00	0	0.00	1.00	
+ Blue-greens																		
< 6225ft	69	20.8	14.4	15.9	-0.28	-654	-3.38	<0.01	-	12	33.1	18.8	27.3	-0.73	-48	-3.22	<0.01	-
>= 1000 days	89	20.3	13.9	16.1	-0.23	-884	-3.13	<0.01	-	14	30.7	18.3	25.6	-0.56	-51	-2.74	<0.01	-
After 2000																		
All obs.	90	15.9	11.2	12.9	-0.06	-232	-0.81	0.42		15	27.0	14.9	24.9	-0.09	-9	-0.40	0.69	
SD./Green Fil.																		
>= 6225ft	48	15.0	13.4	11.7	0.02	18	0.15	0.88		7	29.1	21.4	21.0	0.33	7	0.90	0.37	
< 1000 days	34	14.4	13.4	10.9	-0.01	-5	-0.06	0.95		6	34.0	21.5	26.9	0.07	1	0.00	1.00	
+ Blue-greens																		
< 6225ft	42	16.8	8.0	14.1	-0.14	-123	-1.32	0.19		8	25.2	6.8	25.2	-0.50	-14	-1.61	0.11	
>= 1000 days	56	16.7	9.6	14.0	0.02	36	0.25	0.80		9	22.4	6.5	21.8	-0.17	-6	-0.52	0.60	

Note- for explanation of various terms above, refer to notes in Table 5.

ZEPHYR PT. TREND: (Focusing on Stalked Diatoms/Filamentous Green Algae)

NONE (2000-2015; 1982-2015)

Discussion: Zephyr Pt. results

Chl *a* data, and Chl *a* data separated based on lake elevation and time submerged are plotted in Fig. 17 for Zephyr Pt. Statistical results of the Mann-Kendall trend test along with values for mean, median and Std. Dev. are presented in Table 14. The Mann-Kendall trend test results for Zephyr Pt. indicate there was no significant trend for periphyton Chl *a* for all data (data not separated based on lake elevation or time submerged) during the recent period 2000-2015 (see upper graph in Fig. 17). When the data for 2000-2015 was separated based on lake level (≥6225 ft.) and length of time site was submerged (<1000 days), similarly there was no significant trend for Chl *a* biomass. Therefore, there was no significant trend for Chl *a* biomass associated with the stalked diatoms and or filamentous green algae at Zephyr Pt. during 2000-2015. In contrast there was a statistically significant negative trend for all data (data not separated based on lake elevation or time submerged) 1982-2015 at Zephyr. When the 1982-2015 data was separated based on lake level and length of time site was submerged, there was a statistically significant negative (decreasing) trend for Chl *a* biomass for the data associated with blue-green algae presence (<6225 ft.; ≥1000 days submerged) but not for the data associated with the green filamentous algae and stalked diatoms. The negative trend 1982-2015 was primarily associated with periphyton containing blue green algae. This site is located adjacent to an area characterized with heavy development along the southeast shore.

3.b.2. Trends for Routine Sites, by Region

To see patterns for Chl *a* through time for general regions around the lake, data for Chl *a* for routine sites were separated into groups and trends analyzed using the Mann Kendall trend test. The following groups were used: West Region (Rubicon Pt., Sugar Pine Pt., Pineland); North Region (Tahoe City, Dollar Pt., Incline Condo, Incline West); East Region (Sand Pt., Deadman Pt., Zephyr Pt.). Site mean Chl *a* values for each sampling date were plotted against time for routine sites; the data were also separated based on surface elevation (<6225 ft., ≥6225 ft.) and time submerged (<1000 days submerged, ≥1000 days submerged) and plotted in Figs. 18-20. The results of the trend analysis (Tables 15-17) showed there were a few regional trends.

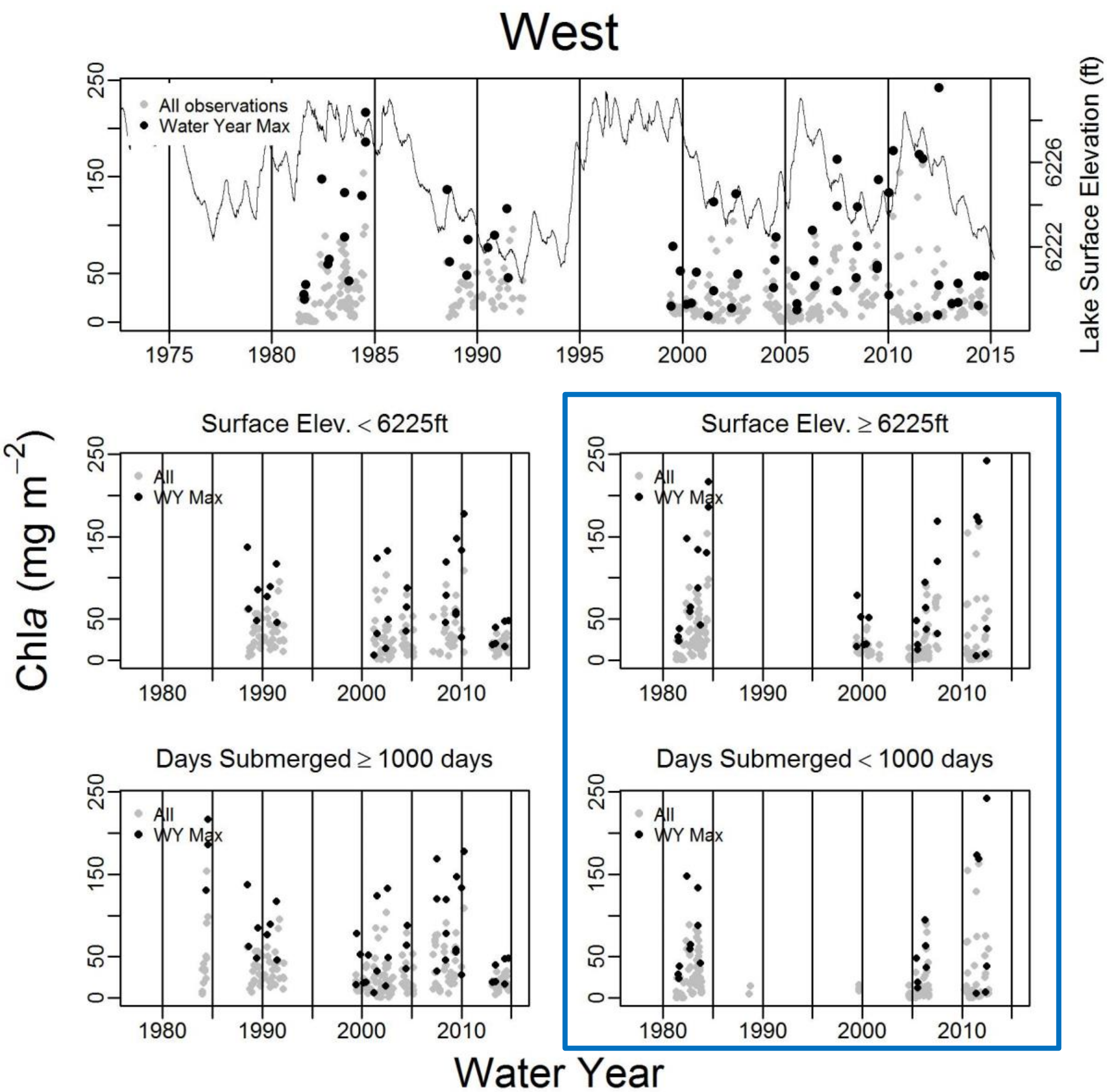


Fig. 18. Patterns for periphyton Chl *a* biomass for routine sites in the West Region. The top graph shows a plot of periphyton mean Chl *a* on each sampling date (gray dots), water year maximum Chl *a* (black dots) and lake surface elevation (fluctuating line). The middle row graphs present data separated based on lake surface elevation at the time of sampling i.e. ≥ 6225ft or <6225 ft. The bottom row graphs present data grouped according to amount of time the 0.5 m sampling site had been continuously submerged since last exposure at surface i.e. ≥1000 days or <1000 days. The two graphs enclosed by the blue rectangle represent biomass which is predominantly associated with stalked diatoms and filamentous green algae those algal groups that are most commonly associated with poor aesthetic quality.

Table 15. Statistical results by region for the West Region (Rubicon, Sugar Pine Pt., Pineland) routine site periphyton Chl *a* monitoring data.

(a) West

	All									Water Year Max							
	#	Mean	SD	Med	*Tau*	*S*	*z*	*p*		#	Mean	SD	Med	*Tau*	*S*	*z*	*p*
Entire period																	
All obs.	414	34.4	37.5	20.7	0.02	619	0.64	0.52		65	74.8	56.6	55.5	-0.03	-17	-0.26	0.79
SD./Green Fil.																	
>= 6225ft	232	32.9	41.5	17.7	-0.01	-85	-0.21	0.83		33	79.5	66.4	52.7	-0.02	-3	-0.09	0.93
< 1000 days	171	29.4	38.9	15.0	0.03	127	0.50	0.62		21	73.1	64.4	47.8	0.11	7	0.52	0.60
+ Blue-greens																	
< 6225ft	182	36.4	31.6	26.7	0.03	186	0.63	0.53		32	70.0	44.8	57.0	-0.01	-2	-0.05	0.96
>= 1000 days	243	38.0	36.0	26.0	0.00	-41	-0.09	0.93		44	75.7	53.2	57.0	-0.09	-28	-0.78	0.44
After 2000																	
All obs.	266	32.1	37.7	17.8	0.07	840	1.73	0.08		45	67.7	57.0	47.8	0.13	41	1.14	0.25
SD./Green Fil.																	
>= 6225ft	138	29.9	41.5	13.8	0.08	256	1.39	0.16		21	69.8	66.9	47.8	0.27	17	1.39	0.17
< 1000 days	92	29.4	45.5	9.6	0.22	299	2.97	<0.01	+	12	75.8	77.9	43.0	0.33	6	0.98	0.33
+ Blue-greens																	
< 6225ft	128	34.5	33.0	24.5	0.05	126	0.76	0.45		24	65.8	48.2	48.5	0.02	2	0.07	0.94
>= 1000 days	174	33.5	32.8	19.9	0.13	659	2.55	0.01	+	33	64.7	48.5	49.2	0.13	21	0.90	0.37

Note- for explanation of various terms above, refer to notes in Table 5.

WEST REGION TREND: (Focusing on Stalked Diatoms/Filamentous Green Algae)

NONE (2000-2015; 1982-2015)

Discussion:West Region Results

Chl *a* data, and Chl *a* data separated based on lake elevation and time submerged are plotted in Fig. 18 for the west region. Statistical results of the Mann-Kendall trend test along with values for mean, median and Std. Dev. are presented in Table 15. The Mann-Kendall trend test results for the west region indicate there was no significant trend for periphyton Chl *a* for all data (data not separated based on lake elevation or time submerged) during the recent period 2000-2015 (see upper graph in Figure 18). When the data for 2000-2015 was separated based on lake level (≥6225 ft.) there also was no trend. However, data separated based on length of time site was submerged (<1000 days) showed a positive trend for Chl *a* biomass. Since the data for (≥6225 ft.) and (<1000 days) did not both indicate a significant trend, and since there was no trend for data not separated based on elevation and time submerged, we conclude there was no overall significant trend for the stalked diatoms and or filamentous green algae for the west region during 2000-2015. In the west region for 1982-2015 data there showed no significant trend for periphyton biomass.

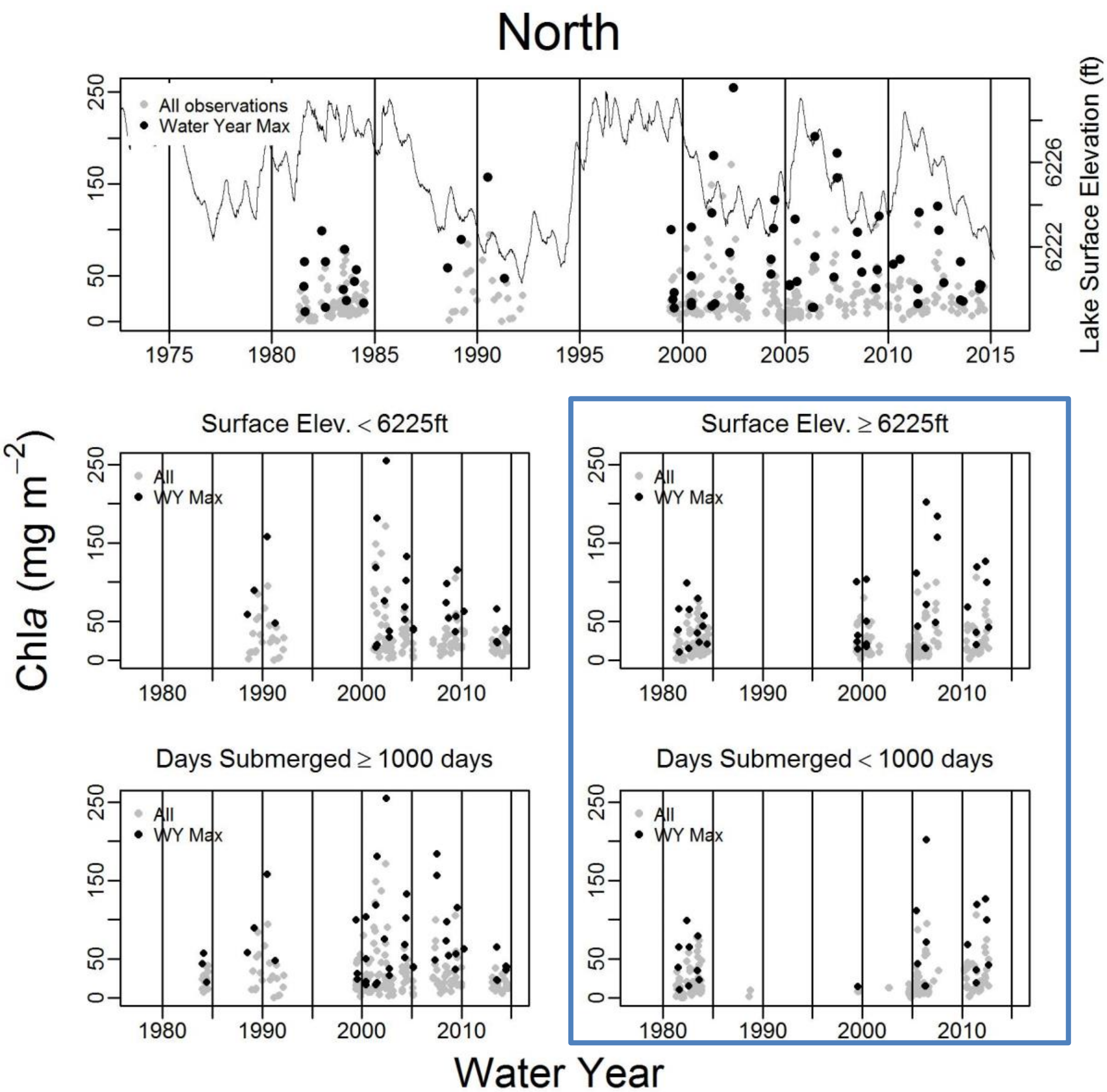


Fig. 19. Patterns for periphyton Chl *a* biomass for routine sites in the North Region. The top graph shows a plot of periphyton mean Chl *a* on each sampling date (gray dots), water year maximum Chl *a* (black dots) and lake surface elevation (fluctuating line). The middle row graphs present data separated based on lake surface elevation at the time of sampling i.e. ≥ 6225ft or <6225 ft. The bottom row graphs present data grouped according to amount of time the 0.5 m sampling site had been continuously submerged since last exposure at surface i.e. ≥1000 days or <1000 days. The two graphs enclosed by the blue rectangle represent biomass which is predominantly associated with stalked diatoms and filamentous green algae those algal groups that are most commonly associated with poor aesthetic quality.

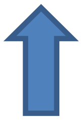
Table 16. Statistical results by region for the North Region (Tahoe City, Dollar Pt., Incline West, Incline Condo) routine site periphyton Chl *a* monitoring data.

(a) North

	All									Water Year Max								
	#	Mean	SD	Med	*Tau*	*S*	*z*	*p*		#	Mean	SD	Med	*Tau*	*S*	*z*	*p*	
Entire period																		
All obs.	439	31.4	33.1	20.0	0.04	967	1.17	0.24		67	67.3	51.0	51.8	0.00	-2	-0.02	0.98	
SD./Green Fil.																		
>= 6225ft	260	27.5	29.5	16.9	0.05	439	1.18	0.24		36	63.0	49.4	46.0	0.12	19	0.87	0.38	
< 1000 days	194	25.5	27.8	15.2	0.09	442	1.83	0.07		23	61.5	47.7	43.7	0.21	13	1.06	0.29	
+ Blue-greens																		
< 6225ft	179	37.0	37.1	24.5	-0.06	-250	-1.02	0.31		31	72.2	53.1	56.3	-0.20	-24	-1.31	0.19	
>= 1000 days	245	36.1	36.1	23.5	0.02	135	0.37	0.71		44	70.3	52.9	52.7	0.01	3	0.07	0.94	
After 2000																		
All obs.	316	33.3	35.5	20.0	0.02	266	0.53	0.60		51	70.7	54.4	51.8	-0.03	-10	-0.26	0.79	
SD./Green Fil.																		
>= 6225ft	164	30.1	33.5	17.3	0.12	404	2.17	0.03	+	24	71.6	55.9	49.0	0.44	28	2.30	0.02	+
< 1000 days	114	27.7	31.3	15.0	0.28	463	4.15	<0.01	+	14	70.3	55.3	55.7	0.45	10	1.54	0.12	
+ Blue-greens																		
< 6225ft	152	36.6	37.4	23.4	-0.07	-210	-1.21	0.23		27	69.8	54.1	53.7	-0.24	-20	-1.38	0.17	
>= 1000 days	202	36.4	37.4	22.8	0.04	205	0.79	0.43		37	70.8	54.8	51.8	0.03	4	0.14	0.89	

Note- for explanation of various terms above, refer to notes in Table 5.

NORTH REGION TREND: (Focusing on Stalked Diatoms/Filamentous Green Algae)



POSITIVE (2000-2015)

NONE (1982-2015)

<u>Discussion: North Region Results</u>

Chl *a* data, and Chl *a* data separated based on lake elevation and time submerged are plotted in Fig. 19 for the North Region. Statistical results of the Mann-Kendall trend test along with values for mean, median and Std. Dev. are presented in Table 16. The Mann-Kendall trend test results for the North region indicate there was no significant trend for periphyton Chl *a* for all data (data not separated based on lake elevation or time submerged) during the recent period 2000-2015 (see upper graph in Figure 19). When the data for 2000-2015 was separated based on lake level (≥6225 ft.) and length of time site was submerged (<1000 days) however, a positive trend for Chl *a* biomass. These results taken together suggest there was a positive trend for Chl *a* biomass associated with the stalked diatoms and or filamentous green algae in the north region during 2000-2015 in the north region. In the north region for 1982-2015 data there was no significant trend for all periphyton biomass data.

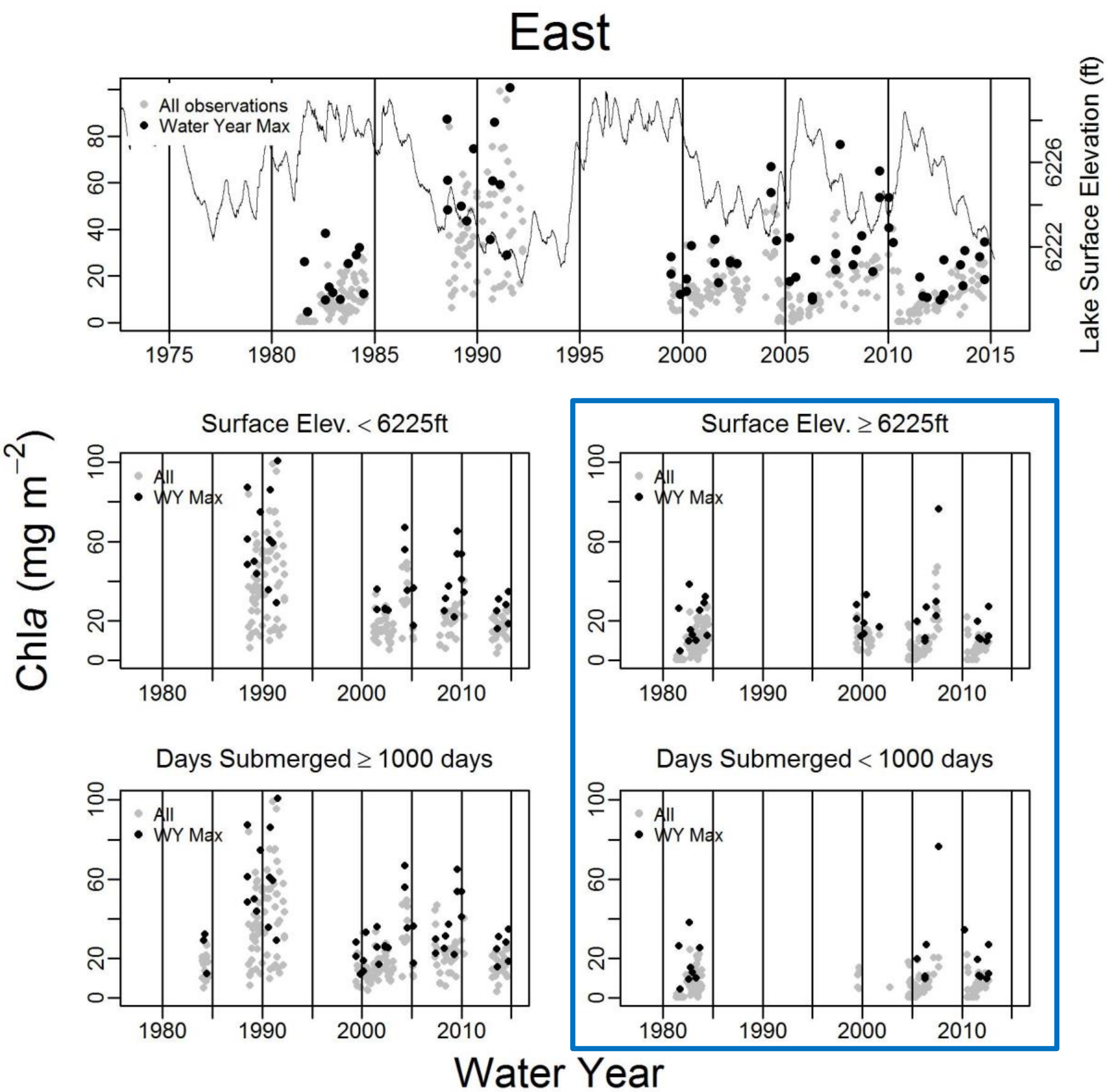


Fig. 20. Patterns for periphyton Chl *a* biomass for routine sites in the East Region. The top graph shows a plot of periphyton mean Chl *a* on each sampling date (gray dots), water year maximum Chl *a* (black dots) and lake surface elevation (fluctuating line). The middle row graphs present data separated based on lake surface elevation at the time of sampling i.e. ≥ 6225ft or <6225 ft. The bottom row graphs present data grouped according to amount of time the 0.5 m sampling site had been continuously submerged since last exposure at surface i.e. ≥1000 days or <1000 days. The two graphs enclosed by the blue rectangle represent biomass which is predominantly associated with stalked diatoms and filamentous green algae those algal groups that are most commonly associated with poor aesthetic quality.

Table 17. Statistical results by region for the East Region (Sand Pt., Deadman Pt., Zephyr Pt.) routine site periphyton Chl *a* monitoring data.

(a) East

	All									Water Year Max								
	#	Mean	SD	Med	*Tau*	*S*	*z*	*p*		#	Mean	SD	Med	*Tau*	*S*	*z*	*p*	
Entire period																		
All obs.	440	20.3	18.2	14.7	-0.01	-386	-0.37	0.71		68	33.1	21.1	27.6	-0.12	-87	-1.34	0.18	
SD./Green Fil.																		
>= 6225ft	231	11.0	9.7	8.9	0.03	298	0.76	0.45		31	20.8	13.5	18.7	-0.02	-3	-0.10	0.92	
< 1000 days	172	8.8	8.9	6.9	0.06	314	1.24	0.22		20	20.5	16.1	14.1	0.02	1	0.00	1.00	
+ Blue-greens																		
< 6225ft	209	30.6	19.8	24.9	-0.25	-1805	-5.32	<0.01	-	37	43.3	21.1	35.8	-0.49	-102	-3.83	<0.01	-
>= 1000 days	268	27.6	18.8	21.8	-0.13	-1533	-3.12	<0.01	-	48	38.3	20.9	31.8	-0.21	-77	-1.95	0.05	-
After 2000																		
All obs.	266	16.6	12.6	13.7	0.00	-25	-0.05	0.96		45	28.8	15.8	25.6	-0.03	-11	-0.29	0.78	
SD./Green Fil.																		
>= 6225ft	139	11.3	10.4	9.1	-0.08	-240	-1.29	0.20		20	21.5	14.9	19.1	-0.09	-5	-0.37	0.71	
< 1000 days	98	8.8	9.5	7.4	0.12	189	1.71	0.09		12	22.4	18.9	15.8	0.07	1	0.00	1.00	
+ Blue-greens																		
< 6225ft	127	22.5	12.2	19.9	0.05	131	0.80	0.42		25	34.6	14.2	31.3	-0.22	-20	-1.27	0.20	
>= 1000 days	168	21.2	11.9	18.4	0.18	823	3.35	<0.01	+	33	31.1	14.1	28.2	0.13	22	0.92	0.36	

Note- for explanation of various terms above, refer to notes in Table 5.

EAST REGION TREND: (Focusing on Stalked Diatoms/Filamentous Green Algae)

NONE (2000-2015; 1982-2015)

Discussion: East Region Results

Chl *a* data, and Chl *a* data separated based on lake elevation and time submerged are plotted in Fig. 20 for the East Region. Statistical results of the Mann-Kendall trend test along with values for mean, median and Std. Dev. are presented in Table 17. The Mann-Kendall trend test results for the East region indicate there was no significant trend for periphyton Chl *a* for all data (data not separated based on lake elevation or time submerged) during the recent period 2000-2015 (see upper graph in Fig. 20). When the data for 2000-2015 was separated based on lake level (≥6225 ft.) and length of time site was submerged (<1000 days) there was no trend for Chl *a* biomass. These results taken together suggest there was no trend for Chl *a* biomass associated with the stalked diatoms and or filamentous green algae in the east region during 2000-2015. Similarly, there was no temporal trend for the Chl *a* biomass associated with the stalked diatoms and or filamentous green algae in the east region during 1982-2015.

3.b.3. Trends for Routine Sites, by Level of Development

The association between periphyton biomass and level of development was also determined for routine and synoptic sites. Figure 21 provides a plan view of Lake Tahoe with the locations of routine periphyton monitoring sites, and the adjacent intervening zones (IVZ). The IVZ are color coded based on the estimated level of development. Detailed maps focusing on each intervening zone and the adjacent periphyton monitoring site are presented in Figs. 22-24.

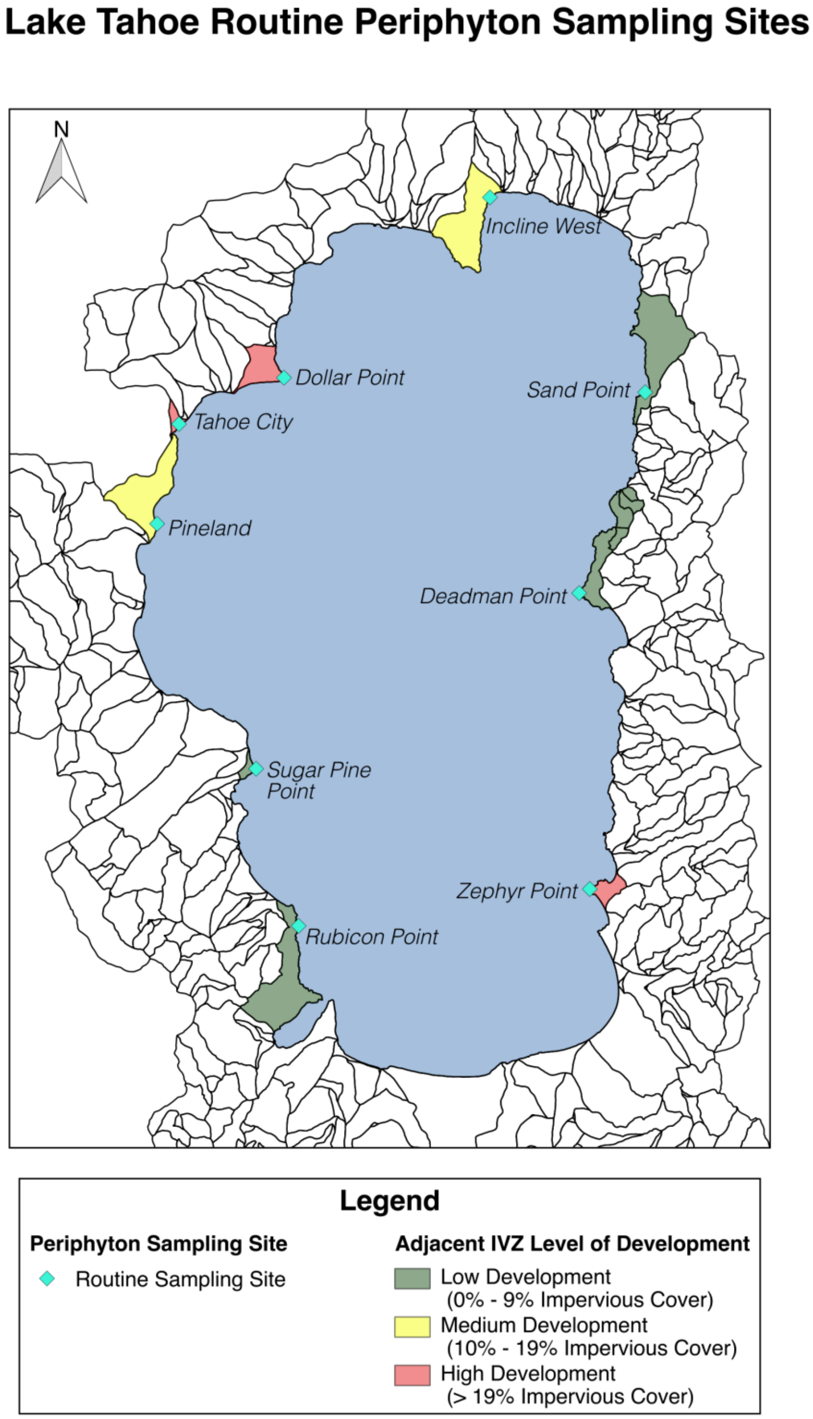


Fig. 21. Map of the routine periphyton monitoring sites and the adjacent intervening zones (IVZ). The IVZ are shaded based on the level of development as indicated in the legend.

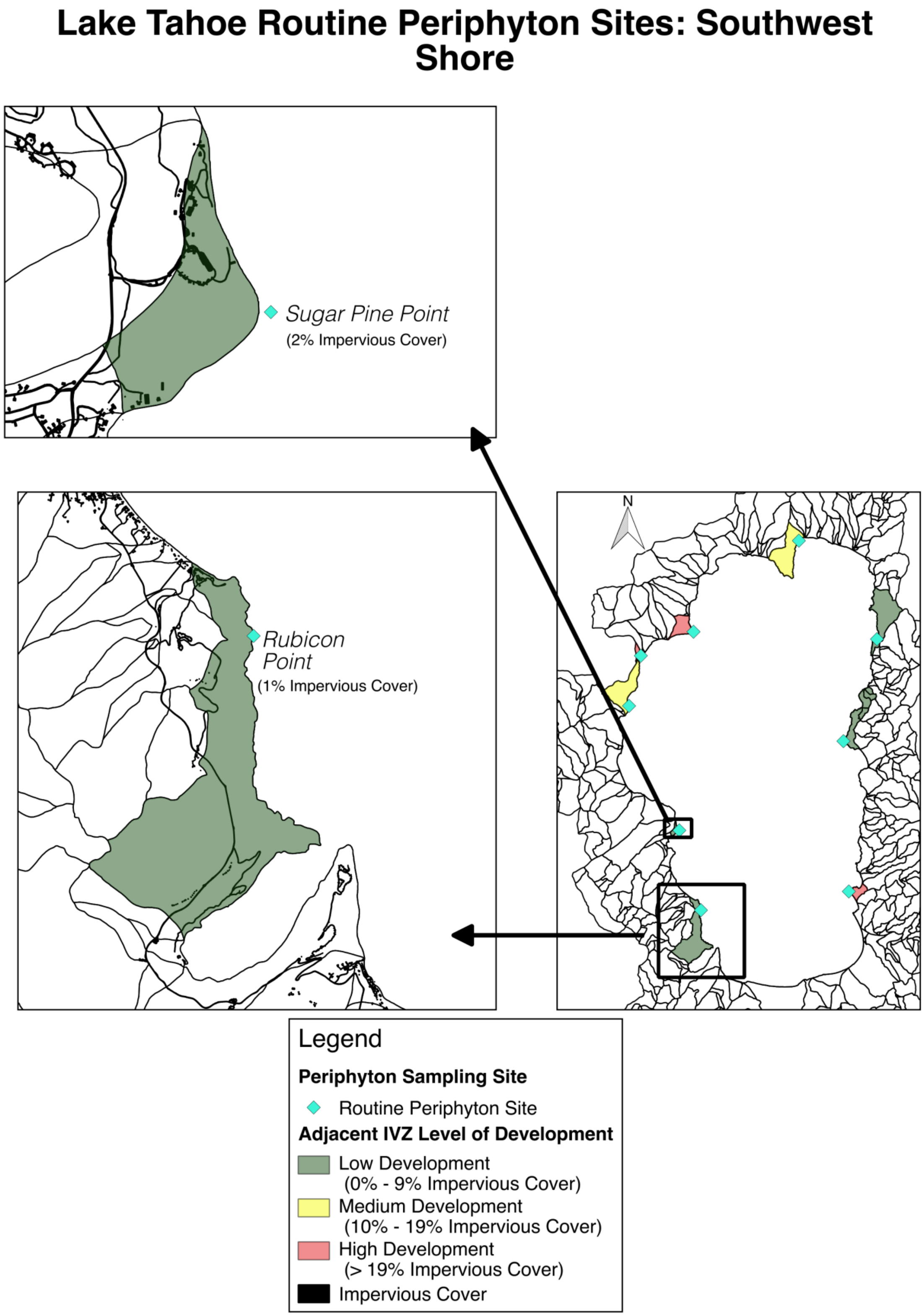


Fig. 22. Detailed maps of intervening zones adjacent to Rubicon Pt. and Sugar Pine Pt. routine periphyton monitoring sites.

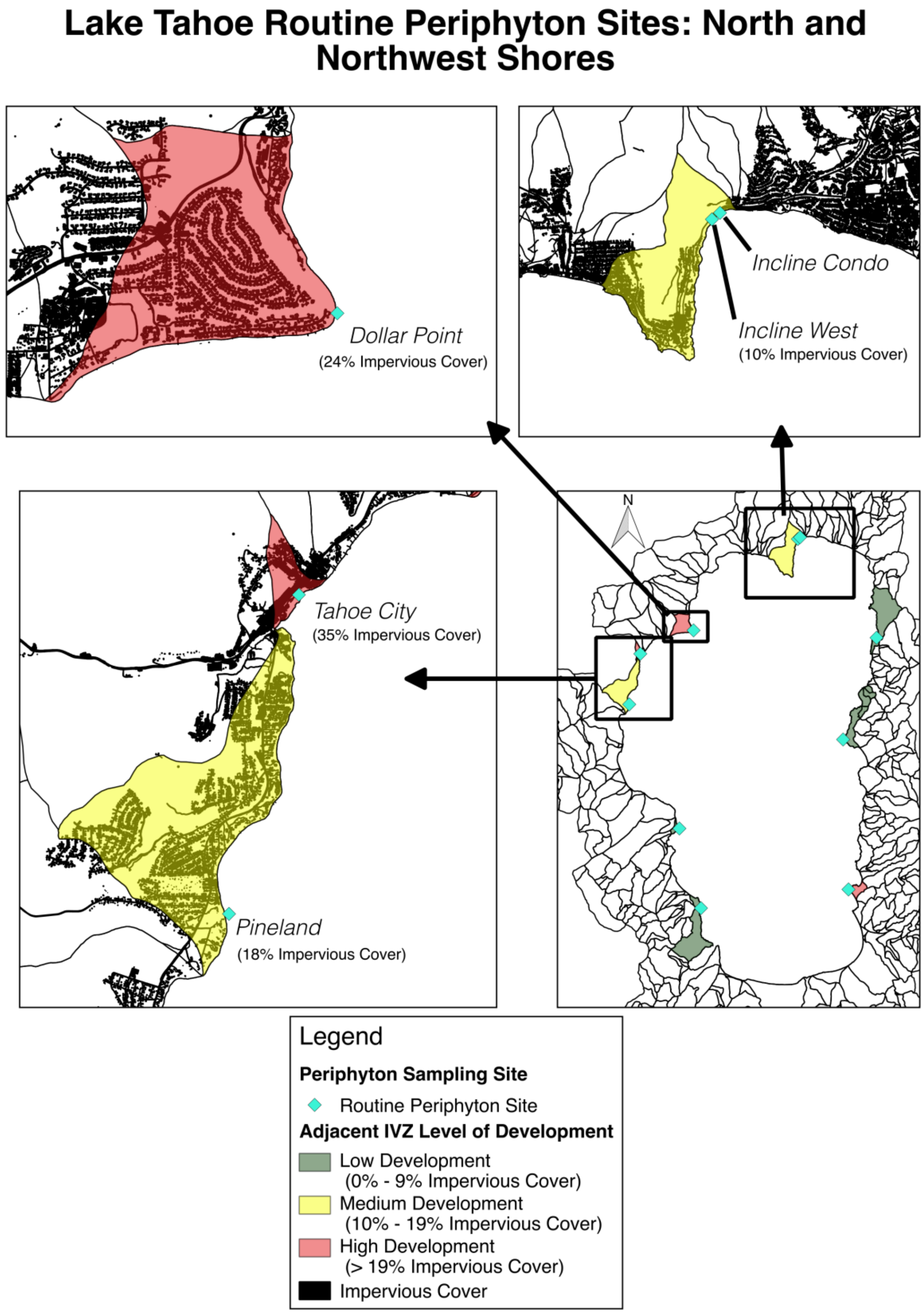


Fig. 23. Detailed maps of intervening zones adjacent to Pineland, Tahoe City, Dollar Point and Incline West routine periphyton monitoring sites.

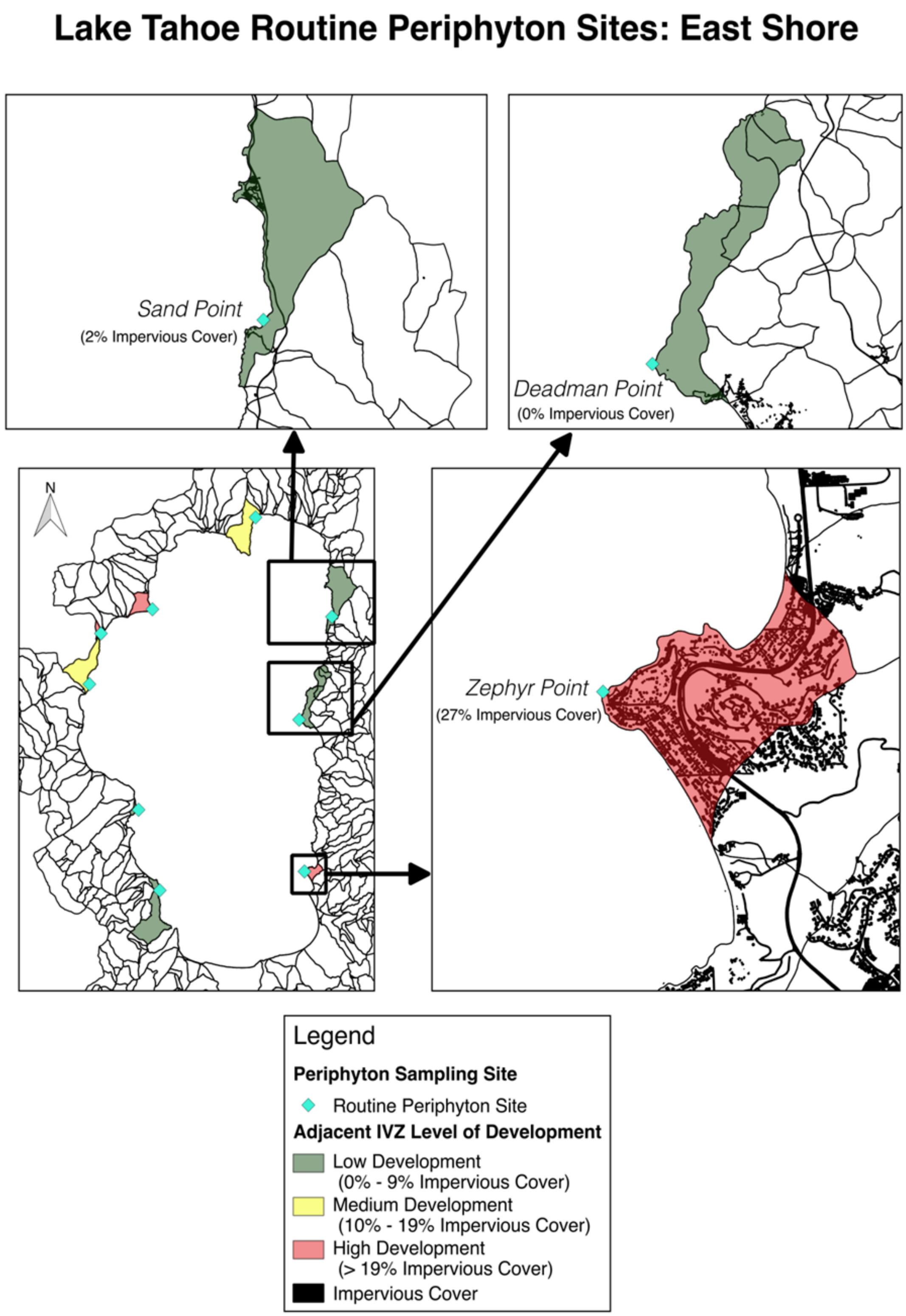


Fig. 24. Detailed maps of intervening zones adjacent to Sand Pt., Deadman Pt. and Zephyr Pt. routine periphyton monitoring sites.

The Kruskal-Wallis test revealed a significant association between the level of development in the intervening zone, and amounts of periphyton biomass ($H(2) = 68.431$, $p < 0.05$). Inspection of mean Chl *a* values calculated for each level of development suggest higher amounts of biomass tended to be associated with higher levels of development in the adjacent intervening zone (Figure 25).

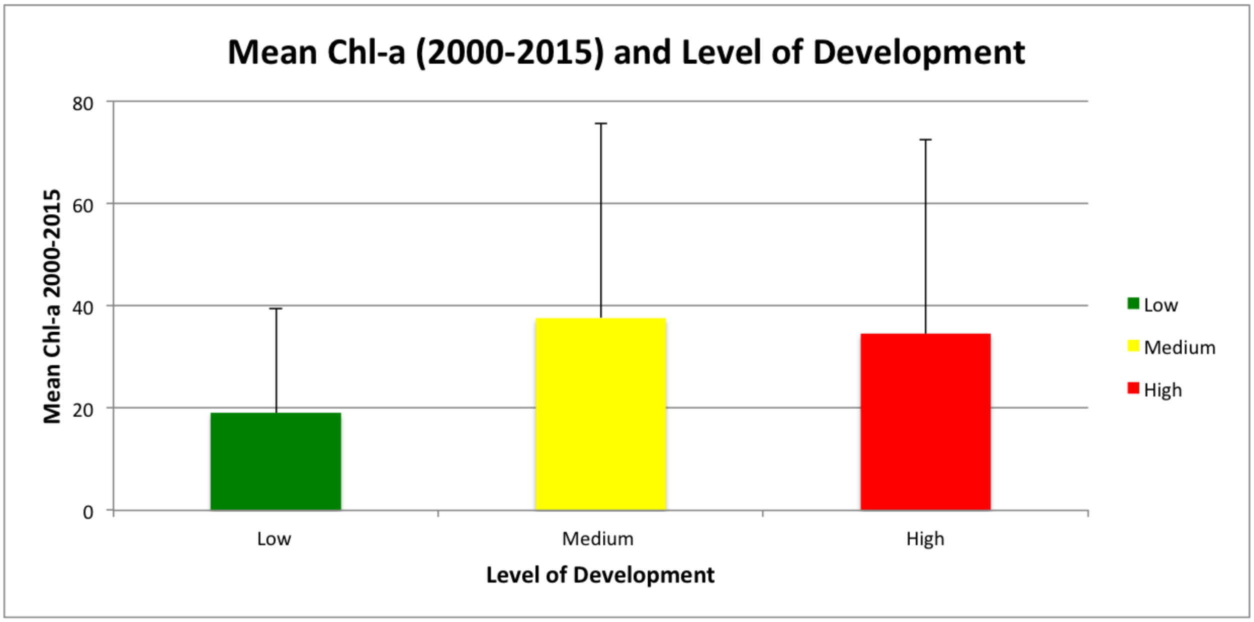


Figure 25. Mean Chlorophyll a concentration for routine periphyton sampling sites (2000-2015) grouped by level of development. Vertical error bars represent one standard deviation.

Table 18 presents a summary of biomass estimates for individual routine sites grouped by IVZ development ratings, and the estimated trends in biomass over time. Low levels of development were associated with low mean Chl *a* at Sugar Pine Pt., Sand Pt. and Deadman Pt. Several sites with higher levels of Chl *a* were in the medium and high development categories. However, two sites differed from this general relationship: Rubicon Pt. is adjacent to an IVZ with a low level of development, yet the mean chlorophyll a was relatively high (30 mg/m^2) compared to other low development sites for which the mean ranged from 12-19 mg/l. In contrast, Zephyr Point is adjacent to an IVZ with a high level of development, yet the mean Chl *a* concentration (16 mg/l) was more similar to levels observed at sites adjacent to a low development areas. These two contrary results suggest other localized factors also influence periphyton biomass levels over the long term. Such factors include hydrologic connectivity among sub-watersheds adjacent to the intervening zone, which directly affects the total amount of nutrients and other material delivered to the lake through the intervening zone. Nearshore currents also play a role in determining the delivery and residence time of nutrients important to periphyton growth. In addition, regional inputs of nutrients such as from tributary inputs and lake upwelling also can impact periphyton biomass.

Looking at levels of development related to temporal trends for the routine sites, a majority of sites showed no trend during the recent 2000-2015 period. These included sites in all three (low, medium and high) development categories. Two sites adjacent to IVZ estimated to have medium levels of development, Pineland and Incline West, exhibited positive trends in periphyton biomass over the period. However it should be noted the magnitude of changes in biomass was relatively small. The level of development determinations used in this analysis are quite simplistic, and do not account for either of the factors identified here. The relationship between levels of development and periphyton biomass is assessed in greater detail with respect to the synoptic PBI data (see Section 3.c.3.).

Table 18. Summary of routine site intervening zone (IVZ) development ratings, overall mean Chlorophyll a concentration for the periods 1982-2015 and 2000-2015 and observed trends for 1982-2015 and 2000-2015 (based on summaries presented in Section 3.B.1.)

	IVZ Level Development	1982-2015 Mean Chl *a* (mg/m^2)	2000-2015 Mean Chl *a* (mg/m^2)	1982-2015 MeanWY Max Chl *a* (mg/m^2)	2000-2015 MeanWY Max Chl *a* (mg/m^2)	Trend 1982-2015	Trend 2000-2015
Rubicon Pt.	Low	32	30	71	65	None	None
Sugar Pine Pt.	Low	20	12	36	26	Negative	None
Sand Pt.	Low	23	16	37	30	None	None
Deadman Pt.	Low	20	19	31	30	None	None
Pineland	Medium	48	54	110	112	Positive	Positive
Incline West	Medium	18	21	31	35	Positive	Positive
Incline Condo	Medium	19	16	39	30	None	None
Tahoe City	High	-	53	-	128	-	None
Dollar Pt.	High	36	34	73	71	None	None
Zephyr Pt.	High	18	16	32	27	None	None

3.b.4. Lake-wide Trend for Routine Sites

The data from all routine sites was combined to determine overall lake-wide trends (Fig. 26). Statistical results are presented in Table 19

LAKE-WIDE TREND: (Focusing on Stalked Diatoms/Filamentous Green Algae)

NONE (2000-2015; 1982-2015)

<u>Discussion: All Routine Sites Trend</u>

Chl *a* data, and Chl *a* data separated based on lake elevation and time submerged are plotted in Fig. 26 for all routine sites combined. Statistical results of the Mann-Kendall trend test along with values for mean, median and Std. Dev. are presented in Table 19. The Mann-Kendall trend test results for all routine sites combined indicate there was no significant trend for periphyton Chl *a* for all data during the recent period 2000-2015 (see upper graph in Figure 26). When the data for 2000-2015 was separated based on lake level (≥ 6225 ft.) similarly there was no trend, while data separated based on length of time site was submerged (<1000 days) indicated a positive trend for Chl *a* biomass. Since the data for (≥ 6225 ft.) and (<1000 days) did not both indicate a significant trend, and since there was no trend for data not separated based on elevation and time submerged, we conclude there was no overall significant trend for the stalked diatoms and or filamentous green algae for all routine sites combined during 2000-2015. A similar conclusion of no overall trend was reached for the 1982-2015 data.

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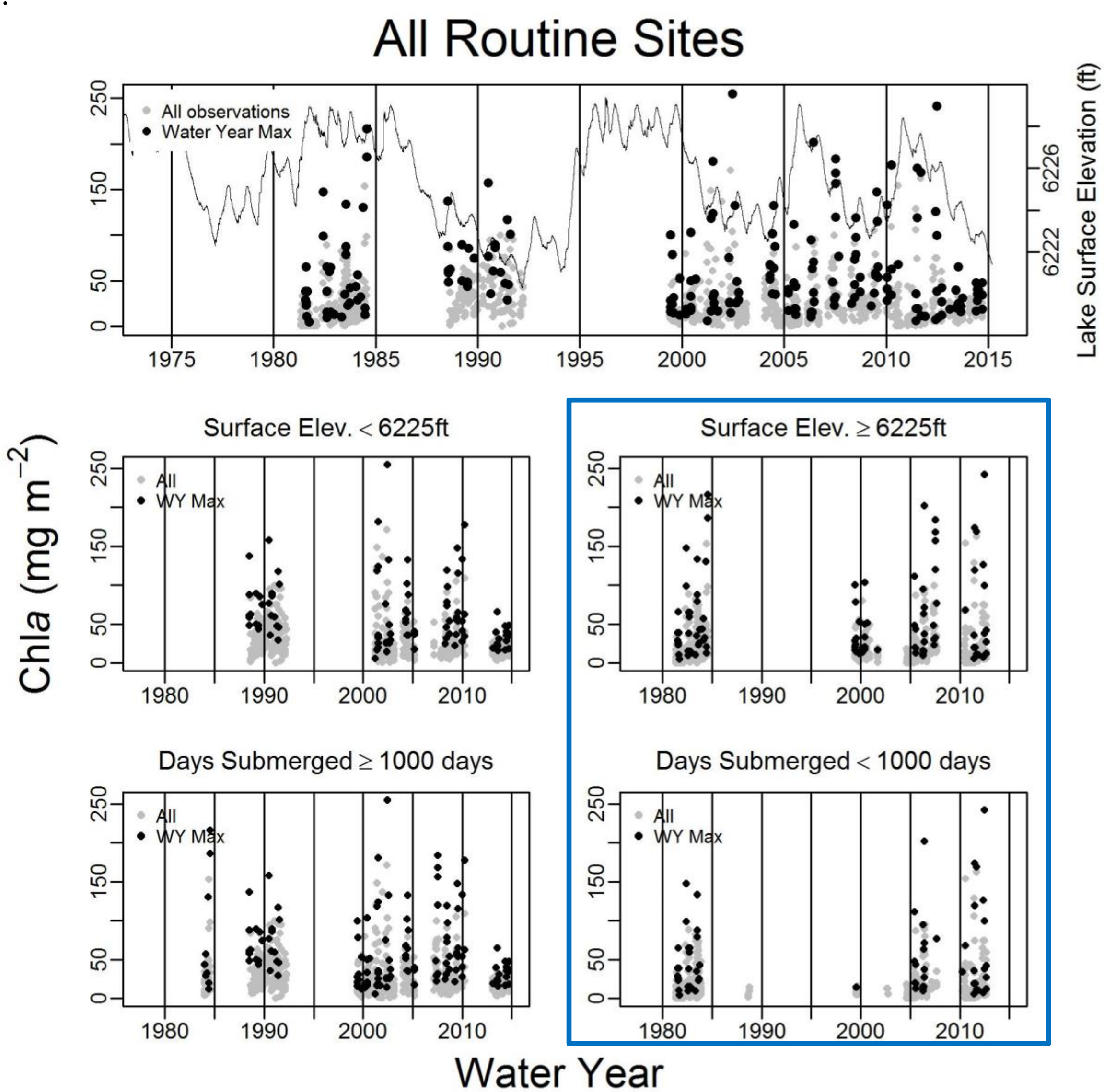


Fig. 26. Patterns for periphyton Chl *a* biomass for routine sites lake-wide. The top graph shows a plot of periphyton mean Chl *a* on each sampling date (gray dots), water year maximum Chl *a* (black dots) and lake surface elevation (fluctuating line). The middle row graphs present data separated based on lake surface elevation at the time of sampling i.e. ≥ 6225ft or < 6225 ft. The bottom row graphs present data grouped according to amount of time the 0.5 m sampling site had been continuously submerged since last exposure at surface i.e. ≥1000 days or <1000 days. The two graphs enclosed by the blue rectangle represent biomass which is predominantly associated with stalked diatoms and filamentous green algae those algal groups that are most commonly associated with poor aesthetic quality.

Table 19. Statistical results for all routine sites based on combining all routine site periphyton Chl *a* monitoring data.

All routine observations

	All									Water Year Max								
	#	Mean	SD	Med	*Tau*	*S*	*z*	*p*		#	Mean	SD	Med	*Tau*	*S*	*z*	*p*	
Entire period																		
All obs. SD./Green Fil.	1293	28.6	31.1	18.5	0.01	1200	0.73	0.46		200	58.1	48.7	40.5	-0.05	-106	-1.02	0.31	
>= 6225ft	723	24.0	31.3	13.5	0.02	652	0.97	0.33		100	55.4	54.2	32.7	0.03	13	0.33	0.74	
< 1000 days	537	21.4	29.4	11.4	0.06	883	2.05	0.04	+	64	52.5	51.8	35.5	0.11	21	1.00	0.32	
+ Blue-greens																		
< 6225ft	570	34.4	30.0	25.2	-0.11	-1869	-3.66	<0.01	-	100	60.8	42.7	48.3	-0.26	-128	-3.28	<0.01	-
>= 1000 days	756	33.7	31.4	23.6	-0.05	-1439	-1.91	0.06		136	60.7	47.2	47.4	-0.11	-102	-1.71	0.09	
After 2000																		
All obs. SD./Green Fil.	848	27.7	31.9	17.3	0.03	1081	1.27	0.20		141	56.3	50.2	37.2	0.02	20	0.31	0.75	
>= 6225ft	441	24.1	32.6	12.9	0.04	420	1.31	0.19		65	55.6	55.8	31.3	0.22	40	1.98	0.05	+
< 1000 days	304	22.1	33.2	10.5	0.21	951	5.11	<0.01	+	38	56.9	59.6	35.1	0.31	17	1.70	0.09	
+ Blue-greens																		
< 6225ft	407	31.5	30.7	22.0	0.01	47	0.16	0.87		76	57.0	45.2	40.0	-0.15	-38	-1.50	0.13	
>= 1000 days	544	30.8	30.8	20.4	0.11	1687	3.84	<0.01	+	103	56.1	46.5	38.8	0.10	47	1.21	0.23	

Note- for explanation of various terms above, refer to notes in Table 5.

3.c. Trends for Synoptic Sites

Once each spring, intensive synoptic sampling of approximately 40 additional sites is completed in combination with monitoring of routine sites. This sampling is timed to occur when periphyton biomass reaches its spring peak. It includes collection of biomass samples (Chl *a*) at a portion of the sites, as well as a rapid assessment method for PBI (Periphyton Biomass Index).

One goal of this section of the periphyton data analysis was to see if time trends in the synoptic site data could be determined using statistical analysis. However, some caution must be exercised with respect to the extent that meaningful trends may be determined from this data due to the following reasons:

1) The synoptic sampling monitoring was not specifically designed to capture inter-annual trends. It was designed to provide more spatial resolution of patterns of biomass around the lake during the period close to the annual maximum biomass. A monitoring program designed to capture inter-annual trends would need to either include more frequent sampling to capture the true peak biomass in the spring or to include frequent, regular monitoring throughout the year to allow determination of an accurate annual mean biomass for comparisons between years.
2) Although we attempt to capture the peak biomass at many sites during synoptic monitoring, the peak may not be captured at all sites. The peak does not always occur at the same time at all sites around the lake. We adjust the timing of the sampling for some regions to account for this, but still may not capture the peak biomass. In addition due to weather conditions or other factors there may be delays in sampling so that the peak is missed. This can result in representative values of biomass from some sites that are lower than the true peak. When trend analysis is done, conclusions based on this data may not correctly represent the trend through time.
3) Due to the significant time involved both in field measurement and lab analysis, we are not typically able to collect Chl *a* data from each synoptic site; nor was the monitoring program designed to do this. Typically we collect chlorophyll data from about a third of the sites. This data is used to check the correlation with PBI, which is measured at all sites. As a result many of the sites are missing Chl *a* data for one or several years. This makes determination of temporal trends for Chl *a* statistically very difficult. This was the primary reason for the introduction of the PBI as a rapid assessment method.

Assessment of PBI and Chl *a* relationships have shown there is an association between the two but it is not always strong. There is quite a bit of variability in PBI relative to levels of Chl *a* in some years. Figure 27 presents examples of variation of the PBI to Chl a trend for three years.

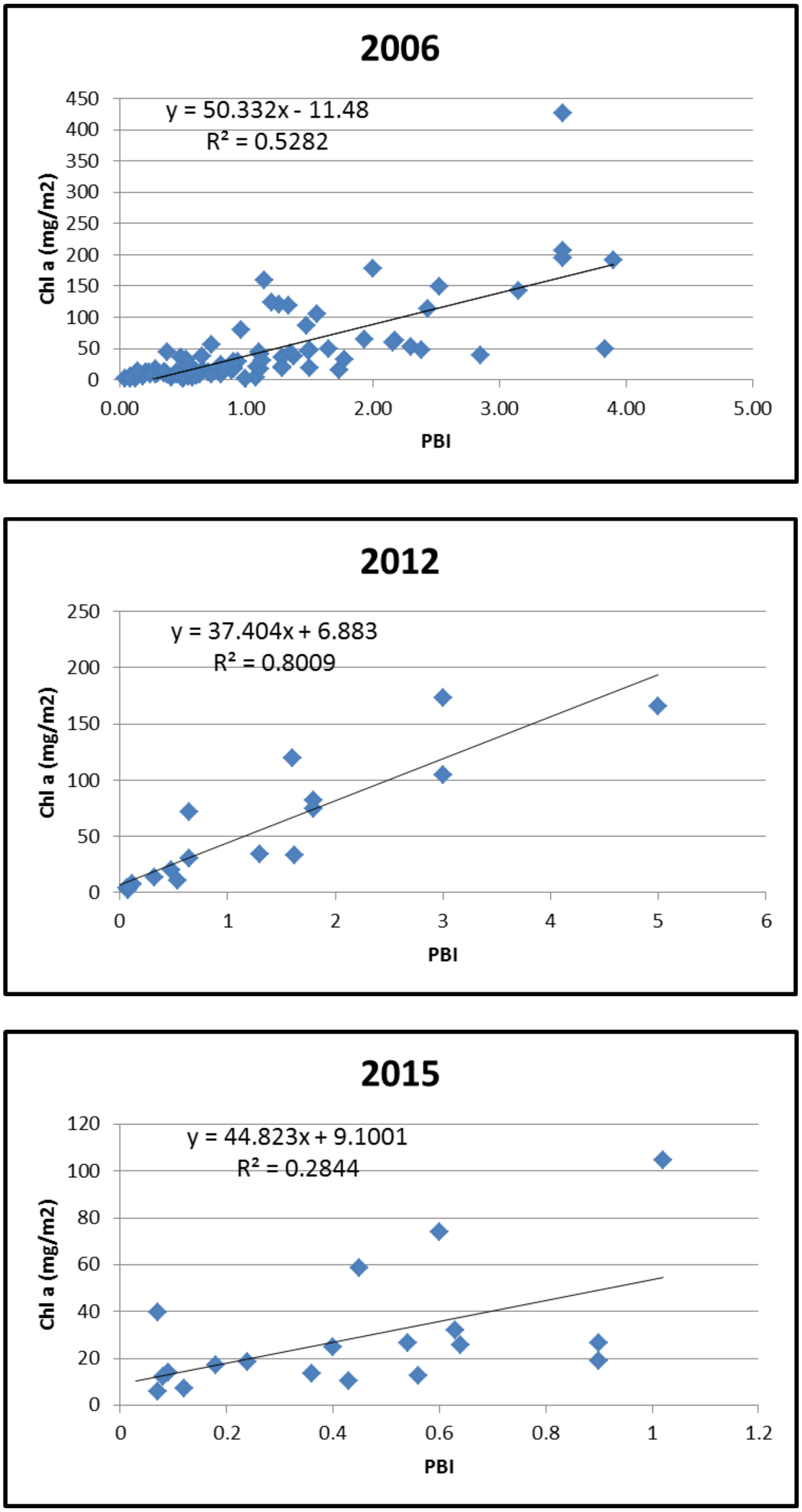


Figure 27. Examples of variability in PBI and Chl *a* association for spring synoptics done during 2006, 2012 and 2013.

The PBI relies on rapidly measured physical features of the overall periphyton mat (length, % coverage), while Chl *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 Chl *a* is a measure of live biomass. The divergence at times between PBI and Chl *a* biomass does not have to be problematic as they do not necessarily measure the same thing. Chl *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 40 sites in addition to the 9-10 routine sites. However, PBI and Chl *a* are not interchangeable, they measure different aspects of the periphyton biomass.

3.c.1. Trends for Synoptic Sites, by Site

A summary of all synoptic site Chl *a* data plotted against time for the period 2003-2015 is presented as a multi-panel figure below (Fig. 28). Inter-annual differences can be high at most sites, with the routine sites being the ones with consistent annual samplings. We did not attempt to statistically determine trends from this data, or to adjust data based on surface elevation or time of submergence, due to so few points associated with many of the sites. Visually it can be seen that for most sites the data are too limited to determine a trend. Many sites along the west and north-west (e.g. Rubicon, Ward Cr., Pineland, Tahoe City, Tahoe City Tributary, Dollar Pt., South Dollar Cr. and Incline West) shore show lower Chl *a* levels the past two years. We believe this may be an impact associated with the ongoing drought (with less nutrients entering the nearshore associated with surface and subsurface inputs).

The PBI measurements were collected each year. Again, these provide a different assessment of levels of periphyton than the Chl *a* measurements. The data for PBI versus time are presented in Fig. 29. For some sites, the pattern for PBI shows substantial fluctuation, with high peaks some years and low values in others. For other sites the PBI values are more consistent year to year. There did not appear to be any sites with a consistent downward or upward trend for PBI based on data presented in the plots.

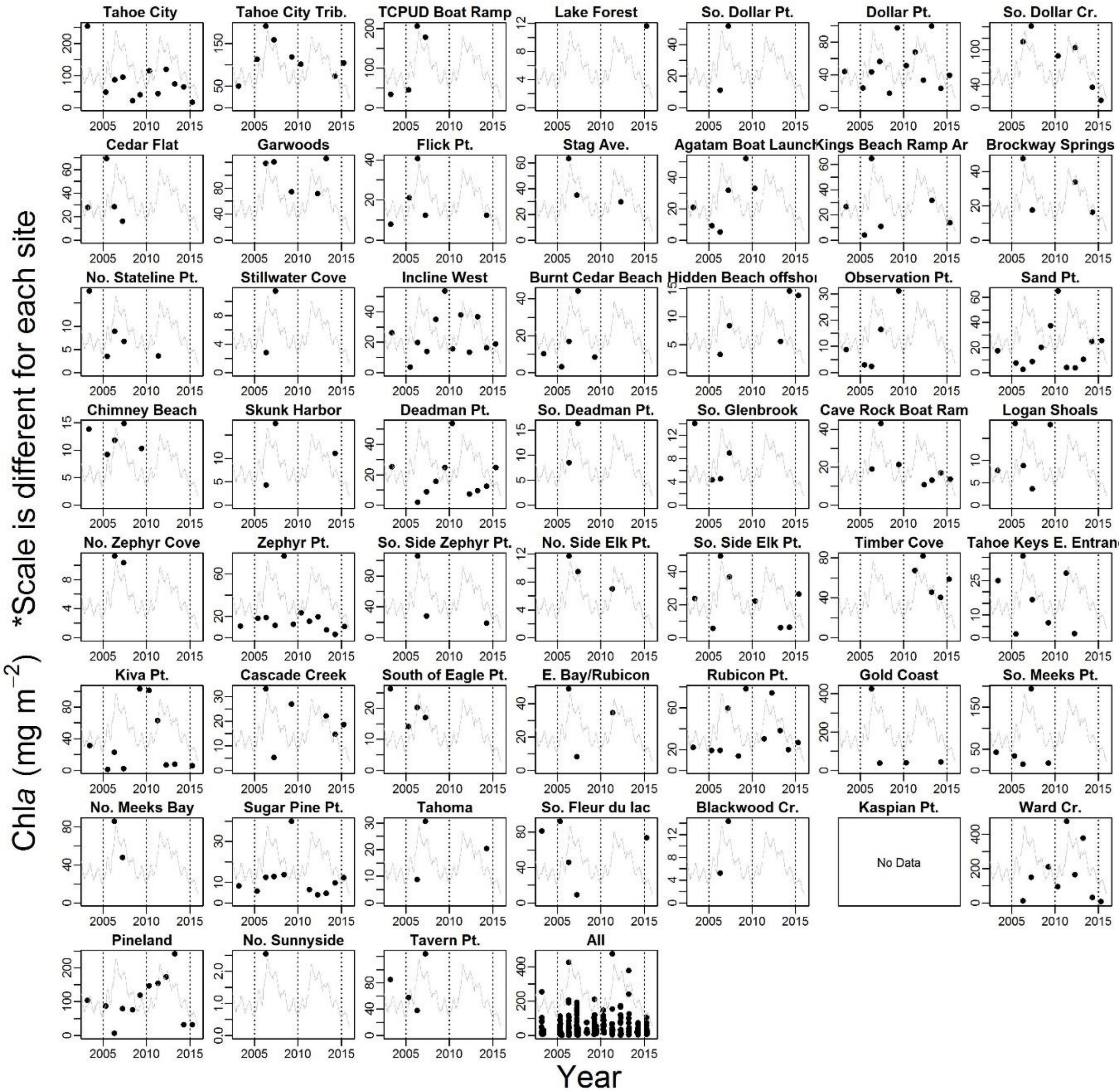


Fig. 28. Summary of all Chl *a* data at synoptic and routine sites through time for the period 2003-2015. Note, the y-axis scale is different for each plot. The last figure is a summary of all data for the period.

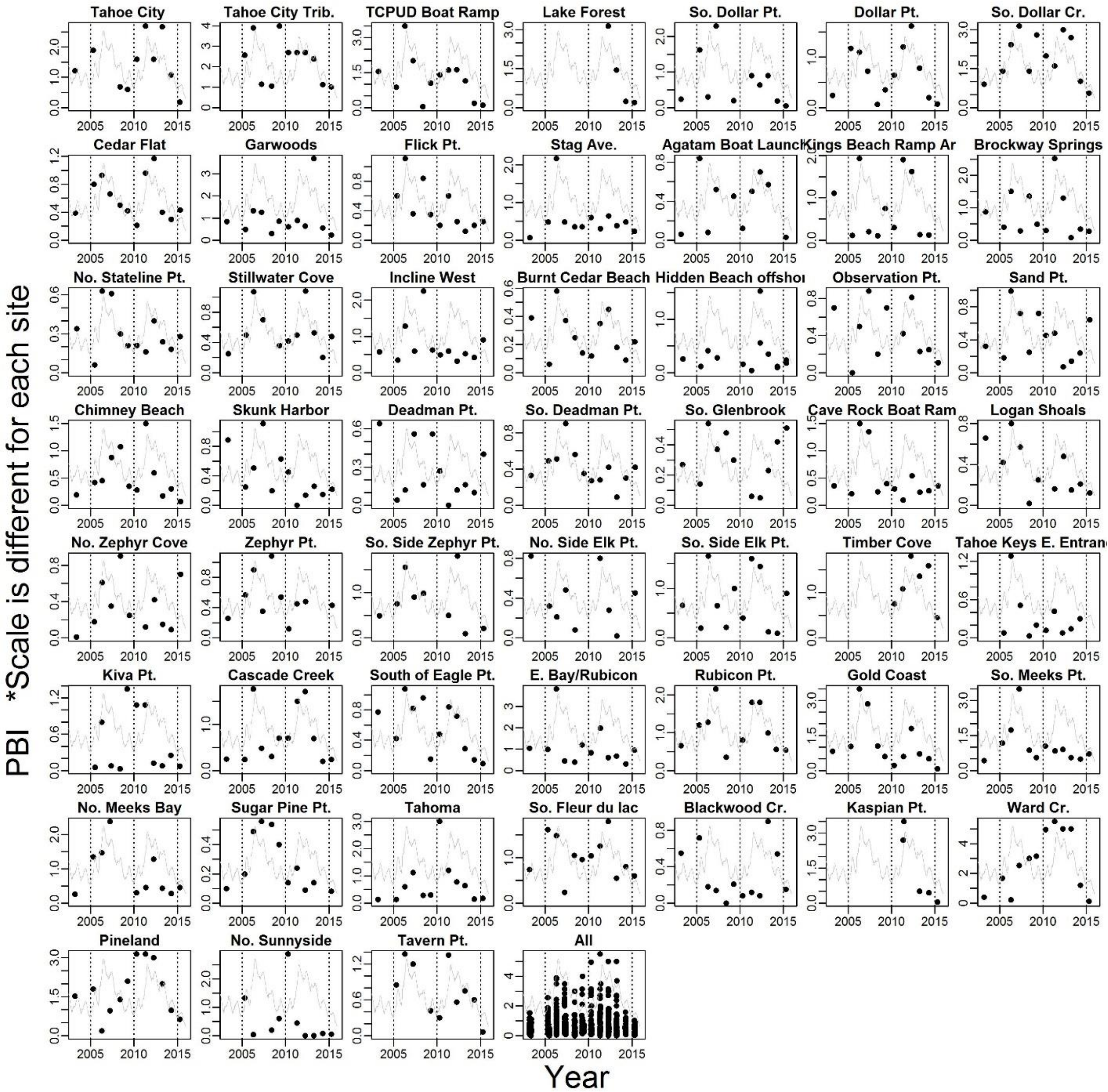


Fig. 29. Summary of all PBI data at synoptic and routine sites through time for the period 2003-2015. PBI is calculated as the % coverage x Length of algae (cm). Note- the y-axis scale is different for each site. The last figure is a summary of all data for the period.

3.c.2. Trends for Synoptic Sites, by Region

The synoptic Chl *a* and PBI data were grouped by region to see if any trends were apparent (the plots of these data and the statistics are included in Appendix 1 (Figs. 39-46). Synoptic sites were grouped into regions as follows: West= Site # 39 Emerald Bay/ Rubicon to #52 Tavern Pt., North= #1-Tahoe City to #18-Burnt Cedar Beach, East = #19 Hidden Beach to #33 South Elk Pt., South= #34 Timber Cove to #39 South of Eagle Pt. Data from 2005 and 2008 was not used since the spring peaks may have been missed at several sites those years; there also was no data for 2004). These grouped data were evaluated for trends using the Mann Kendall test and the results (graphs and data tables) are presented in Appendix 1 (Tables 26-33).

REGIONAL TRENDS FOR SYNOPTIC SITE CHLOROPHYLL A: (West, North, East, South)

POSSIBLY NONE (2003-2015) but small sample sizes and not all sites used from each region. Results must be interpreted with caution.

The results of the Mann Kendall tests indicated there were no statistically significant temporal trends by region for Chl *a* data. Caution should be exercised in interpretation of these results however (as well as for the PBI trends below). The Mann-Kendall test drops the sample sites with less than 4 observations. As a result a portion of the sites from each region were excluded from the analysis by the test. So the Mann-Kendall test was not ideal for analysis of this data set with limited data. In the North region, a significant negative trend was found when all data was used, however, when data was separated based on lake elevation (≥ 6225 ft.) and time submerged (>1000 days) there was no significant trend. Therefore we consider there to have been no significant trend for the stalked diatom and filamentous green algae in this region. There were no other significant trends for chlorophyll between the regions.

REGIONAL TRENDS FOR SYNOPTIC SITE PBI: (West, North, East, South)

POSSIBLY NEGATIVE (2003-2015) but small sample sizes and not all sites used from each region. Results must be interpreted with caution.

The synoptic PBI data were also grouped by region to see if any trends were apparent (see Appendix 1). These grouped data were evaluated for trends using the Mann Kendall test and the results are presented in tables under each figure in Appendix 1. The test was performed only on the sampled sites with more than five observations in the study period. The Mann-Kendall test drops the sample sites with less than four observations. As a result a portion of the sites from each region were excluded from the analysis by the test. So the Mann-Kendall test was not ideal for analysis of this data set with limited data. The results of the Mann Kendall tests indicated that there were statistically significant negative trends for PBI for the period 2003-2015 for all four regions (west, north, east, south). However, due to the potential limitations of the Mann-Kendall test described above when used with small sample sizes, we would not consider these results as definitive indicators of trend for the regions.

We also looked at spatial trends in synoptic periphyton PBI by region. Table 20 presents mean, median, Std. Dev., percentiles and ranges for PBI data at synoptic sites grouped by region. The data show that levels for mean PBI were highest along the west (mean PBI=1.03) and north shores (mean PBI=0.88), followed by the south shore (mean PBI=0.67), the east shore had the lowest values (mean PBI=0.45). PBI ranged the highest on the West Shore (Max. PBI=5.5), followed by the North Shore (Max. PBI=4.0), South Shore (Max. PBI=0.90) and then the east shore Max. PBI=0.90).

Table 20. Summary of mean, median, standard deviation, percentiles and range for all synoptic sites by region.

	West Reg.	North Reg.	East Reg.	South Reg.
Mean	1.03	0.88	0.45	0.67
Std. Dev.	1.14	0.87	0.38	0.53
n	131	169	145	43
10th Percentile	0.09	0.16	0.09	0.10
25th Percentile	0.29	0.25	0.16	0.20
50th Percentile (median)	0.60	0.57	0.35	0.51
75th Percentile	1.27	1.14	0.57	1.08
90th Percentile	2.85	2.32	0.90	1.47
Range - Low	0.00	0.03	0.00	0.07
Range - High	5.50	4.00	1.80	1.80

Figure 30 below, shows the contribution, to PBI biomass, of each land use region relative to the lake-wide mean for PBI. Overall, the percent contribution was similar from year to year, although values were not uniform. Sites in the western region contributed the most to lake-wide PBI with a mean of 33 percent (range = 24-46 percent). The northern region had the second highest relative contribution with a mean of 28 percent (18-39 percent). Sites in the southern part of the lake showed the widest range over the 10 years relative to their absolute values; mean of 24 percent (13-32 percent), and somewhat less than for the north. Consistent with other results in this report, the eastern region showed the lowest relative contribution, with a mean of 14 percent (6-24 percent).

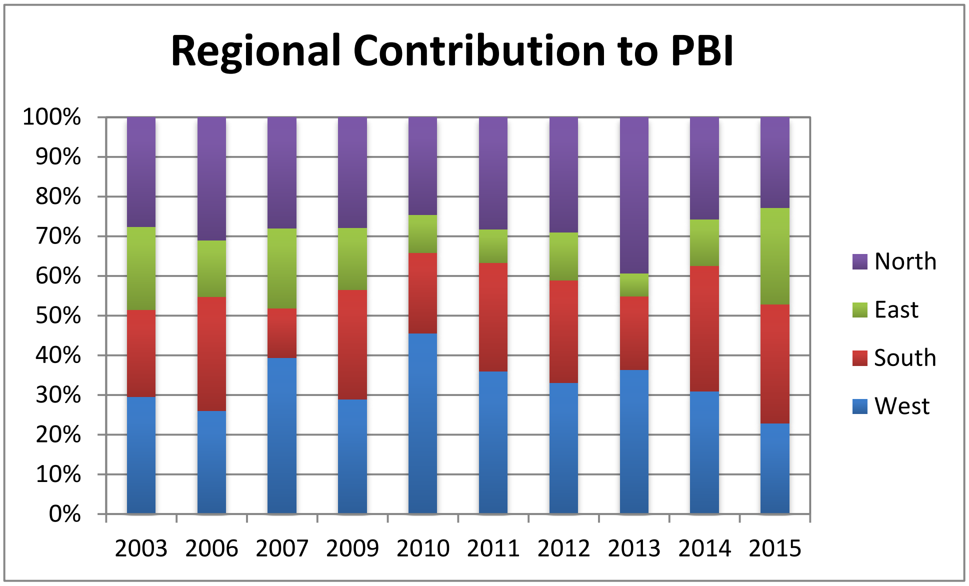


Fig. 30. Relative contribution to PBI by region.

3.c.3. Trends for Synoptic Sites, by Level of Development

A detailed analysis using each of the synoptic sites independently and comparing that site to land use is difficult. First, the land use data made available for this report may not adequately represent the features of the landscape that determine nutrient input, e.g. the pathway of stormwater/ flow differs within each intervening zone (including hydrologic connectivity), the effectiveness and location of BMPs and areas of natural infiltration, location of nutrient sources).

The GIS data, as it exists, does not account for these distinctions. Second, land use in the overall vicinity of the sampling location may not fully represent conditions at the actual sampling location. Third, periphyton growth has been related to nutrient loading through groundwater discharge (Loeb 1986). This can be affected by leaching from historic sewage fields, infiltration from urban runoff, fertilizer leaching and the localized pathway of groundwater flow into the lake. The current land use data does not account for these processes. Fourth, physical factors such as type of lake bottom substrate, wave conditions and long-shore currents can also affect periphyton accumulation at a specific site. Fifth, biomass accumulation can also be affected by grazing pressure from benthic invertebrates. Given all these possibilities, developing a relationship between maximum spring periphyton biomass and the land use data for each of the sites independently is likely to be uncertain.

Consequently, we analyzed the synoptic surveys largely using data collected within each of the land use categories. By combining the PBI results in this fashion there were more data points to investigate relationships between periphyton biomass accumulation and land use.

Approach for Data Evaluation

A map showing each sampling site and intervening zone level of development for the associated intervening zone is provided (Fig. 31). Level of development was based on impervious cover within the entire intervening zone, and included low development (0-9 percent), medium development (10-19 percent) and high development (>20 percent). We also considered land use and biomass when the medium and high development data was combined. This category of medium+high represents those sites with >10 percent imperious cover and denotes a condition of development that exceeds low development (note: at certain site the low development categorization includes no development).

There were also five sites located at or immediately adjacent to the mouths of tributaries (Tahoe City tributary, S. Dollar Creek, Cascade Creek, Blackwood Creek and Ward Creek). These five sites were considered a separate category because of their unique nature. Within each of the four land use categories there were on average, 16 sites in the low development group, 21 in the medium development group, 7 in the high development group and 5 stream mouth sites.

Annual, lake-wide mean PBI values, using data from all sites, was calculated each year. The number of individual sites that exceeded this mean PBI was tabulated for each of the land use categories. These values were then compared to the total number of sites within each land use category and expressed as a percentage. This was done for both a comparison to the mean whole-lake PBI value and the whole-lake mean + one standard deviation (SD) PBI value. The mean + 1 SD accounts for sites with the greatest accumulation of periphyton. These two values are referred to as the mean statistic and the mean + 1 SD statistic in the text. The mean rather than the median was used as it better represented those times when higher biomass was present allowing for a clearer image of the relation to land use. Since the analysis in this section looks at land use and biomass accumulation and not the time trend we were able to summarize the results based on a combination of all years or specific years of interest.

We summarized the data by first taking number of sampled sites that had a measured PBI value greater or equal to each annual mean for all sites. The number these sites within each designated land use category was divided by the total number of sampled sites within the same land use. This value was reported as a percent. For example, if 4 of the 16 sites within the low development grouping had a PBI ≥ the lake-wide mean, the reported value was 25 percent. This approach allows for a direct evaluation biomass accumulation within a category. We also consider land use and biomass when the medium and high development data is combined. The category represent those sites with >10 percent imperious cover and denotes a condition of development that exceeds low development that at times conditions close to background.

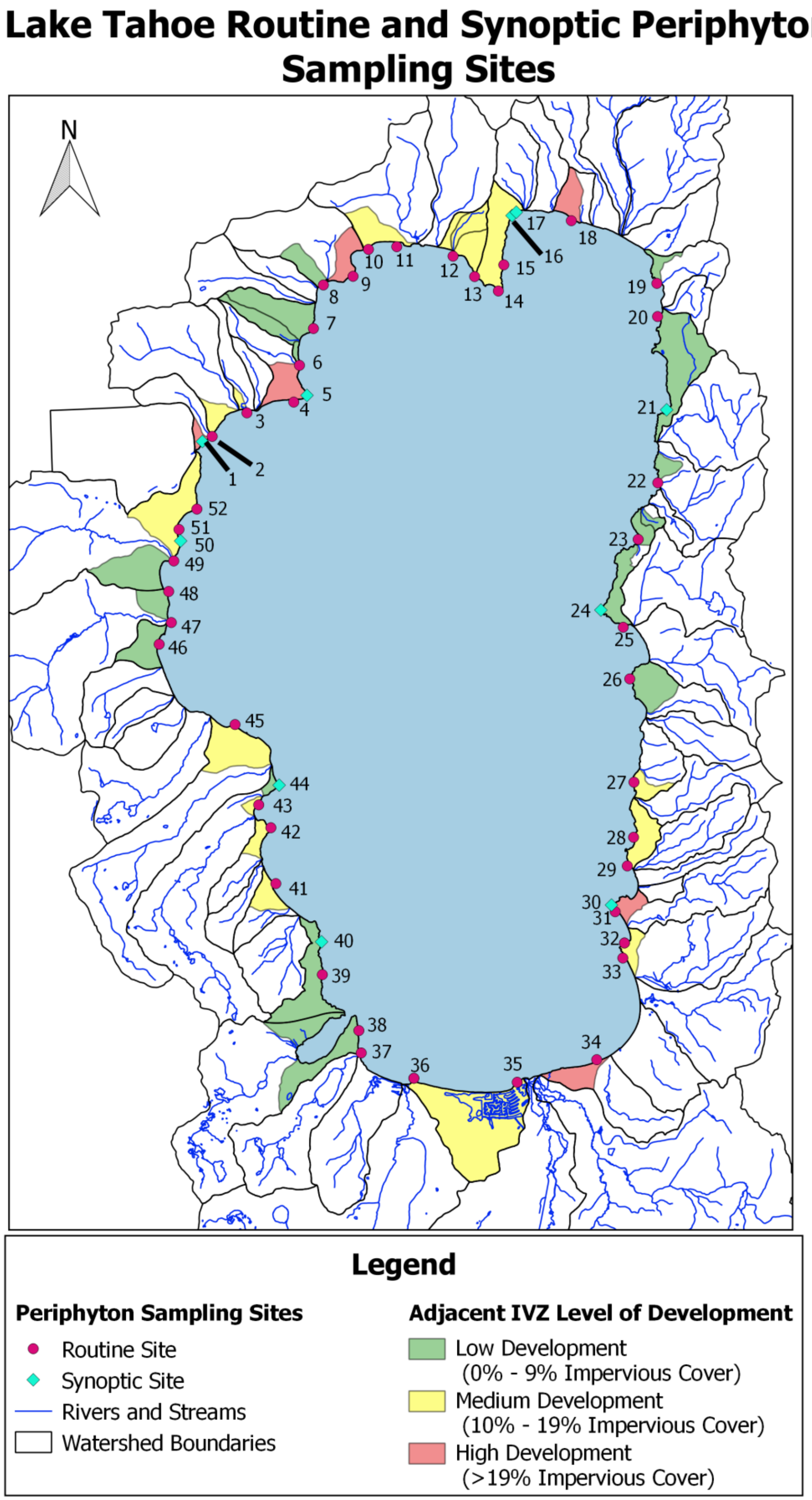


Fig. 31. Map of sites visited during the annual spring biomass maximum Also included is the level of land use as represented by percent impervious cover. With the exception of Ward Creek, Blackwood Creek, Cascade Creek, South Dollar Creek and the urban tributary at Tahoe City, the sampling sites received unchannelized runoff.

PBI Values at Synoptic Sites

Annual lake-wide mean PBI ranged from 0.33 to 1.18 with an average of 0.77 ± 0.29 (± one standard deviation). Values greater than10 percent of the 10-year mean occurred in 2006, 2007, 2011 and 2012. Values lower than 10 percent of the 10-year mean included 2003, 2014 and 2015. Values within 10 percent were 2009, 2010 and 2013 (Fig. 32). We chose this approach for separating the years based on PBI since those years close to the mean of annual means could partially mask the effect of high and low biomass. With the exception of 2013, years when the sampling elevation was ≥ 6225 feet (dominated by stalked diatoms and filamentous green algae) corresponded to higher biomass.

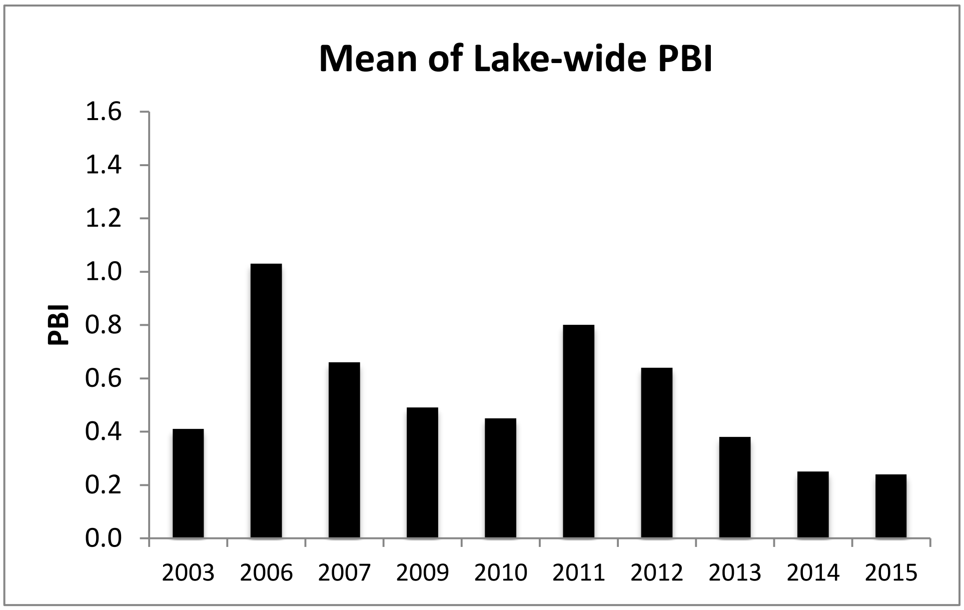
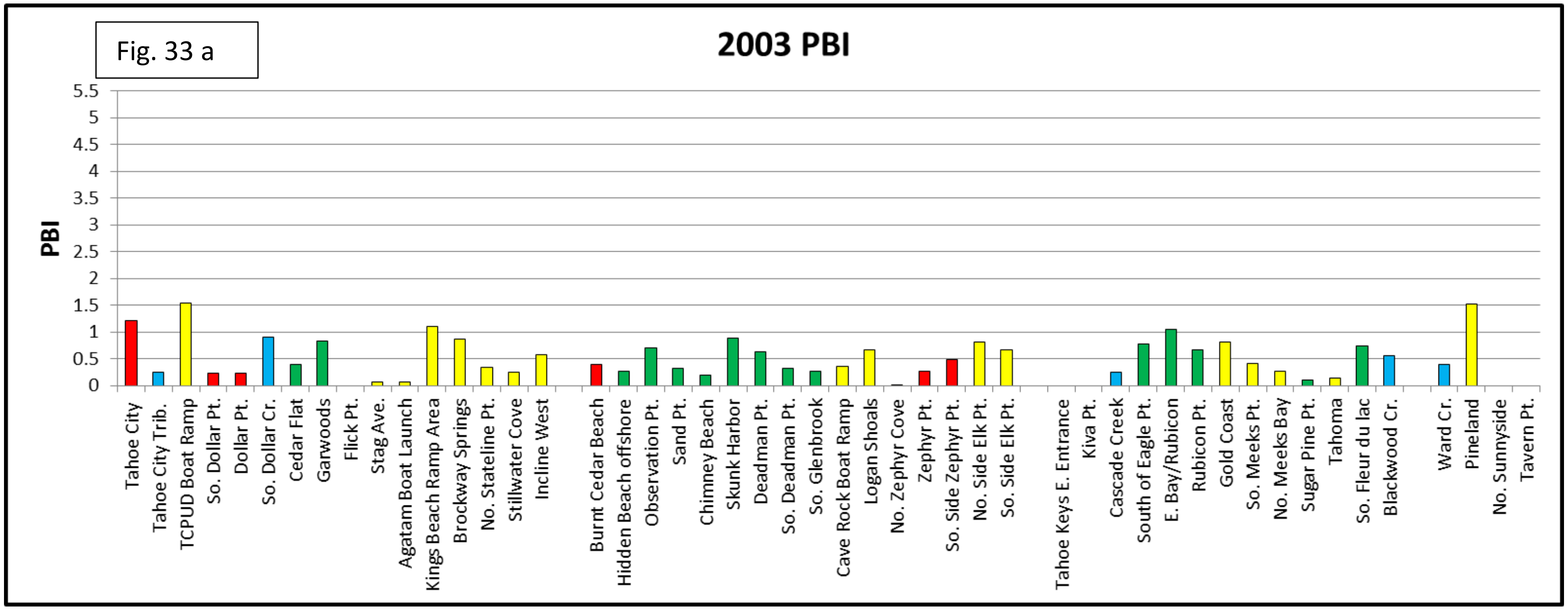


Fig. 32. Arithmetic mean of all measurements taken around the complete the lakeshore. The mean of these annual means was 0.77 with a standard deviation of 0.29.

PBI values are provided for each site during the ten annual synoptic surveys (Fig. 33 a-j). In general: (1) PBI at individual sites within low development were not necessarily the lowest found each year while PBI at individual sites within low development were not necessarily the highest; (2) PBI at individual sites in the medium development category often exceed the annual lake-wide mean, and showed a wide amount of variability both between years at a given location and among years considering all medium development sites; (3) PBI at the low development sites on the east shore were low, however, the low development sites along the south west shore (South of Eagle Point, Emerald Bay/Rubicon and Rubicon) were frequently higher, and (4) values at the stream mouth sites were frequently greater than the annual lake-wide mean, with high biomass.

In 2003, 20 sites exceeded the lake-wide mean of 0.54 for that year. In 2006, 16 sites were higher than the lake-wide PBI mean (1.18), in 2007 – 15 sites exceeded the mean of 0.83, in 2009 – 10



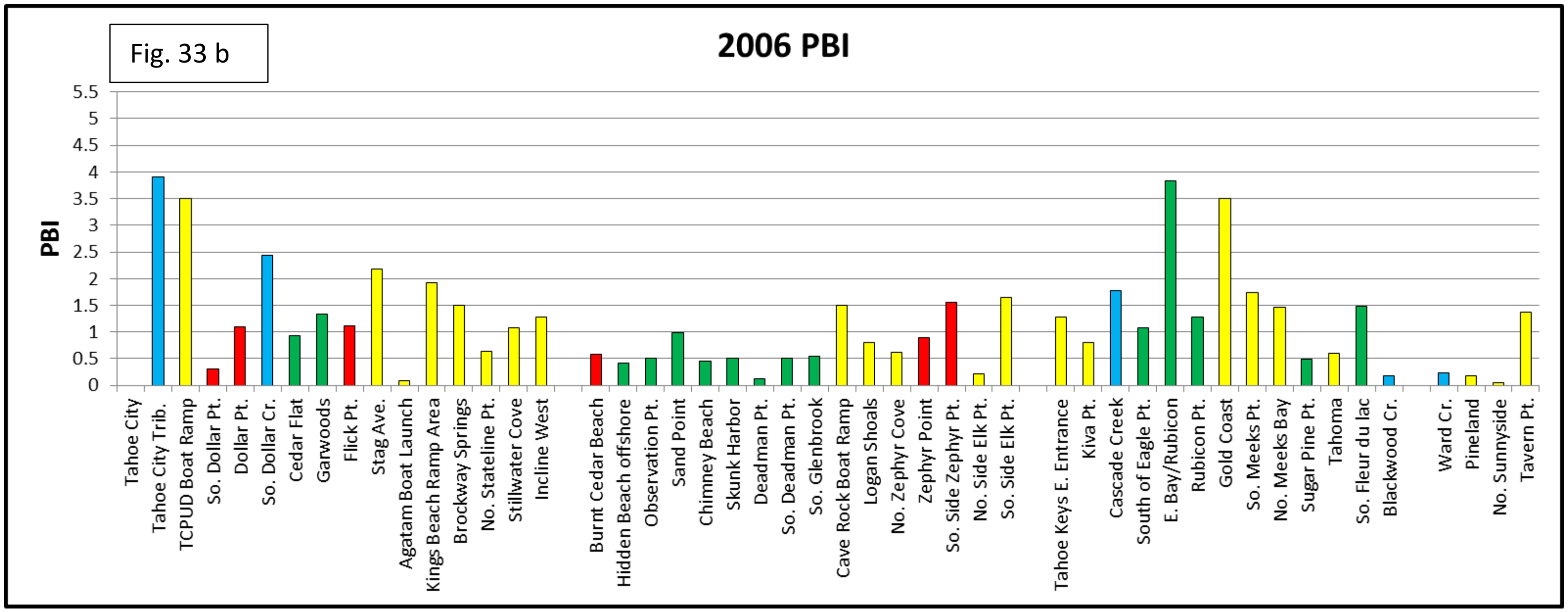


Fig. 33 a-j. Levels of PBI at sites progressing clockwise around the lake beginning at Tahoe City during year shown. Color is the corresponding level of development (percent impervious cover) in adjacent intervening zones (Green = Low development, <10 percent); Yellow=Medium development, 10-19 percent; Red = High development, >19 percent); blue = tributary mouth

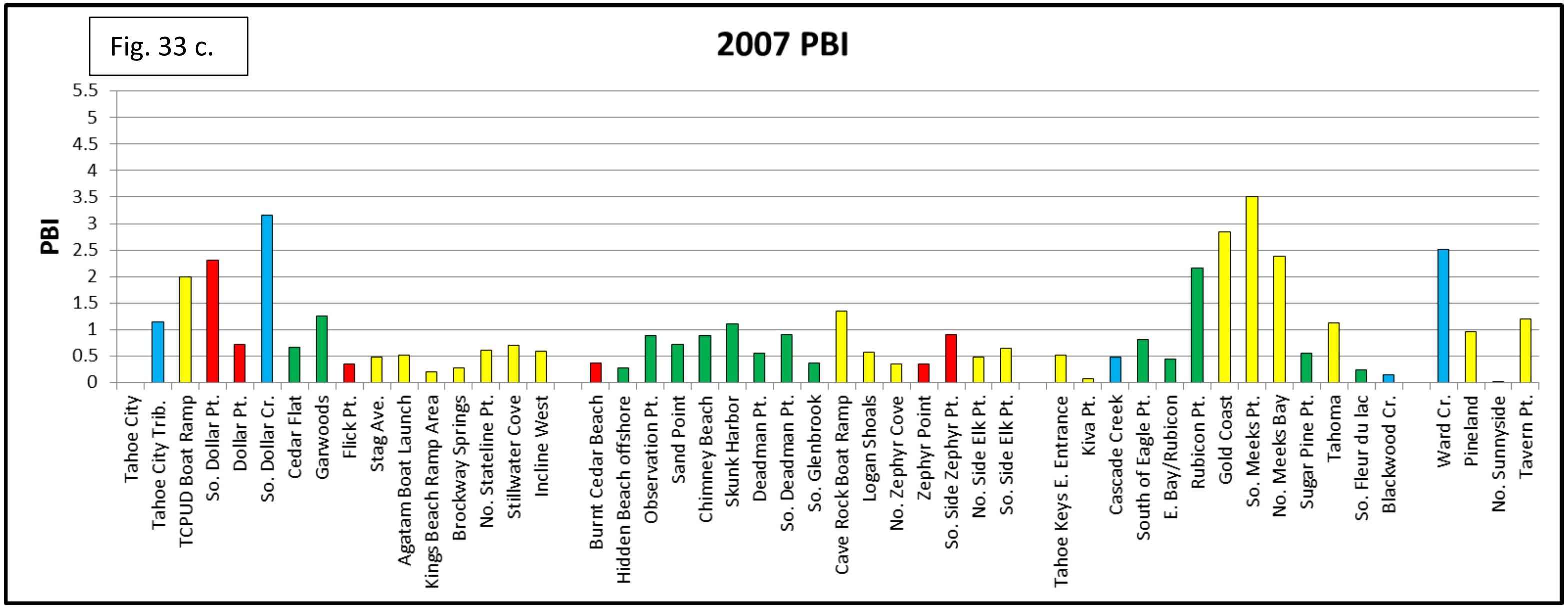


Fig. 33 c.
2007 PBI
PBI
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Tahoe City
Tahoe City Trib.
TCPUD Boat Ramp
So. Dollar Pt.
Dollar Pt.
So. Dollar Cr.
Cedar Flat
Garwoods
Flick Pt.
Stag Ave.
Agatam Boat Launch
Kings Beach Ramp Area
Brockway Springs
No. Stateline Pt.
Stillwater Cove
Incline West
Burnt Cedar Beach
Hidden Beach offshore
Observation Pt.
Sand Point
Chimney Beach
Skunk Harbor
Deadman Pt.
So. Deadman Pt.
So. Glenbrook
Cave Rock Boat Ramp
Logan Shoals
No. Zephyr Cove
Zephyr Point
So. Side Zephyr Pt.
No. Side Elk Pt.
So. Side Elk Pt.
Tahoe Keys E. Entrance
Kiva Pt.
Cascade Creek
South of Eagle Pt.
E. Bay/Rubicon
Rubicon Pt.
Gold Coast
So. Meeks Pt.
No. Meeks Bay
Sugar Pine Pt.
Tahoma
So. Fleur du lac
Blackwood Cr.
Ward Cr.
Pineland
No. Sunnyside
Tavern Pt.

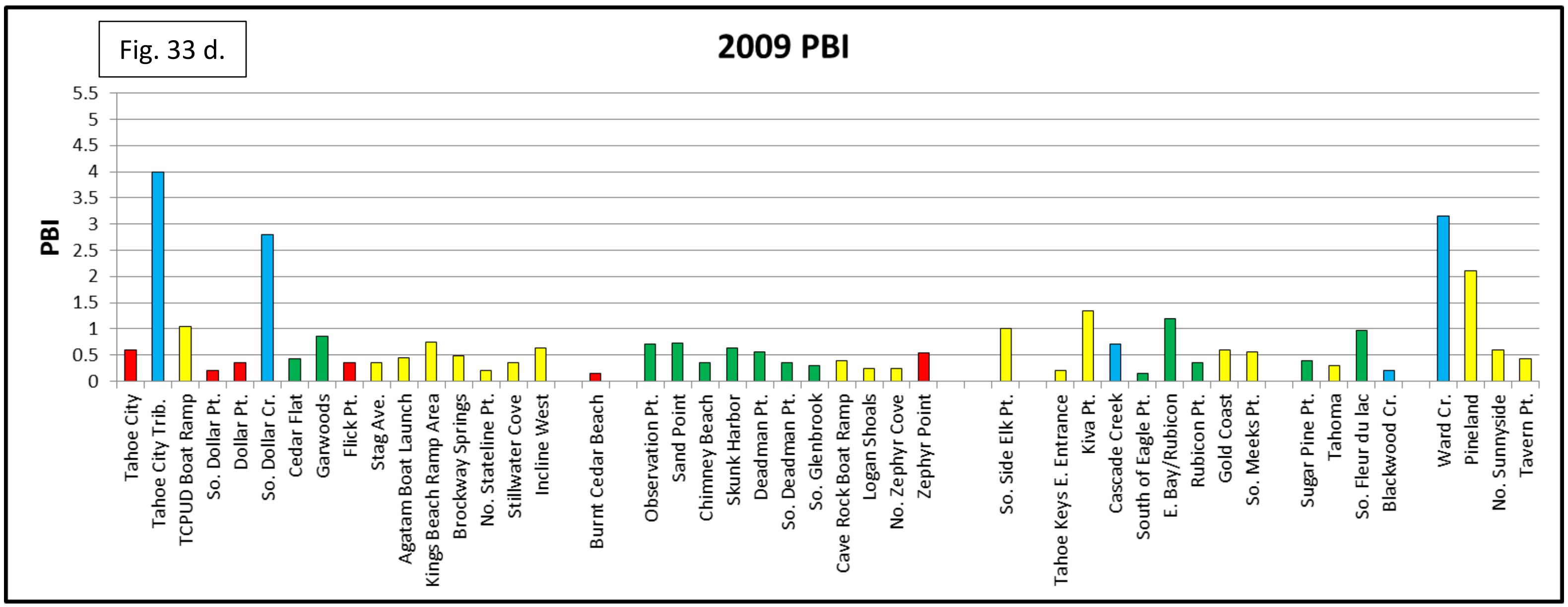


Fig. 33 d.
2009 PBI
PBI
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Tahoe City
Tahoe City Trib.
TCPUD Boat Ramp
So. Dollar Pt.
Dollar Pt.
So. Dollar Cr.
Cedar Flat
Garwoods
Flick Pt.
Stag Ave.
Agatam Boat Launch
Kings Beach Ramp Area
Brockway Springs
No. Stateline Pt.
Stillwater Cove
Incline West
Burnt Cedar Beach
Observation Pt.
Sand Point
Chimney Beach
Skunk Harbor
Deadman Pt.
So. Deadman Pt.
So. Glenbrook
Cave Rock Boat Ramp
Logan Shoals
No. Zephyr Cove
Zephyr Point
So. Side Elk Pt.
Tahoe Keys E. Entrance
Kiva Pt.
Cascade Creek
South of Eagle Pt.
E. Bay/Rubicon
Rubicon Pt.
Gold Coast
So. Meeks Pt.
Sugar Pine Pt.
Tahoma
So. Fleur du lac
Blackwood Cr.
Ward Cr.
Pineland
No. Sunnyside
Tavern Pt.

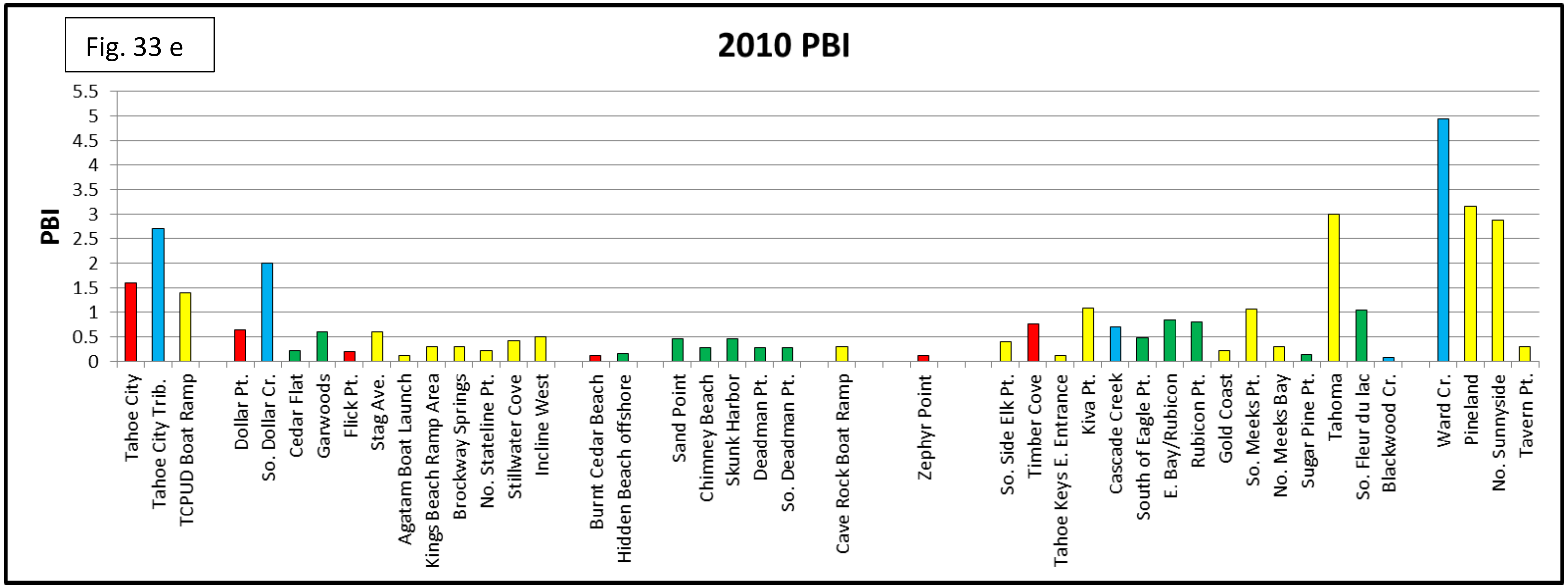


Fig. 33 e
2010 PBI
PBI
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
Tahoe City
Tahoe City Trib.
TCPUD Boat Ramp
Dollar Pt.
So. Dollar Cr.
Cedar Flat
Garwoods
Flick Pt.
Stag Ave.
Agatam Boat Launch
Kings Beach Ramp Area
Brockway Springs
No. Stateline Pt.
Stillwater Cove
Incline West
Burnt Cedar Beach
Hidden Beach offshore
Sand Point
Chimney Beach
Skunk Harbor
Deadman Pt.
So. Deadman Pt.
Cave Rock Boat Ramp
Zephyr Point
So. Side Elk Pt.
Timber Cove
Tahoe Keys E. Entrance
Kiva Pt.
Cascade Creek
South of Eagle Pt.
E. Bay/Rubicon
Rubicon Pt.
Gold Coast
So. Meeks Pt.
No. Meeks Bay
Sugar Pine Pt.
Tahoma
So. Fleur du lac
Blackwood Cr.
Ward Cr.
Pineland
No. Sunnyside
Tavern Pt.

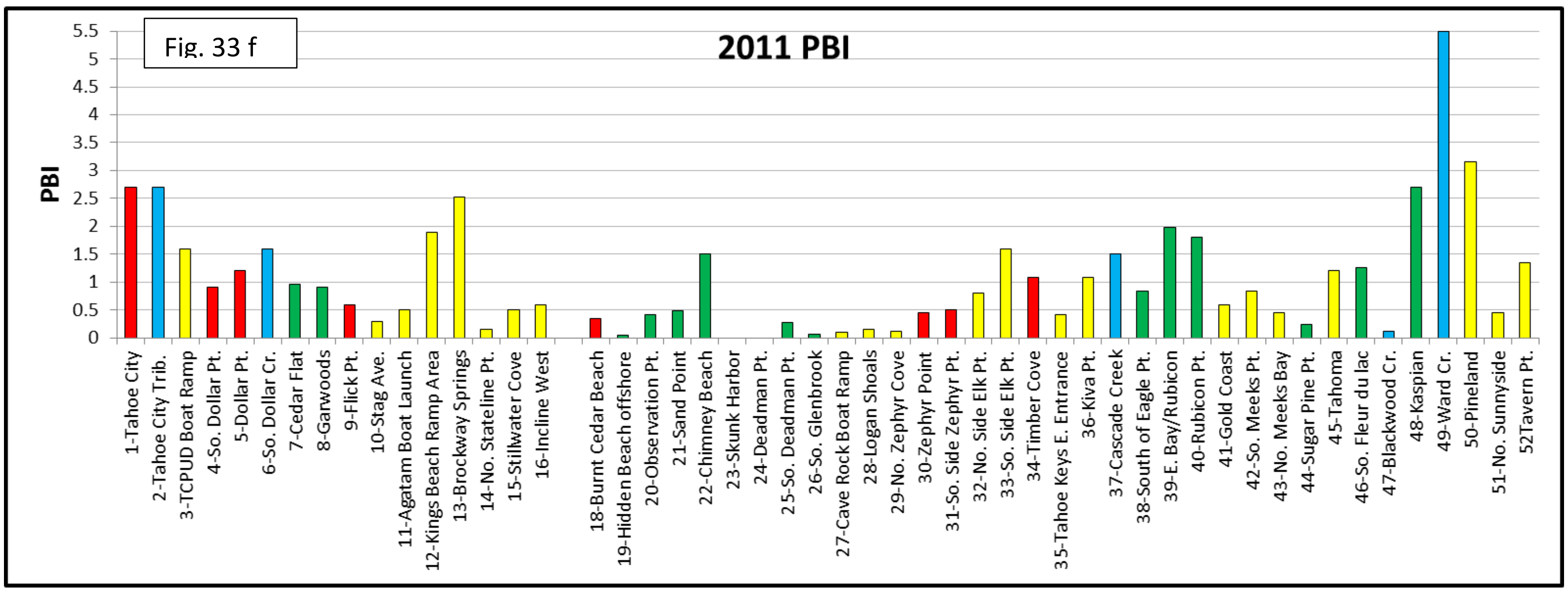


Fig. 33 f
2011 PBI
PBI
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
1-Tahoe City
2-Tahoe City Trib.
3-TCPUD Boat Ramp
4-So. Dollar Pt.
5-Dollar Pt.
6-So. Dollar Cr.
7-Cedar Flat
8-Garwoods
9-Flick Pt.
10-Stag Ave.
11-Agatam Boat Launch
12-Kings Beach Ramp Area
13-Brockway Springs
14-No. Stateline Pt.
15-Stillwater Cove
16-Incline West
18-Burnt Cedar Beach
19-Hidden Beach offshore
20-Observation Pt.
21-Sand Point
22-Chimney Beach
23-Skunk Harbor
24-Deadman Pt.
25-So. Deadman Pt.
26-So. Glenbrook
27-Cave Rock Boat Ramp
28-Logan Shoals
29-No. Zephyr Cove
30-Zephyr Point
31-So. Side Zephyr Pt.
32-No. Side Elk Pt.
33-So. Side Elk Pt.
34-Timber Cove
35-Tahoe Keys E. Entrance
36-Kiva Pt.
37-Cascade Creek
38-South of Eagle Pt.
39-E. Bay/Rubicon
40-Rubicon Pt.
41-Gold Coast
42-So. Meeks Pt.
43-No. Meeks Bay
44-Sugar Pine Pt.
45-Tahoma
46-So. Fleur du lac
47-Blackwood Cr.
48-Kaspian
49-Ward Cr.
50-Pineland
51-No. Sunnyside
52Tavern Pt.

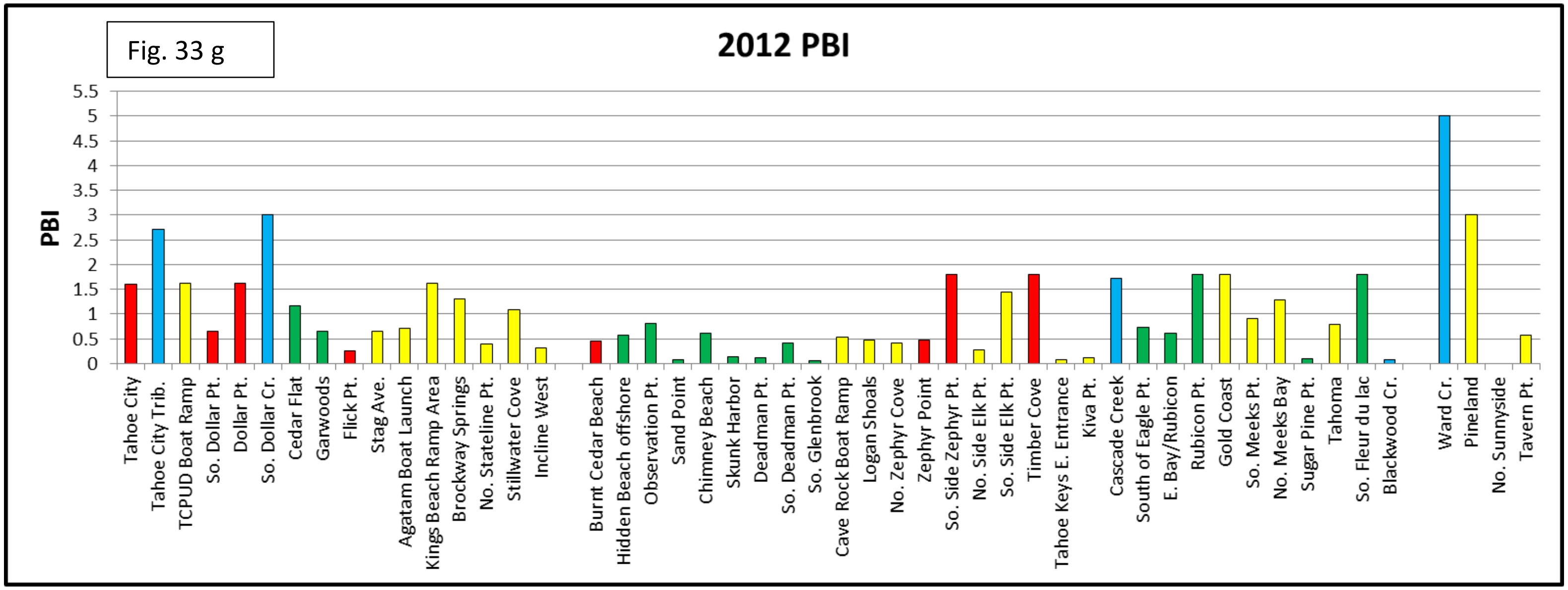


Fig. 33 g
2012 PBI
PBI
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Tahoe City
Tahoe City Trib.
TCPUD Boat Ramp
So. Dollar Pt.
Dollar Pt.
So. Dollar Cr.
Cedar Flat
Garwoods
Flick Pt.
Stag Ave.
Agatam Boat Launch
Kings Beach Ramp Area
Brockway Springs
No. Stateline Pt.
Stillwater Cove
Incline West
Burnt Cedar Beach
Hidden Beach offshore
Observation Pt.
Sand Point
Chimney Beach
Skunk Harbor
Deadman Pt.
So. Deadman Pt.
So. Glenbrook
Cave Rock Boat Ramp
Logan Shoals
No. Zephyr Cove
Zephyr Point
So. Side Zephyr Pt.
No. Side Elk Pt.
So. Side Elk Pt.
Timber Cove
Tahoe Keys E. Entrance
Kiva Pt.
Cascade Creek
South of Eagle Pt.
E. Bay/Rubicon
Rubicon Pt.
Gold Coast
So. Meeks Pt.
No. Meeks Bay
Sugar Pine Pt.
Tahoma
So. Fleur du lac
Blackwood Cr.
Ward Cr.
Pineland
No. Sunnyside
Tavern Pt.

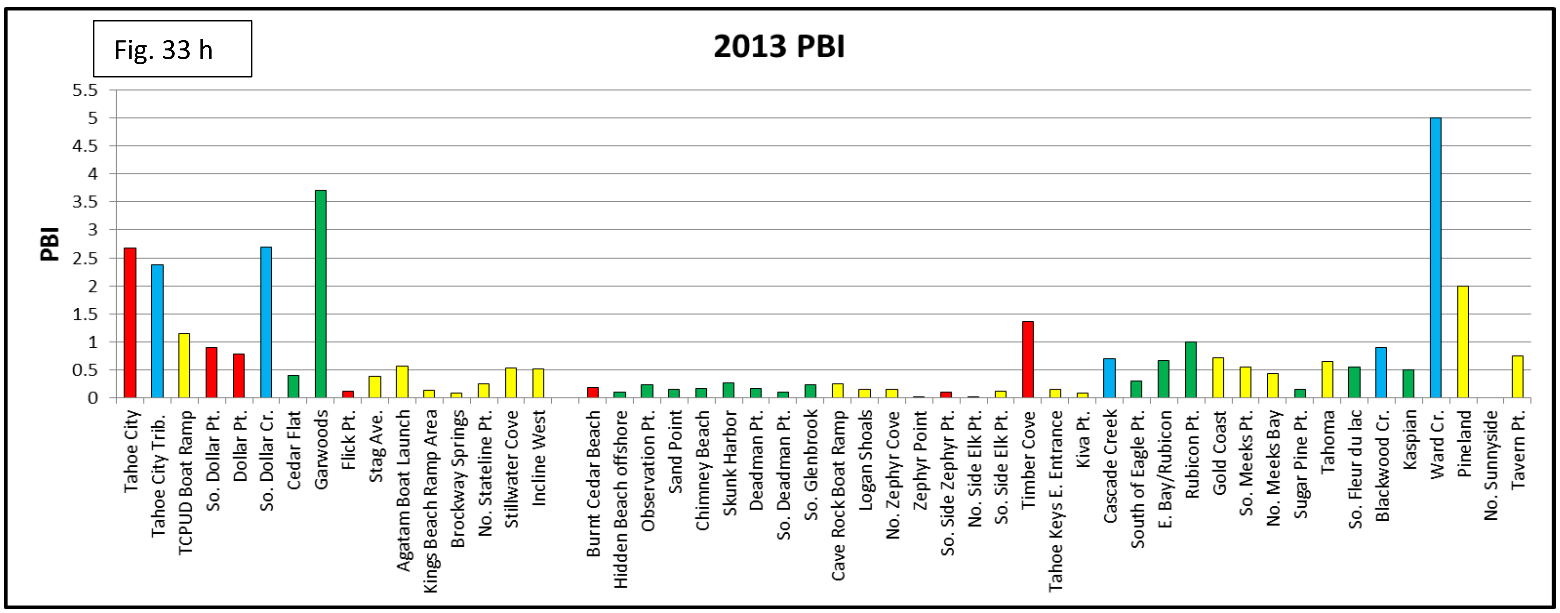


Fig. 33 h
2013 PBI
PBI
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Tahoe City
Tahoe City Trib.
TCPUD Boat Ramp
So. Dollar Pt.
Dollar Pt.
So. Dollar Cr.
Cedar Flat
Garwoods
Flick Pt.
Stag Ave.
Agatam Boat Launch
Kings Beach Ramp Area
Brockway Springs
No. Stateline Pt.
Stillwater Cove
Incline West
Burnt Cedar Beach
Hidden Beach offshore
Observation Pt.
Sand Point
Chimney Beach
Skunk Harbor
Deadman Pt.
So. Deadman Pt.
So. Glenbrook
Cave Rock Boat Ramp
Logan Shoals
No. Zephyr Cove
Zephyr Point
So. Side Zephyr Pt.
No. Side Elk Pt.
So. Side Elk Pt.
Timber Cove
Tahoe Keys E. Entrance
Kiva Pt.
Cascade Creek
South of Eagle Pt.
E. Bay/Rubicon
Rubicon Pt.
Gold Coast
So. Meeks Pt.
No. Meeks Bay
Sugar Pine Pt.
Tahoma
So. Fleur du lac
Blackwood Cr.
Kaspian
Ward Cr.
Pineland
No. Sunnyside
Tavern Pt.

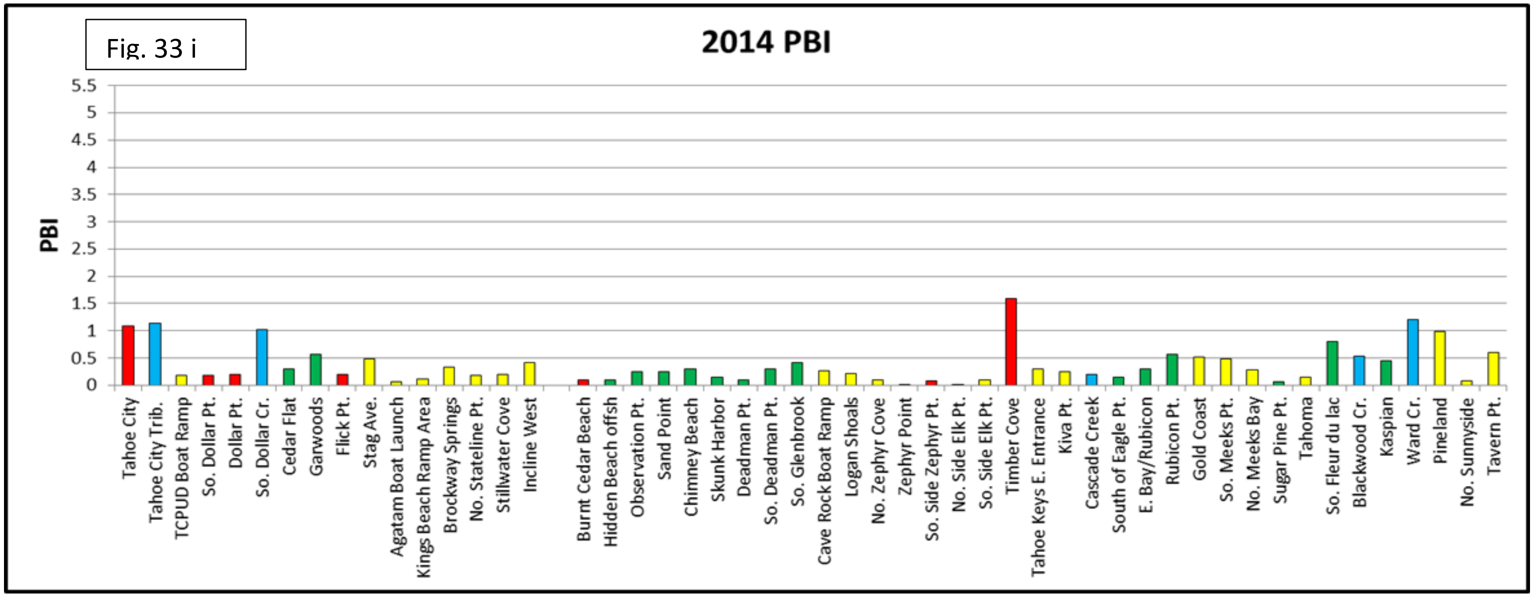


Fig. 33 i
2014 PBI
PBI
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Tahoe City
Tahoe City Trib.
TCPUD Boat Ramp
So. Dollar Pt.
Dollar Pt.
So. Dollar Cr.
Cedar Flat
Garwoods
Flick Pt.
Stag Ave.
Agatam Boat Launch
Kings Beach Ramp Area
Brockway Springs
No. Stateline Pt.
Stillwater Cove
Incline West
Burnt Cedar Beach
Hidden Beach offsh
Observation Pt.
Sand Point
Chimney Beach
Skunk Harbor
Deadman Pt.
So. Deadman Pt.
So. Glenbrook
Cave Rock Boat Ramp
Logan Shoals
No. Zephyr Cove
Zephyr Point
So. Side Zephyr Pt.
No. Side Elk Pt.
So. Side Elk Pt.
Timber Cove
Tahoe Keys E. Entrance
Kiva Pt.
Cascade Creek
South of Eagle Pt.
E. Bay/Rubicon
Rubicon Pt.
Gold Coast
So. Meeks Pt.
No. Meeks Bay
Sugar Pine Pt.
Tahoma
So. Fleur du lac
Blackwood Cr.
Kaspian
Ward Cr.
Pineland
No. Sunnyside
Tavern Pt.

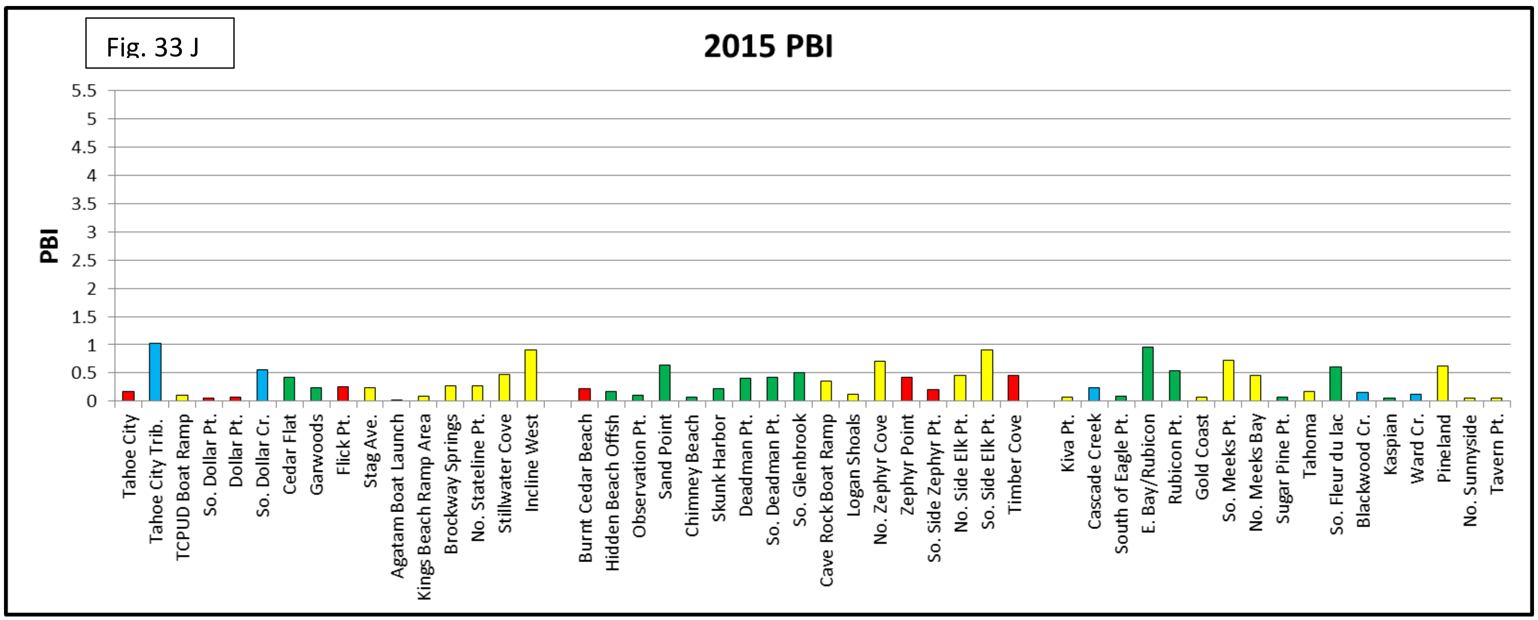


Fig. 33 J
2015 PBI
PBI
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Tahoe City
Tahoe City Trib.
TCPUD Boat Ramp
So. Dollar Pt.
Dollar Pt.
So. Dollar Cr.
Cedar Flat
Garwoods
Flick Pt.
Stag Ave.
Agatam Boat Launch
Kings Beach Ramp Area
Brockway Springs
No. Stateline Pt.
Stillwater Cove
Incline West
Burnt Cedar Beach
Hidden Beach Offsh
Observation Pt.
Sand Point
Chimney Beach
Skunk Harbor
Deadman Pt.
So. Deadman Pt.
So. Glenbrook
Cave Rock Boat Ramp
Logan Shoals
No. Zephyr Cove
Zephyr Point
So. Side Zephyr Pt.
No. Side Elk Pt.
So. Side Elk Pt.
Timber Cove
Kiva Pt.
Cascade Creek
South of Eagle Pt.
E. Bay/Rubicon
Rubicon Pt.
Gold Coast
So. Meeks Pt.
No. Meeks Bay
Sugar Pine Pt.
Tahoma
So. Fleur du lac
Blackwood Cr.
Kaspian
Ward Cr.
Pineland
No. Sunnyside
Tavern Pt.

sites exceeded 0.74, in 2010 – 11 sites exceeded 0.85, in 2011 – 20 sites exceeded 1.04, in 2012 – 12 sites exceeded 1.00, in 2013 – 12 sites exceeded 0.71, in 2014 – 17 sites exceeded 0.37, and in 2015 – 21 sites exceeded 0.33. For reference, on the order of 50 sites were sampled per year.

Synoptic PBI and Land Use

For all years combined, the frequency of times that the measured PBI exceeded the lake-wide mean in the low development category relative to the number of observations made in the low development category was 24 percent, i.e. the mean statistic as defined above (Table 21). For medium and high development the mean statistic was 35 and 25 percent, respectively. When medium and high development categories were combined, measured PBI exceeded the lake-wide mean at 32 percent of the sites. The stream mouth sites had the highest frequency at 60 percent. Using data from all years, and regardless of biomass level, the difference between low development and stream mouth categories was significant ($p<0.05$) as was the difference between medium+high (combined) development and stream mouth categories significant ($p<0.05$). For low development versus medium+high development the relationship was not significant ($p=0.21$).

To investigate the relationship between land use and periphyton we divided PBI into the three biomass categories presented above. In those years when biomass was within 10 percent of the mean of annual means, the percent time when PBI was greater annual mean was 23, 22, 15 and 67 for the low, medium, high and stream mouth categories, respectively (Table 21). When the medium and high land use categories were combined that value was 18 percent. Only the comparisons between low development and stream mouth, and medium+high development and stream mouth were significant ($p<0.03$). As observed for the case of all years combined, the difference between low development and medium+high development was not significant ($p=0.38$).

During years when the mean annual biomass was lower, the PBI value in the low development category was greater than the annual lake-wide mean 41 percent of the time that measurements were made in this category. This was greater than the 24 percent value seen when all years are combined. The values for those years of lower biomass were 38, 27 and 53 percent for the medium, high and stream mouth land uses, respectively. When the medium and high categories were combined this mean statistic was 32 percent. None of the comparisons between categories (i.e. low versus medium+high ($p=0.30$), low versus stream mouth ($p=0.64$) or medium+high versus stream mouth ($p=0.29$) were significant. This was largely due to the large increase in mean statistic for the low development category as noted above.

In contrast, when biomass was higher the mean statistic for the low development category was 20 percent as compared to 42 percent for the medium development category, 32 percent for the high development category, and 65 percent for the stream mouth category. When the medium and high development categories were combined (Table 21) the mean statistic for medium+high development (40 percent) was double that for low development (20 percent). The two-fold increase in the number of times the annual PBI exceeded the mean annual mean within each land use category, was highly significant ($p<0.01$). Further, under these elevated biomass conditions, the mean statistic for the low development category was reduced relative to the stream mouth but at a slightly reduced level of significance ($p=0.06$). There was no difference between the medium+high versus stream mouth categories ($p=0.23$) when biomass was elevated.

Table 21. PBI data summarized on the basis of the percent time that the observation at a single site exceeded the annual mean value, referred to in this report as the mean statistic. Values represent the number of times this exceedance was found relative to all observation for a particular land use.

Land Use	All Years Combined (mean)	PBI Biomass (<mean)	PBI Biomass (>mean)	PBI Biomass (within 10% of mean)
Low	24	41	20	23
Medium	35	38	42	22
High	25	27	32	15
Stream mouths	60	53	65	67
Low	24	41	20	23
Medium + High	32	32	40	18
Stream mouths	60	60	65	67

An identical analysis was made considering those PBI values that exceeded the annual mean ± 1 standard deviation. This was done to better account for those sites were the measured biomass was in the group of the highest PBI values measured, and those that might be considered more problematic. A plot of these data by year is in Fig. 34. The mean of all PBI values is 1.57 with a standard deviation of 0.58. Values greater than10 percent of the 10-year mean occurred in 2006, 2007, 2010, 2011, 2012 and 2013. Values lower than 10 percent of the 10-year mean were found in 2003, 2014 and 2015. Values within 10 percent were seen only in 2009.

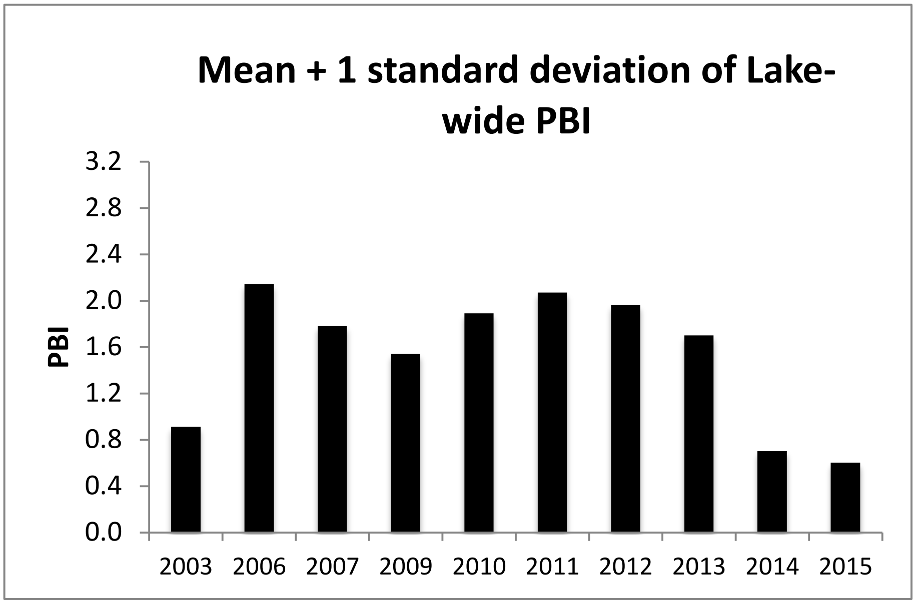


Fig. 34. Arithmetic mean + 1 SD of all measurements taken around the complete the lakeshore. Mean of annual means for this statistic was 1.59 ± 0.58. Sites with a PBI greater than the mean + 1 SD values often considered problematic.

Of the 158 total observations made within the low development category, for all 10 years of sampling, PBI exceeded the mean + 1 SD statistic eight times or 5 percent (Table 22). Similarly 25 of the 214 observations, or 12 percent in the medium development category were greater than the mean + 1 SD statistic. For the high development category and stream mouths the mean +1 SD statistic values were 10 and 31 percent, respectively. When medium and high land use categories were combined the value was 11 percent. For the full 10-year dataset, the low development category was less that the medium+high category ($p<0.06$). The mean + 1 SD statistic for both the low development and medium+high development categories was statistically lower than the stream mouths (both at $p<0.001$.

Results of the comparison for the mean + 1 SD statistic at the three levels of PBI biomass, was very similar to the comparison using the mean statistic in that, (1) for the years with higher biomass the mean + 1 SD statistic was three times higher in medium+high development (10 percent) compared to low development (10 percent) (Table 22). The other two biomass categories did not show much of a difference when comparing low versus medium+high development and (2) the frequency of elevated biomass (mean + 1 SD statistic) was common in the stream mouth category. Due to the low number of observations of values, within each land use category, we considered that any further attempt to determine statistic differences would be hampered by the low sample size and could be misleading.

Table22. Same as for Table 21 except that the data was summarized by first taking number of sampled sites that had a measured PBI value greater or equal to each annual mean + 1 standard deviation for all sites. At this level of PBI biomass accumulation periphyton growth is often problematic.

Land Use	All Years Combined	PBI Biomass (<mean + 1 SD)	PBI Biomass (>mean + 1 SD)	PBI Biomass (within 10% of mean + 1 SD)
Low	5	10	3	0
Medium	12	14	12	5
High	10	14	7	0
Stream mouths	31	27	50	60
Low	5	10	3	0
Medium + High	11	14	10	3
Stream mouths	31	27	50	60

Table 23 provides a closer look at the number of times that more problematic biomass accumulations (i.e. > mean + 1 SD statistic) occurred at each site. This was further divided into land use category.

A total of 25 sites, or nearly one-half of the total number of sites had at least one annual value that exceeded the mean + 1 SD statistic. During that period there were a total of 62 exceedances (not percent), or 13 percent of the total observations regardless of land use. Low development had 8 exceedances, while the high development had 7, medium had 25 and stream mouth had 22 individual exceedances (Table 23).

Within the low development category the Emerald Bay/Rubicon and adjacent Rubicon sites accounted for one-half of the total for this land use category, and the site south of Fleur de lac accounted for two. The Emerald Bay/Rubicon Point area has very little overall development, but the watershed is steep. More is needed to fully understand these apparently ‘anomalous’ observation. Among the medium development sites, Pineland was clearly the most frequent hot spot with exceedance in eight of the ten years. Also within this category the TCPUD Boat Ramp had 3 exceedances. The remaining 12 sites with medium development were higher than the mean + 1 SD statistic during either one or two years and do not represent chronic areas of high peak biomass. It is important to note that this does not mean that the level of PBI biomass at those sites are not an aesthetic nuisance during the 1-2 years when they were found at high levels.

Table 23. Number of times (years) that PBI biomass exceeded the mean + 1 SD statistic at each of individual synoptic sites. Omitted sites did not exceed this statistic.

Site	Low Development (158 observations	Medium Development (214 observations)	High Development (70 observations)	Stream Mouth (50 observations)
Tahoe City			4	
Tahoe City tributary				8
TCPUD Boat Ramp		3		
Soth Dollar Point			1	
South Dollar Creek				7
Garwoods	1			
Stag		1		
Kings Beach Ramp area		1		
Brockway		1		
Incline West		1		
Sand Point	1			
North Zephyr		1		
South side Elk Point		1		
Timber Cove			2	
Emerald Bay/Rubicon	3			
Rubicon	1			
Gold Coast		2		
South Meeks Point		2		
North Meeks Point		1		
Tahoma		1		
South of Fleur de lac	2			
Kaspian		1		
Ward Creek				7
Pineland		8		
North Sunnyside		1		

Tahoe City was the only site within the high development category to exceed the mean + 1 SD statistic in more than two of the 10 years of sampling. This occurred in four of the 10 years; however, in the five years that data is available for Timber Cove there were 2 exceedances (Table 23). Finally, three of the five stream mouth sites (Ward Creek, South Dollar Creek and the Tahoe City tributary) had values above the mean + 1 SD statistic. It is very noteworthy that exceedances occurred in 7-8 of the sampling year – a high frequency, similar to Pineland. The absence of high biomass at the mouth of Blackwood Creek is hypothesized to be due to the fact that longshore currents, stream flow and waves at this site are sufficient to tumble the rocks that make up the bottom substrate thereby removing periphyton by abrasion. While Cascade Creek did exceed the mean + 1 SD statistic, it did not exceed the mean + 1SD statistic'

Summary of PBI and Land Use Development

A significant difference in level of PBI biomass was found between sites adjacent to low development and higher levels of development when biomass was relatively low. This difference was not apparent when biomass was within 10 percent of the long-term mean or higher. In the four years when biomass was higher, the lake elevation was >6225 feet. Based on the earlier conclusion that the ephemeral diatom and filamentous green algal communities occur at elevations >6225 feet and that these algae may be affected nutrient control, management of periphyton in the at sites adjacent to medium+high levels of development areas can be justified.

The data suggest that periphyton accumulation at the mouths of certain creeks/channelized tributaries is important. The highest levels of PBI biomass were consistently found at the sampled stream mouth sites with the exception of Blackwood Creek which appears to be low because of low colonization resulting from physical abrasion. A number of sites including Tahoe City, the TCPUD Boat Ramp, Emerald Bay/Rubicon and, especially Pineland and the mouths of Ward Creek, South Dollar Creek and the Tahoe City tributary, exhibited a chronic condition of very high periphyton accumulation. Other sites were shown to experience significant aesthetic problems during any single year. While the data clearly show the magnitude and the distribution of the problem, it is critical that more specific information regarding all the factors that affect growth at these sites be ascertained to help guide localized restoration.

In the Lake Tahoe TMDL development, science showed the importance of fine sediment particles on lake transparency (Secchi depth). This represented a huge paradigm shift on past restoration philosophy. Subsequently, much of the remediation efforts have focused on these fine particles. While the TMDL recognized the need for nitrogen and phosphorus control in general, in the case of the littoral zone it may hold greater importance. Given the largely stimulatory role that nutrients have on algae, watershed restoration in the intervening zones as well as the land that drains into the channelized tributaries should be given close consideration.

3.c.4. Lake-wide Trend for Synoptic Sites

All the synoptic Chlorophyll a data was then grouped together see if any trends were apparent for the whole lake (Fig. 35 below). Similarly all the data for PBI was grouped together to view whole lake trends for PBI (Figure 36). The data included 2003, 2006, 2007, 2009-2015 (data for 2005 and 2008 was excluded since spring maximum biomass was significantly missed at a portion of the sites). The grouped data were evaluated for trends using the Mann Kendall test and the results are presented in tables below each figure (Tables 24-25).

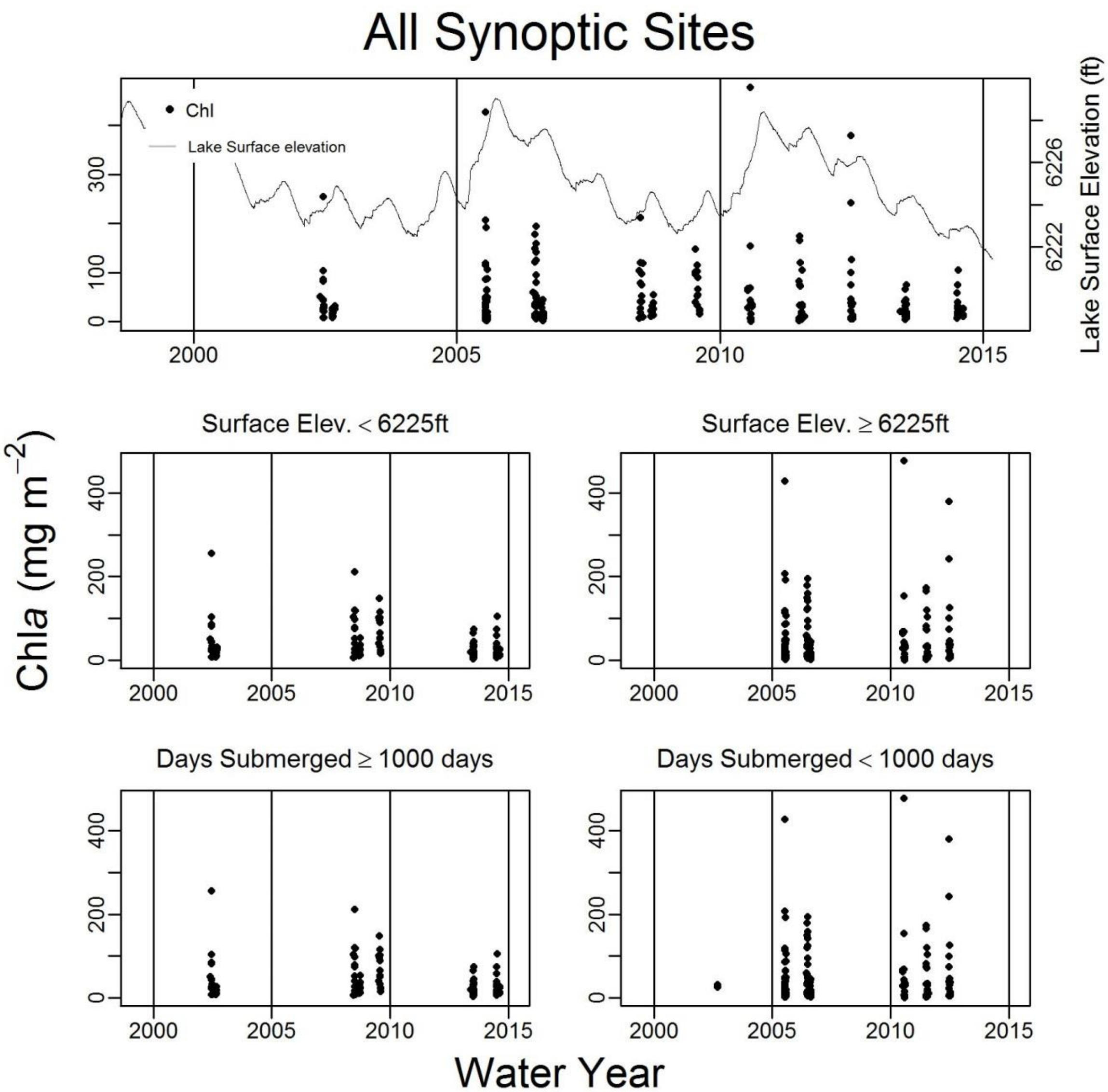


Fig. 35. Summary of all Spring Synoptic Chl *a* data for sites grouped for the whole lake (Upper Panel). The middle panel shows the data separated based on surface elevation <.≥ 6225 ft., and the lower two panels show the data separated based on length of time site was submerged

Table 24. Results for Mann Kendall trend test for Synoptic Chl a for the whole lake.

All	#	Mean	SD	Med	*Tau*	*S*	*z*	*p*
All obs.	257	45.7	62.2	23.8	-0.10	-69	-1.68	0.09
SD./Green Fil.								
>= 6225ft	149	49.6	73.6	19.5	0.16	20	1.31	0.19
< 1000 days	151	49.3	73.1	19.8	0.12	17	1.06	0.29
+ Blue-greens								
< 6225ft	108	40.4	41.3	25.1	-0.18	-20	-1.43	0.15
>= 1000 days	106	40.6	41.6	25.1	-0.17	-18	-1.31	0.19

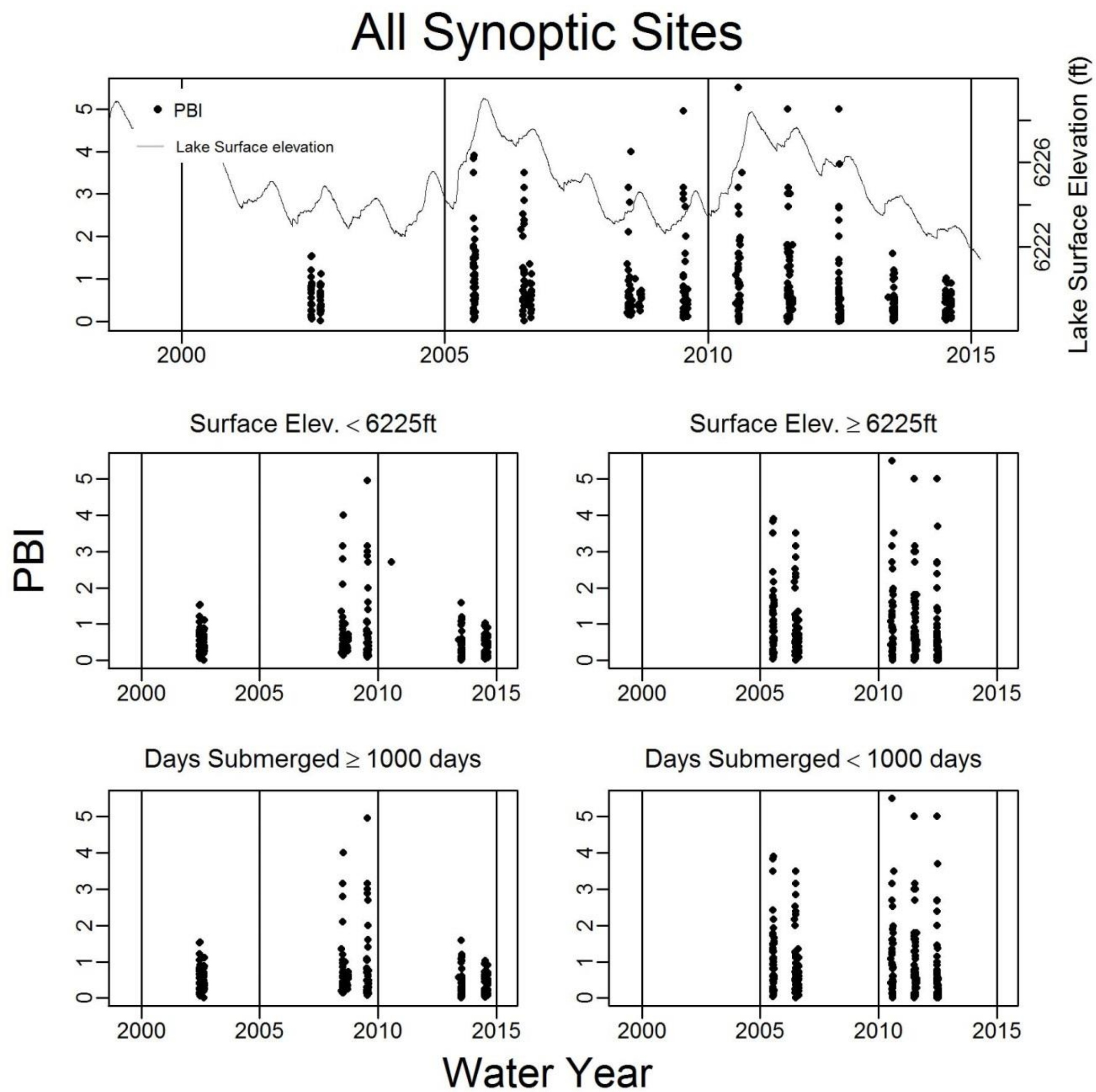


Fig. 36. Summary of all Spring Synoptic PBI data for sites grouped for the whole lake (Upper Panel). The middle panel shows the data separated based on surface elevation <.≥ 6225 ft., and the lower two panels show the data separated based on length of time site was submerged

Table 25. Results for Mann Kendall trend test for Synoptic PBI for the whole lake.

All	#	Mean	SD	Med	*Tau*	*S*	*z*	*p*	
All obs.	489	0.8	0.9	0.5	-0.26	-548	-7.25	<0.01	-
SD./Green Fil.									
>= 6225ft	252	1.0	1.0	0.6	-0.34	-164	-5.72	<0.01	-
< 1000 days	253	1.0	1.0	0.6	-0.34	-165	-5.73	<0.01	-
+ Blue-greens									
< 6225ft	237	0.6	0.7	0.4	-0.32	-135	-5.09	<0.01	-
>= 1000 days	236	0.6	0.6	0.4	-0.31	-132	-5.00	<0.01	-

LAKE-WIDE TREND FOR SYNOPTIC SITE CHLOROPHYLL A:

NONE (2003-2015)

The results of the Mann Kendall tests showed no significant trend for chlorophyll when all the data was analyzed.

LAKE-WIDE TREND FOR SYNOPTIC SITE PBI:

NEGATIVE (2003-2015)

The results for the Mann Kendall test for whole lake synoptic PBI data indicate a statistically significant negative trend. Examination of Figure 36 below shows a distinct drop in PBI levels the last two years. These lower values may reflect impacts associated with the ongoing drought (lower lake level, predominance of low-growing blue-greens at many sites and lowered nutrient inputs). When the PBI data for the whole lake were separated by lake surface elevation at the time of sampling, a statistically significant negative trend similarly was found for PBI when lake levels $\geq$ 6225 ft. and time submerged <1000 days. A similar trend was found for samples collected when lake levels $\geq$ 6225 ft. and time submerged <1000 days.

These results are different from the lake-wide chlorophyll results based on routine sites (Section 3.b.4) which showed no temporal trend during for the same period. Since the routine site Chl *a* data represents a much more complete data set for the period, with multiple samplings during each year, and includes all years except 2004, we would place the most emphasis on the results for the routine site Chl *a* which indicate no overall significant trend for the stalked diatoms and or filamentous green algae for all routine sites combined (lake-wide) during 2000-2015.

Finally to view lake-wide patterns for biomass, charts of PBI vs associated shoreline length were prepared (Figures 37-39 below). For each periphyton site, a length of associated shoreline was determined extending half the distance to the next nearest synoptic site on either side. The percent of each periphyton site shoreline section relative to the total shoreline length were then determined. The PBI associated with each shoreline section were then determined and percent of total shoreline associated with a PBI level plotted for each of the synoptic years (note the data was divided among 3 graphs to better allow discernment of patterns for individual years). The plot curves represent the percentage of the total shoreline with a PBI value (spring maximum) less than or equal to a PBI value.

Figures 37-39 demonstrate that there's annual variation in the amount of shoreline associated with a given level of PBI. For instance in Figure 38 it can be seen that there was a greater proportion of shoreline with higher PBI in WY 2011 and 2012 than in 2010. However, it is apparent from reviewing all the figures that there is not a consistent temporal trend for amount of shoreline associated with a given PBI.

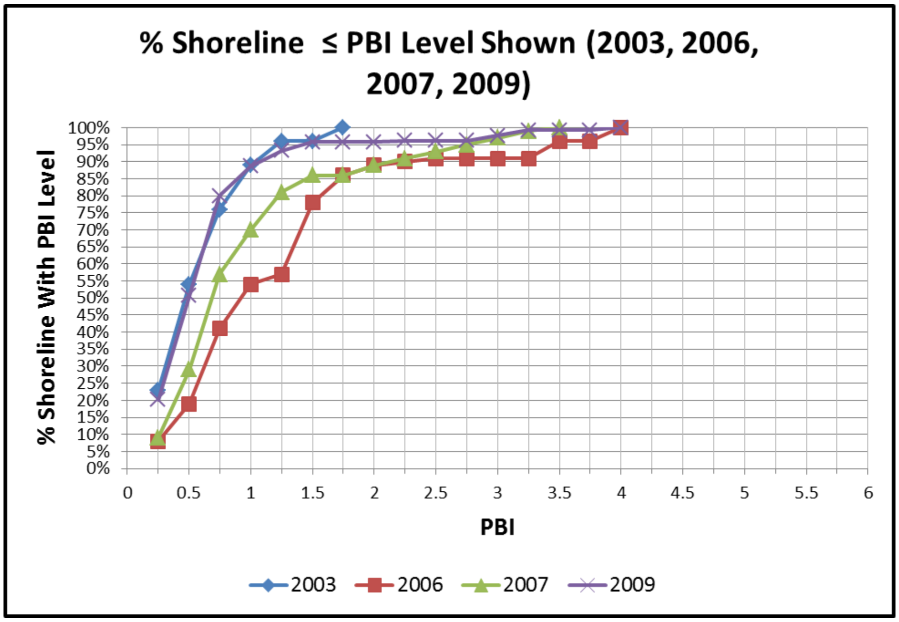


Fig. 37. Percentage of the total shoreline with a PBI value (spring maximum) less than or equal to a PBI value for WY 2003, 2006, 2007, 2009.

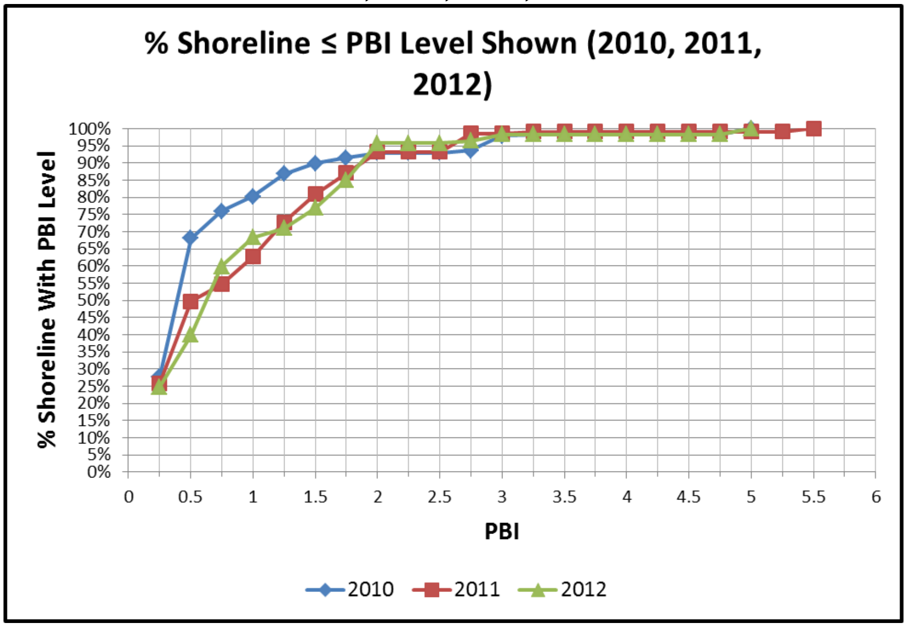


Figure 38. Percentage of the total shoreline with a PBI value (spring maximum) less than or equal to a PBI value for WY 2010-2012.

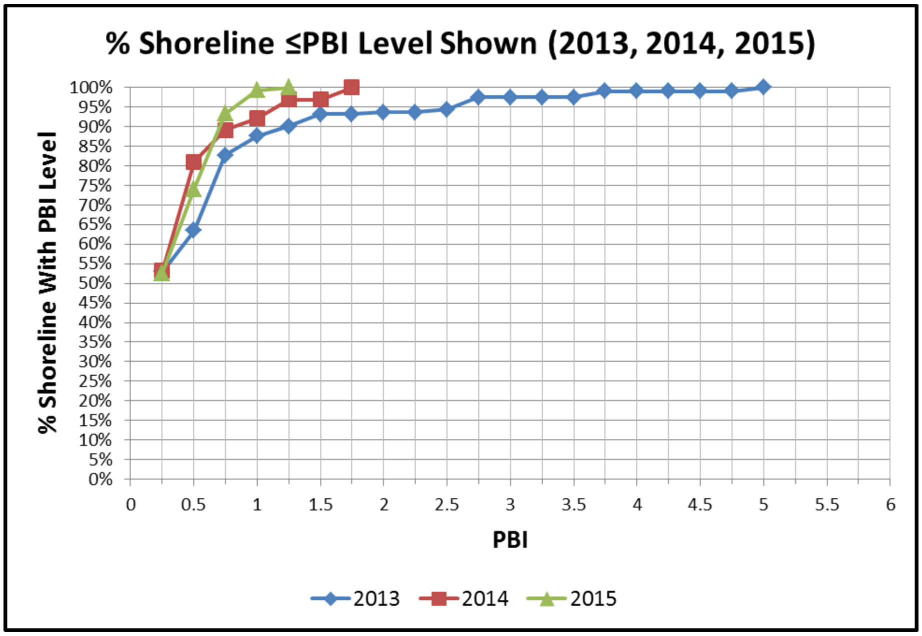


Figure 39. Percentage of the total shoreline with a PBI value (spring maximum) less than or equal to a PBI value for WY 2013-2015.

4. Summary of Findings

1. UC Davis TERC has conducted periphyton monitoring in Lake Tahoe since 1982. Monitoring occurred for select periods in the 1980s (1982-85) and 1990s (1989-93). Near-continuous monitoring has occurred since 2000 with a one-year gap in 2004. Periphyton monitoring has primarily focused on measuring levels of algal biomass (as chlorophyll a) at up to ten "routine" monitoring sites around the lake. Samples of attached algae for measurement of biomass have been collected from natural rock surfaces at depth of 0.5m five or more times per year. These data were assessed using a Mann-Kendall trend test to determine if there were significant temporal trends.
2. On the scale of the whole-lake, (combining all routine sites) no statistically significant overall trend was found for periphyton biomass for the period 2000-2015 and also for data 1982-2015. These results are for the types of algae (stalked diatoms and filamentous green algae) that can develop very heavy growth in the nearshore and are most commonly associated with poor aesthetic quality. As noted earlier, however, these time periods were after the largest decline in pelagic lake clarity had already occurred, and it is possible that the period of periphyton increase may already have occurred.
3. The data were also analyzed by region for presence of trends. The Chlorophyll a data was grouped as follows: West (Rubicon Pt., Sugar Pine Pt. and Pineland); North (Tahoe City, Dollar Pt. and Incline West) and East (Sand Pt., Deadman Pt. and Zephyr Pt.) and the Mann-Kendall test used to test for significant trends. A significant positive (upward) trend was found for the North region for the most recent period, 2000-2015. Statistically significant trends were not found for the other two regions for 2000-2015. No significant trends were found by region for the 1982-2015 period.
4. The data were also analyzed for presence of temporal trends at individual routine sites. 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. Further study would be needed to determine the primary contributing factors to trends at these sites.
5. In assessing trends we recommend greater emphasis should be placed on the analysis of recent data (i.e. 2000-2015) since the data set is nearly continuous. There is less certainty about trends during the 1982-2000 period, since there were multi-year periods when data were not collected and also extended period of drought and extreme low lake levels which affected levels of biomass as a result of the elevation of sampling. The period 1990-1994 represents the lowest, sustained lake level during the last 40 years. Analysis of trends 1982-2015 indicated that: (1) at the whole-lake scale there was no significant temporal trend; (2) similarly at the regional scale there were not temporal trends; (3) at

the scale of individual sites, one site (Sugar Pine Pt.) showed a statistically significant negative (decreasing trend). This site had quite elevated levels of periphyton Chl *a* in the mid-80's with relatively low levels in the 2000's. This site is adjacent to State Park land and an intervening zone characterized as medium development.

6. The association between level of development and periphyton Chl *a* biomass at the routine sites was tested using a Kruskal-Wallis test. The results of the Kruskal-Wallis test revealed a significant association between the level of development in the intervening zone, and amounts of periphyton biomass. Inspection of mean Chl *a* values calculated for each level of development suggest higher amounts of biomass tended to be associated with higher levels of development in the adjacent intervening zone. However there was some variability in this trend with some sites adjacent to high development having low mean biomass (e.g. Zephyr Pt. mean Chl a = 16 mg/m^2) and some sites adjacent to low development had elevated biomass (e.g. Rubicon Pt. mean Chl a = 30 mg/m^2). As indicated above two of ten sites showed small but statistically significant upward trends in Chl *a* biomass. These two sites (Pineland and Incline West) are adjacent to intervening zones (IVZ) characterized as having medium development. The Pineland site is also near a large tributary, Ward Creek which may also impact levels of periphyton there (mean Chl a = 54 mg/m^2).
7. Spatial trends for periphyton biomass, expressed as PBI (periphyton biomass index) were also examined. The data show that levels for mean PBI were highest along the west (mean PBI=1.03) and north shores (mean PBI=0.88), followed by the south shore (mean PBI=0.67), the east shore had the lowest values (mean PBI=0.45). Assessment of the relative contributions year to year to the overall biomass indicated that patterns were relatively similar year to year. The west region contributed the greatest to overall biomass, followed by the north, south and east regions.
8. Data collected once each year during the spring when biomass is greatest ("Spring Synoptic" data) was also used to evaluate trends. Once each spring (starting in 2003), a sampling of approximately 40 sites in addition to the routine sites was conducted, approximately timed with the spring peak biomass. Chlorophyll a samples were typically collected from about a third of the sites, and a rapid assessment method is used to determine PBI at each site. PBI give an aesthetic measure of the level of biomass, it is based on the percent cover and thickness of algae at a site. PBI for all sites combined typically shows a positive association to chlorophyll a, but the degree of association can be variable from year to year. Trends were assessed on synoptic PBI and Chl *a* data at the regional and whole-lake scale. The results of the Mann Kendall tests indicated there were no statistically significant temporal trends by region for Chl *a* data. In contrast, the tests indicated that there were statistically significant negative trends for PBI for all four regions (west, north, east, south). However, due to potential limitations of the Mann-Kendall test when using with small sample sizes, we do not consider these results as definitive indicators of trend for the regions. The results for the Mann Kendall test for

whole lake synoptic PBI data also indicated a statistically significant negative trend. These results are different from the lake-wide chlorophyll results based on routine sites which showed no temporal trend during for the same period. Since the routine site Chl *a* data represents a much more complete data set for the period, with multiple samplings during each year, and includes all years except 2004, we would place greater emphasis on the results for the routine site Chl *a* analysis which indicated no overall significant trend for the stalked diatoms and or filamentous green algae for all routine sites combined (lake-wide) for 2000-2015.

9. Patterns for synoptic PBI and land use categories were also investigated. A significant difference in level of PBI biomass was found between sites adjacent to low development and higher levels of development when biomass was relatively low. This difference was not apparent when biomass was within 10 percent of the long-term mean or higher. In the four years when biomass was higher, the lake elevation was >6225 ft. Based on the earlier conclusion that the ephemeral diatom and filamentous green algal communities occur at elevations >6225 ft. and that these algae may be affected nutrient control, management of periphyton in the at sites adjacent to medium+high levels of development areas can be justified. The data also suggest that periphyton accumulation at the mouths of certain creeks/channelized tributaries is important. The highest levels of PBI biomass were consistently found at the sampled stream mouth sites with the exception of Blackwood Creek which appears to be low because of low colonization resulting from physical abrasion. A number of sites including Tahoe City, the TCPUD Boat Ramp, Emerald Bay/Rubicon and, especially Pineland and the mouths of Ward Creek, South Dollar Creek and the Tahoe City tributary, exhibited a chronic condition of very high periphyton accumulation. Other sites were shown to experience significant aesthetic problems during any single year. While the data clearly show the magnitude and the distribution of the problem, it is critical that more specific information regarding all the factors that affect growth at these sites be ascertained to help guide localized restoration. Given the largely stimulatory role that nutrients have on algae, watershed restoration in the intervening zones as well as the land that drains into the channelized tributaries should be given close consideration.
10. There are three primary algal types that occur in the nearshore zone at this depth: (1) stalked diatoms, (2) filamentous green algae, and (3) cyanophytes. In this analysis much attention is given to the stalked diatoms and filamentous green algae. These algae have substantial growth rates resulting in rapid colonization of suitable areas in mid- to late-winter and spring. They can take advantage of localized soluble nutrients, and can establish a thick cover over the substrate within a matter of months and die-back and slough from the rocks later in the spring into summer. They are the algae types most commonly associated with poor aesthetic quality associated with periphyton in the nearshore. The other type of algae, Cyanophytes (blue-green algae), are typically found in the nearshore slightly deeper than the stalked diatoms and filamentous green algae.

These algae create a coating on the rocks which is either a slimy, crusty coating or a slightly furry, coating, which is less thick than the stalked diatoms and filamentous green algae. The cyanophytes are slower-growing and persist on the rocks throughout the year. As lake level declines, these algae are closer to the water surface and consequently become part of the biomass sample collected during periphyton monitoring.

11. The blue-green algae biomass at some sites such as Deadman Pt. and Sand Pt. during low lake levels can be quite elevated compared with higher lake level years in which there is little or no contribution of blue greens to the Chl *a* biomass and little biomass associated with other algal types. The blue green algae biomass is relatively consistent throughout the year. The presence of blue greens can confound the determination of trends. For instance when lake level drops, elevated biomass at some sites is due largely to the presence of blue greens and not reflective of increased seasonal growth of diatoms and filamentous greens. Based upon an analysis of field data on general algal types at sampling sites, we used 6225 ft. as a demarcation point for the potential influence of blue-green algae Chl *a* on sample Chl *a*. Data were separated based on the lake elevation of 6225 ft. and temporal trends also analyzed. Data for samples collected at 0.5 m when lake elevation was $\geq$ 6225 ft. were considered to represent the stalked diatoms and filamentous blue greens, without blue greens.
12. We also looked at the effect of length of time substrate was submerged on algal types at the sampling site and biomass. Blue greens were found to develop on rocks at many sites after a time of submergence of about1000 days or nearly 3 years.
13. During low lake-level years it is important to recognize that blue-green algae may also be located near the surface, resulting in algae-coated-rocks near or above the surface (in some places where there is usually little algae at the surface). This is a lake level effect not necessarily associated with nutrient inputs. It is different from the thick spring growth of stalked diatoms and filamentous green algae that may develop in response to nutrient inputs.
14. In the Lake Tahoe TMDL development, science showed the importance of fine sediment particles on lake transparency (Secchi depth). This represented a huge paradigm shift on past restoration philosophy. Subsequently, much of the remediation efforts have focused on these fine particles. While the TMDL recognized the need for nitrogen and phosphorus control in general, in the case of the littoral zone it may hold greater importance. Given the largely stimulatory role that nutrients have on algae, watershed restoration in the intervening zones as well as the land that drains into the channelized tributaries should be given close consideration.

5. Recommendations for Future Analysis and Future Work

This report provided the first comprehensive assessment for temporal trends in the routine and synoptic periphyton database, and the relationship between biomass accumulation and land use. The results from this report hopefully will provide information to select the types of data which best identify temporal and spatial trends for the periphyton. There are also many other useful analyses that could be done with the routine and synoptic data. For instance, correlations between biomass and other environmental variables either collected with this study or as part of lake and watershed monitoring could be evaluated to help assess primary factors controlling biomass at selected sites. As part of the periphyton monitoring work for Lahontan, we will be working to get the periphyton data into a readily accessible database such as CEDEN.

In general, the primary results of this analysis are that temporal trends during the period of record are either statistically insignificant or very slight. One reason for this may be that given the number of controlling variables (e.g. water level, time submerged, algal type etc.) the data record is still relatively sparse. Another possibility is that since the monitoring commenced in the mid-1980s, the trends are as indicated by the data, with the period of increasing density of periphyton having occurred earlier. While there are no quantitative data to support this, there is an overwhelming amount of anecdotal data to suggest that extremely low periphyton levels were once the norm for Lake Tahoe's shoreline.

By contrast, the spatial trends are a little more definitive, with areas of medium and high development displaying higher levels of periphyton biomass. Whether this is due to the presence of the development itself or whether it is also tied to the fact that development often occurred in areas of flatter land (meadows, wetlands etc.) has yet to be determined.

The Lake Tahoe Nearshore Evaluation and Monitoring Framework (Heyvaert et al. 2013) recommended that periphyton monitoring using the same methodology and at an intensity similar to what has been historically performed should be continued. Clearly if duplicate samples or samples at multiple depths at each site were taken, better estimates of uncertainty would be attained. With a great intensity of measurement, temporal trends may possibly emerge and spatial variability may be more clearly demarcated.

However, increased intensity of the present monitoring program will provide little insight on what actions the basin agencies should be taking to control periphyton growth. If that is the desire of basin managers, then a better quantitative understanding of the underlying **processes** that can lead to a predictive modeling tool for periphyton is necessary. Some preliminary first steps have been taken in this direction by TERC researchers, by combining the data being collected by the real-time Nearshore Network with a new periphyton model. This model is anticipated to be able to separate and prioritize the role of variations in water level, light climate, nutrient supply and surrounding land use on periphyton growth. An important goal of this model will be to determine the level of response in periphyton biomass based on changing environmental conditions and management actions. However, it is still at an early stage, and many critical unknowns still exist.

While some may be inclined to equate the finding of few significant trends to a conclusion that there is no periphyton problem at Lake Tahoe, we strongly caution against this. This caution is supported by the finding that periphyton growth at many locations around the lake is aesthetically degraded regardless of temporal trends. As stated, the period of measurement occurred after the major land use changes had already occurred and water clarity had been drastically reduced. More importantly, there is growing evidence that the littoral zones of lakes worldwide are degrading at an alarmingly rapid rate. Lake Baikal and Lake Superior share many similarities with Lake Tahoe. A recent paper, (Timoshkin et al. 2016) document some of the changes, particularly in Lake Baikal, where multiple changes have occurred in the littoral zone in just five years. While some of the drivers are different, there are many commonalities.

We would welcome a meeting with TRPA and Lahontan Regional Water Quality Control Board (and potentially additional stakeholders) to determine what the primary needs are from the agencies with respect to periphyton monitoring. What data are most useful to assess progress with respect to the periphyton threshold? What additional data needs are required to inform Agency's actions?

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Appendix A. Synoptic data grouped according to region. Temporal patterns for Chl *a* and PBI. Data from 2005 and 2008 was excluded since biomass peaks were significantly missed at some sites. Sites were grouped into regions as follows: West= Site # 39 Emerald Bay/ Rubicon to #52 Tavern Pt., North= #1-Tahoe City to #18-Burnt Cedar Beach, East = #19 Hidden Beach to #33 South Elk Pt., South= #34 Timber Cove to #39 South of Eagle Pt. (Next Page)

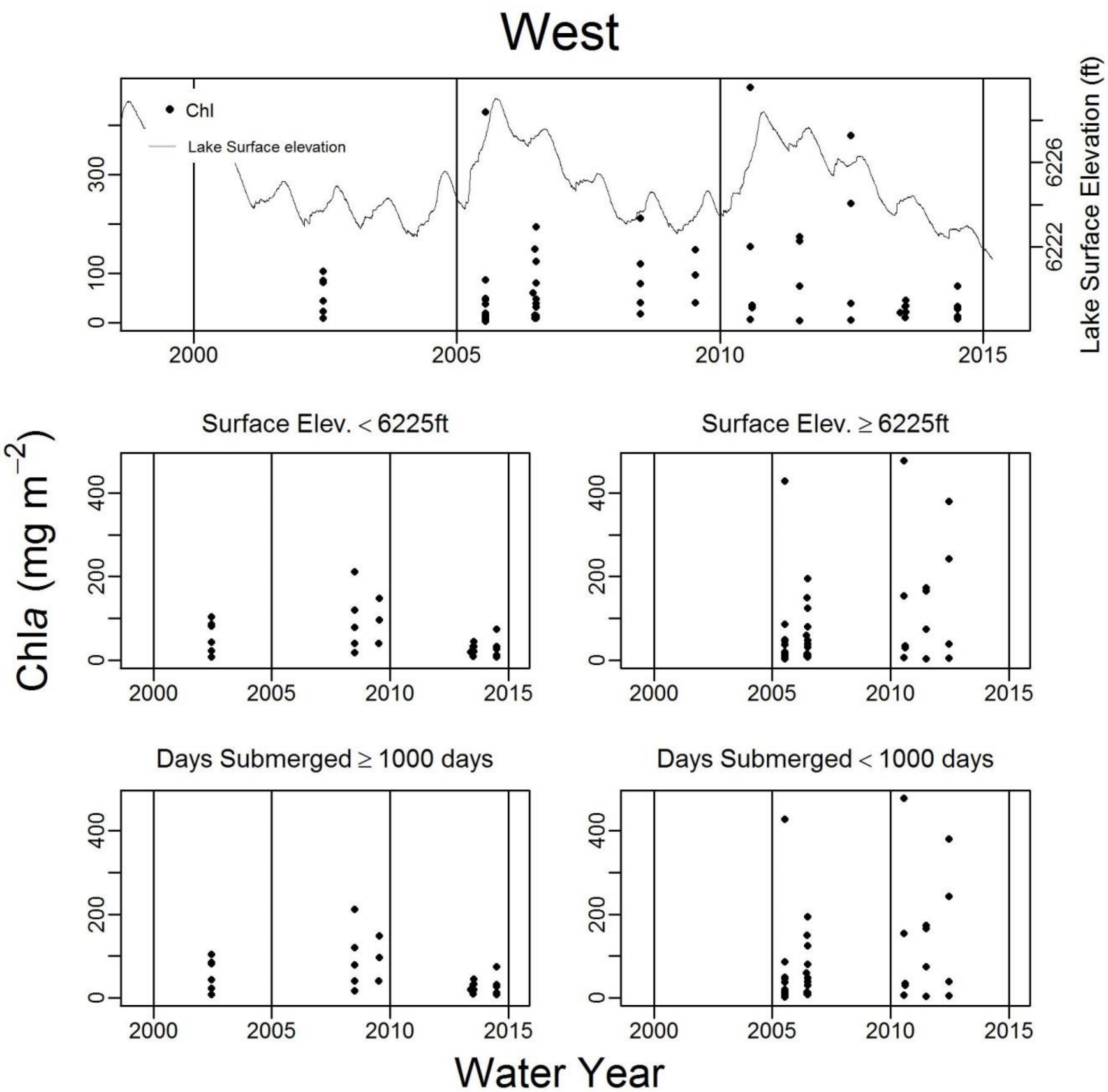

Fig. 39. Summary of Spring Synoptic Chl *a* data for sites grouped in the West region (Upper Panel). The middle panel shows the data separated based on surface elevation <,≥ 6225 ft., and the lower two panels show the data separated based on length of time site was submerged.

Table 26. Results for Mann Kendall trend test for Synoptic chlorophyll a for the West region.

West	#	Mean	SD	Med	*Tau*	*S*	*z*	*p*
All obs.	63	74.3	98.1	38.2	0.03	5	0.19	0.85
SD./Green Fil.								
>= 6225ft	38	86.2	119.0	38.0	0.35	14	1.59	0.11
< 1000 days	38	86.2	119.0	38.0	0.35	14	1.59	0.11
+ Blue-greens								
< 6225ft	25	56.2	49.9	39.7	-0.21	-6	-0.77	0.44
>= 1000 days	25	56.2	49.9	39.7	-0.21	-6	-0.77	0.44

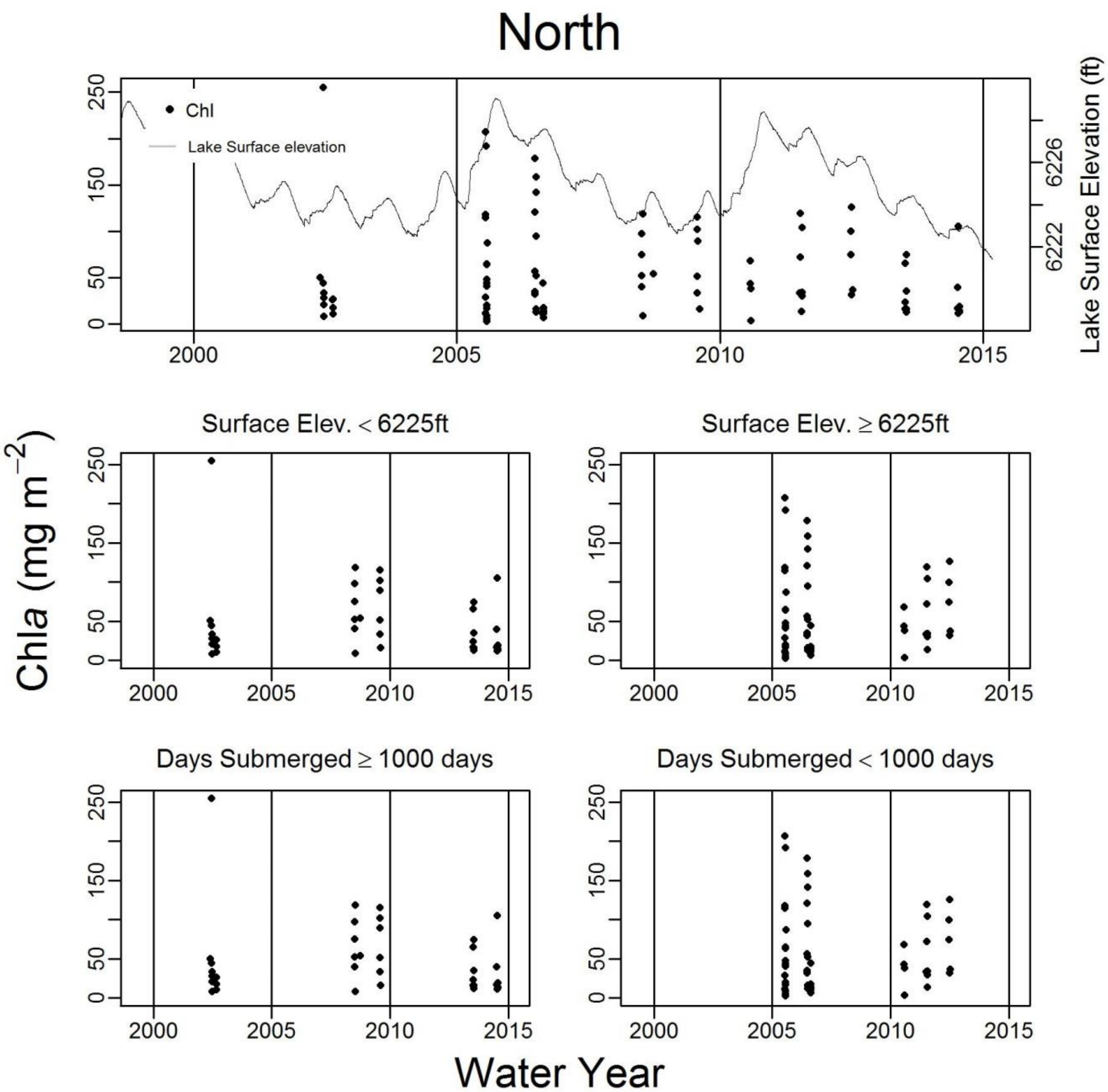

Fig. 40. Summary of Spring Synoptic Chl *a* data for sites grouped in the North region (Upper Panel). The middle panel shows the data separated based on surface elevation <.≥ 6225 ft., and the lower two panels show the data separated based on length of time site was submerged.

Table 27. Results for Mann Kendall trend test for Synoptic Chl *a* for the North region.

North	#	Mean	SD	Med	*Tau*	*S*	*z*	*p*	
All obs.	88	54.9	50.6	37.4	-0.22	-49	-2.08	0.04	-
SD./Green Fil.									
>= 6225ft	50	60.0	52.8	41.9	0.17	6	0.65	0.51	
< 1000 days	50	60.0	52.8	41.9	0.17	6	0.65	0.51	
+ Blue-greens									
< 6225ft	38	48.2	47.4	33.3	-0.25	-10	-1.10	0.27	
>= 1000 days	38	48.2	47.4	33.3	-0.25	-10	-1.10	0.27	

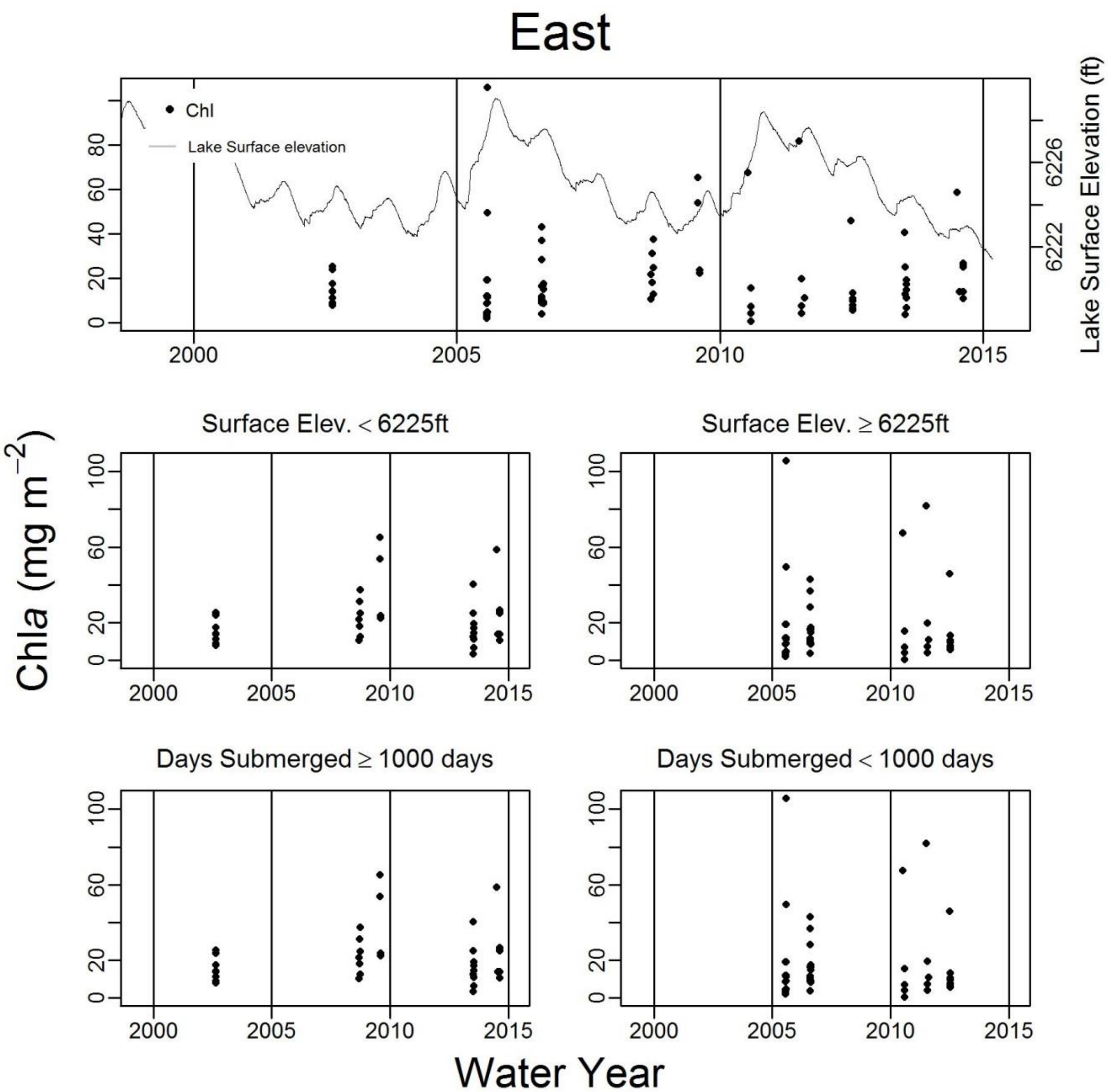

Fig. 41. Summary of Spring Synoptic Chl *a* data for sites grouped in the East region (Upper Panel). The middle panel shows the data separated based on surface elevation <.≥ 6225 ft., and the lower two panels show the data separated based on length of time site was submerged.

Table 28. Results for Mann Kendall trend test for Synoptic Chl *a* for the East region.

East	#	Mean	SD	Med	*Tau*	*S*	*z*	*p*
All obs.	82	19.4	18.7	13.5	-0.01	-3	-0.09	0.93
SD./Green Fil.								
>= 6225ft	47	17.5	21.3	10.3	0.11	4	0.39	0.70
< 1000 days	47	17.5	21.3	10.3	0.11	4	0.39	0.70
+ Blue-greens								
< 6225ft	35	21.9	14.3	18.1	-0.06	-2	-0.13	0.90
>= 1000 days	35	21.9	14.3	18.1	-0.06	-2	-0.13	0.90

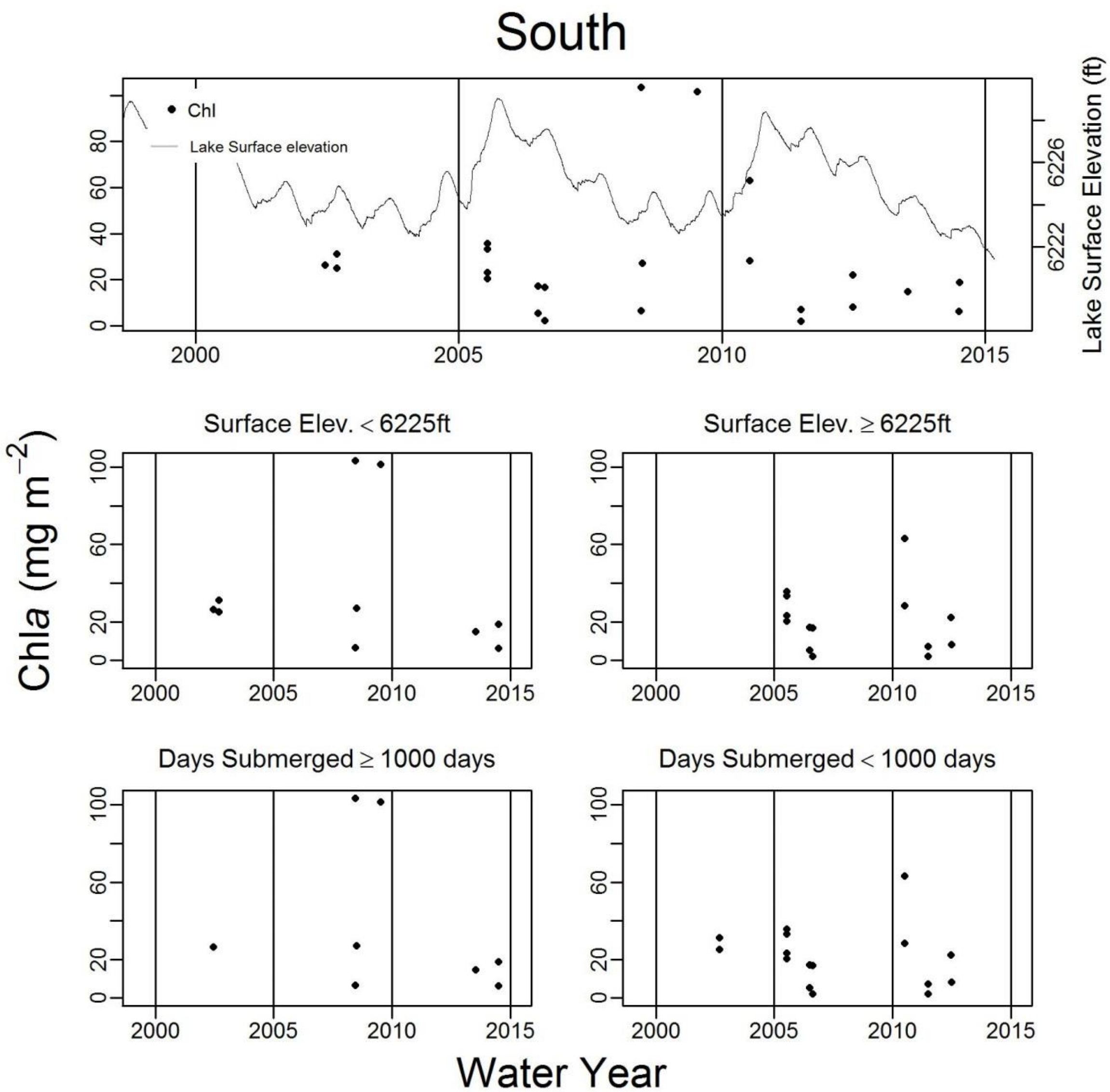

Fig. 42. Summary of Spring Synoptic Chl *a* data for sites grouped in the East region (Upper Panel). The middle panel shows the data separated based on surface elevation <.≥ 6225 ft., and the lower two panels show the data separated based on length of time site was submerged.

Table 29. Results for Mann Kendall trend test for Synoptic Chl *a* for the South region.

South	#	Mean	SD	Med	*Tau*	*S*	*z*	*p*
All obs.	24	26.8	26.9	21.1	-0.33	-22	-1.72	0.09
SD./Green Fil.								
>= 6225ft	14	20.2	16.5	18.6	-0.25	-4	-0.60	0.55
< 1000 days	16	21.2	15.6	21.1	-0.28	-7	-0.89	0.37
+ Blue-greens								
< 6225ft	10	36.0	36.0	25.6	-0.33	-2	-0.34	0.73
>= 1000 days	8	38.0	40.5	22.5				

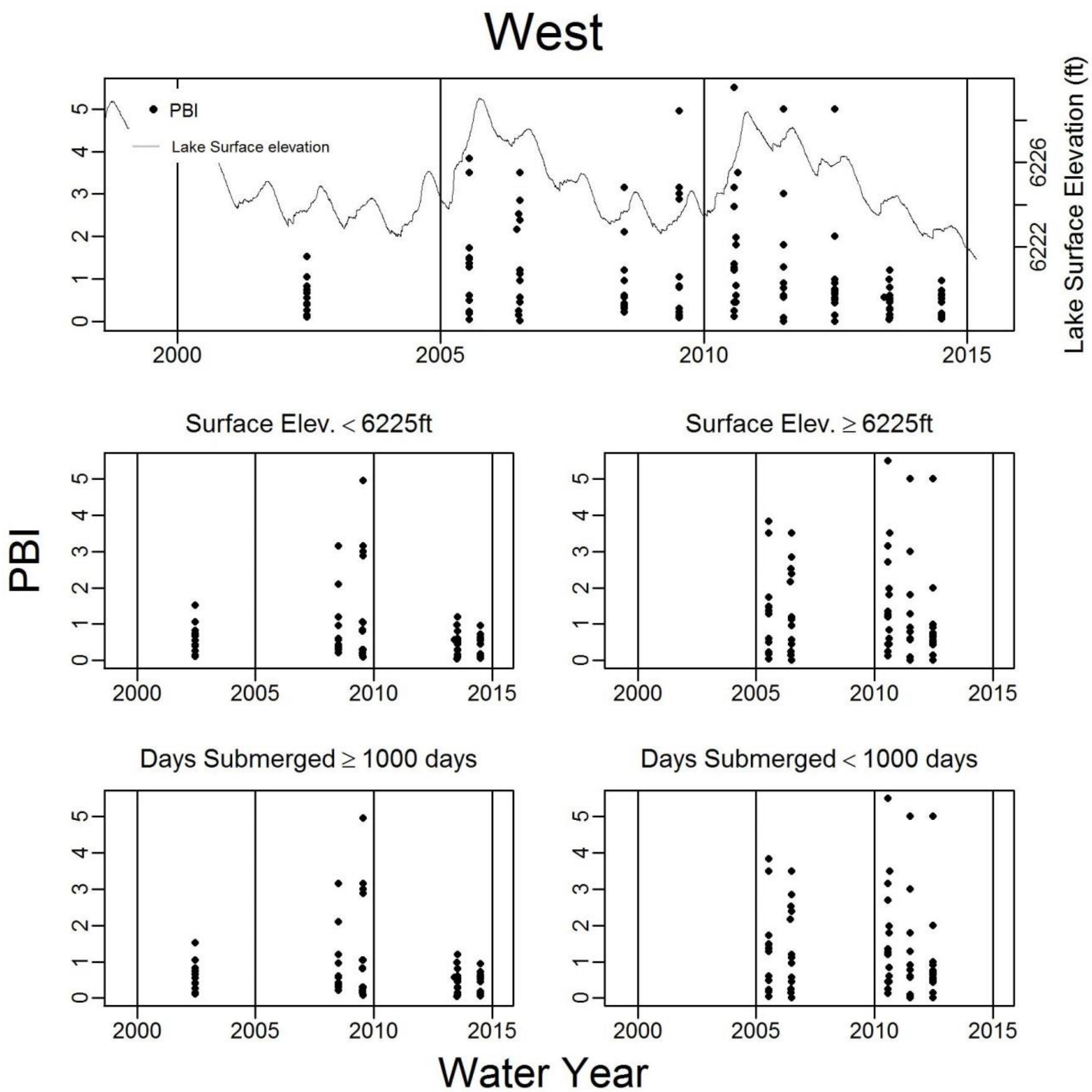

Fig. 43. Summary of Spring Synoptic PBI data for sites grouped in the West region (Upper Panel). The middle panel shows the data separated based on surface elevation <.≥ 6225 ft., and the lower two panels show the data separated based on length of time site was submerged.

Table 30. Results for Mann Kendall trend test for Synoptic PBI for the West region.

West	#	Mean	SD	Med	*Tau*	*S*	*z*	*p*	
All obs.	132	1.1	1.2	0.6	-0.19	-108	-2.73	0.01	-
SD./Green Fil.									
>= 6225ft	68	1.3	1.3	0.9	-0.25	-33	-2.19	0.03	-
< 1000 days	68	1.3	1.3	0.9	-0.25	-33	-2.19	0.03	-
+ Blue-greens									
< 6225ft	64	0.7	0.9	0.5	-0.22	-26	-1.80	0.07	-
>= 1000 days	64	0.7	0.9	0.5	-0.22	-26	-1.80	0.07	-

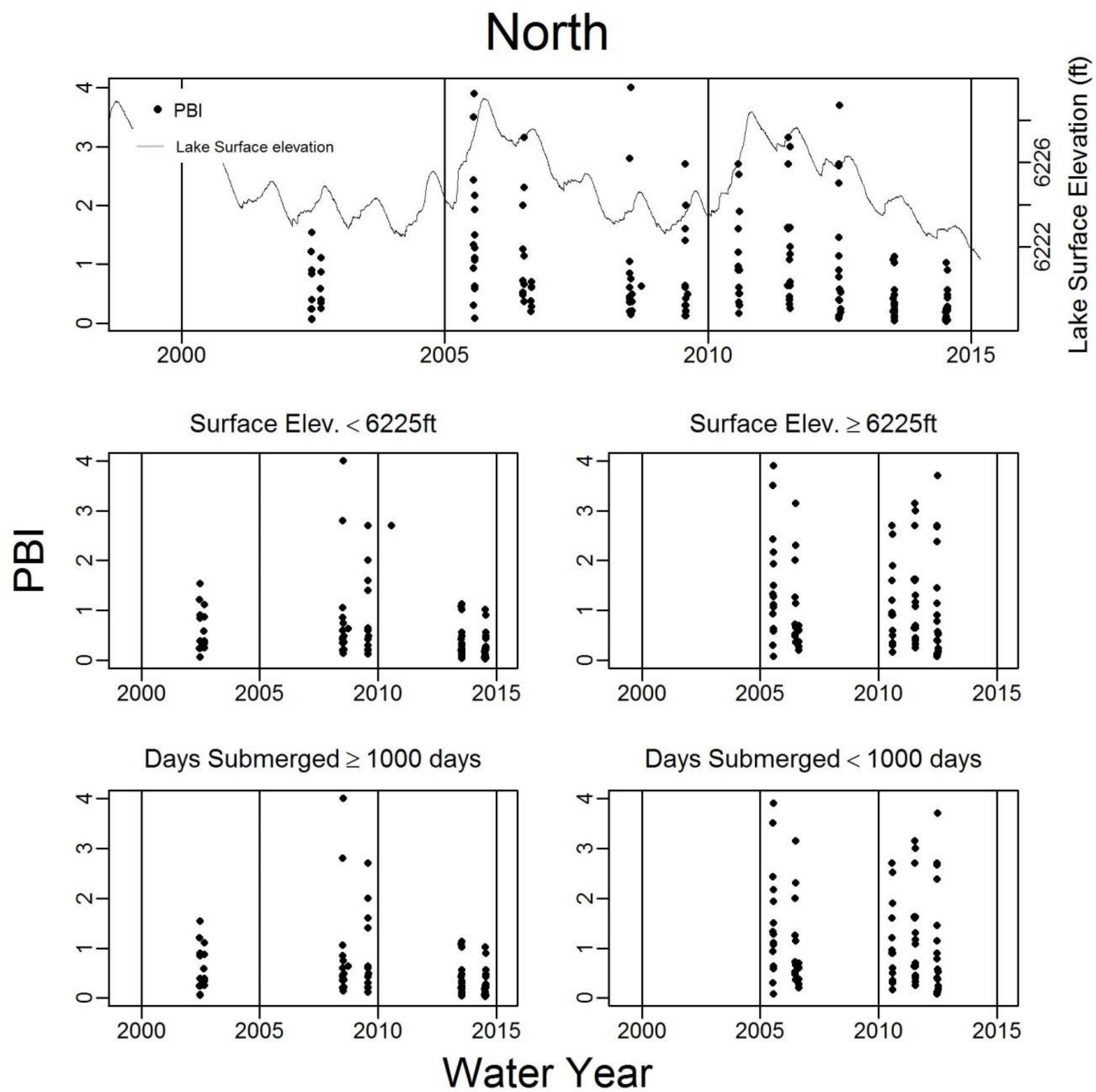

Fig. 44. Summary of Spring Synoptic PBI data for sites grouped in the North region (Upper Panel). The middle panel shows the data separated based on surface elevation <.≥ 6225 ft., and the lower two panels show the data separated based on length of time site was submerged

Table 31. Results for Mann Kendall trend test for Synoptic PBI for the North region

North	#	Mean	SD	Med	*Tau*	*S*	*z*	*p*	
All obs.	169	0.9	0.9	0.6	-0.27	-195	-4.38	<0.01	-
SD./Green Fil.									
>= 6225ft	84	1.2	0.9	0.9	-0.29	-46	-2.81	<0.01	-
< 1000 days	85	1.2	1.0	0.9	-0.29	-47	-2.83	<0.01	-
+ Blue-greens									
< 6225ft	85	0.6	0.7	0.4	-0.41	-67	-4.06	<0.01	-
>= 1000 days	84	0.6	0.7	0.4	-0.41	-64	-3.93	<0.01	-

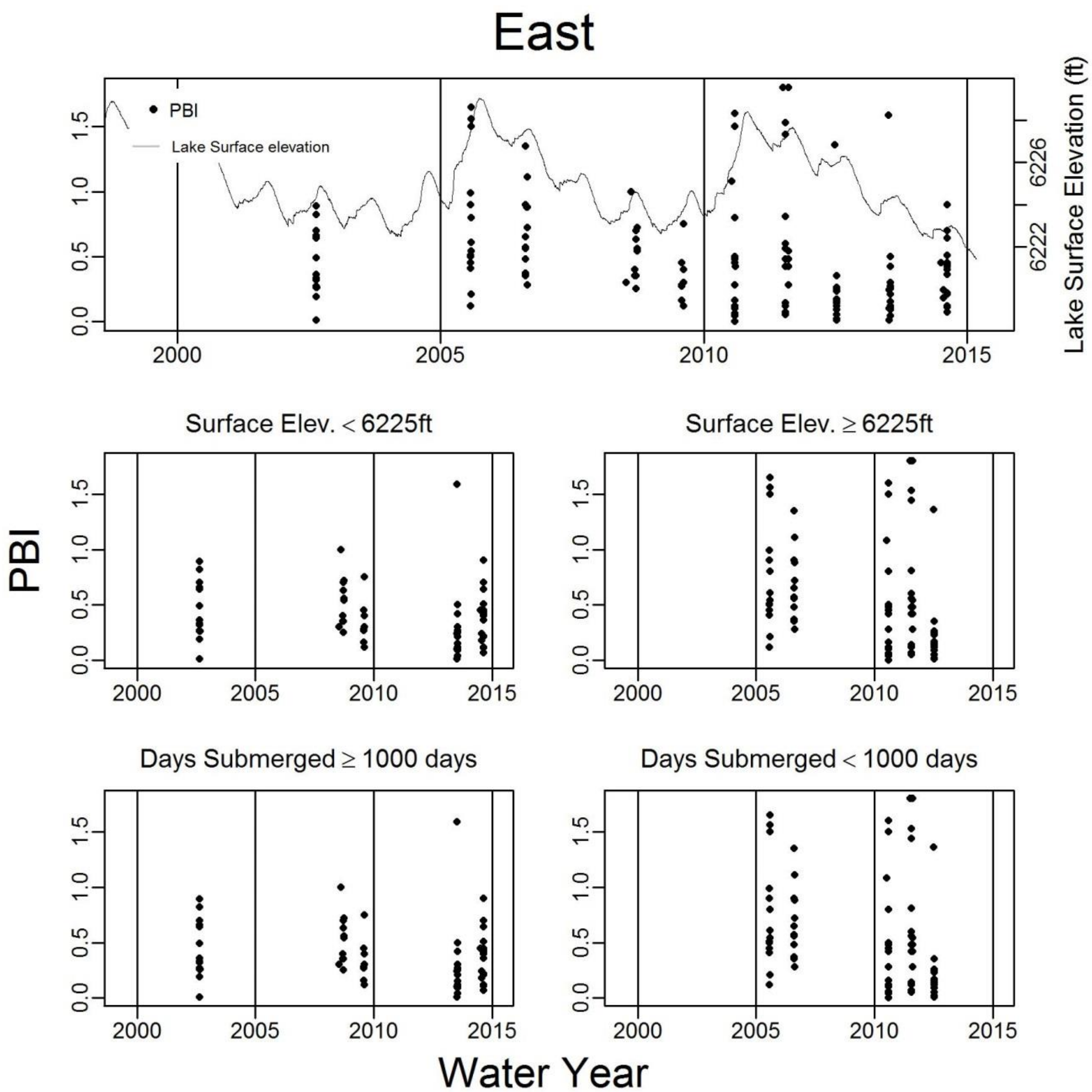

Fig. 45. Summary of Spring Synoptic PBI data for sites grouped in the East region (Upper Panel). The middle panel shows the data separated based on surface elevation <.≥ 6225 ft., and the lower two panels show the data separated based on length of time site was submerged

Table 32. Results for Mann Kendall trend test for Synoptic PBI for the East region

East	#	Mean	SD	Med	*Tau*	*S*	*z*	*p*	
All obs.	151	0.5	0.4	0.4	-0.28	-186	-4.37	<0.01	-
SD./Green Fil.									
>= 6225ft	80	0.6	0.5	0.5	-0.40	-64	-3.79	<0.01	-
< 1000 days	80	0.6	0.5	0.5	-0.40	-64	-3.79	<0.01	-
+ Blue-greens									
< 6225ft	71	0.4	0.3	0.3	-0.21	-25	-1.72	0.09	-
>= 1000 days	71	0.4	0.3	0.3	-0.21	-25	-1.72	0.09	-

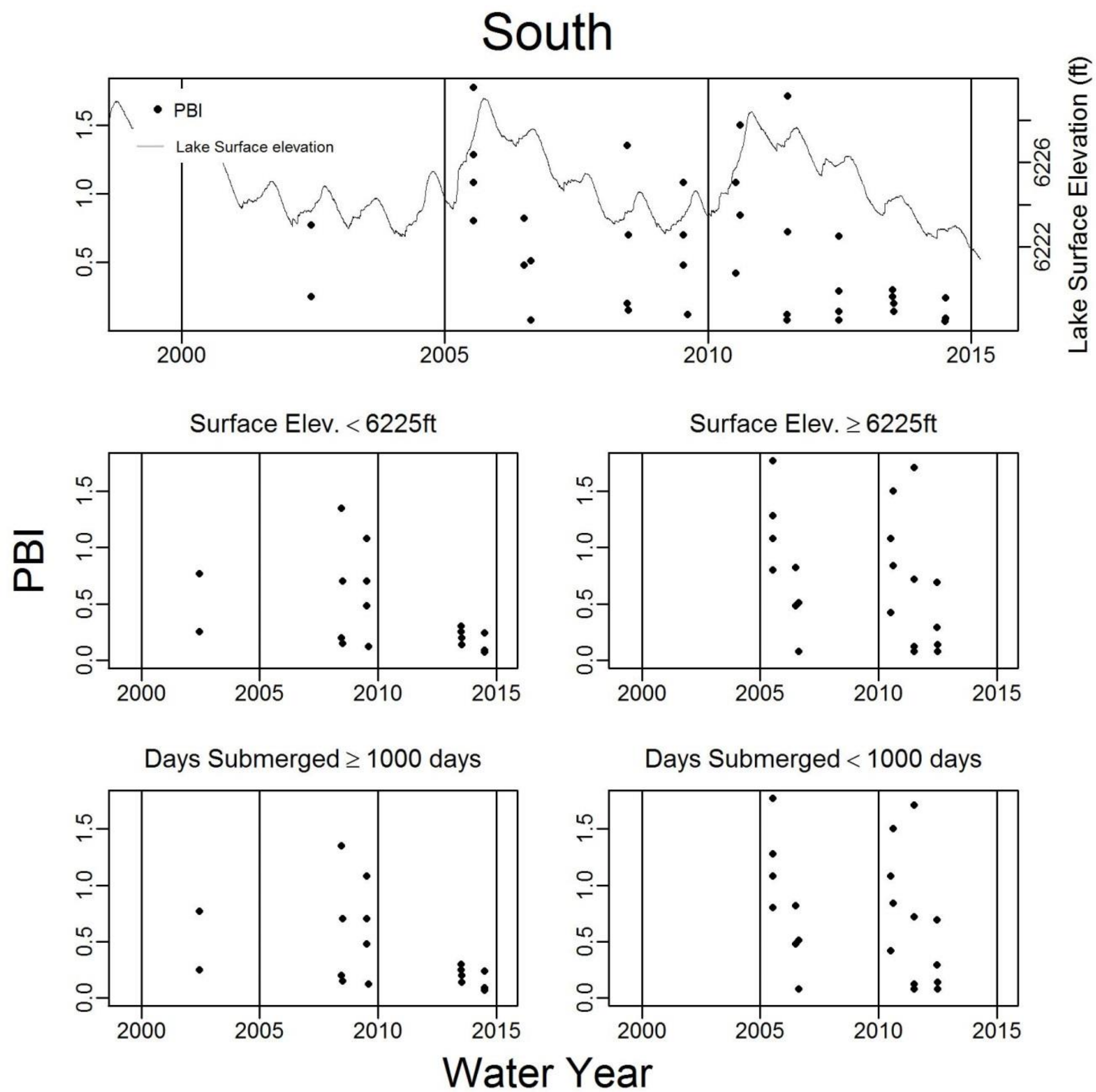

Fig. 46. Summary of Spring Synoptic PBI data for sites grouped in the South region (Upper Panel). The middle panel shows the data separated based on surface elevation <.≥ 6225 ft., and the lower two panels show the data separated based on length of time site was submerged

Table 33. Results for Mann Kendall trend test for Synoptic PBI for the South region

South	#	Mean	SD	Med	*Tau*	*S*	*z*	*p*	
All obs.	37	0.6	0.5	0.5	-0.38	-59	-2.88	<0.01	-
SD./Green Fil.									
>= 6225ft	20	0.7	0.5	0.7	-0.53	-21	-2.47	0.01	-
< 1000 days	20	0.7	0.5	0.7	-0.53	-21	-2.47	0.01	-
+ Blue-greens									
< 6225ft	17	0.4	0.4	0.3	-0.65	-17	-2.50	0.01	-
>= 1000 days	17	0.4	0.4	0.3	-0.65	-17	-2.50	0.01	-