Biological Condition Index Development for the Truckee River: Periphyton Assemblage

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Acknowledgements:

Efforts to evaluate the approach of using indices of biological integrity (IBIs) in Nevada have been spearheaded by the Nevada Department of Environmental Protections' Bureau of Water Quality Planning. Karen Vargas' efforts to bring a multitude of perspectives together to work and provide feedback on this effort has been especially commendable Many other people and organizations have contributed to the collection of the data and information as well as the approaches to interpretation which are reported upon within this document. Notably, Washoe County personnel (Gail Prockish) logged many hours on the river during the collection of periphyton samples that ultimately lead to generating the majority of the periphyton assemblage data that was used within this report. The Truckee Meadows Water Reclamation Facility (Tom Swan, Mike Brisbin) helped support analytical efforts and contributed to the collection of periphyton samples through the contribution of resources and personnel. Their mission to responsibly monitor and evaluate the river's function has made the evaluation of the periphyton-based metrics possible. The Pyramid Lake Paiute Tribe has ultimately enabled the collection of samples and information from the reaches of the Truckee River that lie downstream of Wadsworth. Moreover, they have continuously provided perspective and consultations regarding monitoring programs on the Lower River. An army of graduate students from the Desert Research Institute participating in graduate programs at UNR (Hydrology, Environmental Sciences and Health and Environmental Resource Sciences) and DRI technicians ultimately has made the monitoring programs a valuable contribution to the efforts for monitoring and protecting Nevada's water resources. Without any one of the aforementioned efforts and resources, the modest progress regarding periphyton and IBI development for the Lower Truckee River would not have been possible.

Executive Summary:

The objectives of the current activities were to determine if sufficient data was available to derive preliminary periphyton-based metrics that could be used in a periphyton-based indices of ecological condition for the Lower Truckee River, which could in turn be used to derive more comprehensive indices of biological integrity (IBI) based on fish, macroinvertebrates and periphyton populations. Derivation of metrics and indices was made possible through the use of relatively recent (2000 to 2004) seasonal periphyton data that was collected from 11 to 15 locations from California-Nevada border to Pyramid Lake. Although, the levels of taxonomic information from the different data sets were not always comparable, several candidate metrics and indices encompassing information from both the species level and the genera level were identified, calculated and evaluated.

Notable among the metrics most amenable for a Truckee River Periphyton Index were the Siltation Index, Shannon Diversity Index, Eutraphentic Index, Diatom Generic Richness, % *Achnanthes minutissima*, Chlorophyll a and Ash Free Dry Weight. These metrics covered several aspects of the periphyton community characteristics (richness, composition, tolerance, and habit) that are desired attributes to be accounted for in multimetric indices.

Application of a periphyton-based multimetric index to the mainstem of the Truckee River indicates a general upstream to downstream trend for decreasing ecological condition. However, these results are based on a limited amount of periphyton data and also need to be evaluated in combination with Index's for fishes and macroinvertebrates in order to gain a more complete picture of the "condition" of the lower Truckee River.

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Introduction:

The Nevada Division of Environmental Protection has set a goal to use biological indicators to provide assessment of the ecological condition of the Truckee River. Periphyton assemblages are an integral component of any stream's ecosystem and a periphyton community assessment can provide information regarding the base of a stream's food web and a stream's biogeochemical cycling of materials. Periphyton have growth kinetics and response times to disturbance that typically are manifested on the time-scales of days to weeks and hence represent a means for bioassessment programs to gain information regarding potential responses to stressors over short time periods.

Fortunately, information on periphyton taxa autecology and response to different types of stressors has been studied to the degree that metrics for stream assessments can be developed (e.g. Stevenson and Bahls 1999, Coste et al. 1991; Rumeau and Coste 1988, Kelly et al. 1995).

Information on the taxa and composition of periphyton assemblages on the Lower Truckee River are evaluated in order to derive and support the potential development of multimetric indices of biological integrity. This information is evaluated in order to provide the basis for a more comprehensive Index based on fishes, macroinvertebrates as well as periphyton.

Data Acquisition and Aggregation

Sources:

Data on periphyton assemblages was aggregated from the Cities of Reno and Sparks periphyton biomass monitoring programs of 2000 to 2001 and 2001 to 2002 as well as their McCarran Ranch restoration monitoring program which has occurred in 2003-2004. The 2000-2002 sampling was implemented monthly, while 2003-2004 sampling occurred quarterly (Appendix B). These data encompass sampling sites located near the Nevada-California border to Pyramid Lake (Figure 1: Site Map, Appendices A: site description and locations). The general periphyton sampling protocols on which this data are based are described for the sake of completeness and future reference.

Field Methods for epilithic algal collection

Sampling sites were chosen along the river based on characteristics such as stream morphology, location relative to point sources, accessibility and wadeability. Each sampling site was then divided into five or six transects so as to establish a riffle, glide, riffle, glide, riffle sequence, where possible (Porter et al. 1993). Each transect was mapped using a line-transect approach wherein differences in flow regime, depth, and substrate were characterized moving from bank to bank. Based on differences in flow characteristics and substrate, each transect was divided into subunits and numbered sequentially from the working bank to the far bank. A common reference point, above the bank full discharge of the river corridor, was identified and used throughout the sampling program to measure distance to bank and facilitate continuity in unit identification

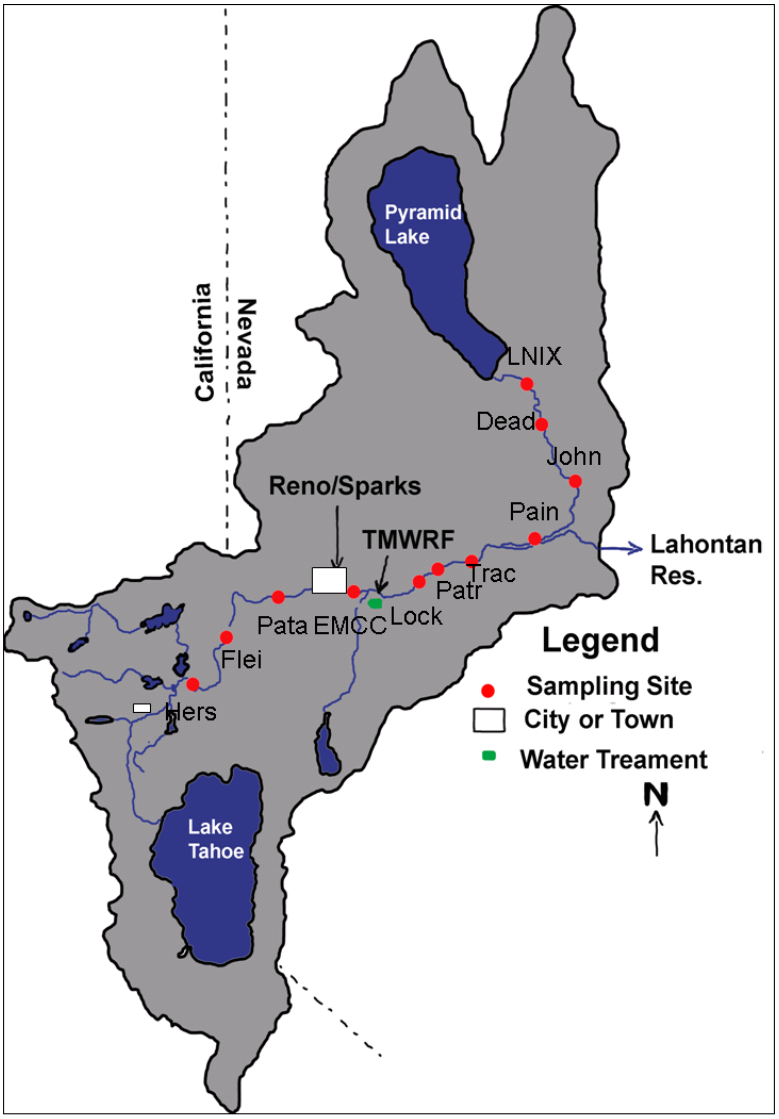

Figure 1. Sampling sites along the lower Truckee River, NV and distance from Lake Tahoe in parenthesis. HERS(32), FLEI (56), PATA (80), EMCC (97), LOCK (106), PATR (115), TRAC (122), PAIN (139), JOHN (152), DEAD (166), LNIX (178) [modified from California Dept. of Water Resources (1991)].

Epilithic samples were collected from each unit with cobble. Three cobbles were taken at random from within the accessible units and were placed in a plastic tub for processing. The SG-92 method (Porter et al. 1993) of sampling periphyton was used on each of the three cobbles. This was accomplished using an SG-92, which is made by placing a neoprene seal on the base of a 30 ml disposable syringe with the needle end cut off. The SG-92 was held tightly against the cobble and, an electric drill with a stainless steel wire dremmel brush attachment was then used to detach the periphyton from the cobble inside the known area of the SG-92 (Porter 1993). Areas of visually high, medium and low periphyton coverage were chosen, one from each of the three cobbles, for a composite sample of the three cobbles. Filtered stream water (FSW) (filtered through a 47 mm Whatman GF/F filter with ~180 mm Hg vacuum) was used as the transporting medium (solvent) for the periphyton detached from the cobble. Approximately 10 mls of FSW was added to the inside of the SG-92 during scraping, all of the solution (FSW

containing detached periphyton) was placed into a HDPE bottle for transport to the lab. The scraping and rinsing procedure was repeated three times for each SG-92 sampling area using three separate aliquots of FSW. The epilithic sample included the three rinses from each of the three cobbles along with any periphyton adhering to the brush upon completion of the composite. The sample was kept on ice in a darkened area until lab processing was completed.

Subsambling/Preservation for Microscopy

A subset of the epilithic and water quality samples was preserved with 0.5% v/v glutaraldehyde for microscopy. Twenty milliliters of the homogenized samples were placed in twenty milliliters borosilicate glass scintillation vials. After fixing with glutaraldehyde, the capped vials were sealed with parafilm and placed in a refrigerator until microscopic analysis.

Microscopy

The 2000-2002 samples were processed by PhycoTech, Inc. as outlined at www.phycotech.com and data was compiled at Desert Research Institute (DRI). Samples collected from 2003 and 2004 were analyzed at DRI's Systems Microbial Ecology Lab (SMEL). Within the SMEL, differential interference contrast (DIC) microscopy using an Olympus BX-60 was used for enumeration and identification of genera. Counting methods followed those utilized by PhycoTech, Inc. In short, a minimum of 400 natural unit counts were made from a 100 uL subsample observed under a 25mm x 25mm cover-slip and viewed at 400x. The minimum count was accomplished by random fields along a 15 mm transect. The side margins of the cover-slip were avoided due to possible edge affects. For larger taxa (>200um) an additional slide was completely enumerated at 100x. The large taxa counts were then estimated for the area observed at 400x to allow calculation of the 400x and 100x counts. For taxa determination to the generic level, 10 ml of subsample was acid washed (HNO3) and mounted in Naphrax © for viewing at 1000x.

Aggregation

Periphyton assemblage data was produced from two entities for the P-IBI assessment. PhycoTech, Inc. produced the 2000-2002 dataset, while the DRI SMEL produced the 2003-2004 dataset. Samples from both entities were pooled together into one compiled dataset. Candidate metrics were calculated for each dataset and the values compiled into a final spreadsheet for P-IBI manipulation and final determination. We explicitly note that the aggregation of the data sets combined information that had both genera-level and species-level taxonomic information. Recognizing that several difficulties can arise when trying to use algal species information in metrics (eg. species identifications are technically challenging, appropriate expertise is hard to find and the number of species in the metrics become large), we evaluated the use of genera-level metrics. Kelly et al. (1995) found that values for indices based on genera and those on species were highly correlated. This correlated performance between species and genera, supports past studies (Coste et al. 1991; Rumeau and Coste 1988) showing that the Specific Pollution Sensitivity Index and Generic Diatom Index, as well as two trophic diatom indices, were

similar and yielded similar information when comparing organic pollution or inorganic nutrient metrics. In our work, we examined the possible bias introduced by considering only genera scores for the commonly-used Pollution Tolerance Index rather than species-level scores and found that the scores were, on the majority, lower than those based on species. The same consideration was applied to the Shannon Diversity Index, with scores generated from genera and species compared through various sampling periods. The genera-based scores were once again conservative (i.e. lower than those calculated based on species), however, the trends were similar between the two (correlation values r= 0.78 for Shannon Diversity metric and r=0.73 for PTI). Because metrics and indices are ultimately normalized to the range of metric values, it appears that the genera-based metrics and indices will perform in a similar manner to the species-based metrics- a conclusion also supported by the findings in Kelly et al (1995)- without the ultimate cost of time and expertise needed for species taxon identifications.

Metric Selection

Candidate metrics were identified from various sources (Table 1) that have used the metrics for IBI development and further application to periphyton assessments to aid surface water bioassessment programs. Specifically, metric from Ohio, Kentucky, and Montana were initially identified as metrics being used in the U.S. and around the world. Note that the metrics fall into two general categories: autecological and community-based. Autecological metrics are based on known ecological functions of specific biota, whereas community-based metrics are based on known responses of communities to varied stressors. Examples of autecological metrics included the Pollution Tolerance Index, Siltation Index, and Eutraphentic Index, and community-based indices include the well known Shannon Diversity Index, Species Richness, and Generic Richness. From the suite of metrics that have been used in other studies and applications, only those with sufficient data within the existing Truckee River algal database were investigated (as indicated in red in Table 1).

Table 1. Common Periphyton Metrics

List of developed Federal and State periphyton metrics				Additional Metrics	
EPA Metrics		**Kentucky Metrics**	**Montana Metrics**	**Hill et al. 2000**	**Davis Derived**
Species richness	Inferred Ecological Conditions with Simple Autecological Indices (SAI)	Total Number of Diatom Taxa (TNDT)	Dominant Phylum (Soft-bodied)	Cyanobacteria %	Fragilaria %
Total Number of Genera	Inferred Ecological Conditions with Weighted Average Indices	Shannon Diversity	Indicator Taxa (Soft-bodied)	Dominant Diatom %	Cymbella %
Total Number of Divisions	Impairment of Ecological Conditions	Pollution Tolerance Index	Number of Genera (Soft-bodied)	Eutraphentic Diatom %	
Shannon Diversity (for diatoms)	Chla	Siltation Index (%NNS)	Shannon Diversity Index	Diatom Species Richness	
Percent Community Similarity (PS_c) of Diatoms	AFDW	Fragilaria Group Richness (FGR)	Pollution Index	Diatom %	
Pollution Tolerance Index for Diatoms		Cymbella Group Richness (CGR)	Siltation Index	Acidophillic	
Percent Sensitive Diatoms		*Future Potential Metrics:*	Similarity Index	Motile Diatom	
Percent *Achnanthes minutissima*		*Total Number of All Algal Genera (TNG)*	Disturbance Index (*Achnanthes minutissima*)	Chlorophyll a	
Percent live diatoms		*Total Number of Divisions Represented*		AFDW	
Percent Aberrant Diatoms				Phosphotase activity	
Percent Motile Diatoms					
Simple Diagnostic Metrics:					
% acidobiontic + % acidophilic					
% alkalibiontic + % alkaliphilic					
% halophilic					
% mesosaprobic + % oligosaprobic + % saprophilic					
% eutrophic					

Candidate Metrics Evaluate:

Several metrics were chosen as potential contributors to the multimetric indices (Table 2) for a variety of reasons. Some of the metrics listed in Table 1 (Inferred Ecological Conditions with Simple Autecological Indices and Similarity Index) require reference-test site comparisons, which was not applicable due to reference conditions being unknown. A general lack of the applicable data interfered with calculating most all of the other metrics (such as percent live diatoms, percent aberrant diatoms). Despite not evaluating all the metrics that have been reported in the literature, the list of candidate metrics (Table 2 and described below) offered a range of candidate metrics that covered a range of conditions desirable for the final index calculations. The metrics and their expected responses are briefly described below.

Table 2. Candidate Metrics Evaluated for the Lower Truckee River

Metric Title	Ecological Information Group	Expected Response to Perturbaton	EPA Approved	Other Authority
Species richness	Composition	Decrease	Yes	
Total Number of Genera	Richness	Decrease	Yes	Kentucky
Total Number of Divisions	Composition	Decrease	Yes	Kentucky
Shannon Diversity (for diatoms)	Composition	Decrease	Yes	Kentucky Montana
Pollution Tolerance Index for Diatoms	Tolerance/Intolerance	Decrease	Yes	Kentucky Montana
Percent *Achnanthes minutissima* .	Habitat Disturbance	Increase	Yes	
Percent Motile Diatoms	Habitat	Increase	Yes	Kentucky Montana
% eutrophic	Environmental Diagnostic	Increase	Yes	Hill et al. 2000
Fragilaria Group Richness (FGR)	Richness	Decrease		Kentucky
Cymbella Group Richness (CGR)	Richness	Decrease		Kentucky
Number of Genera (Soft-bodied)	Richness	Decrease		Montana
% Cyanobacteria	Composition	Increase		Hill et al. 2000
% Dominant Diatom	Tolerance/Intolerance	Increase		Hill et al. 2000
% Fragilaria	Composition	TBD		Davis unpublished
% Cymbella	Composition	TBD		Davis unpublished
Chlorophyll a	Environmental Diagnostic	Increase	Yes	
Ash Free Dry Weight	Environmental Diagnostic	Increase	Yes	
Autotrophic Index	Environmental Diagnostic	Increase		

Species Richness

The Species Richness metric is the total number of all algae species present in the assemblage. A decrease is expected when several/many species are stressed due to increased pollution. However, in headwater or low nutrient systems, there can actually be an increase in species richness with an influx of nutrients (Stevenson and Bahls 1999).

Total number of Divisions

The number of divisions (Cyanophyta, Chlorophyta, etc.) represented in the assemblage is expected to be highest in areas with good water quality and high biotic integrity (Stevenson and Bahls 1999).

Shannon Diversity (SD)

Shannon Diversity Index (a measure of taxa richness and evenness) is primarily calculated because of its' common application among biologists. Its' use is widespread and because of its' relative ease of interpretation and it can be readily compared with other systems. Bahls (1993) used the Shannon Diversity Index because it is sensitive to water quality changes, and Stevenson (1984) suggests that relative changes in species diversity, rather than the actual value by itself, is useful in indicating changes in water quality (Kentucky Division of Water 2002).

Pollution Tolerance Index (PTI)

The Pollution Index is based on the ratio of diatoms in each of the three groups: 1) most tolerant; 2) less tolerant; 3) sensitive among the total diatom population. The ratio is then multiplied by the respective group number (1, 2, or 3), and the sum of the products for each of the three gives the Pollution Index score. Bahls (1993) outlines the criteria used to assign diatom taxa to pollution tolerance groups, as several ecological variables are analyzed.

Achnanthes minutissima %

The percent abundance of *A.minutissima* has bee found to be associated with the time elapsed since last scouring or toxic pollution event, with increased abundance indicative of magnitude of the disturbance (e.g. 0-25% = no disturbance, 25-50% = minor disturbance, 50-75% = moderate disturbance, 75-100% = severe disturbance). It has been recorded that this species frequently dominates in streams subjected to acid mine drainage, as well as other chemical perturbations (Stevenson and Bahls 1999).

Siltation Index

The Siltation Index is the relative abundance of *Navicula* and *Nitzschia* species within the diatom population which is indicative of unstable substrates, thus relating the degree of sedimentation on the stream bottom (Bahls 1993). Navicula and Nitzschia abundance increases in environments with sediments due to the fact that they are raphid, motile diatoms, which facilitates the ability of gliding to more suitable conditions.

Eutraphentic Index (% eutrophic)

The Eutraphentic Diatom metric is the relative abundance of eutraphilic diatom genera among the diatom population. The metric is used to help target sites impacted by macronutrients (nitrogen, phosphorous, inorganic carbon, and silica). Higher percentages of this metric are indicative of increased nutrient and organic enrichment in the stream (Hill et al. 2000). Examples of eutraphilic diatoms include Cocconeis, Diatoma, Fragilaria, Synedra and Rhoicosphenia.

Fragilaria Group Richness (FGR)

The greater the total number of genera within the Fragilaria taxa group (Ctenophora, Fragilaria, Fragilariforma, Pseudostaurosira, Stauroforma, Staurosira, Staurosirella, Tabularia, Synedra) indicates higher water quality. It is anticipated that an increase in pollution is reflected by a decline in the FGR (Kentucky Division of Water 2002).

Cymbella Group Richness (CGR)

The greater the total number of genera within the Cymbella taxa group (Cymbella, Cymbopleura, Encyonema, Encyonemopsis, Navicella, Pseudoencyonema, and Reimera) indicates more pristine water quality. The CGR is expected to decrease with increased water pollution (Kentucky Division of Water 2002).

Soft-Bodied (Non-diatom) Genera Richness

The Number of Non-Diatom Genera metric is simply the number of non-diatom species/genera enumerated. It is utilized due to the number of non-diatom genera being inversely proportional to the degree of pollution, as an increase in nutrients may cause an increase in the number of non-diatom genera (Bahls 1993).

Cyanobacteria Index

The Cyanobacteria metric is the percentage of the assemblage composed of Cyanobacteria. Increased composition of this division within the assemblage is often indicative of increased nutrient and organic enrichment, as well as toxic materials, to the system (Hill et al. 2000).

Dominant Diatom Index

The dominant diatom metric is based on the relative abundance of a single genus in the assemblage. Select genera may become dominant by possessing characteristics allowing better adaptability to unfavorable conditions such as nutrient enrichment or toxic stress (Hill et al. 2000). Thus the % dominance by one taxon often increases with increased environmental stresses.

Diatom Genera Richness

The Number of Diatom Genera has been shown to exhibit an inverse relation to the degree of pollution and is often used in periphyton-based bioassessments (Bahls 1993). Diatom genera richness values should be high in low impact sites where sensitive genera

experience reduced stress as compared to an impacted sites (Stevenson and Bahls 1999). It is also been proposed that the genera richness provides a more robust measure of diversity than species richness, due to closely related species within some genera, thus artificially boosting measures of richness (Stevenson and Bahls 1999).

Fragilaria % (% F)

The relative abundance of the genera Fragilaria within the sampled diatom population was calculated. This metric was incorporated due to the detection of possible trends that covaried along the river's gradient, thus possibly yielding insight into ecological condition. Although covariations have been noted it remains unclear exactly what these trends indicate in regards to water quality (Davis unpublished).

Cymbella % (% C)

The relative abundance of the genera Cymbella within the sampled diatom population was assessed. This metric was incorporated due to the detection of possible trends that covaried along the river's gradient, thus possibly yielding insight into ecological condition. Although covariations have been noted it remains unclear exactly what these trends indicate in regards to water quality (Davis unpublished). However, Cymbella is a genera that exhibits pollution and eutrophic sensitivity and are prevelant in throughout the lower Truckee River. Their contribution to the assemblage composition is viewed as a system-specific water quality metric.

Standing Stock of Benthic Chlorophyll a

The standing stock of chlorophyll a is measure of the total amount of periphyton pigment on a streams substrate. This measure is a surrogate for autotrophic biomass and is generally insensitive to taxonomic composition or habit, and can be used as primary indicator of the trophic state of a stream (Dodds et al. 1998). Chlorophyll *a* standing stocks are expected to increase with increasing nutrient enrichment in shallow wadeable streams. However, benthic chlorophyll *a* could decrease in extreme conditions of toxic pollutants- whereby populations of all benthic algae and most living organisms would decrease.

Ash-free Dry Weight (AFDW)

AFDW is a measure of the total amount of organic matter (algae and detritus) on the benthic substrates. AFDW generally increases in response to organic matter pollution and nutrient enrichments.

Autotrophic Index

The ratio of AFDW:Chla is a measure of the amount of organic matter relative to the periphyton biomass. Ratios of 50 to 200 are typical for periphyton dominated benthic assemblage. Values in excess of 200 can indicate poor water quality (APHA 1998).

Metric Scores

A compilation of the candidate metric score's minimum, maxima and percentiles (Table 3) shows that several of the metrics exhibited a range of values that could potentially be useful in the compilation of a multimetric index. Specifically, the PTI, Siltation, Eutra, Cyano, Dom, SD, SB, *A.minutissma*, Chla, AFDW, and AI all exhibited at least a 3-fold variability that is desirable for signal detection in a metric. However, some of the metrics were more constant and did not exhibit the variations that are necessary for their further evaluation as candidate metrics (FGR, CGR, DG, Spec. Rich). The metrics showing desirable variability are briefly discussed below and most pertinent metrics cumulative frequency distributions and scores along the mainstem are presented in appendix C.

Table 3. summary statistics (min, max and percentiles) for candidate metrics

		Metric Statistics (percentiles) All Data (n=198)								
Abbrev.	**Metric Title**	**min**	**5**	**10**	**25**	**50**	**75**	**90**	**95**	**max**
PTI	Pollution Tolerance Index	2.00	**2.26**	2.32	2.50	2.66	2.78	2.88	2.93	2.99
Siltation	Siltation Index	0.01	0.07	0.09	0.17	0.30	0.44	0.60	0.68	0.78
Eutra.	Eutraphentic Index	0.16	0.42	0.51	0.65	0.76	0.84	0.91	0.95	1.00
Cyano	Cyanobacteria %	0.09	0.25	0.32	0.51	0.72	0.89	0.95	0.98	1.00
Dom	Dominant %	0.10	0.15	0.18	0.22	0.31	0.48	0.58	0.63	0.80
FGR	Fragilaria Group Richness	0.00	1.00	1.00	1.00	2.00	2.00	2.00	2.00	2.00
CGR	Cymbella Group Richness	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	2.00
SD-Genera	Shannon Diversity Index (ln)- Diatom Genera	0.20	0.82	0.98	1.38	1.71	1.88	2.06	2.11	2.32
DG	Diatom Genera Richness	6.00	8.00	9.00	10.00	12.00	14.00	15.00	16.00	18.00
SB	Soft-bodied Genera Richness	3.00	4.00	5.00	6.00	8.00	9.00	11.00	12.00	15.00
Fragilaria	Fragilaria %	0.00	0.01	0.03	0.07	0.15	0.40	0.64	0.78	0.95
Cymbella	Cymbella %	0.00	0.00	0.00	0.01	0.02	0.05	0.08	0.12	0.70
A. minutissima	*Achnanthes minutissima* %	0.00	0.00	0.00	0.01	0.03	0.06	0.13	0.19	0.40
Spec. Rich	Species Ricness (ALL Divisions)	15.00	19.00	22.00	26.00	31.00	37.00	40.00	44.00	47.00
Tot. # Div.	Total number of Divisions	2.00	2.00	3.00	3.00	3.00	3.00	4.00	5.00	6.00
Chla	chla (ug/cm2)	0.03	1.80	3.38	6.76	16.22	42.46	86.22	132.95	368.89
AFDW	AFDW (ug/cm2)	52.89	469.62	979.82	2007.08	4041.53	7104.53	10238.09	14874.67	30180.49
AI	Autotroph Index	6.73	71.88	97.38	129.73	208.38	338.17	524.61	775.43	15335.51

Pollution Tolerance Index scores did not exhibit large changes through time among the various sites sampled during 2000-2004 sampling periods. Scores remained near the 2.5-3 score for the majority of the time. A mean PTI score of 2.63 would seem to indicate relatively sensitive genera within the attached alga assemblages in the LTR.

The Siltation Index showed approximately a seven-fold variation throughout the years and months of sampling. The relatively low compiled mean score of 0.32 from 2000 to 2004 seems to suggest that sedimentation is a minor impairment in the river. On a site-by-site basis, the averages increased to a peak below Reno, in the Patrick site area (CE 210 = 0.50), with a sharp decline just past Derby Dam at Painted Rock (0.11). The sites with the lowest scores (John's Ranch and Little Nixon) exhibited consistently low scores (< 0.20). This apparent trend could possibly be attributed the depositional area upstream from the dam reducing the sediment load at the downstream sites.

The Eutraphentic metric averaged 0.73 for all the sites and remained near or above 0.60 across the samples throughout 2000-2004. Only a slight increase in values along the downstream gradient was apparent. The abundance of eutraphentic diatom taxa within the assemblages suggests that the lower Truckee River is a nutrient enriched system. The lowest scores (0.16) were exhibited at the upstream site, just above the city of Reno, at the Patagonia site.

Cyanobacteria metric fraction averaged 0.68. Throughout the seasons the value remained near or above 0.50, signaling that the numbers of Cyanophyta was a large component of the lower Truckee periphyton assemblages. No obvious trends were demonstrated along the downstream gradient or upon seasonal/year comparisons, as the fractions highly variable from site to site. The lower most sites, Dead Ox and Little Nixon, potentially showed consistent increased abundances of cyanobacteria. However these higher relative abundances were only on the order of 10%.

Dominant metric fractions averaged 0.35 indicating that the assemblages possessed a third of their total composition due to a single genera of diatom. The EMCC site exhibited the lowest mean value, 0.26, for the 2000-2004 period, and Hershdale the greatest value, 0.52.

Shannon Diversity Index values for diatom genera ranged from 0.19 to 2.32. The lowest value was from the Painted Rock site (Pain) during the early June sampling of 2001. The value was affected by the dominance of Fragilaria species in the assemblages (0.84). The mean SD value was 1.60 for the compiled data for 2000-2004.

Diatom Genera Richness averaged 11.6 for the sampling period of 2000-2004. The highest number, 18, was documented at the Little Nixon site in 2000 while the lowest, 6, was at CE 50, which showed the lowest average value throughout 2000-2004. Downstream trends were not evident, as the number of genera remained relatively uniform within the reaches.

Soft-bodied Genera Richness averaged 7.25 for the 2000-2001 samples. The maximum richness value, 15, was observed at the Little Nixon site and the lowest, 3, at Tracy. The Tracy site repeatedly demonstrated a low soft-bodied generic richness throughout the sampling period of 2000-2001during the winter months. However, the number increased (to 14) during the summer. Note that data availability restricted the analysis to only the 2000-2001 period for Soft-bodied Genera.

The Cymbella metric fraction averaged 0.04, with many sites containing no composition of the genera. Cymbella is generally regarded as a "good" water quality

indicator as it is sensitive to pollution. The highest abundance, 0.70, was recorded at the Patagonia site in 2001 and was due the abundance of one sensitive species, *Cymbella affinis*. The Patagonia site repeatedly exhibited a significant portion of Cymbella within the diatom assemblage.

Achnanthes minutissima fractions averaged 0.05 for the 2000-2001 and 2003-2004 sampled assemblages. Patagonia demonstrated the highest mean (0.13) followed by the next site downstream, EMCC (0.09). The remainder of the downstream sites averaged at or below the compiled mean.

Species Richness averaged 31 for the 2000-2001 dataset (again, the 2000-2001 data was the only dataset that determined taxa to the species level). The majority of the sites averaged very close to this value however EMCC showed a higher average of 39.

Benthic chlorophyll a standing stocks on the lower Truckee exhibited an average value of 35.3 ug cm^{-2} (353 mg m^{-2}) and a range from 0.03 to 368 ug cm^{-2}. It has been proposed that a mean value of 150 mg m^{-2} is highly likely to represent a potential nuisance level. However, it has been noted that this value should be applied as baseline trophic criteria for classifying the system and not as an absolute boundary condition as each stream system is likely to sustain ecosystem function at different biomass levels (Dodds et al. 1998).

Ash-free dry weight averaged 5388.6 ug cm^{-2} for the compiled 2000-2004 dataset. It is apparent that a trend of increasing AFDW occurs along the river's downstream gradient, with peak values characteristic of the middle and lower reaches of the LTR. The greatest value (11,298ug cm^{-2}) occurred at the CE 50 site during 2003-2004.

Index Development

A redundancy evaluation was undertaken through the construction of a metric correlation matrix (Table 4). The matrix shows that the PTI and siltation metrics (also commonly known as the motile metric) were highly correlated (r = 0.87) in the data set for the Truckee River. This correspondence and apparent correlation is interesting because these metrics are based on different autoecological characteristics of the taxa involved (specifically tolerance and habit). A precedent has been set by Kentucky whereby they use the PTI and the siltation index in their Bioassesment index (Kentucky Division of Water 2002). However, because of their high correlation in the Truckee River it is unlikely that the final Truckee River P-IBI should use both metrics- unless it is eventually determined that sites with apparent higher sedimentation are also ones that contain pollutants (which would explain their correspondence).

Other metrics that exhibited potential redundancy included the range of richness metrics (e.g. Species richness, Diatom Richness, Fragilaria Richness etc..) although the only pair that exhibited greater than 70% apparent correlation was the Diatom Genera Richness and Species Richness). The two biomass measures- chlorophyll *a* and AFDW- also showed an expected high degree of correspondence (r = 0.84). Because several metrics have been identified which cover several of the desired metric categories, it appears as if the existing periphyton information is sufficient to derive candidate multimetric IBIs.

Table 4. Correlation matrix for candidate periphyton metrics (Pearson correlation coefficient).

	Pollution Index Score	Siltation Index	Eutraphentic Score	Cyanobacteria %	Dominant %	Fragilaria Group Richness	Cymbella Group Richness	Shannon Diversity Diatoms (Genera)	Diatom Genera Richness	Soft-Bodied Genera Richness	Fragilaria %	Cymbella %	*Achnanthes minutissima* %	Species Richness (ALL)	Total Number of Divisions	Chla (ug/cm2)
Pollution Index Score	1.00															
Siltation Index	**-0.87**	1.00														
Eutraphentic Score	0.38	-0.33	1.00													
Cyanobacteria %	0.23	-0.18	0.16	1.00												
Dominant %	0.08	-0.14	0.13	-0.21	1.00											
Fragilaria Group Richness	0.11	-0.13	0.13	-0.09	-0.12	1.00										
Cymbella Group Richness	-0.05	0.09	-0.13	-0.36	-0.06	0.12	1.00									
Shannon Diversity Diatoms (Genera)	-0.10	0.17	-0.24	0.07	**-0.59**	0.13	0.24	1.00								
Diatom Genera Richness	0.09	-0.13	0.10	-0.30	-0.14	0.48	0.46	0.23	1.00							
Soft-Bodied Genera Richness	0.04	-0.12	-0.11	0.27	-0.04	0.13	0.00	0.21	0.26	1.00						
Fragilaria %	0.55	-0.61	**0.56**	0.17	0.17	0.20	-0.22	-0.45	0.17	-0.15	1.00					
Cymbella %	0.08	-0.03	-0.45	-0.04	0.03	-0.12	0.19	0.09	-0.13	0.06	-0.22	1.00				
Achnanthes minutissima %	-0.12	0.16	-0.44	0.02	-0.17	-0.02	0.28	0.27	0.10	0.05	-0.27	0.12	1.00			
Species Richness (ALL)	0.13	-0.14	0.09	-0.20	-0.20	0.33	0.43	0.19	**0.80**	0.47	0.18	-0.03	-0.07	1.00		
Total Number of Divisions	0.06	-0.08	0.14	0.03	0.01	0.04	-0.09	-0.06	0.11	0.49	0.20	-0.13	-0.15	0.34	1.00	
Chla (ug/cm2)	0.13	-0.12	0.14	-0.12	-0.05	0.07	0.04	0.06	0.05	-0.09	0.01	-0.13	-0.13	0.03	0.01	1.00
AFDW (ug/cm2)	0.16	-0.18	0.12	-0.14	-0.06	0.13	0.00	0.01	0.07	-0.15	0.12	-0.21	-0.17	0.04	0.04	**0.84**
Autotropy Index	0.07	-0.06	0.02	0.13	0.06	-0.07	0.00	0.00	-0.12	0.08	-0.05	0.09	0.08	-0.09	0.01	-0.13

In order to combine metric scores into a common index the metrics need to be standardized to a common scale. This was accomplished by standardizing to a "best" value within the existing database. The "best" value corresponded to the 10th or 90th percentile- depending on the response of the metric to the stressor. The 90th and 10th percentiles were used as "best" values rather than the highest values in the data sets as these highest values may represent true outliers and may not represent the conditions on the river (Tetra Tech Report on BMI- IBI development 2004). An example of the standardization of metrics from one site is illustrated in Table 5.

Table 5. Example of metric standardization and its possible application to an assemblage IBI collected from the Patagonia site in December 2001.

METRIC	Expected Response to Perturbation	Percentile Used	Standard ("BEST") Value	Measured Metric Value	Standardized Metric Score
Siltation	Increase	10th	0.08	0.47	58.08
Eutraphentic	Increase	10th	0.52	0.59	84.76
Shannon Diversity (Diatom Genera)	Decrease	90th	2.05	1.72	84.01
Cymbella %	Decrease	90th	0.08	0.09	100.00
Chla (ug/cm2)	Increase	10th	3.38	6.56	98.38

To accommodate the range of ecological metric categories (or ecological information) in a periphyton-based IBI and maximize the range of the metric values represented in the IBI several different combination of metrics were calculated. Table 6 lists the combination of five metrics that covered the desired metric categories and provided a relatively wide range of IBI values along the Truckee mainstem (Figure 1). Note that the inclusion of the biomass metric (Chla) and the % eutraphentic metric could possibly be providing a redundant weighting toward detecting enhanced trophic condition due to nutrient pollutants- however, since the redundancy analysis did not show significant correlation and nutrient pollution is believed to a primary stressor threat to the lower Truckee river the inclusion of both metrics in the index is likely warranted.

Table 6. Core metrics used in the proposed (tentative) periphyton IBI.

Metric Title	Ecological Information Group	Expected Response to Perturbaton
Shannon Diversity (for diatom genera)	Composition	Decrease
Percent Motile Diatoms	Habitat	Increase
% Eutraphentic	Environmental Diagnostic	Increase
% Cymbella	Composition	Decrease
Chlorophyll a	Environmental Diagnostic	Increase

The average index scores (Figure 2) indicate a general upstream to downstream trend with higher values at the HERS, FLEI, PATA and EMCC sites, lower values at the intermediate sites of CE50 and PAIN, and slightly higher values again occurring at the JOHN, DEAD and LNIX locations. This result is not unlike that obtained with the proposed (tentative) macroinvertebrate IBI (Tetra Tech Report on BMI- IBI development 2004). However, the macroinvertebrate-based IBI had lowest scores at the Tracy and Lockwood sites. It is unknown at present if these apparent differences in relative ranking of sites is merely a result of differences in data coverage, differences in collection sites, differences in the metrics used in the IBIs (e.g. differences could be due to the possible exclusion of pollution tolerant indices in the P-IBI) or if the P-IBIs and B-IBIs are simply capturing different composite attributes of the system which may not always covary among sites and times sampled.

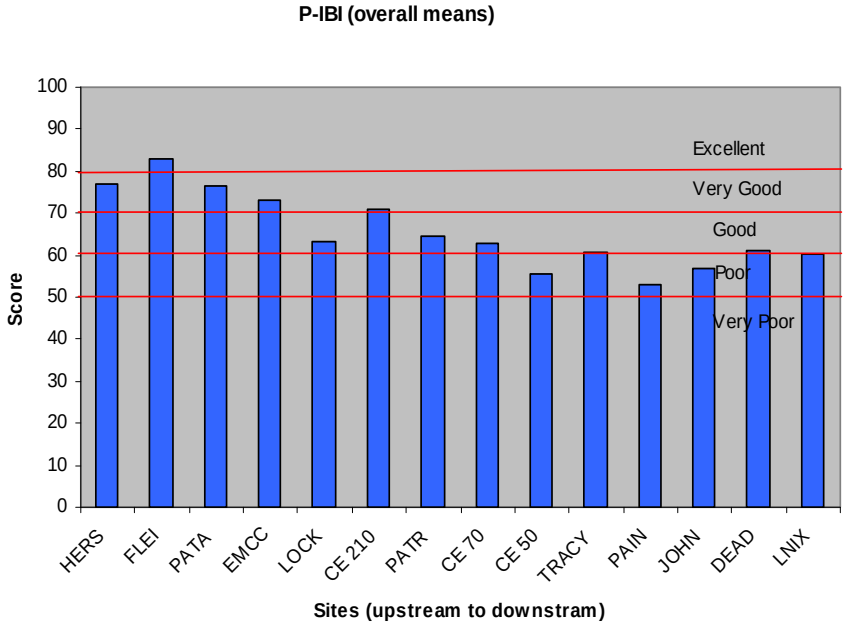

Figure 2. Periphyton index of biological condition score for the mainstem sampling sites along the Truckee River. Values are means for each site from 2000-2004.

Because the benchmarks for the P-IBI have yet to be set for the mainstem of the Truckee River, the precedent of demarcating a narrative description of the index scoring range can follow the standard protocol of assigning the IBI values of 80-100, 70-79, 60-69, 50-59, 40-49 and 0-39 to the "excellent", "very good", "good", "fair", "poor" and "very poor" conditions. It should be noted that these are not standards and are being presented as a tentative set of benchmarks. However, these narrative descriptions should be further examined in combination with the other IBI's evaluations. If these were utilized as narrative categories, the sites in Nevada and downstream of Reno over the past few years, would score within the Fair to Good categories.

Recommendations

In summary, information on periphyton assemblages in the Lower Truckee River is relatively limited when compared to the historical database available for benthic macroinvertebrates. Despite the limited amount of information available, it appears as if there is sufficient information available that forms the basis for developing a proposed (tentative) periphyton based indices. Moreover, this multi-metric indices offers the possibility of being used in combination with the information on benthic macroinvertebrates and fishes to ascertain the overall ecological condition of the river. Before doing so, however, there are several recommendations that can be considered to address potential weaknesses in the periphyton-based metrics, which can help refine and validate the periphyton index:

- Further test the applicability of defining the "best" values at the 10th and 90th percentiles. The elimination of potentially "good" sites makes the resultant metrics and index potentially weighted toward "bad" conditions.
- Pursue the use of reference conditions to help evaluate the scale at which the periphyton metrics should be scaled.
- Evaluate the correspondence of PTI metric and Siltation metric, through specific studies of the sites to determine if the PTI should be included in the IBI. This would add a tolerance condition to the index.
- Given the general lack of periphyton data (only 3 years of data- compared to over ten years of data for macroinvertebrates), more periphyton collections and data could help in expanding the range of ecological conditions, which the periphyton database represents.
- Evaluate the periphyton collection methods. Because the periphyton database was generated from samples collected at predetermined sampling habitats on the river to document periphyton dynamics the samples were not collected in a manner that is consistent with randomization procedures that are standard for bioassessment programs (which often composite samples from the "best" habitats in a reach).
- As more data become available, recalibrate and validate the index.
- Evaluate the taxonomic consistency when combining future datasets.
- Combine metric information with physical, chemical variables and apply multivariate statistics to dataset to aid in determining effectiveness of the developed index in capturing ecosystem changes.

Addendum (2/7/2006)

Since the completion of the LTR P-BCI report in February 2005, Wang et al. (2005) reported the development of a diatom-based index of biotic integrity for the Interior Plateau Ecoregion (IPE), USA (central Kentucky and parts of Ohio, Indiana, and Tennessee). The development of the index was investigated to determine its' prospective usefulness in distinguishing human disturbance in watersheds (represented as the inverse of % forested area). The robustness of the IPE index was challenged with a test dataset from the same region (with different taxonomists doing the identifications). The index was compared with IBIs (Montana IBI (Bahls 1993), Kentucky Division of Water (1993) IBI, Hill et al. 2000 IBI) to highlight the performance of each at separating reference sites from impaired sites. All three indices elucidate impaired sites from reference sites. However, the IPE index had more separation power.

The core metrics for each index were assessed and showed that the Shannon Diversity (Kentucky and Montana) and Species Richness (Kentucky) responded oppositely than the anticipated inverse response with impairment, as did the % Dominant (Hill et al. 2000) metric. The use of species diversity metrics for assessing water quality conditions has been questioned in the past (Archibald 1972, Stevenson 1984).

Wang et al. (2005) address the issue of IBI criteria development (thresholds). They found the lowest mis-classification of sites within the test dataset when the criterion is established by averaging the 25th and 75th IBI scores for the reference and impaired sites, respectively. As the authors' point out, the use of just the 25th is considered the EPA Rapid Bioassessment Protocol standard.

The publication offers insight into several strengths and weaknesses of the tentative LTR Periphyton-based Biological Condition Index. The IPE index developers' use of similar literature as the LTR P-BCI developers is definitely noteworthy. Also they investigated more composition metrics within the context of specific genera (genera group richness) as certain genera may exhibit congeneric responses to impairment within distinct regions. They also affirm the need to develop meaningful metrics that describe biological condition at a site, and that these metrics should be weighted within the final index based on the specific concerns of management. As an example, they propose that the number of resident species as being valued by the public.

The need to take a more regional view of the periphyton assemblages within the Great Basin becomes apparent from the comparison with the IPE. The ability to test the P-BCI ability to capture the ecosystem changes that are of concern would be enhanced by expanding the geographic and human disturbance range within the Great Basin Region.

Lastly, the authors reiterate the need for an integrated approach (fish, invertebrate, water quality attributes) for assessing disturbance and to avoid mis-classifying sites.

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Glossary

Assemblage - a group of organisms in a given habitat. For example, fish assemblage, benthic macroinvertebrate or periphyton assemblage.

Autecology – (also called Species Ecology) the study of the interactions of an individual organism or a single species with the living and nonliving factors of its environment. Autecology is primarily experimental and deals with easily measured variables such as light, humidity, and available nutrients in an effort to understand the needs, life history, and behaviour of the organism or species.

Biological Assessments or Bioassessments - evaluation of the biological condition of a waterbody using biological surveys and other direct measurements of resident biota in surface waters.

Epilithic- growing on stone

Divisions- (phylum) the major taxonomic group plants; contains classes. For algae, based on combination of characteristics (e.g. photosynethetic pigments, starchlike reserve products, cell coverings).

Genera- hierarchal taxonomic level grouping species

Index-The multi-metric (a compilation of metrics) derived into a composite score that represents various measured aspects of the assemblage.

Metric- A calculated term representing an aspect of biological assemblage, function, or other measurable characteristic of the biota that changes in some predictable way with a stressor.

Multivariate Community Analysis - statistical methods (e.g. ordination or discriminant analysis) for analyzing physical and biological community data using multiple variables.

Periphyton-a broad organismal assemblage composed of attached algae, bacteria, their secretions, associated detritus, and various species of microinvertebrates

Reference Site - specific locality on a waterbody which is unimpaired or minimally impaired and is representative of the expected biological integrity of other localities on the same waterbody or nearby waterbodies

APPENDICES

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Appendix A: Periphyton Sampling Site Locations and Description

Site	Abbrev.	Distance from Tahoe (km)	Latitude	Longitude	Brief Description
Hershdale	Hers	32	39.369	120.075	Rapid dominated reach just above bridge at hershdale, which is ~1 km downstream of I-80 bridge at the Hershdale exit.
Fleichman	Flei	56			Riffle and Run dominated reach, the downstream extent of which is ~ 150 meters upstream of steamboat diversion.
Patatgonia	Pata	80	39.50278	-119.896156	Named for the Patagonia outlet store nearby, this riffle dominated transect is ~100 meters downstream of Mayberry Park in Reno.
East McCarran	Emcc	97	39.51799	-119.744499	Riffle dominate reach upstream of the East McCarran bridge extending to above Glendale Park.
Lockwood	Lock	106	39.50845	-119.654831	Riffle and glide dominated reach extending upstream from the bridge at Lockwood to the Ostrich Farm.
DRI-CE 210	CE210	113	39.53456	-119.597362	Riffle and Rapid dominated "undisturbed" transect on Channel Survey Xsection ~100 meters downstream of McDiv
Patrick	Patr	115	39.54609	-119.584656	Riffle dominated transect on Channel Survey Xsection ~50 meters above Patrick Bridge
DRI-CE 145	CE145	115	39.54476	-119.585167	Rapid dominated transect on Channel Survey Xsection ~ 200 meters above Patrick Bridge
DRI-CE 140	CE140	115	39.54582	-119.584172	Riffle dominated transect on Channel Survey Xsection ~50 meters above Patrick Bridge
DRI-CE 70	CE70	117	39.54715	-119.563341	Riffle dominated transect on Channel Survey Xsection near McCarran Ranch Well #4.
DRI-CE 50	CE50	118	39.54782	-119.558005	Riffle dominated transect on Channel Survey Xsection below large river bend and bar upstream of railroad bridge
Tracy	Trac	122	39.56466	-119.486366	This riffle dominated transect is located ~40 meters above the Clark Bridge.
Painted Rock	Pain	139	39.59036	-119.366714	Riffle dominated reach extending upstream from Painted Rock Bridge ~100 meters.
John's Ranch	John	152	39.66330	-119.276039	Riffle dominated reach near Fred John's ranch in Wadsworth, NV.
Dead Ox	Dead	166	39.74221	-119.321457	Glide and Riffle dominated reach ~ 1 km downstream from Numana Fish Hatchery.
Little Nixon	Lnix	178	39.80431	-119.349487	Riffle and glide dominated reach extending upstream ~500 meters above empty concrete bridge abutments upstream of Nixon, NV.

Appendices B: Metric Scores

Date	Site	Distance from Tahoe (km)	Pollution Index Score	Siltation Index	Eutraphentic Score	Cyanobacteria %	Dominant %	*FGR*	CGR	Shannon Diveristy (Genera)	Diatom Generic Richness	Soft-Bodied Genera Richness
7/24/2000	EMCC 1	139	2.65	0.34	0.64	0.84	0.20	2.00	1.00	2.32	13.00	14.00
7/24/2000	Lock 4	106	2.80	0.20	0.80	0.90	0.24	2.00	1.00	1.94	10.00	11.00
7/24/2000	Pata 5	80	2.66	0.32	0.65	0.77	0.22	1.00	1.00	2.12	13.00	11.00
7/25/2000	EMCC 6	139	2.62	0.37	0.61	0.54	0.17	2.00	1.00	2.15	13.00	9.00
7/25/2000	Lock 1	106	2.72	0.28	0.77	0.88	0.25	1.00	1.00	1.97	10.00	9.00
7/25/2000	Lock 1	106	2.78	0.22	0.84	1.00	0.49	2.00	1.00	1.72	10.00	10.00
7/26/2000	Patr 3	115	2.76	0.24	0.79	0.48	0.35	1.00	1.00	1.84	10.00	5.00
7/26/2000	Patr 5	115	2.73	0.21	0.79	0.89	0.27	1.00	1.00	2.00	11.00	11.00
7/26/2000	Trac 3	122	2.74	0.22	0.81	0.92	0.31	2.00	1.00	1.85	14.00	14.00
7/27/2000	Pain 1	139	2.86	0.13	0.90	0.91	0.52	2.00	1.00	1.34	12.00	9.00
7/27/2000	Trac 4	122	2.88	0.12	0.89	0.90	0.51	1.00	0.00	1.44	9.00	8.00
7/27/2000	Trac 5	122	2.76	0.11	0.76	0.92	0.49	2.00	0.00	1.65	12.00	11.00
7/31/2000	DEAD 1	166	2.83	0.16	0.83	0.96	0.49	2.00	0.00	1.44	10.00	10.00
7/31/2000	John 3	152	2.83	0.14	0.84	0.93	0.49	1.00	1.00	1.52	11.00	10.00
8/2/2000	LNIX 4	178	2.69	0.07	0.69	0.87	0.35	2.00	1.00	1.67	13.00	15.00
8/29/2000	Pata 3	80	2.66	0.30	0.58	0.94	0.35	2.00	1.00	1.81	12.00	12.00
8/30/2000	Lock 1	106	2.26	0.74	0.52	0.99	0.17	2.00	0.00	1.52	8.00	7.00
8/30/2000	Lock 4	106	2.45	0.51	0.77	0.94	0.20	2.00	1.00	1.67	12.00	8.00
8/31/2000	Patr 5	115	2.59	0.36	0.81	0.96	0.22	1.00	1.00	1.76	12.00	12.00
9/1/2000	Trac 1	122	2.66	0.23	0.77	0.97	0.20	1.00	0.00	1.76	12.00	9.00
9/1/2000	Trac 2	122	2.77	0.09	0.89	0.98	0.23	1.00	1.00	2.09	12.00	9.00
9/6/2000	John 1	152	2.67	0.22	0.78	0.98	0.18	2.00	0.00	1.80	12.00	14.00
9/6/2000	John 6	152	2.52	0.43	0.61	0.99	0.17	1.00	0.00	1.76	7.00	8.00
9/7/2000	LNIX 8	178	2.83	0.11	0.89	0.97	0.62	1.00	1.00	1.19	10.00	8.00
9/7/2000	Lock 4	106	2.49	0.47	0.59	0.96	0.23	2.00	1.00	1.87	11.00	9.00
10/4/2000	Pata 5	80	2.84	0.16	0.28	0.94	0.67	1.00	1.00	1.00	7.00	6.00
10/4/2000	Patr 2	115	2.74	0.26	0.81	0.98	0.54	1.00	0.00	1.13	7.00	6.00
10/5/2000	John 5	152	2.75	0.13	0.75	0.94	0.22	2.00	0.00	2.12	13.00	9.00
10/5/2000	LNIX 8	178	2.90	0.08	0.84	0.81	0.31	2.00	1.00	1.88	18.00	10.00
10/5/2000	Trac 3	122	2.91	0.08	0.94	0.77	0.60	2.00	1.00	1.34	15.00	11.00
10/5/2000	Trac 5	122	2.57	0.42	0.79	0.91	0.30	2.00	1.00	1.75	14.00	10.00
10/30/2000	Pata 5	80	2.78	0.25	0.46	0.91	0.30	1.00	1.00	2.10	14.00	12.00
11/1/2000	EMCC 4	139	2.66	0.24	0.82	0.69	0.25	2.00	1.00	1.72	15.00	9.00
11/2/2000	Lock 5	106	2.64	0.35	0.86	0.93	0.27	2.00	1.00	1.84	12.00	6.00
11/2/2000	Patr 1	115	2.69	0.29	0.85	0.96	0.13	2.00	1.00	2.07	11.00	6.00
11/6/2000	Trac 2	122	2.71	0.26	0.78	0.86	0.15	2.00	1.00	2.27	14.00	7.00
11/6/2000	Trac 5	122	2.81	0.34	0.86	0.71	0.20	2.00	1.00	1.85	15.00	8.00
11/8/2000	Pain 3	139	2.91	0.08	0.93	0.84	0.11	2.00	1.00	1.14	15.00	8.00
11/9/2000	John 1	152	2.76	0.07	0.78	0.73	0.32	2.00	1.00	1.78	11.00	5.00
11/10/2000	DEAD 6	166	2.81	0.11	0.92	0.93	0.21	2.00	0.00	1.74	9.00	4.00
11/14/2000	LNIX 8	178	2.72	0.11	0.80	0.65	0.21	2.00	1.00	2.01	13.00	10.00
11/30/2000	Pata 5	80	2.53	0.44	0.74	0.94	0.25	1.00	1.00	1.73	10.00	7.00
12/1/2000	Lock 5	106	2.52	0.46	0.79	0.89	0.15	2.00	1.00	2.05	16.00	7.00
12/1/2000	Patr 1	115	2.62	0.36	0.74	0.91	0.16	1.00	1.00	2.06	10.00	7.00
12/7/2000	John 6	152	2.91	0.08	0.92	0.56	0.35	2.00	1.00	1.60	12.00	8.00

Date	Site	Distance from Tahoe (km)	Fragilaria %	Cymbella %	Achnanthes minutissima %	Species Richness	Total Number of Divisions	chla (ug/cm2)	AFDW (ug/cm2)	Autotrophic Index
7/24/2000	EMCC 1	139	0.07	0.11	0.13	47.00	4.00	1.58	561.01	355.21
7/24/2000	Lock 4	106	0.02	0.07	0.02	32.00	3.00	1.02	243.11	239.47
7/24/2000	Pata 5	80	0.06	0.14	0.13	38.00	3.00	1.03	403.95	393.99
7/25/2000	EMCC 6	139	0.08	0.14	0.06	37.00	3.00	0.77	1581.78	2048.34
7/25/2000	Lock 1	106	0.14	0.06	0.00	31.00	3.00	2.47	1124.13	455.12
7/25/2000	Lock 1	106	0.27	0.07	0.02	31.00	3.00	12.77	3564.86	279.24
7/26/2000	Patr 3	115	0.07	0.02	0.04	23.00	3.00	6.57	2987.74	454.56
7/26/2000	Patr 5	115	0.22	0.04	0.04	31.00	3.00	3.02	1496.97	496.08
7/26/2000	Trac 3	122	0.05	0.02	0.00	38.00	3.00	2.61	272.02	104.40
7/27/2000	Pain 1	139	0.10	0.01	0.01	27.00	3.00	2.09	1222.03	584.61
7/27/2000	Trac 4	122	0.16	0.00	0.01	24.00	3.00	22.31		
7/27/2000	Trac 5	122	0.51	0.00	0.02	30.00	3.00	10.98	3999.12	364.20
7/31/2000	DEAD 1	166	0.50	0.00	0.00	25.00	3.00	6.32	7039.32	1113.08
7/31/2000	John 3	152	0.05	0.03	0.00	29.00	3.00	0.21	52.89	256.11
8/2/2000	LNIX 4	178	0.37	0.01	0.00	38.00	3.00	0.24	98.31	402.78
8/29/2000	Pata 3	80	0.10	0.02	0.35	39.00	3.00	4.94		
8/30/2000	Lock 1	106	0.09	0.00	0.04	23.00	4.00	1.76	1235.11	700.93
8/30/2000	Lock 4	106	0.13	0.00	0.14	36.00	3.00	15.72	3274.79	208.38
8/31/2000	Patr 5	115	0.44	0.02	0.02	39.00	6.00	3.34	1219.84	365.49
9/1/2000	Trac 1	122	0.49	0.00	0.03	33.00	5.00	46.09	6678.13	144.88
9/1/2000	Trac 2	122	0.45	0.04	0.00	33.00	4.00	20.37	1459.15	71.63
9/6/2000	John 1	152	0.51	0.00	0.06	34.00	5.00	8.64	2765.76	320.18
9/6/2000	John 6	152	0.26	0.00	0.13	21.00	3.00	5.16	925.61	179.43
9/7/2000	LNIX 8	178	0.67	0.01	0.05	29.00	4.00	8.50	4283.81	503.82
9/7/2000	Lock 4	106	0.13	0.03	0.04	32.00	4.00	15.72	3274.79	208.38
10/4/2000	Pata 5	80	0.08	0.70	0.02	16.00	2.00	9.14		
10/4/2000	Patr 2	115	0.64	0.00	0.03	25.00	3.00	5.50		
10/5/2000	John 5	152	0.31	0.00	0.08	33.00	3.00	5.15	979.82	190.10
10/5/2000	LNIX 8	178	0.40	0.07	0.02	46.00	3.00	10.17	1693.46	166.56
10/5/2000	Trac 3	122	0.68	0.02	0.01	40.00	4.00	15.05	3019.93	200.68
10/5/2000	Trac 5	122	0.28	0.01	0.13	39.00	3.00	9.40	5425.53	577.18
10/30/2000	Pata 5	80	0.08	0.30	0.15	45.00	3.00			
11/1/2000	EMCC 4	139	0.48	0.02	0.03	42.00	4.00	26.99	7042.54	260.97
11/2/2000	Lock 5	106	0.33	0.01	0.04	27.00	3.00	65.28	7706.71	118.05
11/2/2000	Patr 1	115	0.31	0.01	0.02	41.00	2.00	86.08	10629.21	123.48
11/6/2000	Trac 2	122	0.27	0.05	0.06	37.00	2.00	17.20	4421.52	257.05
11/6/2000	Trac 5	122	0.36	0.03	0.03	44.00	3.00	26.77	5015.48	187.35
11/8/2000	Pain 3	139	0.78	0.01	0.01	40.00	3.00	32.16	6977.19	216.92
11/9/2000	John 1	152	0.34	0.03	0.02	29.00	2.00	32.19	4261.64	132.38
11/10/2000	DEAD 6	166	0.41	0.00	0.03	19.00	3.00	6.14	10545.75	1717.06
11/14/2000	LNIX 8	178	0.35	0.00	0.01	37.00	4.00	93.26	19578.95	209.95
11/30/2000	Pata 5	80	0.12	0.05	0.15	26.00	3.00	7.97	2021.78	253.80
12/1/2000	Lock 5	106	0.12	0.03	0.00	41.00	3.00	88.40	6388.30	72.27
12/1/2000	Patr 1	115	0.15	0.04	0.06	30.00	3.00	97.71	9995.78	102.30
12/7/2000	John 6	152	0.67	0.01	0.03	34.00	4.00	94.37	9738.80	103.19

Date	Site	Distance from Tahoe (km)	Pollution Index Score	Siltation Index	Eutraphentic Score	Cyanobacteria %	Dominant %	*FGR*	CGR	Shannon Diveristy (Genera)	Diatom Generic Richness	Soft-Bodied Genera Richness
12/7/2000	Trac 4	122	2.73	0.24	0.78	0.91	0.15	2.00	1.00	1.39	14.00	9.00
12/7/2000	Trac 5	122	2.58	0.43	0.90	0.67	0.35	2.00	1.00	1.88	17.00	5.00
12/13/2000	LNIX 6	178	2.68	0.11	0.75	0.87	0.34	2.00	1.00	1.77	14.00	9.00
1/5/2001	Pata 5	80	2.60	0.37	0.73	0.91	0.20	2.00	1.00	1.82	12.00	7.00
1/8/2001	Lock 5	106	2.70	0.30	0.86	0.65	0.24	2.00	1.00	1.71	12.00	6.00
1/9/2001	Patr 1	115	2.30	0.67	0.64	0.93	0.23	1.00	0.00	1.67	9.00	4.00
1/9/2001	Trac 2	122	2.93	0.04	0.94	0.45	0.67	2.00	1.00	0.83	13.00	6.00
1/10/2001	Trac 4	122	2.51	0.49	0.72	0.83	0.10	2.00	1.00	1.98	14.00	6.00
1/11/2001	John 1	152	2.78	0.09	0.81	0.96	0.24	2.00	0.00	1.61	7.00	4.00
1/12/2001	LNIX 4	178	2.73	0.14	0.86	0.83	0.35	2.00	1.00	1.76	13.00	4.00
1/29/2001	Pata 6	80	2.62	0.38	0.78	0.99	0.19	2.00	1.00	1.80	8.00	4.00
1/30/2001	Lock 5	106	2.62	0.36	0.77	0.82	0.18	2.00	1.00	2.07	15.00	4.00
1/31/2001	Patr 1	115	2.53	0.47	0.70	0.88	0.13	2.00	1.00	1.96	12.00	6.00
2/1/2001	Trac 4	122	2.41	0.55	0.70	0.93	0.20	2.00	1.00	1.78	10.00	5.00
2/1/2001	Trac 5	122	2.87	0.13	0.91	0.51	0.52	2.00	1.00	1.34	12.00	5.00
2/2/2001	John 1	152	2.54	0.42	0.79	0.74	0.23	2.00	1.00	1.83	13.00	5.00
2/5/2001	LNIX 8	178	2.64	0.19	0.80	0.55	0.16	2.00	1.00	1.65	14.00	5.00
2/28/2001	Pata 5	80	2.58	0.41	0.50	0.94	0.40	0.00	1.00	1.54	9.00	5.00
3/1/2001	EMCC 1	139	2.49	0.49	0.66	0.93	0.36	2.00	1.00	1.55	10.00	8.00
3/1/2001	Lock 1	106	2.24	0.74	0.35	0.84	0.55	1.00	0.00	1.18	10.00	8.00
3/5/2001	Patr 3	115	2.47	0.53	0.50	0.85	0.19	1.00	1.00	1.76	12.00	5.00
3/6/2001	Trac 3	122	2.48	0.52	0.54	0.79	0.28	2.00	1.00	1.81	11.00	3.00
3/6/2001	Trac 5	122	2.61	0.37	0.61	0.86	0.19	1.00	1.00	1.80	10.00	6.00
3/7/2001	Pain 1	139	2.77	0.21	0.82	0.77	0.30	2.00	1.00	1.98	12.00	8.00
3/8/2001	John 6	152	2.77	0.22	0.71	0.70	0.22	2.00	0.00	2.02	12.00	4.00
3/13/2001	DEAD 5	166	2.73	0.23	0.86	0.78	0.39	2.00	1.00	1.39	14.00	5.00
3/16/2001	LNIX 4	178	2.62	0.26	0.82	0.85	0.23	1.00	1.00	1.43	12.00	8.00
3/30/2001	John 6	152	2.72	0.27	0.94	0.46	0.22	2.00	1.00	1.80	12.00	5.00
3/30/2001	LNIX 8	178	2.91	0.08	0.96	0.75	0.51	2.00	1.00	1.73	15.00	6.00
4/2/2001	Trac 3	122	2.78	0.43	0.86	0.85	0.29	1.00	1.00	1.73	10.00	3.00
4/2/2001	Trac 4	122	2.78	0.19	0.86	0.95	0.19	1.00	1.00	1.83	9.00	3.00
4/3/2001	Patr 1	115	2.67	0.30	0.63	0.82	0.19	2.00	1.00	1.65	14.00	8.00
4/4/2001	Lock1	106	2.76	0.23	0.83	0.32	0.24	2.00	1.00	1.16	14.00	4.00
4/5/2001	Pata 1	80	2.80	0.18	0.76	0.87	0.18	2.00	1.00	0.65	11.00	6.00
4/30/2001	Pata1	80	2.75	0.25	0.68	0.89	0.34	2.00	1.00	1.60	8.00	4.00
5/1/2001	Lock 5	106	2.28	0.72	0.89	0.98	0.30	2.00	0.00	1.27	6.00	7.00
5/2/2001	Patr 1	115	2.34	0.64	0.72	0.98	0.25	1.00	1.00	1.99	10.00	4.00
5/3/2001	Trac 3	122	2.38	0.59	0.91	0.96	0.26	1.00	0.00	1.46	8.00	7.00
5/3/2001	Trac 4	122	2.28	0.71	0.88	0.95	0.32	1.00	0.00	1.33	9.00	7.00
5/7/2001	John 1	152	2.79	0.21	0.96	0.71	0.61	2.00	1.00	1.19	14.00	6.00
5/8/2001	John 6	152	2.88	0.10	0.97	0.65	0.58	2.00	1.00	0.75	13.00	8.00

Date	Site	Distance from Tahoe (km)	Fragilaria %	Cymbella %	Achnanthes minutissima %	Species Richness	Total Number of Divisions	chla (ug/cm2)	AFDW (ug/cm2)	Autotrophic Index
12/7/2000	Trac 4	122	0.28	0.04	0.06	38.00	3.00	98.84	7104.53	71.88
12/7/2000	Trac 5	122	0.29	0.01	0.04	44.00	3.00	141.85	7199.96	50.76
12/13/2000	LNIX 6	178	0.56	0.01	0.01	40.00	4.00	42.46	8075.64	190.19
1/5/2001	Pata 5	80	0.12	0.03	0.20	29.00	2.00	5.31	1004.73	189.22
1/8/2001	Lock 5	106	0.05	0.01	0.00	26.00	3.00	106.26	5254.64	49.45
1/9/2001	Patr 1	115	0.09	0.00	0.05	23.00	2.00	14.60	2201.94	150.87
1/9/2001	Trac 2	122	0.84	0.00	0.00	36.00	3.00	72.82	14874.67	204.27
1/10/2001	Trac 4	122	0.09	0.01	0.05	30.00	2.00	132.95	8869.37	66.71
1/11/2001	John 1	152	0.28	0.00	0.00	15.00	2.00	86.22	5870.57	68.09
1/12/2001	LNIX 4	178	0.56	0.02	0.02	33.00	2.00	40.17	8411.27	209.41
1/29/2001	Pata 6	80	0.24	0.05	0.05	21.00	2.00	6.57	916.19	139.48
1/30/2001	Lock 5	106	0.29	0.03	0.03	35.00	2.00	24.05	3274.04	136.11
1/31/2001	Patr 1	115	0.13	0.01	0.05	30.00	3.00	33.40	13378.66	400.54
2/1/2001	Trac 4	122	0.01	0.03	0.00	24.00	2.00	32.69	3070.11	93.92
2/1/2001	Trac 5	122	0.74	0.01	0.01	33.00	3.00	79.99	7255.94	90.72
2/2/2001	John 1	152	0.30	0.01	0.02	33.00	3.00	24.81	4185.19	168.67
2/5/2001	LNIX 8	178	0.57	0.01	0.01	33.00	3.00	24.46	6100.94	249.39
2/28/2001	Pata 5	80	0.00	0.05	0.40	23.00	2.00	3.95	746.13	188.80
3/1/2001	EMCC 1	139	0.11	0.02	0.21	27.00	3.00	9.06	2094.07	231.04
3/1/2001	Lock 1	106	0.03	0.00	0.03	25.00	4.00	50.45	8213.92	162.82
3/5/2001	Patr 3	115	0.21	0.04	0.11	32.00	3.00	31.17	5935.43	190.43
3/6/2001	Trac 3	122	0.22	0.04	0.03	27.00	2.00	33.70	13837.96	410.68
3/6/2001	Trac 5	122	0.28	0.00	0.19	29.00	2.00	8.67	1909.46	220.11
3/7/2001	Pain 1	139	0.11	0.01	0.07	30.00	3.00	48.31	7503.02	155.30
3/8/2001	John 6	152	0.32	0.00	0.02	32.00	3.00	71.16	12423.50	174.59
3/13/2001	DEAD 5	166	0.63	0.02	0.00	35.00	3.00	12.95	3695.36	285.42
3/16/2001	LNIX 4	178	0.54	0.01	0.01	37.00	3.00	12.13	4313.13	355.68
3/30/2001	John 6	152	0.48	0.00	0.00	34.00	2.00	28.41	3682.53	129.62
3/30/2001	LNIX 8	178	0.46	0.00	0.01	27.00	3.00	26.23	4324.36	164.83
4/2/2001	Trac 3	122	0.43	0.02	0.05	36.00	4.00	5.10	2118.05	415.35
4/2/2001	Trac 4	122	0.33	0.03	0.03	18.00	2.00	10.38	3170.66	305.36
4/3/2001	Patr 1	115	0.52	0.02	0.16	27.00	2.00	3.75	2285.64	610.31
4/4/2001	Lock1	106	0.66	0.02	0.02	39.00	3.00	54.12	9911.58	183.15
4/5/2001	Pata 1	80	0.87	0.05	0.06	38.00	3.00	48.83	9142.88	187.25
4/30/2001	Pata1	80	0.39	0.10	0.19	18.00	3.00	1.89	1564.56	828.75
5/1/2001	Lock 5	106	0.13	0.00	0.00	18.00	3.00	0.89	385.10	431.01
5/2/2001	Patr 1	115	0.02	0.02	0.16	21.00	2.00	7.67	1548.26	201.86
5/3/2001	Trac 3	122	0.25	0.00	0.00	22.00	4.00	58.18		
5/3/2001	Trac 4	122	0.09	0.00	0.00	26.00	3.00	11.40	1479.17	129.73
5/7/2001	John 1	152	0.69	0.00	0.00	33.00	3.00	14.54	9128.67	627.99
5/8/2001	John 6	152	0.82	0.00	0.00	37.00	4.00	27.31	3382.50	123.83

Date	Site	Distance from Tahoe (km)	Pollution Index Score	Siltation Index	Eutraphentic Score	Cyanobacteria %	Dominant %	*FGR*	CGR	Shannon Diveristy (Genera)	Diatom Generic Richness	Soft-Bodied Genera Richness
5/8/2001	LNIX 8	178	2.70	0.28	0.93	0.90	0.49	2.00	1.00	1.29	12.00	10.00
5/29/2001	Pata 6	80	2.82	0.18	0.66	0.89	0.22	2.00	1.00	1.43	11.00	8.00
5/30/2001	EMCC 3	139	2.88	0.10	0.87	0.55	0.32	2.00	1.00	1.02	14.00	6.00
5/31/2001	Lock 5	106	2.80	0.19	0.91	0.70	0.11	1.00	1.00	1.56	12.00	6.00
6/1/2001	Patr 3	115	2.85	0.15	0.79	0.76	0.19	2.00	1.00	1.98	13.00	10.00
6/4/2001	Trac 1	122	2.82	0.17	0.86	0.95	0.23	2.00	1.00	1.94	14.00	11.00
6/4/2001	Trac 5	122	2.94	0.06	0.95	0.87	0.39	1.00	0.00	1.31	9.00	8.00
6/5/2001	Pain 6	139	2.99	0.01	1.00	0.44	0.18	2.00	0.00	0.20	9.00	6.00
6/6/2001	John 6	152	2.95	0.05	0.97	0.69	0.50	1.00	1.00	0.99	12.00	7.00
6/7/2001	DEAD 6	166	2.90	0.09	0.69	0.90	0.57	2.00	0.00	1.53	10.00	8.00
6/8/2001	LNIX 4	178	2.98	0.01	0.99	0.55	0.69	1.00	0.00	0.27	9.00	5.00
6/22/2001	Lock 1	106	2.87	0.13	0.89	0.81	0.63	1.00	1.00	1.10	11.00	4.00
6/22/2001	Lock 5	106	2.94	0.06	0.98	0.78	0.72	1.00	0.00	0.60	9.00	6.00
6/22/2001	Pata 2	80	2.74	0.24	0.87	0.88	0.52	2.00	1.00	1.28	10.00	6.00
6/22/2001	Pata 6	80	2.76	0.22	0.66	0.87	0.40	1.00	1.00	1.69	10.00	3.00
6/25/2001	Patr 1	115	2.90	0.10	0.83	0.54	0.45	1.00	1.00	1.38	7.00	5.00
6/25/2001	Patr 3	115	2.77	0.21	0.90	0.81	0.31	1.00	1.00	1.80	12.00	4.00
6/25/2001	Trac 2	122	2.97	0.02	0.98	0.66	0.43	1.00	0.00	1.16	13.00	7.00
6/26/2001	John 2	152	2.98	0.01	0.99	0.56	0.77	2.00	1.00	0.40	14.00	4.00
6/26/2001	John 6	152	2.96	0.02	0.97	0.63	0.41	1.00	1.00	0.39	14.00	7.00
6/26/2001	Trac 5	122	2.93	0.07	0.91	0.86	0.35	2.00	1.00	1.58	13.00	5.00
6/27/2001	LNIX 4	178	2.74	0.24	0.89	0.88	0.51	2.00	1.00	1.50	13.00	7.00
6/27/2001	LNIX 8	178	2.88	0.08	0.92	0.80	0.56	2.00	1.00	0.83	11.00	8.00
9/6/2001	John 3	152	2.76	0.21	0.83	0.90	0.29	2.00	1.00	1.82	13.00	6.00
11/6/2001	PATA 2	80	2.45	0.52	0.67	0.53	0.49	2.00	1.00	1.54	12.00	
11/7/2001	LOCK 5	106	2.86	0.11	0.90	0.36	0.50	2.00	1.00	1.72	16.00	
11/15/2001	TRAC 1	122	2.32	0.22	0.45	0.57	0.45	2.00	1.00	0.77	13.00	
11/19/2001	PATR 1	115	2.85	0.12	0.87	0.74	0.58	2.00	1.00	1.61	15.00	
11/26/2001	FLEI 1	56	2.56	0.42	0.76	0.83	0.36	1.00	1.00	1.92	11.00	
12/6/2001	PATA 2	80	2.49	0.47	0.59	0.47	0.41	1.00	1.00	1.72	11.00	
12/7/2001	LOCK 5	106	2.60	0.38	0.73	0.46	0.31	1.00	1.00	2.00	13.00	
12/11/2001	PATR 1	115	2.78	0.22	0.84	1.00	0.49	1.00	1.00	1.59	9.00	
12/13/2001	TRAC 1	122	2.31	0.42	0.47	0.24	0.28	2.00	1.00	0.87	15.00	
1/4/2002	PATA 2	80	2.46	0.53	0.55	0.42	0.47	1.00	1.00	1.33	8.00	
1/7/2002	LOCK 5	106	2.40	0.60	0.83	0.11	0.54	2.00	1.00	1.63	13.00	
1/8/2002	PATR 1	115	2.54	0.44	0.76	0.64	0.30	1.00	1.00	1.83	11.00	
1/8/2002	TRAC 1	122	2.26	0.65	0.78	0.42	0.60	2.00	1.00	0.63	12.00	
1/14/2002	FLEI 1	56	2.67	0.30	0.32	0.41	0.43	2.00	1.00	1.69	13.00	
2/4/2002	PATA 2	80	2.79	0.20	0.27	0.54	0.59	1.00	1.00	1.30	11.00	
2/6/2002	LOCK 5	106	2.55	0.43	0.70	0.14	0.31	1.00	1.00	2.05	14.00	
2/7/2002	PATR 1	115	2.42	0.56	0.80	0.46	0.43	1.00	1.00	1.75	15.00	

Date	Site	Distance from Tahoe (km)	Fragilaria %	Cymbella %	Achnanthes minutissima %	Species Richness	Total Number of Divisions	chla (ug/cm2)	AFDW (ug/cm2)	Autotrophic Index
5/8/2001	LNIX 8	178	0.57	0.01	0.01	38.00	4.00	7.89	3521.06	446.51
5/29/2001	Pata 6	80	0.37	0.13	0.09	42.00	4.00	12.58	6599.75	524.61
5/30/2001	EMCC 3	139	0.76	0.02	0.04	44.00	4.00	24.45	8588.72	351.24
5/31/2001	Lock 5	106	0.49	0.02	0.02	28.00	4.00	45.97	6930.34	150.77
6/1/2001	Patr 3	115	0.36	0.04	0.04	35.00	3.00	368.89	28732.43	77.89
6/4/2001	Trac 1	122	0.46	0.01	0.01	36.00	3.00	169.49	16843.43	99.38
6/4/2001	Trac 5	122	0.44	0.00	0.02	25.00	3.00	5.64	1358.12	240.81
6/5/2001	Pain 6	139	0.84	0.00	0.00	23.00	3.00	28.14	5635.40	200.30
6/6/2001	John 6	152	0.75	0.01	0.01	31.00	3.00	154.35	16284.66	105.50
6/7/2001	DEAD 6	166	0.59	0.00	0.09	21.00	3.00	20.59	5534.95	268.86
6/8/2001	LNIX 4	178	0.95	0.00	0.01	22.00	3.00	63.38	4620.83	72.91
6/22/2001	Lock 1	106	0.73	0.03	0.02	30.00	2.00	11.62	2903.94	249.99
6/22/2001	Lock 5	106	0.87	0.00	0.01	22.00	3.00	36.04	8537.17	236.87
6/22/2001	Pata 2	80	0.59	0.05	0.06	28.00	3.00	6.65	1793.13	269.59
6/22/2001	Pata 6	80	0.44	0.12	0.13	22.00	2.00	1.91	978.65	512.33
6/25/2001	Patr 1	115	0.12	0.02	0.13	16.00	3.00	292.12	30180.49	103.32
6/25/2001	Patr 3	115	0.35	0.03	0.01	25.00	3.00	28.34	7539.30	266.01
6/25/2001	Trac 2	122	0.51	0.00	0.00	33.00	3.00	42.60	16822.83	394.86
6/26/2001	John 2	152	0.93	0.03	0.00	31.00	3.00	33.21	4657.48	140.24
6/26/2001	John 6	152	0.93	0.00	0.00	36.00	3.00	8.23	1444.47	175.51
6/26/2001	Trac 5	122	0.46	0.02	0.00	28.00	3.00	103.25	10141.67	98.23
6/27/2001	LNIX 4	178	0.56	0.03	0.00	30.00	3.00	9.66	4041.53	418.37
6/27/2001	LNIX 8	178	0.82	0.01	0.02	35.00	3.00	5.17	4008.35	775.43
9/6/2001	John 3	152	0.34	0.01	0.03	28.00	3.00	17.47	7773.13	444.85
11/6/2001	PATA 2	80	0.12	0.02			3.00	6.76	863.27	127.66
11/7/2001	LOCK 5	106	0.51	0.00			3.00	7.24	431.63	59.64
11/15/2001	TRAC 1	122	0.15	0.00			3.00	52.95	9097.27	171.80
11/19/2001	PATR 1	115	0.58	0.02			3.00	64.18	431.63	6.73
11/26/2001	FLEI 1	56	0.09	0.04			3.00	2.45	1404.87	573.21
12/6/2001	PATA 2	80	0.12	0.09			3.00	6.56	2040.17	310.78
12/7/2001	LOCK 5	106	0.04	0.00			3.00	10.40	1175.13	113.04
12/11/2001	PATR 1	115	0.09	0.07			3.00	0.03	469.62	15335.51
12/13/2001	TRAC 1	122	0.05	0.02			3.00	27.31	7045.31	257.98
1/4/2002	PATA 2	80	0.05	0.05			3.00	7.58	1950.04	257.37
1/7/2002	LOCK 5	106	0.07	0.04			3.00	27.54	2578.28	93.63
1/8/2002	PATR 1	115	0.24	0.04			3.00	16.22	3882.08	239.27
1/8/2002	TRAC 1	122	0.09	0.01			3.00	9.19	3031.90	330.00
1/14/2002	FLEI 1	56	0.03	0.11			3.00	8.23	2277.35	276.62
2/4/2002	PATA 2	80	0.04	0.11			3.00	9.95	2521.81	253.53
2/6/2002	LOCK 5	106	0.13	0.04			3.00	60.58	6962.30	114.93
2/7/2002	PATR 1	115	0.20	0.04			3.00	23.32	4598.38	197.15

Date	Site	Distance from Tahoe (km)	Pollution Index Score	Siltation Index	Eutraphentic Score	Cyanobacteria %	Dominant %	*FGR*	CGR	Shannon Diveristy (Genera)	Diatom Generic Richness	Soft-Bodied Genera Richness
2/7/2002	TRAC 1	122	2.48	0.50	0.80	0.32	0.41	1.00	1.00	0.82	12.00	
2/15/2002	FLEI 1	56	2.52	0.45	0.42	0.65	0.32	1.00	1.00	1.69	11.00	
3/4/2002	LOCK 5	106	2.61	0.38	0.72	0.26	0.30	1.00	1.00	1.94	13.00	
3/4/2002	PATA 2	80	2.66	0.33	0.59	0.66	0.24	2.00	1.00	1.81	8.00	
3/5/2002	PATR 1	115	2.23	0.76	0.74	0.57	0.57	1.00	1.00	1.44	11.00	
3/6/2002	TRAC 1	122	2.60	0.38	0.84	0.52	0.28	2.00	1.00	0.85	16.00	
3/19/2002	HERS 3	32	2.06	0.11	0.83	0.30	0.79	1.00	1.00	0.84	12.00	
3/21/2002	FLEI 1	56	2.79	0.19	0.41	0.80	0.37	1.00	1.00	1.68	8.00	
5/3/2002	PATA 2	80	2.88	0.11	0.54	0.13	0.35	1.00	1.00	1.79	10.00	
5/6/2002	LOCK 5	106	2.86	0.13	0.71	0.91	0.53	1.00	1.00	1.49	10.00	
5/6/2002	PATR 1	115	2.66	0.33	0.65	0.61	0.20	1.00	1.00	0.89	10.00	
5/9/2002	FLEI 1	56	2.94	0.05	0.17	0.87	0.80	1.00	1.00	0.91	10.00	
5/9/2002	HERS 3	32	2.71	0.27	0.27	0.59	0.24	2.00	1.00	1.81	12.00	
5/28/2002	LOCK 5	106	2.81	0.19	0.62	0.19	0.24	2.00	1.00	1.97	11.00	
5/28/2002	PATA 2	80	2.71	0.28	0.47	0.24	0.39	1.00	1.00	1.81	11.00	
5/29/2002	PATR 1	115	2.61	0.39	0.71	0.56	0.33	1.00	1.00	0.76	9.00	
5/31/2002	FLEI 1	56	2.86	0.14	0.81	0.59	0.30	2.00	1.00	1.95	12.00	
9/12/2003	CE 210	113	2.62	0.37	0.70	0.35	0.27	2.00	1.00	2.11	11.00	
9/12/2003	CE 210	113	2.52	0.43	0.66	0.39	0.33	2.00	1.00	2.10	14.00	
9/12/2003	CE 210	113	2.35	0.63	0.64	0.30	0.50	2.00	1.00	1.69	11.00	
9/15/2003	Pata 1	80	2.63	0.17	0.67	0.32	0.29	2.00	1.00	1.89	10.00	
9/15/2003	Pata 2	80	2.43	0.42	0.16	0.25	0.30	2.00	1.00	2.16	15.00	
9/15/2003	Pata 2	80	2.52	0.35	0.55	0.37	0.27	2.00	1.00	2.08	14.00	
9/16/2003	CE 140	115	2.70	0.28	0.58	0.48	0.21	2.00	1.00	2.15	15.00	
9/16/2003	CE 140	115	2.77	0.22	0.81	0.46	0.29	2.00	1.00	2.03	14.00	
9/16/2003	CE 145	115	2.31	0.66	0.64	0.40	0.47	2.00	1.00	1.66	13.00	
9/17/2003	CE 50	118	2.22	0.71	0.29	0.82	0.41	0.00	0.00	1.14	6.00	
9/17/2003	CE 50	118	2.83	0.15	0.81	0.84	0.56	0.00	1.00	1.57	10.00	
9/17/2003	CE 50	118	2.00	0.33	0.74	0.81	0.48	0.00	0.00	1.35	6.00	
9/18/2003	CE 70	117	2.46	0.42	0.38	0.90	0.17	0.00	1.00	1.66	7.00	
9/18/2003	CE 70	117	2.51	0.49	0.67	0.39	0.17	1.00	1.00	1.95	12.00	
9/19/2003	Tracy 1	122	2.50	0.50	0.66	0.52	0.23	2.00	1.00	1.85	12.00	
9/19/2003	Tracy 2	122	2.56	0.36	0.50	0.61	0.27	2.00	1.00	2.00	13.00	
9/19/2003	Tracy 4	122	2.50	0.47	0.51	0.72	0.19	1.00	1.00	1.95	9.00	
12/15/2003	CE 50	118	2.56	0.43	0.71	0.49	0.33	1.00	1.00	1.67	9.00	
12/15/2003	CE 50	118	2.77	0.18	0.78	0.23	0.51	2.00	1.00	1.53	11.00	
12/15/2003	CE 50	118	2.28	0.71	0.77	0.43	0.61	2.00	1.00	1.36	10.00	
12/16/2003	CE 140	115	2.04	0.49	0.58	0.58	0.38	2.00	1.00	0.98	13.00	
12/16/2003	CE 140	115	2.20	0.43	0.62	0.49	0.26	2.00	1.00	0.98	13.00	
12/16/2003	CE 70	117	2.23	0.77	0.87	0.09	0.73	2.00	1.00	1.05	12.00	
12/16/2003	CE 70	117	2.57	0.31	0.62	0.57	0.28	2.00	1.00	1.99	10.00	

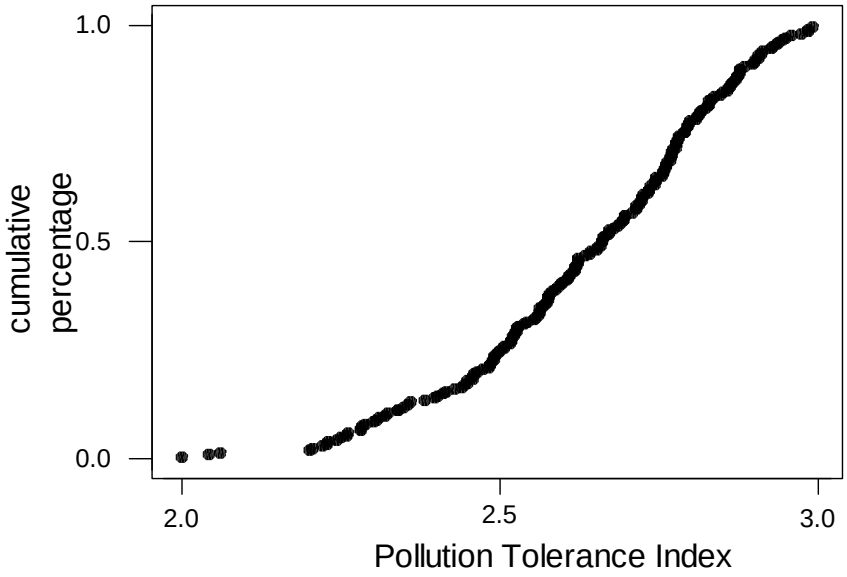
Date	Site	Distance from Tahoe (km)	Fragilaria %	Cymbella %	Achnanthes minutissima %	Species Richness	Total Number of Divisions	chla (ug/cm2)	AFDW (ug/cm2)	Autotrophic Index
2/7/2002	TRAC 1	122	0.13	0.03			4.00	16.76	2007.08	119.76
2/15/2002	FLEI 1	56	0.03	0.10			3.00	5.56	1041.47	187.17
3/4/2002	LOCK 5	106	0.11	0.05			3.00	111.25	10238.09	92.03
3/4/2002	PATA 2	80	0.18	0.13			3.00	10.72	2598.55	242.39
3/5/2002	PATR 1	115	0.05	0.01			3.00	8.45	1302.67	154.08
3/6/2002	TRAC 1	122	0.27	0.02			3.00	6.89	2127.96	308.98
3/19/2002	HERS 3	32	0.79	0.02			3.00	5.36	1767.49	329.45
3/21/2002	FLEI 1	56	0.01	0.37			3.00	3.94	1005.25	255.38
5/3/2002	PATA 2	80	0.35	0.19			3.00	27.67	5930.70	214.33
5/6/2002	LOCK 5	106	0.02	0.04			2.00	1.80	66.40	36.98
5/6/2002	PATR 1	115	0.20	0.08			2.00	3.44	3739.83	1087.39
5/9/2002	FLEI 1	56	0.04	0.02			3.00	0.52	529.46	1010.77
5/9/2002	HERS 3	32	0.21	0.21			3.00	3.89	2595.67	666.62
5/28/2002	LOCK 5	106	0.24	0.14			3.00	4.23	1444.54	341.15
5/28/2002	PATA 2	80	0.13	0.05			3.00	12.64	5187.56	410.29
5/29/2002	PATR 1	115	0.08	0.06			3.00	3.15	1157.62	368.07
5/31/2002	FLEI 1	56	0.26	0.06			3.00	3.98	4466.18	1122.67
9/12/2003	CE 210	113	0.07	0.03	0.04		3.00	38.31	4852.64	126.66
9/12/2003	CE 210	113	0.08	0.08	0.03		3.00	31.38	5059.21	161.21
9/12/2003	CE 210	113	0.09	0.06	0.05		3.00	14.96	3629.79	242.55
9/15/2003	Pata 1	80	0.03	0.06	0.02		3.00	10.57	3574.61	338.17
9/15/2003	Pata 2	80	0.24	0.04	0.06		3.00	11.22	5859.98	522.42
9/15/2003	Pata 2	80	0.15	0.04	0.06		2.00	7.81	2480.05	317.57
9/16/2003	CE 140	115	0.15	0.00	0.11		3.00	85.43	9067.12	106.13
9/16/2003	CE 140	115	0.06	0.03	0.02		3.00	79.38	7729.84	97.38
9/16/2003	CE 145	115	0.07	0.07	0.04		3.00	13.38	3350.10	250.40
9/17/2003	CE 50	118	0.00	0.00	0.00		2.00	34.65	7074.70	204.20
9/17/2003	CE 50	118	0.00	0.03	0.03		3.00	136.31	14423.96	105.82
9/17/2003	CE 50	118	0.00	0.00	0.00		3.00	18.89	2560.42	135.56
9/18/2003	CE 70	117	0.00	0.04	0.04		3.00	18.23	2915.64	159.95
9/18/2003	CE 70	117	0.02	0.06	0.03		3.00	16.77	3446.79	205.51
9/19/2003	Tracy 1	122	0.13	0.04	0.03		3.00	15.37	5074.75	330.17
9/19/2003	Tracy 2	122	0.16	0.03	0.01		3.00	60.50	11837.74	195.67
9/19/2003	Tracy 4	122	0.03	0.08	0.06		3.00	16.98	3459.34	203.77
12/15/2003	CE 50	118	0.02	0.04	0.02		3.00	302.42	14265.87	47.17
12/15/2003	CE 50	118	0.03	0.02	0.00		3.00	238.06	22114.63	92.90
12/15/2003	CE 50	118	0.05	0.02	0.00		3.00	45.86	7351.07	160.31
12/16/2003	CE 140	115	0.16	0.04	0.07		3.00	28.22	4902.91	173.75
12/16/2003	CE 140	115	0.12	0.01	0.02		3.00	73.43	9366.28	127.55
12/16/2003	CE 70	117	0.04	0.02	0.01		3.00	28.61	2987.34	104.40
12/16/2003	CE 70	117	0.18	0.02	0.05		3.00	232.66	25926.75	111.44

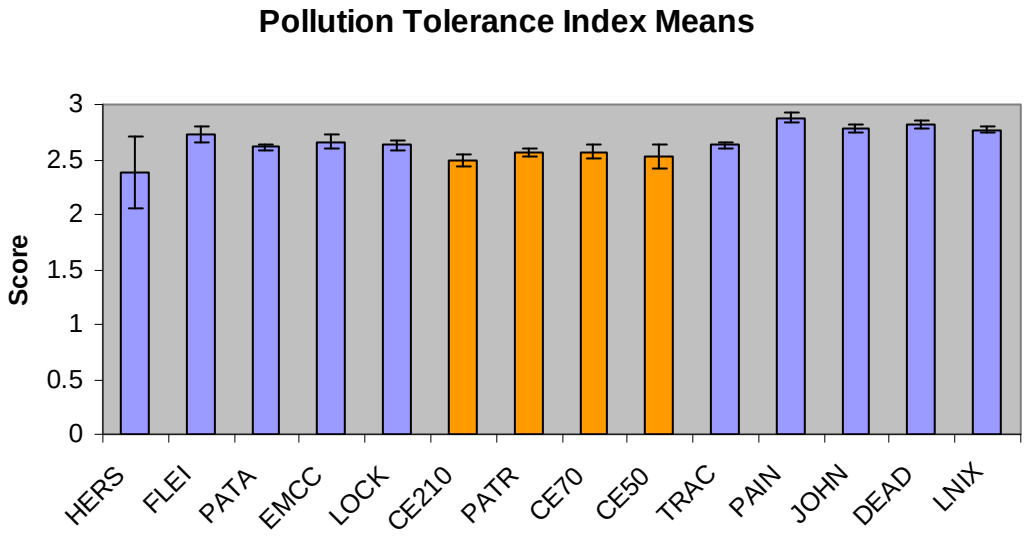
Date	Site	Distance from Tahoe (km)	Pollution Index Score	Siltation Index	Eutraphentic Score	Cyanobacteria %	Dominant %	*FGR*	CGR	Shannon Diveristy (Genera)	Diatom Generic Richness	Soft-Bodied Genera Richness
12/16/2003	CE 70	117	2.69	0.26	0.68	0.19	0.37	2.00	1.00	1.78	9.00	
12/18/2003	CE 210	113	2.32	0.52	0.56	0.66	0.34	2.00	1.00	2.01	12.00	
12/18/2003	CE 210	113	2.40	0.60	0.69	0.72	0.46	1.00	1.00	1.55	10.00	
12/18/2003	CE 210	113	2.20	0.78	0.81	0.26	0.75	2.00	2.00	1.10	13.00	
12/18/2003	Trac 2	122	2.29	0.68	0.73	0.32	0.61	2.00	1.00	1.51	12.00	
12/18/2003	Tracy 1	122	2.35	0.52	0.62	0.48	0.49	2.00	1.00	1.77	13.00	
12/19/2003	Pata 1	80	2.36	0.60	0.75	0.28	0.50	0.00	1.00	1.56	10.00	
12/19/2003	Pata 2	80	2.25	0.66	0.65	0.18	0.57	1.00	1.00	1.50	12.00	
12/19/2003	Pata 2	80	2.44	0.53	0.70	0.51	0.46	2.00	1.00	1.68	13.00	
3/19/2004	CE 140	115	2.49	0.44	0.70	0.34	0.14	1.00	2.00	2.00	18.00	
3/19/2004	CE 140	115	2.58	0.42	0.73	0.99	0.19	1.00	1.00	1.87	10.00	
3/19/2004	CE 140	115	2.52	0.69	0.88	0.78	0.18	1.00	1.00	1.85	9.00	
3/19/2004	CE 140	115	2.58	0.42	0.83	0.65	0.17	1.00	1.00	1.73	9.00	
3/19/2004	CE 140	115	2.47	0.44	0.68	0.61	0.12	1.00	2.00	2.11	15.00	
6/23/2004	CE 140	115	2.58	0.37	0.69	0.56	0.27	1.00	1.00	2.05	13.00	
6/23/2004	CE 145	115	2.49	0.48	0.70	0.56	0.23	0.00	1.00	1.69	8.00	
6/23/2004	CE 210	113	2.53	0.47	0.74	0.81	0.25	2.00	1.00	1.79	10.00	
6/23/2004	CE 210	113	2.46	0.32	0.69	0.64	0.15	2.00	1.00	2.30	14.00	
6/23/2004	Trac 1	122	2.62	0.35	0.71	0.53	0.19	2.00	2.00	1.96	15.00	
6/23/2004	Trac 2	122	2.56	0.30	0.54	0.37	0.21	2.00	1.00	2.07	14.00	
6/23/2004	Trac 4	122	2.71	0.24	0.67	0.47	0.28	2.00	2.00	2.15	18.00	
6/24/2004	CE 50	118	2.87	0.13	0.81	0.60	0.63	1.00	1.00	1.31	9.00	
6/24/2004	CE 50	118	2.44	0.56	0.78	0.79	0.27	1.00	1.00	1.59	9.00	
6/24/2004	CE 50	118	2.79	0.18	0.69	0.46	0.40	2.00	2.00	2.07	14.00	
6/24/2004	CE 70	117	2.57	0.39	0.75	0.51	0.33	2.00	1.00	1.84	13.00	
6/24/2004	CE 70	117	2.72	0.25	0.82	0.56	0.52	1.00	1.00	1.17	10.00	
6/24/2004	CE 70	117	2.82	0.17	0.87	0.61	0.76	1.00	1.00	0.92	9.00	
6/25/2004	Pata 1	80	2.34	0.65	0.63	0.48	0.33	1.00	2.00	1.58	10.00	
6/25/2004	Pata 2	80	2.59	0.39	0.44	0.32	0.25	2.00	2.00	2.10	17.00	
6/25/2004	Pata 2	80	2.56	0.42	0.60	0.34	0.20	2.00	1.00	1.85	15.00	

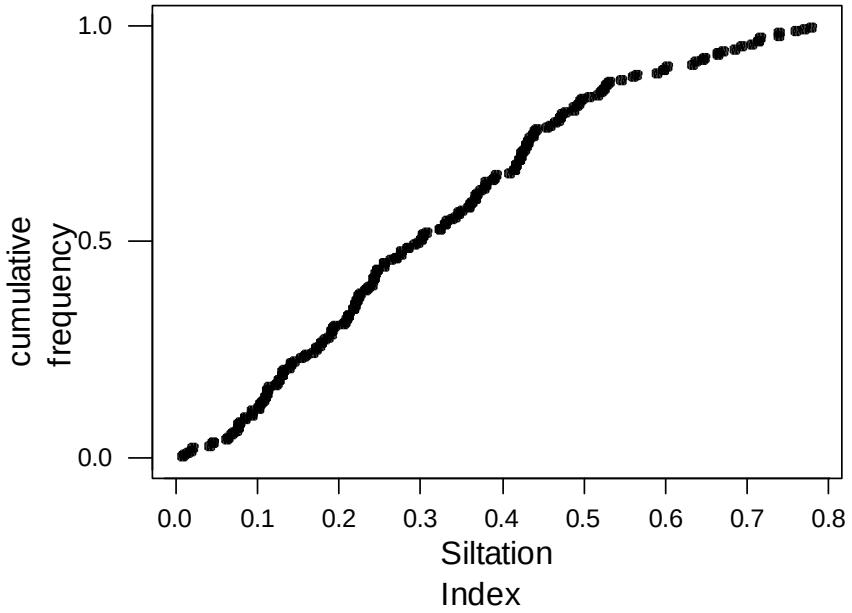
Date	Site	Distance from Tahoe (km)	Fragilaria %	Cymbella %	Achnanthes minutissima %	Species Richness	Total Number of Divisions	chla (ug/cm2)	AFDW (ug/cm2)	Autotrophic Index
12/16/2003	CE 70	117	0.05	0.09	0.00		3.00	64.83	6742.02	103.99
12/18/2003	CE 210	113	0.01	0.06	0.05		3.00	29.86	5458.92	182.79
12/18/2003	CE 210	113	0.03	0.06	0.04		3.00	18.31	4943.85	269.96
12/18/2003	CE 210	113	0.02	0.03	0.06		3.00	39.82	4264.29	107.09
12/18/2003	Trac 2	122	0.06	0.00	0.03		3.00	61.20	9891.09	161.61
12/18/2003	Tracy 1	122	0.04	0.02	0.09		3.00	35.32	4438.01	125.66
12/19/2003	Pata 1	80	0.00	0.05	0.03		2.00	15.39	4447.30	288.96
12/19/2003	Pata 2	80	0.06	0.08	0.07		3.00	18.27	6155.87	337.00
12/19/2003	Pata 2	80	0.08	0.06	0.06		2.00	13.44	3310.42	246.40
3/19/2004	CE 140	115	0.09	0.05	0.09		3.00	95.66		
3/19/2004	CE 140	115	0.20	0.05	0.03		3.00	64.55		
3/19/2004	CE 140	115	0.11	0.06	0.03		3.00	43.27		
3/19/2004	CE 140	115	0.31	0.01	0.00		3.00	21.34		
3/19/2004	CE 140	115	0.19	0.06	0.02		3.00	7.82		
6/23/2004	CE 140	115	0.12	0.01	0.04		3.00	9.50		
6/23/2004	CE 145	115	0.00	0.00	0.00		3.00	4.96		
6/23/2004	CE 210	113	0.05	0.04	0.00		3.00	3.38		
6/23/2004	CE 210	113	0.10	0.03	0.05		3.00	15.62		
6/23/2004	Trac 1	122	0.04	0.02	0.19		3.00	10.19		
6/23/2004	Trac 2	122	0.14	0.01	0.21		3.00	19.70		
6/23/2004	Trac 4	122	0.07	0.03	0.16		3.00	13.40		
6/24/2004	CE 50	118	0.08	0.03	0.11		3.00	62.48		
6/24/2004	CE 50	118	0.05	0.00	0.05		3.00	3.43		
6/24/2004	CE 50	118	0.08	0.04	0.19		3.00	64.84		
6/24/2004	CE 70	117	0.11	0.00	0.06		3.00	62.69		
6/24/2004	CE 70	117	0.13	0.03	0.03		3.00	18.43		
6/24/2004	CE 70	117	0.01	0.00	0.00		3.00	19.07		
6/25/2004	Pata 1	80	0.04	0.06	0.11		3.00	5.39		
6/25/2004	Pata 2	80	0.13	0.06	0.25		3.00	3.55		
6/25/2004	Pata 2	80	0.14	0.07	0.20		3.00	5.98		

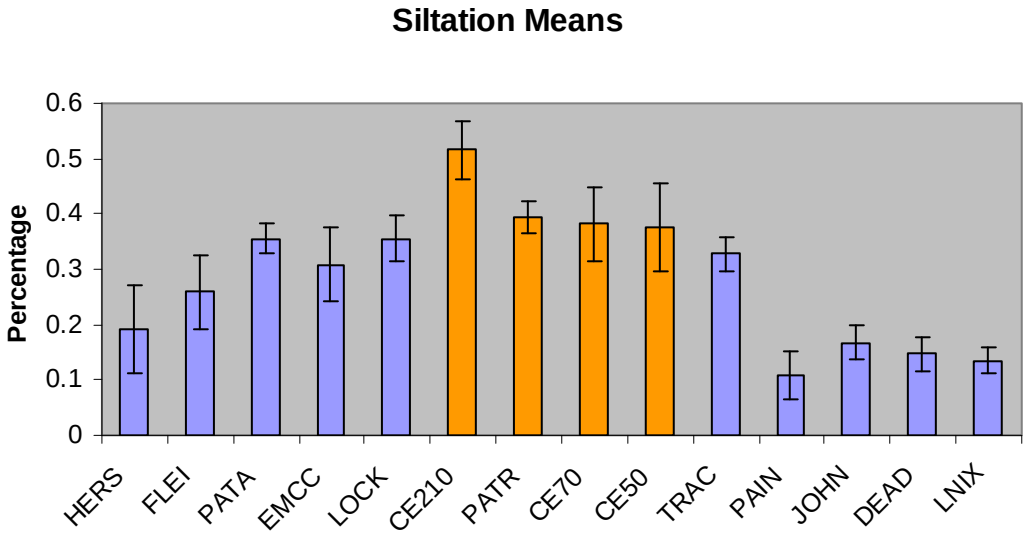
Appendix C: Cumulative Frequency Distributions for key Metrics and Scores for Truckee River Mainstem

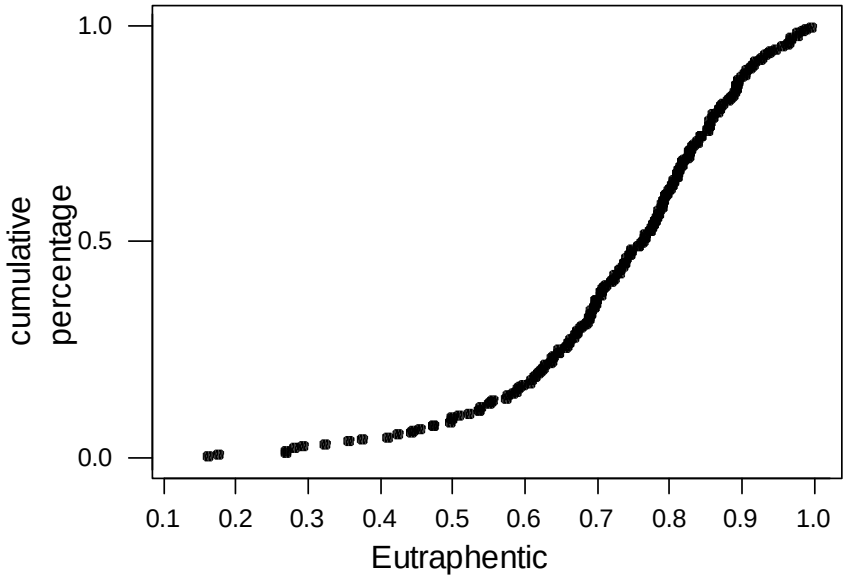
(Note: Error Bars are 1 S.E. and orange bars signify sites at the Patrick ranch and are much closer in proximity to one another than the rest of the sampling sites).

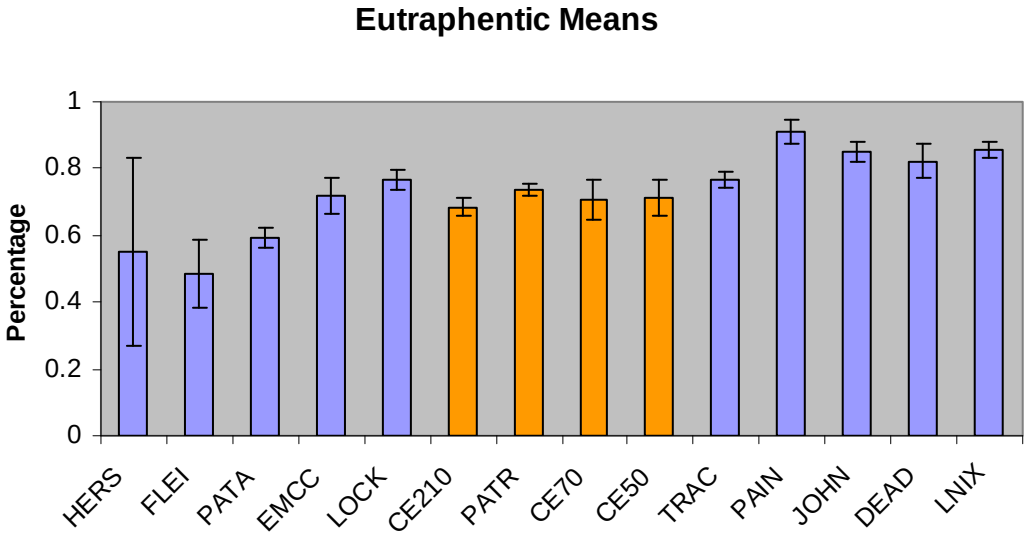

1.0
0.5
0.0
cumulative percentage
2.0
2.5
3.0
Pollution Tolerance Index

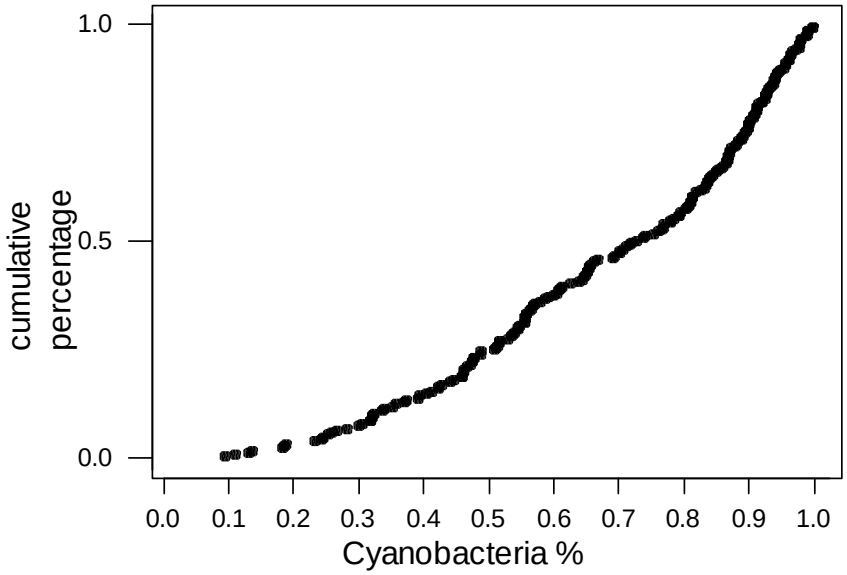

Pollution Tolerance Index Means
Score
3
2.5
2
1.5
1
0.5
0
HERS
FLEI
PATA
EMCC
LOCK
CE210
PATR
CE70
CE50
TRAC
PAIN
JOHN
DEAD
LNIX

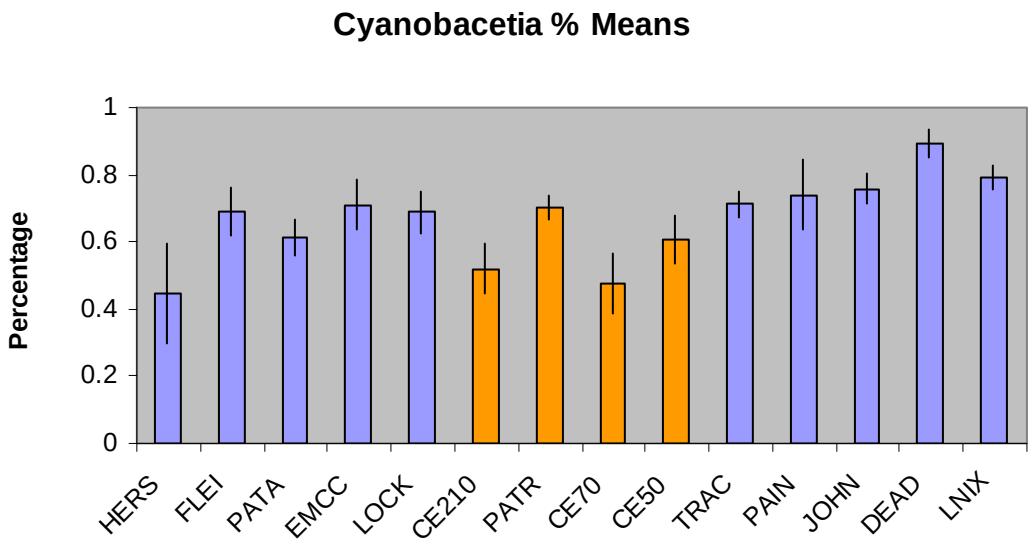

1.0
0.5
0.0
cumulative frequency
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
Siltation Index

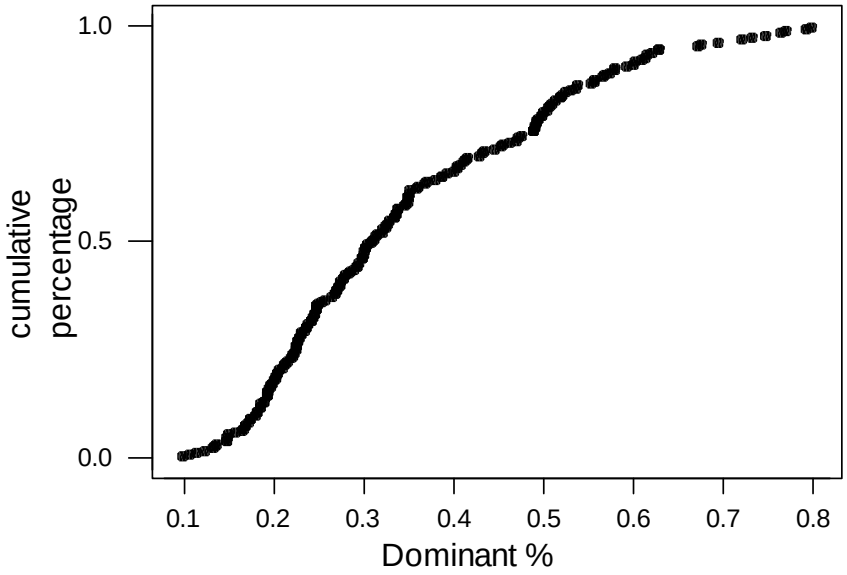

Siltation Means
Percentage
0.6
0.5
0.4
0.3
0.2
0.1
0
HERS
FLEI
PATA
EMCC
LOCK
CE210
PATR
CE70
CE50
TRAC
PAIN
JOHN
DEAD
LNIX

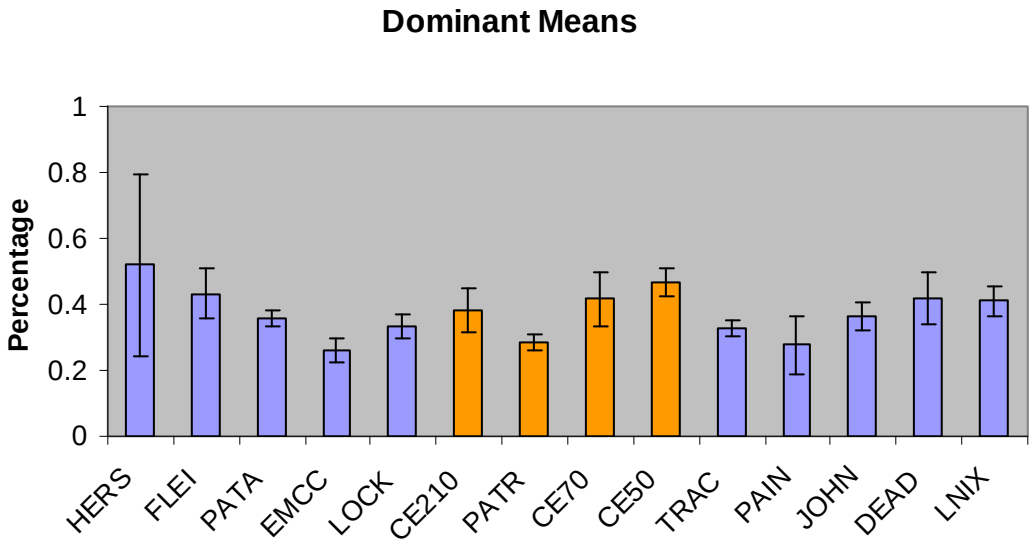

1.0
0.5
0.0
cumulative percentage
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Eutraphentic

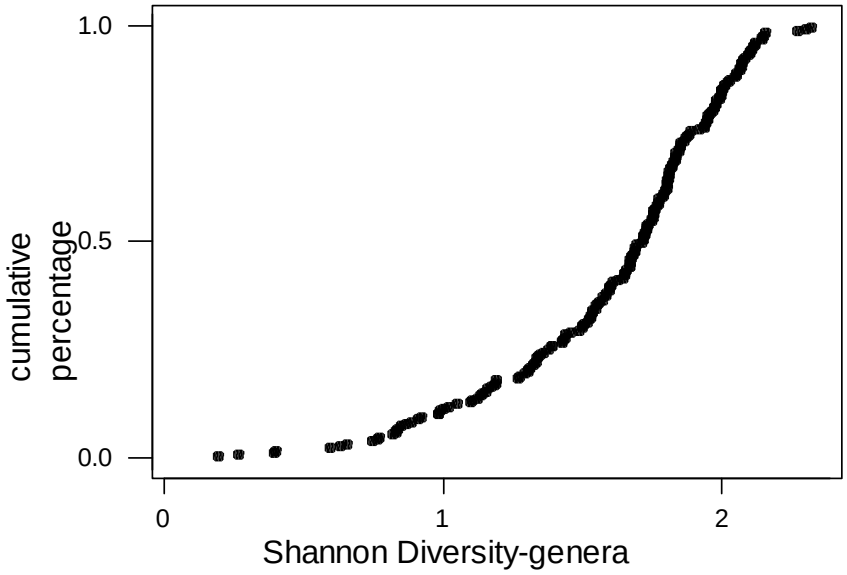

Eutraphentic Means
Percentage
1
0.8
0.6
0.4
0.2
0
HERS
FLEI
PATA
EMCC
LOCK
CE210
PATR
CE70
CE50
TRAC
PAIN
JOHN
DEAD
LNIX

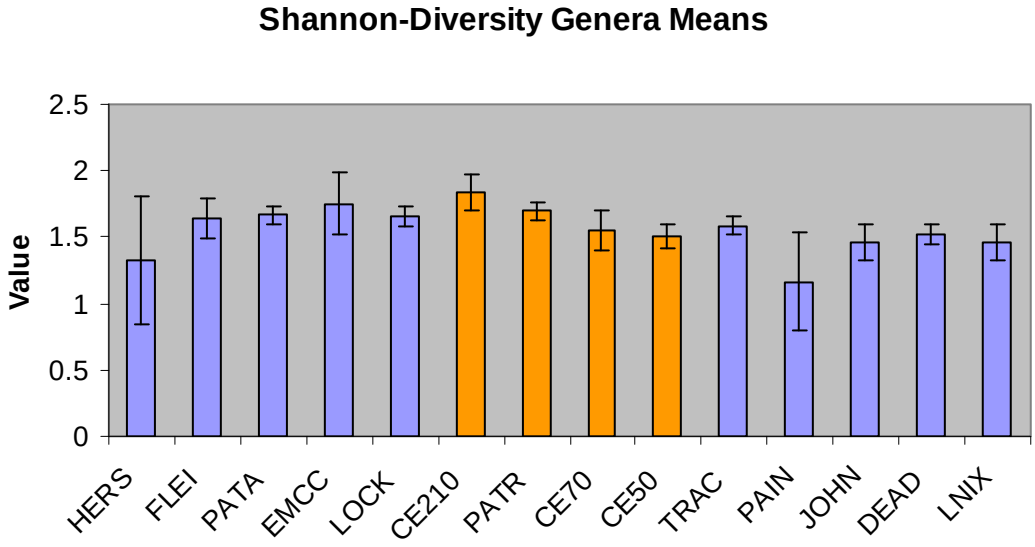

1.0
0.5
0.0
cumulative percentage
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0
Cyanobacteria %

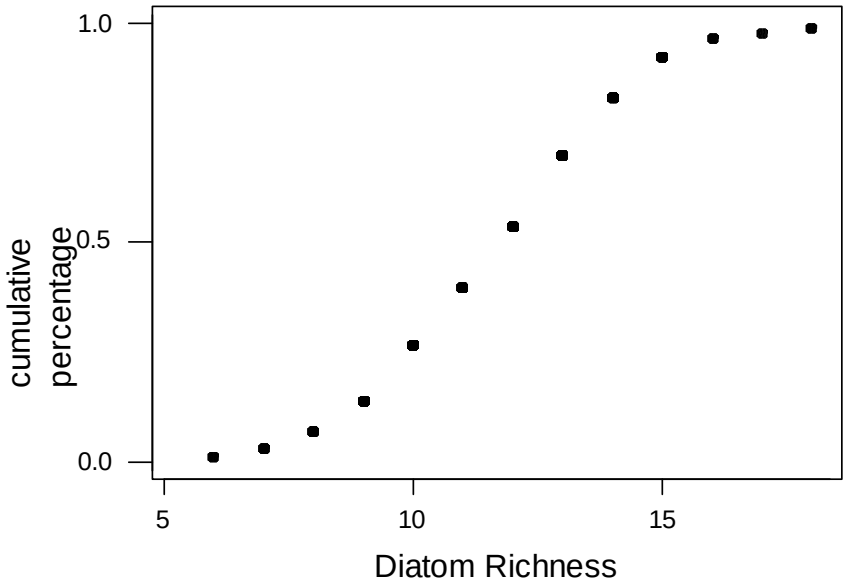

Cyanobacetia % Means
Percentage
1
0.8
0.6
0.4
0.2
0
HERS
FLEI
PATA
EMCC
LOCK
CE210
PATR
CE70
CE50
TRAC
PAIN
JOHN
DEAD
LNIX

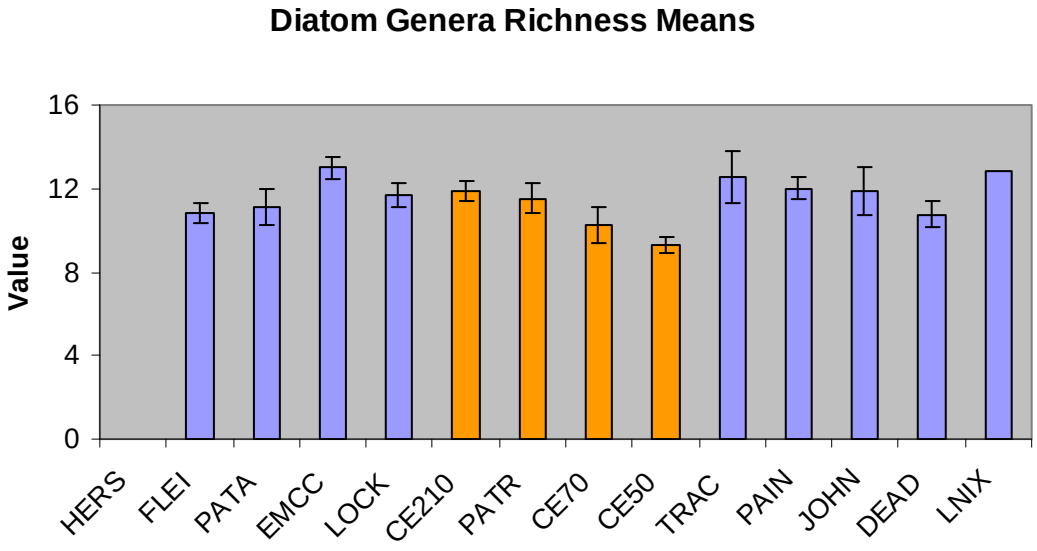

1.0
0.5
0.0
cumulative percentage
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
Dominant %

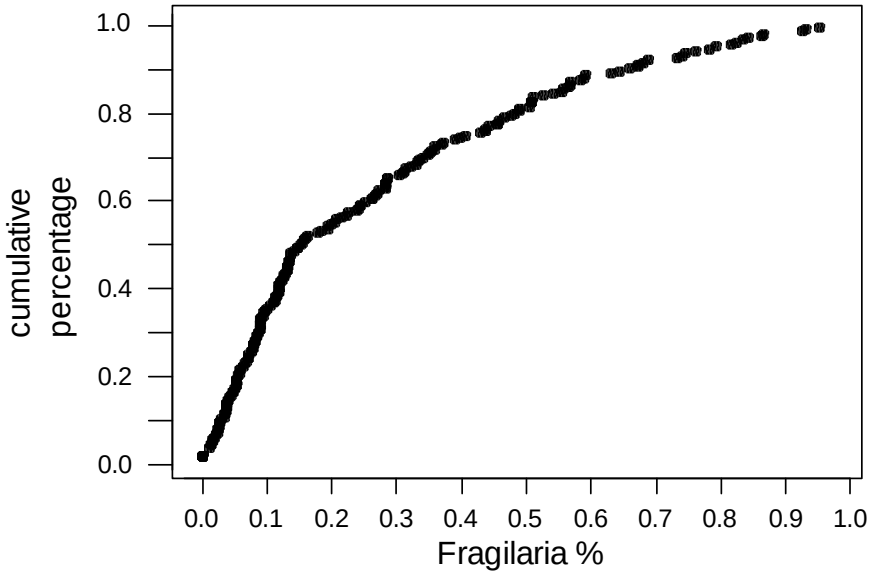

Dominant Means
Percentage
1
0.8
0.6
0.4
0.2
0
HERS
FLEI
PATA
EMCC
LOCK
CE210
PATR
CE70
CE50
TRAC
PAIN
JOHN
DEAD
LNIX

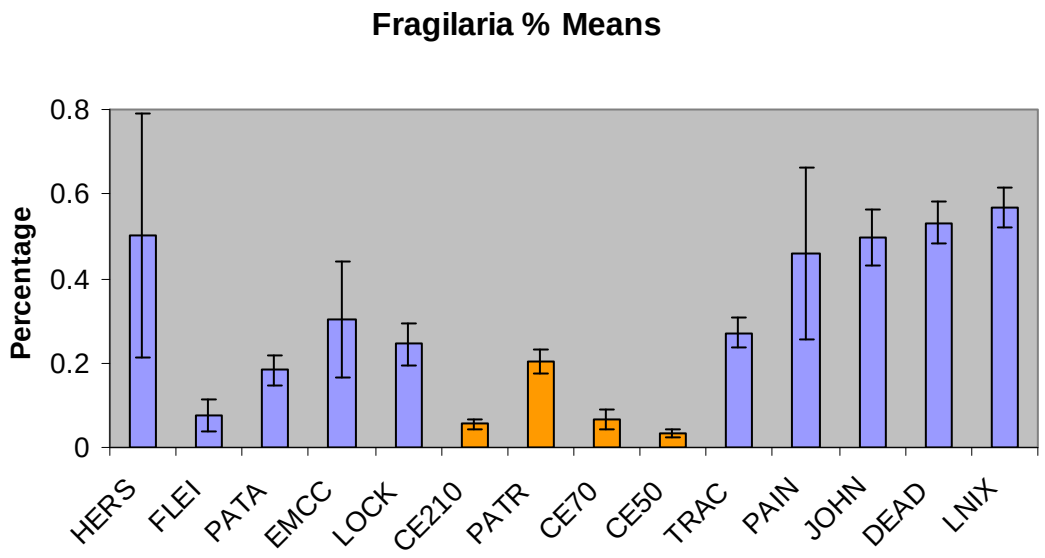

1.0
0.5
0.0
cumulative percentage
0
1
2
Shannon Diversity-genera

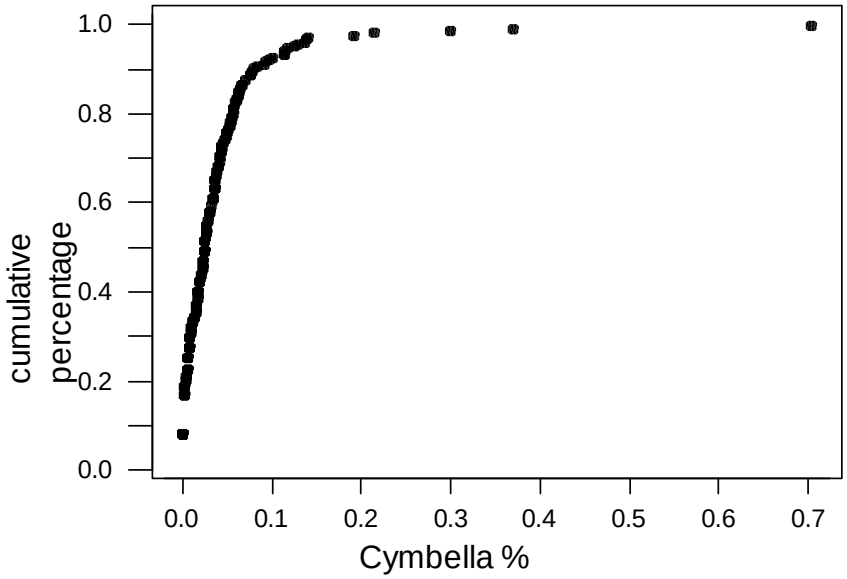

Shannon-Diversity Genera Means
Value
2.5
2
1.5
1
0.5
0
HERS
FLEI
PATA
EMCC
LOCK
CE210
PATR
CE70
CE50
TRAC
PAIN
JOHN
DEAD
LNIX

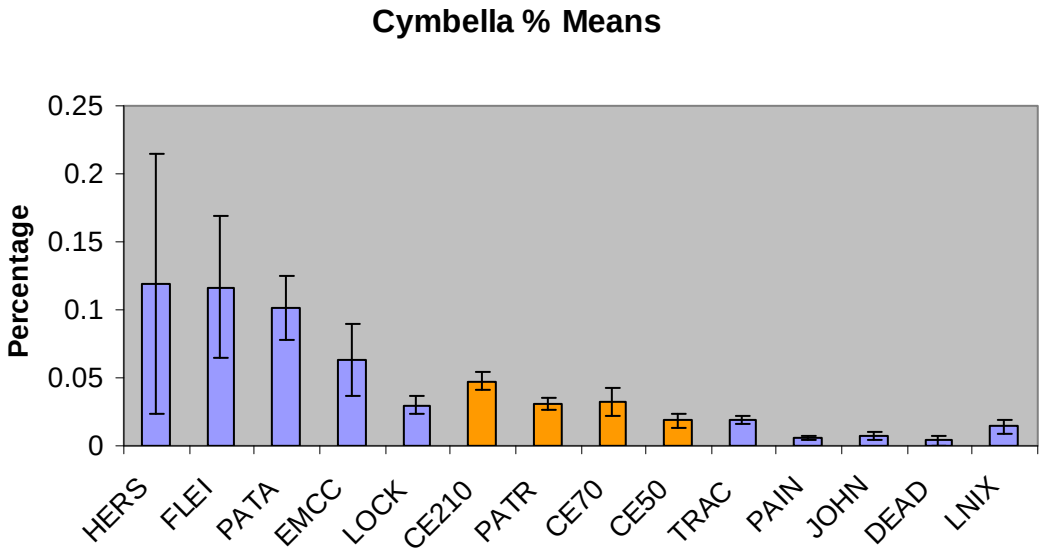

1.0
0.5
0.0
cumulative percentage
5
10
15
Diatom Richness

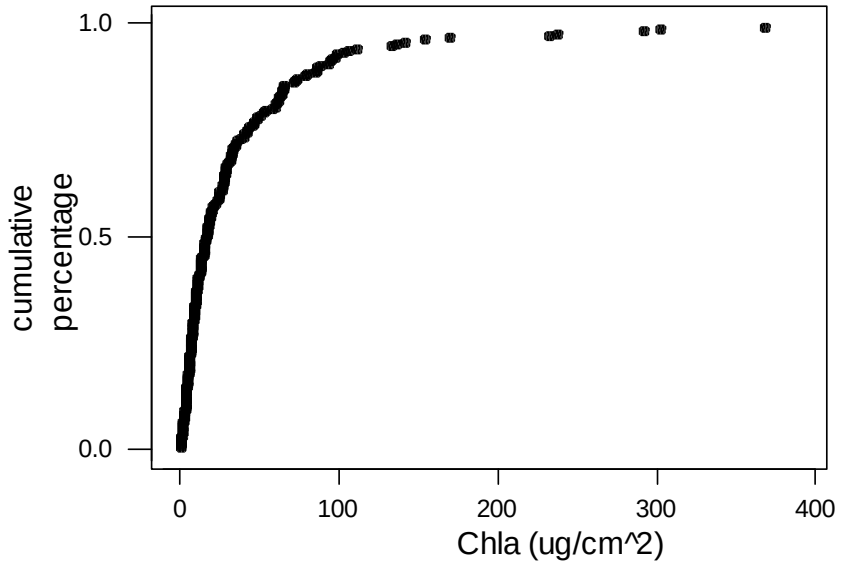

Diatom Genera Richness Means
16
12
8
4
0
Value
HERS
FLEI
PATA
EMCC
LOCK
CE210
PATR
CE70
CE50
TRAC
PAIN
JOHN
DEAD
LNIX

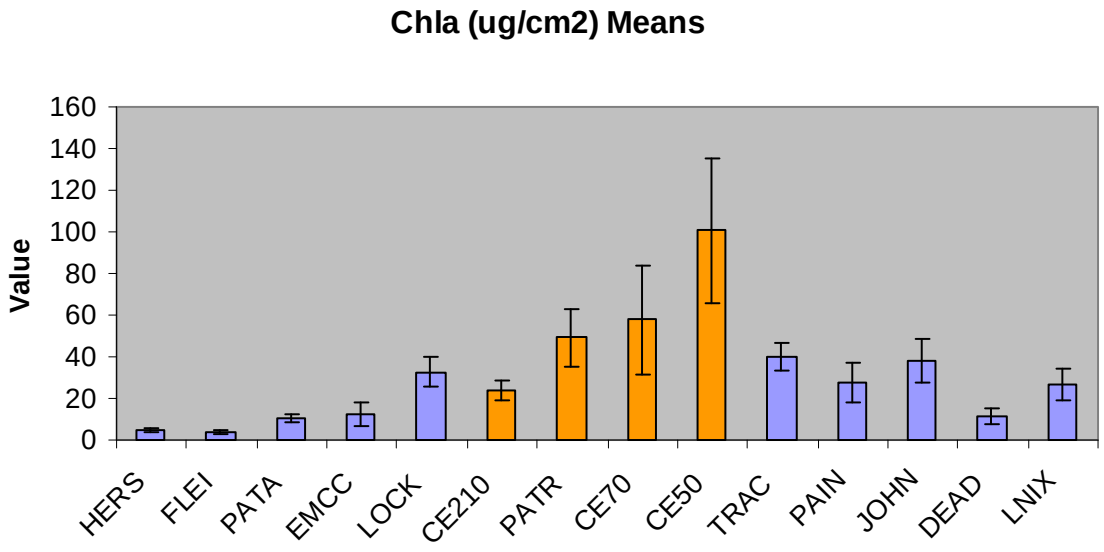

cumulative percentage
1.0
0.8
0.6
0.4
0.2
0.0
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0
Fragilaria %

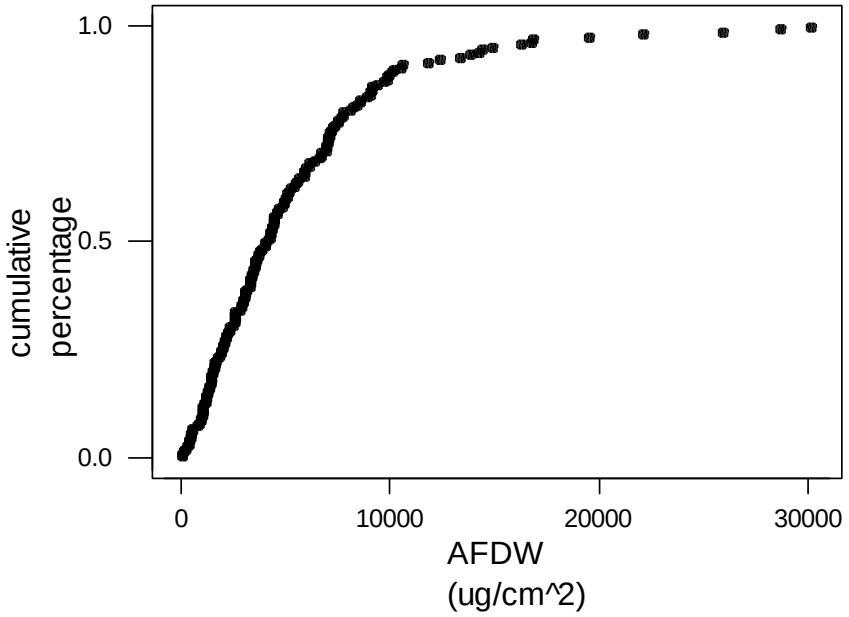

Fragilaria % Means
Percentage
0.8
0.6
0.4
0.2
0
HERS
FLEI
PATA
EMCC
LOCK
CE210
PATR
CE70
CE50
TRAC
PAIN
JOHN
DEAD
LNIX

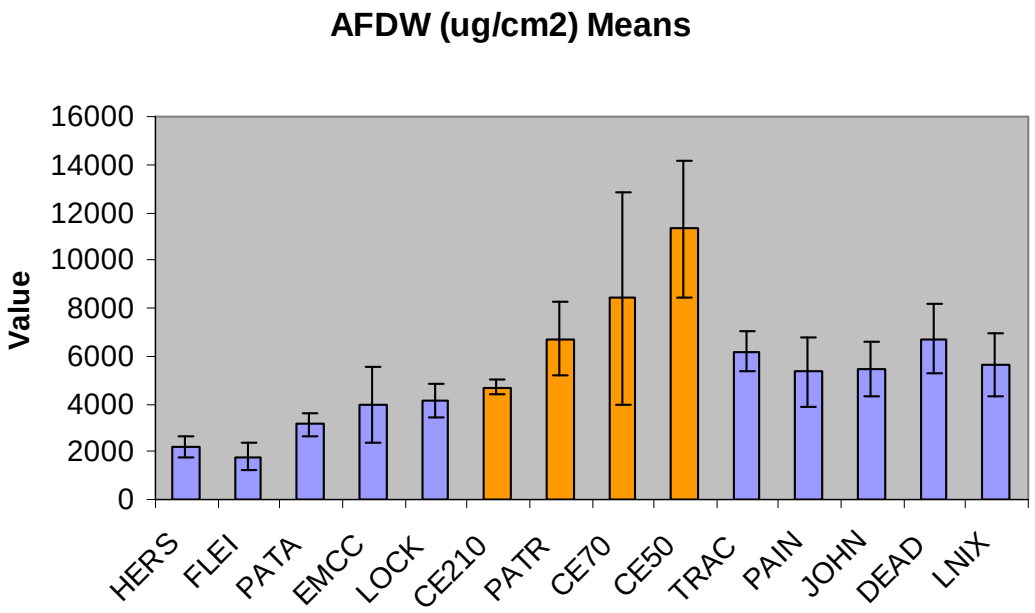

1.0
0.8
0.6
0.4
0.2
0.0
cumulative percentage
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Cymbella %

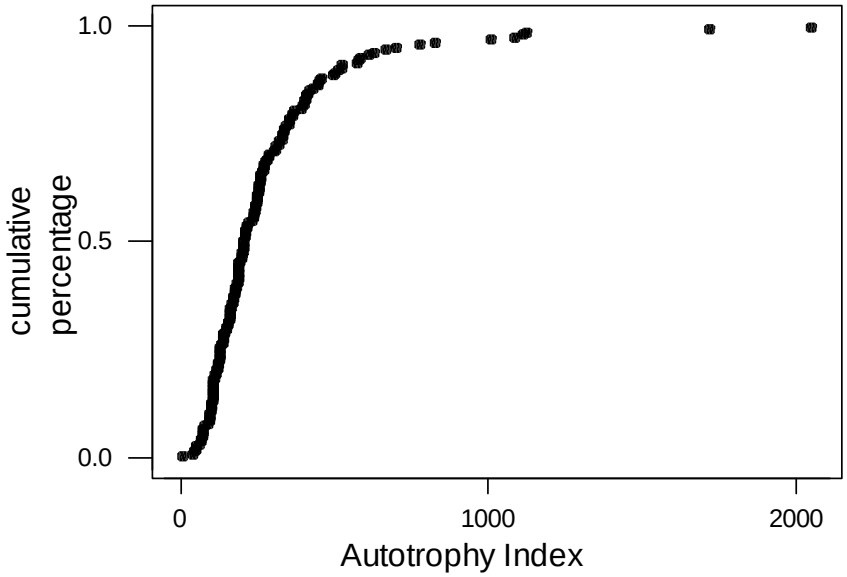

Cymbella % Means
0.25
0.2
0.15
0.1
0.05
0
Percentage
HERS
FLEI
PATA
EMCC
LOCK
CE210
PATR
CE70
CE50
TRAC
PAIN
JOHN
DEAD
LNIX

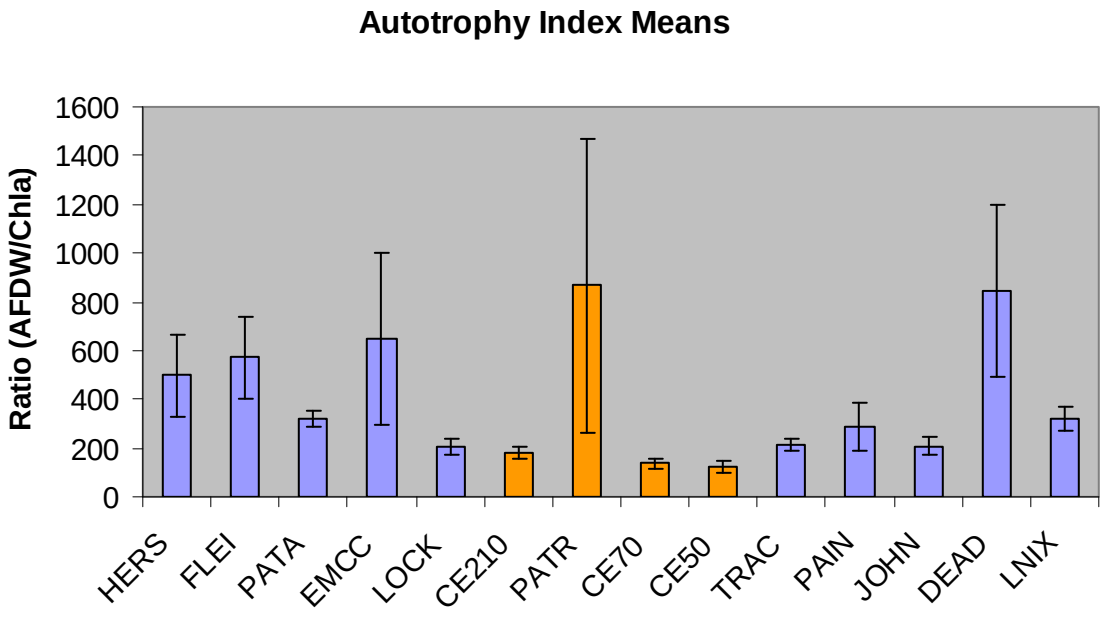

1.0
0.5
0.0
cumulative percentage
0
100
200
300
400
Chla (ug/cm^2)


Chla (ug/cm2) Means
Value
160
140
120
100
80
60
40
20
0
HERS
FLEI
PATA
EMCC
LOCK
CE210
PATR
CE70
CE50
TRAC
PAIN
JOHN
DEAD
LNIX


1.0
0.5
0.0
cumulative
percentage
0
10000
20000
30000
AFDW
(ug/cm^2)


AFDW (ug/cm2) Means
Value
16000
14000
12000
10000
8000
6000
4000
2000
0
HERS
FLEI
PATA
EMCC
LOCK
CE210
PATR
CE70
CE50
TRAC
PAIN
JOHN
DEAD
LNIX


1.0
0.5
0.0
cumulative percentage
0
1000
2000
Autotrophy Index


Autotrophy Index Means
Ratio (AFDW/Chla)
1600
1400
1200
1000
800
600
400
200
0
HERS
FLEI
PATA
EMCC
LOCK
CE210
PATR
CE70
CE50
TRAC
PAIN
JOHN
DEAD
LNIX