An Investigation of a Bloom of the Desmid Gonatozygon

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Abstract

We investigated a bloom of the desmid *Gonatozygon aculeatum var. aculeatum* in Walker's Lake, Chippewa County, Michigan. A Pearson's Correlation was used to determine the degree of correlation between substrate, temperature, pH, depth, and relative abundances of *Gonatozygon, Bulbochaete, Oedogonium,* and *Oscillatoria* in samples taken from Walker's Lake. No significant correlation affecting *Gonatozygon* distribution was found between the variables. Walker's Lake was limed in August,1989. To determine the part that the liming played in the *Gonatozygon* bloom, we designed an experiment in which samples from Walker's Lake were acidified, and samples from an adjacent lake in which Gonatozygon was absent were limed. Only the Whitmarsh Lake treatment showed a significant difference from its control, the limed samples had a greater percent abundance of healthy *Gonatozygon* cells. The experimental results supported our hypothesis that liming positively affects *Gonatozygon* health, but did not support the hypothesis that acidification adversely affects *Gonatozygon* health.

Introduction

A sample taken on July 7, 1990 in Walker's Lake, Chippewa County, Michigan revealed a bloom of the desmid *Gonatozygon aculeatum var. aculeatum.* Both unicells and long filaments were found in abundance. *Gonatozygon* occurs rarely and sparsely enough that this warranted interest. It is a member of the order Desmidiales and the family Mesotaeniaceae, the "false desmids." According to Round, *Gonatozygon* is part of the metaphyton; the algal flora that grows among primary and secondary epiphytes, often partially immersed in the mucilage produced by the latter, but without any obvious mode of attachment (Round 1981, p. 233). Smith considers it to be generally free-floating, but sites that it is sometimes attached to submerged water plants by a gelatinous disk at one end of a cell (Smith 1950, p. 307). Unlike the Desmidiaceae, or "true desmids," Mesotaeniaceae occur as commonly in hard-water habitats as soft-water habitats. *Gonatozygon*, however, is reported to be found mostly in soft-water or acid habitats, including *Sphagnum* (Prescott 1972, p. 5).

Both the surrounding vegetation and past water chemistry data from the Michigan Department of Natural Resources indicate that Walker's Lake is an historically acidic lake. The entire margin is densely lined with *Chamaedaphne calyculata* (leatherleaf) with *Andromeda glaucophylla* (bog rosemary) and *Larix larcina* (tamarack) interspersed. A mat of *Sphagnum* underlies most of the shrubby vegetation. In open areas next to the shore, *Drosera rotundifolia* (round-leaved sundew) grows in profusion. The most visible algal growth was found on the small, semi-aquatic plant *Eriocaulon septangulare* (pipewort) , which grows on the sandy shores of soft-water lakes or rooted in calcareous mud (Fassett 1940, p. 169; Crum 1988, p. 72). In most areas, Walker's Lake has a shallow littoral zone extending out 10-20 feet. There are both regions of soft, organic substrate and firm, sandy substrate. *E. septangulare* grows on

both substrates, but is found most commonly at sites with a firm sandy base.

Within a quarter mile of the main body of Walker's Lake, there are three other potential habitats for *Gonatozygon* , Whitmarsh Lake, Brown Lake, and a backwater area of Walker's Lake. The backwater area is connected to Walker's Lake by a narrow corridor of stagnant water littered with numerous logs. The substrate consists of a deeper organic muck than in other areas around Walker's Lake. *Utricularia* dominates the submerged growth and a healthy mat of Sphagnun underlies a relatively sparse growth of *C. calyculata*. A plant very similar to *E. septangulare*, if not the same taxa, grows in thick submerged mats here also. Whitmarsh Lake has has similar vegetation around the margin, predominantly *C. calyculata* and *Sphagnum*. However, the depth off the edge of the *Sphagnum* mat was about three feet, which left few sites for *E. septangulare* growth. We only found *E. septangulare* growing in a disturbed area next to the road in the shallows created by gravel and asphalt. Brown Lake drops off even more steeply from the edge of the Sphagnum mat than does Whitmarsh Lake. It also has more open bog vegetation. *Sphagnum* dominates with *C. calyculata, L. larcina* , and *Sarracenia purpurea* interspersed.

We examined the microhabitats of Walker's Lake to find correlations between *Gonatozygon* abundance and substrate, temperature, pH, depth, and relative abundances of other algae. We expected that *Gonatozygon* would be positively correlated with *E. septangulare* growing on a sandy substrate because that is where we found the most abundant algal growth. When we learned that Walker's Lake had been recently limed and the two adjacent lakes lacked *Gonatozygon* , we hypothesized that the liming stimulated the *Gonatozygon* bloom.

Materials and Methods

Twenty samples from around Walker's Lake were taken, and the substrate, temperature, depth, and pH, as measured by a pH pen, was noted for each. Six of the twenty-two samples were taken at three foot intervals along a transect from the shoreline out toward the center of the lake to the mucky substrate on which no algal growth was observed. The first 300-400 trichomes of blue-greens and the first 300-400 cells of other algae were counted and identified to the generic level. The percent of the total counted was then used to measure the relative abundance of *Gonatozygon* , *Bulbochaete*, *Oedogonium*, and *Oscillatoria* . Substrate types were given numerical values from one to eight as follows: 1) *E. septangulare* growing on sandy substrate, 2) *E. septangulare* growing on mucky substrate, 3) muck bottom without *E. septangulare*, 4) sandy bottom without *E. septangulare* (though some detritous on surface), 5)

submerged log or stick, 6) plankton tow, 7) *Sphagnum*. , and 8) *Utricularia* suqeeze. The ranking was based on what we perceived to be the optimum *Gonatozygon* habitat. Using the MacIntosh SYSTAT program, a Pearson's Correlation was run to decipher correlations between the substrate, pH, temperature, depth, and relative abunances of *Gonatozygon* , *Bulbocheate*, and *Oedogonium* .

We set up two experiments using water taken from Walker's Lake and Whitmarsh Lake. The Walker's Lake water was acidified with sulfuric acid to pH 6.0. The Whitmarsh lake water was alkalinized to pH 6.7 with a solution of hydrated lime produced for garden use. Three repetitions of each treatment and the control for each treatment were run, amounting to twelve flasks total. Each 250mL flask contained 150mL of sample water and was inoculated with 3 mL of a rich sample of *Gonatozygon* taken from Walker's Lake. The Walker's Lake flasks each were provided with several plants of the native *E. septangulare* . The Whitmarsh Lake flasks were provided with several plants the *E. septangulare* analogue that was native to Whitmarsh Lake. The flasks were placed in a window with full sunlight in a water bath to moderate temperature changes. The Whitmarsh Lake sample was limed a second time during the first day to reestablish the pH difference between the treatment and the control. The experiment was allowed to run nine days without further disturbance.

The first 100 cells of *Gonatozygon* were counted and assessed individually for their degree of health. Those with green, full chloroplasts were given a rating of one, or healthy. *Gonatozygon* with shrunken, pale chloroplasts were designated as sick, and given a rating of two. *Gonatozygon* cells without chloroplasts were called dead and given a rating of three. The Chi-square test was used on both sets of treatments and controls separately to test the statistical significance of the differences between the percent of *Gonatozygon* in each state of health.

Results

The survey sampling of Walker's Lake revealed little variation of the algal composition with microhabitat. In eighteen of the twenty sample sites , including a plankton tow, *Gonatozygon* was consistently one of the three most abundant genera regardless of substrate (Appendix 1). The two samples where *Gonatozygon* was absent or negligible were a *Sphagnum* squeeze and a *Utricularia* squeeze from the still backwater area of Walker's Lake (samples 19 and 20). The pH at these two sites (6.9 and 7.1) did not differ from the main portion of the lake. In the *Sphagnum* squeeze, *Gonatozygon* composed only 2% of the genera, the sample being dominated by

Tabellaria . The *Utricularia* sample was dominated by the Desmidiaceae, specifically *Staurastrum* . It was the only sample from Walker's Lake in which *Gonatozygon* was entirely absent. The Pearson Correlation analysis of the twenty samples (Table 3) revealed significant negative correlations between temperature and depth and pH and *Oedogonium* .

Samples from Whitmarsh Lake (7,8,11,37,38 and 40) were dominated by *Mougeotia* (7 and 8), *Oedogonium*, *Dinobryon*, *Haplosiphon* and *Spirogyra* respectively. *Gonatozygon* was noticeably absent from all samples. Samples from Brown Lake (9 and 10) were dominated by *Mougeotia*, and *Hyalotheca* respectively. Again, *Gonatozygon* was not detected in any of these samples.

The pH ranged from 6.6 to 7.2 in Walker's Lake, and from 6.0 to 6.5 in Whitmarsh Lake. We did not take pH readings from Brown Lake.

The results of our two experimental trials which tested the effects of liming and acidification are found in Tables 1 and 2. The chonicle of Walker's Lake pH , (Table 1), reveals an initial decline in the ph of both the control and treatment groups to 5.9 (control) and 5.7(treatment). We did no further pH modification for this experiment. The final pH reveals a buffering of the control groups to 6.4, 6.6 and 6.7. The experimental groups buffered themselves to 6.2, 6.1 and 6.3.

The chronicles of Whitmarsh Lake (Table 2) indicate a change from pH 6.1 to pH 6.3, 6.4 and 6.4 in the control groups and a decline in pH from 6.7 to 6.3, 6.25 and 6.3 in the experimental groups after the addition of substrate. We relimed the treatment groups to pH 6.8. Final pH readings at the close of the experiment were 6.7, 6.7 and 6.8 for the controls, and 6.9, 6.9 and 7.0 for the treatment groups, indicating that buffering had taken place in the both groups regardless of liming.

The results of the Walker's Lake experiment and Whitmarsh Lake experiment are summarized in Figure 1. In the Walker's Lake experiment the relative abundance of healthy, sick and dead *Gonatozygon* in the control group was 14%, 83% and 3% respectively. In the treatment group which was acidified, 17.7% were healthy, 80.8% were sick, and 1.5% were dead. The Chi-square statistical test indicates a chi-square observed value of 2.07, with a Chi-square critical value of 5.99. Acidification of Walker's Lake, therefore , did not have a significant effect on *Gonatozygon* health.

The same tabulations were made for Whitmarsh Lake experiment. In the control group, 25.8% of the *Gonatozygon* were healthy, 72.1% were sick and 2.1% were dead. In the treatment

groups (samples which were limed), 61.6% of the Gonatozygon were healthy, 37.1% were sick and 1.3% were dead. The Chi-squared observed value is 83.82, with the critical value of 5.99. The liming of the treatment groups had a significant effect on *Gonatozygon* health. *Gonatozygon* was healthiest in the Whitmarsh Lake treatment samples which had been limed.

Discussion

This investigation of *Gonatozygon* was based on the initial discovery of a bloom found in Walker's Lake. We first sampled Walker's Lake and two neighboring lakes, Whitmarsh Lake and Brown Lake to determine the microhabitats in which *Gonatozygon* occurred. As we sampled these lakes, we recorded temperature, depth, pH , and substrate. Unfortunately, because of problems with the pH pen, we were unable to record the pH in Brown Lake and Whitmarsh Lake during this first trip.

The analysis of these initial samples revealed an absence of *Gonatozygon* in Whitmarsh Lake and Brown Lake and an abundance in Walker's Lake. We set out to determine what was unique in Walker's Lake that was so conducive to *Gonatozygon* growth. We decided to do a more detailed survey of the microhabitats in the Walker's Lake and investigate the history of the lakes. We contacted the Michigan Department of Natural Resources (MDNR) and inquired about past work /studies done in the area. We learned that Walker's Lake was extensively limed in August 1989 for the purposes of a bluegill and largemouth bass fishery. Over two and a half tons of powdered limestone was made into a slurry and distributed by boat throughout Walker's Lake. This work was done by the MDNR and Living Lakes Inc., a private consulting firm in Washington, D.C.. According to their reports, the pH of Walker's Lake was altered from 4.58 in May 1989 to 6.53 in March 1990 and Whitmarsh Lake had a pH of 5.0 in March 1980 (Scott, pers. comm.).

We returned to Walker's Lake to sample microhabitats. We found *Gonatozygon* to be abundant throughout the main body of water regardless of substrate, small fluctuations in pH and temperature except for the two samples taken from the backwater area which were dominated by algae more characteristic of calcium -deficient water ,*Staurastrum* and *Tabellaria* (Crum 1988,p.144). The Pearson Correlation did not indicate a correlation between substrate and *Gonatozygon* , but this may be a result of biased sampling. Two samples were taken from the backwater area compared with eighteen from the main body of water.

We based our experimental design on the results obtained in

our survey. The hypothesis tested is that liming of acidic waters is directly related to *Gonatozygon* abundance and health, and inversely, acidifying neutral water has a negative impact on *Gonatozygon* health and abundance. The pH of our treatment groups was determined by what was found in the field. Whitmarsh Lake, devoid of *Gonatozygon*, was found to have a pH of 6.1. Accordingly, the treatment groups from Walker's Lake were acidified to this level. Conversely, Whitmarsh Lake treatment groups were limed to pH 6.8, the pH of Walker's Lake where *Gonatozygon* was abundant.

Results of the Walker 's Lake experiment and Whitmarsh Lake experiment reject the hypothesis that acidification has a negative effect on *Gonatozygon* health and support the hypothesis that liming is positively correlated with *Gonatozygon* health. However, buffering occurred in both groups, in both experiments, presumably because of the closed systems. The most unexpected result was found in the control groups of the Whitmarsh Lake experiment. Inoculated with the *Gonatozygon* slurry and, untreated, the control groups buffered themselves to nearly the same pH as the treatment groups. The healthiest, most vital *Gonatozygon* found anywhere, were in the control and treatment samples from Whitmarsh Lake.

Conclusions

In this investigation, we attempted to test the effects of pH and substrate on *Gonatozygon* health and distribution. We found that *Gonatozygon* is not restricted to soft-water or *Sphagnum* environments as previously recorded in the literature. To the contrary, it is very responsive to the liming process. This poses many questions. Does *Gonatozygon* actually favor a more neutral environment or is there something in the liming process which stimulates its growth? Is some previously limiting nutrient released by the process of liming? More detailed water chemistry analysis under more controlled experimental conditions would have to be set up to determine the limiting factors of *Gonatozygon.* It would also be useful to document more carefully where and when it occurs in various lake systems.

Acknowledgements

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FIGURE 1. ***Gonatozygon*** **Health Distribution**

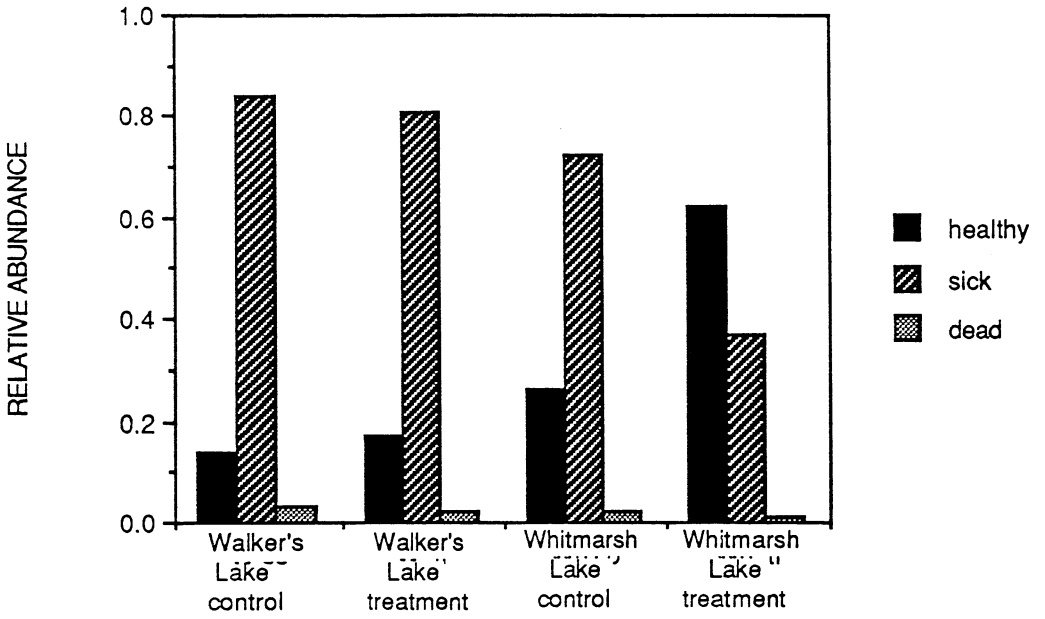

Table 1. CHRONICLE OF WALKER"S LAKE pH

	repetition	starting pH	post treatment pH	post substrate pH	additional modification	final pH
Control	1	6.7	6.7	5.9	NO	6.4
	2	6.7	6.7	5.9	NO	6.7
	3	6.7	6.7	5.9	NO	6.6
Treatment	1	6.7	6.0	5.7	NO	6.2
	2	6.7	6.0	5.7	NO	6.1
	3	6.7	6.0	5.7	NO	6.3

Table 2. CHRONICLE OF WHITMARSH LAKE pH

	repetition	starting pH	post treatment pH	post substrate pH	additional modification	final pH
Control	1	6.1	6.1	6.4	NO	6.7
	2	6.1	6.1	6.3	NO	6.7
	3	6.1	6.1	6.4	NO	6.8
Treatment	1	6.1	6.7	6.3	YES, to 6.8	6.9
	2	6.1	6.7	6.25	YES, to 6.8	6.9
	3	6.1	6.7	6.3	YES, to 6.8	7.0

TABLE 3. PEARSON CORRELATION MATRIX: WALKER'S LAKE

	SUB	PH	T	DEPTH
SUB	1.000			
PH	-0.083	1.000		
T	-0.019	-0.190	1.000	
DEPTH	-0.297	-0.018	**-0.774**	1.000
GON	-0.386	0.086	0.058	0.210
BULB	0.043	0.161	-0.036	-0.138
OED	-0.199	**-0.514**	0.132	0.093
OSC	-0.108	-0.032	-0.089	0.238

	GON	BULB	OED	OSC
GON	1.000			
BULB	-0.213	1.000		
OED	-0.102	-0.202	1.000	
OSC	0.405	-0.385	0.107	1.000

NUMBER OF OBSERVATIONS: 20 CRITICAL VALUE: 0.433

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APPENDIX A
Sample Counts

SAMPLE 1- Walker's Lake
T= 78°C pH= 7.2
depth= 2.5
substrate= sandy bottom without E. septangulare

Chlorophyta	
Bulbocheate	123
Chlamydomonas	00
Dictyosphaerium	00
Gloeocystis	00
Mougeotia	00
Oedogonium	99
Oocystis	00
Pediastrum	00
Scenedesmus	00
Tetraedron	00
Zoochlorella	00
(Mesotaeniaceae)	
Cylindrocystis	00
Gonatozygon	79
Netrium	00
(Desmidaceae)	
Closterium	00
Cosmarium	02
Euastrum	00
Sphaerozosma	03
Spondylosium	00
Staurastrum	02
Tetmemorus	00
Chrysophyta	
Dinobryon	00
Rhipidodendron	00
Synura	00
Cyanophyta	
Anabeana	00
Chroococcus	00
Merismopedia	00
Oscillatoria	08
Euglenophyta	
Euglena	01
Trachelomonas	00
Pyrrhophytra	
Cryptomonas	00
Gloeodinium	00
Gymnodinium	00
Bacillariophyta	
Surirella	00
Tabellaria	04
TOTAL	**322**

SAMPLE 2- Walker's Lake
T= 77°C pH= 7.1
depth= 11.5
substrate= submerged log or stick

Chlorophyta	
Bulbocheate	237
Chlamydomonas	00
Dictyosphaerium	00
Gloeocystis	00
Mougeotia	00
Oedogonium	00
Oocystis	00
Pediastrum	00
Scenedesmus	00
Tetraedron	00
Zoochlorella	00
(Mesotaeniaceae)	
Cylindrocystis	00
Gonatozygon	61
Netrium	00
(Desmidaceae)	
Closterium	00
Cosmarium	00
Euastrum	00
Sphaerozosma	00
Spondylosium	00
Staurastrum	02
Tetmemorus	00
Chrysophyta	
Dinobryon	00
Rhipidodendron	00
Synura	00
Cyanophyta	
Anabeana	00
Chroococcus	00
Merismopedia	00
Oscillatoria	01
Euglenophyta	

Euglena	00
Trachelomonas	00
Pyrrhophytra	
Cryptomonas	00
Gloeodinium	00
Gymnodinium	00
Bacillariophyta	
Surirella	00
Tabellaria	04
TOTAL	315

SAMPLE 3- Walker's Lake
T= 72°C pH= 7.1
depth= 22.0
substrate= sandy bottom
without E. septangulare

Chlorophyta	
Bulbocheate	69
Chlamydomonas	00
Dictyosphaerium	01
Gloeocystis	00
Mougeotia	10
Oedogonium	00
Oocystis	00
Pediastrum	01
Scenedesmus	04
Tetraedron	00
Zoochlorella	01
(Mesotaeniaceae)	
Cylindrocystis	00
Gonatozygon	151
Netrium	00
(Desmidaceae)	
Closterium	02
Cosmarium	07
Euastrum	01
Sphaerozosma	10
Spondylosium	01
Staurastrum	29
Tetmemorus	00
Chrysophyta	
Dinobryon	00
Rhipidodendron	00
Synura	00
Cyanophyta	
Anabeana	06
Chroococcus	00
Merismopedia	01
Oscillatoria	08
Euglenophyta	

Euglena	00
Trachelomonas	00
Pyrrhophytra	
Cryptomonas	00
Gloeodinium	01
Gymnodinium	00
Bacillariophyta	
Surirella	01
Tabellaria	04
TOTAL	312

SAMPLE 4- Walker's Lake
T= 72°C pH= 7.2
depth= 24.0
substrate= E.septangulare on sandy bottom

Chlorophyta

Bulbocheate	20
Chlamydomonas	00
Dictyosphaerium	07
Gloeocystis	00
Mougeotia	97
Oedogonium	00
Oocystis	00
Pediastrum	00
Scenedesmus	00
Tetraedron	00
Zoochlorella	01

(Mesotaeniaceae)

Cylindrocystis	00
Gonatozygon	50
Netrium	00

(Desmidaceae)

Closterium	08
Cosmarium	28
Euastrum	00
Sphaerozosma	00
Spondylosium	00
Staurastrum	63
Tetmemorus	00

Chrysophyta

Dinobryon	00
Rhipidodendron	00
Synura	00

Cyanophyta

Anabeana	30
Chroococcus	00
Merismopedia	00
Oscillatoria	26

Euglenophyta

Euglena	17
Trachelomonas	01

Pyrrhophytra

Cryptomonas	00
Gloeodinium	00
Gymnodinium	00

Bacillariophyta

Surirella	00
Tabellaria	17

TOTAL 383

SAMPLE 5- Walker's Lake
T= 77°C pH= 7.1
depth= 11.5
substrate= sandy bottom without E. septangulare

Chlorophyta

Bulbocheate	18
Chlamydomonas	00
Dictyosphaerium	01
Gloeocystis	00
Mougeotia	64
Oedogonium	48
Oocystis	00
Pediastrum	00
Scenedesmus	00
Tetraedron	00
Zoochlorella	00

(Mesotaeniaceae)

Cylindrocystis	00
Gonatozygon	101
Netrium	00

(Desmidaceae)

Closterium	01
Cosmarium	00
Euastrum	01
Sphaerozosma	01
Spondylosium	00
Staurastrum	06
Tetmemorus	00

Chrysophyta

Dinobryon	00
Rhipidodendron	00
Synura	00

Cyanophyta

Anabeana	48
Chroococcus	00
Merismopedia	00
Oscillatoria	16

Euglenophyta

Euglena	01
Trachelomonas	00
Pyrrhophytra	
Cryptomonas	00
Gloeodinium	01
Gymnodinium	00
Bacillariophyta	
Rhopalodia	02
Surirella	01
Tabellaria	01
TOTAL	311

SAMPLE 6- Walker's Lake
T= 77°C pH= 7.1
depth= 11.5
substrate= sandy bottom
without E. septangulare

Chlorophyta	
Bulbocheate	60
Chlamydomonas	00
Dictyosphaerium	00
Gloeocystis	00
Mougeotia	28
Oedogonium	55
Oocystis	00
Pediastrum	00
Scenedesmus	02
Tetraedron	00
Zoochlorella	00
(Mesotaeniaceae)	
Cylindrocystis	00
Gonatozygon	135
Netrium	00
(Desmidaceae)	
Closterium	02
Cosmarium	01
Euastrum	00
Sphaerozosma	01
Spondylosium	00
Staurastrum	07
Tetmemorus	00
Chrysophyta	
Dinobryon	00
Rhipidodendron	00
Synura	00
Cyanophyta	
Anabeana	06
Chroococcus	00
Merismopedia	00
Oscillatoria	61
Euglenophyta	
Euglena	00
Trachelomonas	00
Pyrrhophytra	
Cryptomonas	00
Gloeodinium	00
Gymnodinium	00
Bacillariophyta	
Surirella	05
Tabellaria	05
TOTAL	373

SAMPLE 12- Walker's Lake
T= 74°C pH= 6.6
depth= 26.0
substrate= submerged log or stick

Chlorophyta	
Bulbocheate	55
Chlamydomonas	00
Dictyosphaerium	00
Gloeocystis	00
Mougeotia	00
Oedogonium	244
Oocystis	00
Pediastrum	00
Scenedesmus	00
Tetraedron	00
Zoochlorella	00
(Mesotaeniaceae)	
Cylindrocystis	11
Gonatozygon	38
Netrium	00
(Desmidaceae)	
Closterium	01
Cosmarium	02
Euastrum	00
Sphaerozosma	02
Spondylosium	00
Staurastrum	05
Tetmemorus	00
Chrysophyta	
Dinobryon	00
Rhipidodendron	00
Synura	00
Cyanophyta	
Anabeana	00
Chroococcus	00
Merismopedia	00
Oscillatoria	03
Euglenophyta	
Euglena	00
Trachelomonas	00
Pyrrhophytra	
Cryptomonas	00
Gloeodinium	00
Gymnodinium	00
Bacillariophyta	
Surirella	00
Tabellaria	02
Cryptomonadophyta	
Cryptomonas	01
TOTAL	364

SAMPLE 15- Walker's Lake
T= 76°C pH= 7.1
depth= 16.0
substrate=E. septangulare growing on sandy substrate

Chlorophyta	
Bulbocheate	85
Chlamydomonas	00
Dictyosphaerium	01
Gloeocystis	02
Mougeotia	19
Oedogonium	58
Oocystis	00
Pediastrum	00
Scenedesmus	00
Tetraedron	00
Zoochlorella	00
(Mesotaeniaceae)	
Cylindrocystis	00
Gonatozygon	148
Netrium	00
(Desmidaceae)	
Closterium	03
Cosmarium	13
Euastrum	00
Sphaerozosma	04
Spondylosium	01
Staurastrum	17
Tetmemorus	00
Chrysophyta	
Dinobryon	00
Rhipidodendron	00
Synura	00
Cyanophyta	
Anabeana	11
Chroococcus	52
Merismopedia	00
Oscillatoria	04
Euglenophyta	

Euglena	00
Trachelomonas	00
Pyrrhophytra	
Cryptomonas	00
Gloeodinium	00
Gymnodinium	00
Bacillariophyta	
Surirella	00
Tabellaria	19
TOTAL	436

SAMPLE 17- Walker's Lake
T= 76°C pH= 7.1
depth= 5.0
substrate=E. septangulare
growing on sandy substrate

Chlorophyta	
Bulbocheate	129
Chlamydomonas	00
Dictyosphaerium	00
Gloeocystis	00
Mougeotia	23
Oedogonium	132
Oocystis	00
Pediastrum	00
Scenedesmus	01
Tetraedron	00
Zoochlorella	00
(Mesotaeniaceae)	
Cylindrocystis	00
Gonatozygon	96
Netrium	00
(Desmidaceae)	
Closterium	00
Cosmarium	03
Euastrum	00
Sphaerozosma	01
Spondylosium	00
Staurastrum	01
Tetmemorus	00
Chrysophyta	
Dinobryon	00
Rhipidodendron	00
Synura	00
Cyanophyta	
Anabeana	01
Chroococcus	00
Merismopedia	00
Oscillatoria	05
Euglenophyta	

Euglena	00
Trachelomonas	00
Pyrrhophytra	
Cryptomonas	00
Gloeodinium	00
Gymnodinium	00
Bacillariophyta	
Surirella	00
Tabellaria	05
TOTAL	397

SAMPLE 18- Walker's Lake
T= 76°C pH= 7.1
depth= 23.0
substrate= E. septangulare
growing on muck substrate

Chlorophyta	
Bulbocheate	00
Chlamydomonas	00
Dictyosphaerium	01
Gloeocystis	00
Mougeotia	04
Oedogonium	14
Oocystis	00
Pediastrum	00
Scenedesmus	18
Tetraedron	01
Zoochlorella	00
(Mesotaeniaceae)	
Cylindrocystis	00
Gonatozygon	54
Netrium	00
(Desmidaceae)	
Closterium	05
Cosmarium	25
Euastrum	03
Micrasterias	01
Sphaerozosma	11
Spondylosium	00
Staurastrum	27
Tetmemorus	00
Chrysophyta	
Dinobryon	00
Rhipidodendron	00
Synura	00
Cyanophyta	
Anabeana	00
Chroococcus	00
Merismopedia	00
Oscillatoria	02
Euglenophyta	
Euglena	00
Trachelomonas	00
Pyrrhophytra	
Cryptomonas	00
Gloeodinium	00
Gymnodinium	00
Bacillariophyta	
Surirella	00
Tabellaria	163
TOTAL	329

SAMPLE 19- Walker's Lake
T= (76°C) pH=(7.1)
depth= --
substrate= Sphagnum

Chlorophyta	
Bulbocheate	00
Chlamydomonas	13
Dictyosphaerium	00
Gloeocystis	00
Mougeotia	05
Oedogonium	00
Oocystis	01
Pediastrum	00
Scenedesmus	07
Tetraedron	01
Zoochlorella	03
(Mesotaeniaceae)	
Cylindrocystis	15
Gonatozygon	06
Netrium	00
(Desmidaceae)	
Closterium	03
Cosmarium	16
Euastrum	06
Pleurotaenium	01
Sphaerozosma	08
Spondylosium	00
Staurastrum	23
Tetmemorus	02
Chrysophyta	
Dinobryon	00
Rhipidodendron	00
Synura	00
Cyanophyta	
Anabeana	00
Chroococcus	01
Merismopedia	00
Oscillatoria	06
Euglenophyta	

Euglena	38
Trachelomonas	00
Pyrrhophytra	
Cryptomonas	00
Gloeodinium	00
Gymnodinium	00
Bacillariophyta	
Pinnularia	02
Surirella	00
Tabellaria	176
TOTAL	328

SAMPLE 20- Walker's Lake
T= 76°C pH= 6.9
depth=--
substrate= Utricularia

Chlorophyta	
Bulbocheate	00
Chlamydomonas	00
Dictyosphaerium	00
Gloeocystis	00
Mougeotia	20
Oedogonium	000
Oocystis	00
Pediastrum	00
Scenedesmus	01
Tetraedron	00
Zoochlorella	00
(Mesotaeniaceae)	
Cylindrocystis	00
Gonatozygon	00
Netrium	00
(Desmidaceae)	
Arthrodesmus	06
Closterium	00
Cosmarium	31
Euastrum	04
Sphaerozosma	00
Spondylosium	00
Staurastrum	256
Tetmemorus	00
Chrysophyta	
Dinobryon	00
Rhipidodendron	09
Synura	30
Cyanophyta	
Anabeana	00
Chroococcus	00
Merismopedia	01
Oscillatoria	01
Euglenophyta	
Euglena	02
Trachelomonas	00
Pyrrhophytra	
Cryptomonas	00
Gloeodinium	00
Gymnodinium	01
Bacillariophyta	
Asterionella	02
Surirella	00
Tabellaria	00
TOTAL	365

SAMPLE 21- Walker's Lake
T= 74°C pH= 6.6
depth= 26.0
substrate= submerged log or stick

Chlorophyta	
Bulbocheate	308
Chlamydomonas	00
Dictyosphaerium	00
Gloeocystis	01
Mougeotia	03
Oedogonium	00
Oocystis	00
Pediastrum	00
Scenedesmus	00
Tetraedron	00
Zoochlorella	00
(Mesotaeniaceae)	
Cylindrocystis	00
Gonatozygon	15
Netrium	00
(Desmidaceae)	
Closterium	00
Cosmarium	00
Euastrum	00
Sphaerozosma	00
Spondylosium	00
Staurastrum	00
Tetmemorus	00
Chrysophyta	
Dinobryon	00
Rhipidodendron	00
Synura	00
Cyanophyta	
Anabeana	00
Chroococcus	00
Merismopedia	00
Oscillatoria	01
Euglenophyta	
Euglena	00
Trachelomonas	00
Pyrrhophytra	
Cryptomonas	00
Gloeodinium	00
Gymnodinium	00
Bacillariophyta	
Surirella	00
Tabellaria	01
TOTAL	329

SAMPLE 24- Walker's Lake
T= 74°C pH= 7.0
depth= 12.5
substrate= submerged log or stick

Chlorophyta	
Bulbocheate	241
Chlamydomonas	00
Dictyosphaerium	00
Gloeocystis	00
Mougeotia	00
Oedogonium	000
Oocystis	01
Pediastrum	00
Scenedesmus	00
Tetraedron	00
Zoochlorella	00
(Mesotaeniaceae)	
Cylindrocystis	00
Gonatozygon	69
Netrium	00
(Desmidaceae)	
Closterium	00
Cosmarium	00
Euastrum	00
Sphaerozosma	00
Spondylosium	00
Staurastrum	02
Tetmemorus	00
Chrysophyta	
Dinobryon	00
Rhipidodendron	00
Synura	00
Cyanophyta	
Anabeana	01
Chroococcus	00
Merismopedia	00
Oscillatoria	08
Euglenophyta	

Euglena	00
Trachelomonas	00
Pyrrhophytra	
Cryptomonas	00
Gloeodinium	00
Gymnodinium	00
Bacillariophyta	
Surirella	00
Tabellaria	00
TOTAL	321

SAMPLE 27- Walker's Lake
T= 78°C pH= 6.9
depth= 15.0
substrate= E. septangulare
growing on sandy substrate

Chlorophyta	
Bulbocheate	05
Chlamydomonas	00
Dictyosphaerium	00
Gloeocystis	01
Mougeotia	24
Oedogonium	34
Oocystis	01
Pediastrum	00
Scenedesmus	02
Tetraedron	00
Zoochlorella	00
(Mesotaeniaceae)	
Cylindrocystis	00
Gonatozygon	167
Netrium	00
(Desmidaceae)	
Closterium	02
Cosmarium	00
Euastrum	01
Pleurotaenium	01
Sphaerozosma	05
Spondylosium	01
Staurastrum	29
Tetmemorus	00
Chrysophyta	
Dinobryon	00
Rhipidodendron	00
Synura	00
Cyanophyta	
Anabeana	01
Chroococcus	03
Merismopedia	00
Oscillatoria	11

Euglenophyta	
Euglena	05
Trachelomonas	00
Pyrrhophytra	
Cryptomonas	00
Gloeodinium	00
Gymnodinium	00
Bacillariophyta	
Surirella	00
Tabellaria	28
TOTAL	343

SAMPLE 28- Walker's Lake
T= 78°C pH= 7.0
depth= 2.0
substrate= E. septangulare
growing on sandy substrate

Chlorophyta	
Bulbocheate	09
Chlamydomonas	00
Dictyosphaerium	01
Gloeocystis	01
Mougeotia	13
Oedogonium	30
Oocystis	00
Pediastrum	00
Scenedesmus	00
Tetraedron	00
Zoochlorella	00
(Mesotaeniaceae)	
Cylindrocystis	00
Gonatozygon	183
Netrium	01
(Desmidaceae)	
Closterium	04
Cosmarium	08
Euastrum	00
Sphaerozosma	02
Spondylosium	00
Staurastrum	36
Tetmemorus	00
Chrysophyta	
Dinobryon	00
Rhipidodendron	00
Synura	00
Cyanophyta	
Anabeana	27
Chroococcus	00
Merismopedia	00
Oscillatoria	24
Euglenophyta	
Euglena	00
Trachelomonas	00
Pyrrhophytra	
Cryptomonas	00
Gloeodinium	00
Gymnodinium	00
Bacillariophyta	
Surirella	00
Tabellaria	11
TOTAL	350

SAMPLE 31- Walker's Lake
T= 78°C pH= 6.8
depth= 13.0
substrate= E. septangulare
growing on sandy substrate

Chlorophyta	
Bulbocheate	39
Chlamydomonas	05
Dictyosphaerium	00
Gloeocystis	00
Mougeotia	00
Oedogonium	104
Oocystis	00
Pediastrum	00
Scenedesmus	01
Tetraedron	00
Zoochlorella	00
(Mesotaeniaceae)	
Cylindrocystis	00
Gonatozygon	139
Netrium	00
(Desmidaceae)	
Closterium	02
Cosmarium	09
Euastrum	00
Sphaerozosma	00
Spondylosium	00
Staurastrum	25
Tetmemorus	00
Chrysophyta	
Dinobryon	00
Rhipidodendron	00
Synura	00
Cyanophyta	
Anabeana	03
Chroococcus	00
Merismopedia	00
Oscillatoria	31
Euglenophyta	

Euglena	01
Trachelomonas	00
Pyrrhophytra	
Cryptomonas	00
Gloeodinium	00
Gymnodinium	00
Bacillariophyta	
Surirella	00
Tabellaria	10
TOTAL	350

SAMPLE 32- Walker's Lake
T= 78°C pH= 6.9
depth= 10.0
substrate= E. septangulare
growing on sandy substrate

Chlorophyta	
Bulbocheate	03
Chlamydomonas	09
Dictyosphaerium	01
Gloeocystis	00
Mougeotia	23
Oedogonium	148
Oocystis	00
Pediastrum	00
Scenedesmus	00
Tetraedron	00
Zoochlorella	00
(Mesotaeniaceae)	
Cylindrocystis	00
Gonatozygon	89
Netrium	00
(Desmidaceae)	
Closterium	03
Cosmarium	03
Euastrum	00
Sphaerozosma	00
Spondylosium	01
Staurastrum	20
Tetmemorus	00
Chrysophyta	
Dinobryon	00
Rhipidodendron	00
Synura	00
Cyanophyta	
Anabeana	04
Chroococcus	00
Merismopedia	00
Oscillatoria	42
Euglenophyta	

Euglena	00
Trachelomonas	00
Pyrrhophytra	
Cryptomonas	00
Gloeodinium	01
Gymnodinium	00
Bacillariophyta	
Surirella	00
Tabellaria	20
TOTAL	367

SAMPLE 35- Walker's Lake
T= 76°C pH= 7.0
depth= 12.0
substrate= E. septangulare
growing on mucky substrate

Chlorophyta	
Bulbocheate	14
Chlamydomonas	00
Dictyosphaerium	00
Gloeocystis	00
Mougeotia	03
Oedogonium	157
Oocystis	00
Pediastrum	00
Scenedesmus	02
Tetraedron	00
Zoochlorella	00
(Mesotaeniaceae)	
Cylindrocystis	00
Gonatozygon	25
Netrium	00
(Desmidaceae)	
Arthrodesmus	01
Closterium	01
Cosmarium	04
Euastrum	02
Sphaerozosma	01
Spondylosium	00
Staurastrum	22
Tetmemorus	00
Chrysophyta	
Dinobryon	00
Rhipidodendron	00
Synura	00
Cyanophyta	
Anabeana	00
Chroococcus	00
Merismopedia	00
Oscillatoria	00
Euglenophyta	
Euglena	01
Trachelomonas	00
Pyrrhophytra	
Cryptomonas	00
Gloeodinium	00
Gymnodinium	00
Bacillariophyta	
Surirella	00
Tabellaria	23
TOTAL	339

SAMPLE 36- Walker's Lake
T= 78°C pH= 7.0
depth= --
substrate= plankton tow

Chlorophyta	
Bulbocheate	00
Chlamydomonas	39
Dictyosphaerium	00
Gloeocystis	00
Mougeotia	29
Oedogonium	.10
Oocystis	00
Pediastrum	00
Scenedesmus	02
Tetraedron	00
Zoochlorella	00
(Mesotaeniaceae)	
Cylindrocystis	00
Gonatozygon	123
Netrium	00
(Desmidaceae)	
Closterium	00
Cosmarium	04
Desmidium	01
Euastrum	00
Sphaerozosma	00
Spondylosium	00
Staurastrum	02
Tetmemorus	00
Chrysophyta	
Dinobryon	18
Rhipidodendron	00
Synura	00
Cyanophyta	
Anabeana	29
Chroococcus	00
Merismopedia	00
Oscillatoria	57
Euglenophyta	

Euglena	07
Trachelomonas	00
Pyrrhophytra	
Cryptomonas	00
Gloeodinium	00
Gymnodinium	00
Bacillariophyta	
Surirella	00
Tabellaria	03
TOTAL	324

SAMPLE 7- Whitmarsh Lake
T= 72°C pH= --
depth= --
substrate= Utricularia
squeeze

Chlorophyta	
Bulbocheate	00
Mougeotia	313
Oedogonium	180
Spirogyra	00
(Mesotaeniaceae)	
Gonatozygon	00
Netrium	01
(Desmidaceae)	
Closterium	04
Cosmarium	07
Euastrum	04
Micrasterias	01
Staurastrum	02
Xanthidium	01
Chrysophyta	
Dinobryon	01
Cyanophyta	
Anabeana	00
Glaucocystis	00
Hapalosiphon	00
Merismopedia	00
Oscillatoria	01
Euglenophyta	
Euglena	00
Bacillariophyta	
Fragilaria	00
Surirella	00
Tabellaria	00
TOTAL	341

SAMPLE 8- Whitmarsh Lake
T= 72°C pH= --
depth= 17
substrate= submerged lo or
stick

Chlorophyta	
Bulbocheate	00
Mougeotia	230
Oedogonium	.00
Spirogyra	57
(Mesotaeniaceae)	
Gonatozygon	00
Netrium	00
(Desmidaceae)	
Closterium	00
Cosmarium	00
Euastrum	.00
Penium	01
Staurastrum	05
Xanthidium	01
Chrysophyta	
Dinobryon	03
Cyanophyta	
Anabeana	00
Glaucocystis	00
Hapalosiphon	00
Merismopedia	00
Oscillatoria	00
Euglenophyta	
Euglena	00
Bacillariophyta	
Fragilaria	00
Surirella	00
Tabellaria	00
TOTAL	329

SAMPLE 11- Whitmarsh Lake
T= 76°C pH= 6.5
depth=--
substrate= E. septangulare
growing on gravel

Chlorophyta	
Bulbocheate	00
Mougeotia	31
Oedogonium	331
Scenedesmus	01
Spirogyra	06
Zoochlorella	01
(Mesotaeniaceae)	
Gonatozygon	00
Netrium	00
(Desmidaceae)	
Closterium	00
Cosmarium	01
Euastrum	00
Staurastrum	00
Chrysophyta	
Dinobryon	00
Cyanophyta	
Anabeana	00
Glaucocystis	00
Hapalosiphon	00
Merismopedia	00
Oscillatoria	00
Euglenophyta	
Euglena	00
Bacillariophyta	
Fragilaria	00
Surirella	00
Tabellaria	00
TOTAL	371

SAMPLE 37- Whitmarsh Lake
T= 76°C pH= 6.5
depth= 17
substrate= E. septangulare-like plant on gravel

Chlorophyta	
Bulbocheate	13
Coelastrum	01
Mougeotia	45
Oedogonium	.70
Quadrigula	00
Scenedesmus	01
Spirogyra	05
(Mesotaeniaceae)	
Gonatozygon	00
Netrium	05
(Desmidaceae)	
Closterium	12
Cosmarium	03
Euastrum	07
Staurastrum	01
Chrysophyta	
Dinobryon	56
Cyanophyta	
Anabeana	42
Glaucocystis	01
Hapalosiphon	00
Merismopedia	00
Oscillatoria	51
Euglenophyta	
Euglena	01
Bacillariophyta	
Fragilaria	00
Surirella	01
Tabellaria	00
TOTAL	323

SAMPLE 38- Whitmarsh Lake
T= 76°C pH= 6.5
depth= 17
substrate= E. septangulare-like plant on gravel

Chlorophyta	
Bulbocheate	28
Coelastrum	00
Mougeotia	04
Oedogonium	.16
Quadrigula	01
Scenedesmus	00
Spirogyra	00
(Mesotaeniaceae)	
Gonatozygon	00
Netrium	00
(Desmidaceae)	
Closterium	00
Cosmarium	00
Euastrum	00
Staurastrum	01
Chrysophyta	
Dinobryon	00
Cyanophyta	
Anabeana	01
Glaucocystis	00
Hapalosiphon	300+
Merismopedia	01
Oscillatoria	00
Euglenophyta	
Euglena	00
Bacillariophyta	
Fragilaria	00
Surirella	00
Tabellaria	00
TOTAL	355

SAMPLE 40- Whitmarsh Lake

T= 76°C pH= 6.5

depth=--

substrate= plankton tow

Chlorophyta	
Bulbocheate	00
Mougeotia	40
Oedogonium	95
Spirogyra	212
Zoochlorella	01
(Mesotaeniaceae)	
Gonatozygon	00
Netrium	05
(Desmidaceae)	
Closterium	00
Cosmarium	00
Euastrum	00
Staurastrum	00
Chrysophyta	
Dinobryon	08
Cyanophyta	
Anabeana	00
Glaucocystis	00
Hapalosiphon	00
Merismopedia	00
Oscillatoria	01
Euglenophyta	
Euglena	00
Bacillariophyta	
Fragilaria	01
Surirella	00
Tabellaria	00
TOTAL	358

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SAMPLE 9- Brown Lake

T= -- pH= --

depth= --

substrate=aquatic vegetation

squeeze

Chlorophyta

Bulbocheate	00
Dictyosphaerium	00
Eremosphaera	01
Gloeocystis	01
Mougeotia	267
Oedogonium	.00
Oocystis	00
Scenedesmus	00
Spirogyra	06
Zoochlorella	00
Zygnema	00

(Mesotaeniaceae)

Gonatozygon	00
Netrium	00

(Desmidaceae)

Arthrodesmus	02
Bambusina	24
Closterium	00
Cosmarium	02
Euastrum	.00
Hyalotheca	00
Micrasterias	04
Pleurotaenium	01
Staurastrum	08

Chrysophyta

Dinobryon	00
Rhipidodendron	00

Cyanophyta

Anabeana	00
Chroococcus	01
Merismopedia	05
Oscillatoria	01

Euglenophyta

Euglena	00

Bacillariophyta

Astrionella	09
Tabellaria	00

TOTAL 332

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SAMPLE10- Brown Lake

T= -- pH= --

depth= --

substrate= Utricularia

squeeze

Chlorophyta

Bulbocheate	00
Dictyosphaerium	01
Eremosphaera	00
Gloeocystis	00
Mougeotia	28
Oedogonium	.00
Oocystis	02
Scenedesmus	00
Spirogyra	00
Zoochlorella	01
Zygnema	05

(Mesotaeniaceae)

Gonatozygon	00
Netrium	01

(Desmidaceae)

Arthrodesmus	31
Bambusina	49
Closterium	00
Cosmarium	04
Euastrum	.04
Hyalotheca	85
Micrasterias	01
Pleurotaenium	00
Staurastrum	45

Chrysophyta

Dinobryon	00
Rhipidodendron	28

Cyanophyta

Anabeana	00
Chroococcus	01
Merismopedia	03
Oscillatoria	00

Euglenophyta

Euglena	03
Bacillariophyta	
Astrionella	35
Tabellaria	00
TOTAL	327

APPENDIX B
Nutrient Comparison between Walker's Lake and Whitmarsh Lake

	Walker's Lake	Whitmarsh Lake
Total Phosphate	21.265µg/L	25.187µg/L
Dissolved Phosphate	3.357µg/L	6.277µg/L
Nitrates	0.00µg/L	0.00µg/L
NH_3	25.2µg/L	8.8µg/L
Cl	0.07mg/L	0.17mg/L
SiO_2 (Dissolved Silica)	0.1mg/L	0.2mg/L
pH	6.7	6.1
Conductivity	30.9µmho	22.6µmho