Euglenophyta	Euglena	MUC	7	2.3	3	1.0	3	1.0		0.0		0.0	2	0.7	4			
	Phacus 1	MUC	**29**	9.7	**31**	10.3	5	1.7	8	2.7	2	0.7		0.0	5	2		
	Phacus 2	MUC		0.0		0.0	11	3.7	9	3.0	**20**	6.7	5	1.7	4	1		
	Trachelomonas	MUC	17	5.7	4	1.3	1	0.3		0.0	11	3.7	2	0.7	5			
3	TOTAL		3	**18**	3	**13**	4	**7**	2	**6**	3	**11**	3	**3**			2	GENERA IN TOP 5 TAXA
Cryptophyta	Cryptomonas	MUC	**21**	7.0	9	3.0	**37**	12.3	**56**	18.7	**26**	8.7	**21**	7.0	6	5		
1	TOTAL		1	**7**	1	**3**	1	**12**	1	**19**	1	**9**	1	**7**			1	GENERA IN TOP 5 TAXA
Dinophyta	Amphidinium	MUC	5	1.7	7	2.3	6	2.0	3	1.0	3	1.0	2	0.7	6			
	Peridinium	MUC	**18**	6.0		0.0	2	0.7		0.0	4	1.3	2	0.7	4	1		
2	TOTAL		2	**8**	1	**2**	2	**3**	1	**1**	2	**2**	2	**1**			1	GENERA IN TOP 5 TAXA
71				100.		100.		100.		100.		100.		100.				

Ochrophyta	Actinocylus	CDIA		0.0		0.0		0.0		0.0	1	0.3	3	1.0	2			
	Asterionella	PDIA	13	4.3	**27**	9.0	**23**	7.7	8	2.7	17	5.7	4	1.3	6	2		
	Aulacoseira	CDIA	3	1.0		0.0	2	0.7	1	0.3		0.0		0.0	3			
	Bumilleriopsis	TRIB		0.0		0.0		0.0	3	1.0	2	0.7		0.0	2			
	Cocconeis	PDIA	5	1.7		0.0	4	1.3		0.0		0.0	3	1.0	3			
	Cyclotella	CDIA	1	0.3	4	1.3	6	2.0	7	2.3		0.0		0.0	4			
	Cymbella	PDIA		0.0		0.0	3	1.0		0.0	1	0.3		0.0	2			
	Diatoma	PDIA	3	1.0		0.0		0.0		0.0	2	0.7		0.0	2			
	Dinobryon	CRYS	7	2.3		0.0	1	0.3		0.0		0.0	7	2.3	3			
	Epithemia	PDIA		0.0		0.0	2	0.7	3	1.0	1	0.3		0.0	3			
	Fragilaria 1	PDIA	14	4.7	**21**	7.0	**19**	6.3	4	1.3	1	0.3		0.0	5	2		
	Fragilaria 2	PDIA		0.0		0.0	3	1.0	12	4.0	18	6.0	8	2.7	4			
	Gomphonema	PDIA	1	0.3		0.0		0.0	1	0.3	3	1.0		0.0	3			
	Gyrosigma	PDIA		0.0	3	1.0	6	2.0	3	1.0		0.0		0.0	3			
	Melosira	CDIA		0.0		0.0		0.0		0.0		0.0		0.0	0			
	Navicula 1	PDIA	8	2.7	3	1.0	**17**	5.7	3	1.0		0.0	1	0.3	5	1		
	Navicula 2	PDIA		0.0	14	4.7	5	1.7	6	2.0	6	2.0	4	1.3	5			
	Ochromonas	CRYS	3	1.0		0.0		0.0		0.0	1	0.3		0.0	2			
	Pinnularia	PDIA		0.0		0.0		0.0	1	0.3		0.0		0.0	1			
	Stephanodiscus	CDIA		0.0	2	0.7	3	1.0		0.0	2	0.7		0.0	3			
	Synedra	PDIA	5	1.7		0.0	4	1.3	2	0.7		0.0	5	1.7	4			
	Synura	SYN	3	1.0		0.0		0.0		0.0		0.0	3	1.0	2			
	Tabellaria	PDIA		0.0	2	0.7	5	1.7	7	2.3		0.0	4	1.3	4			
21	TOTAL		12	**22**	8	**25**	15	**34**	14	**20**	12	**18**	10	**14**			3	GENERA IN TOP 5 TAXA

Chlorophyta	Ankistrodesmus	NMUC		0.0	2	0.7	12	4.0	8	2.7	3	1.0		0.0	4		
	Botryococcus	COL	3	1.0	1	0.3		0.0	1	0.3		0.0	1	0.3	4		
	Bulbochaete	BF		0.0		0.0		0.0		0.0	2	0.7		0.0	1		
	Chlamydomonas	MUC	4	1.3		0.0	2	0.7		0.0		0.0		0.0	2		
	Chlorococcum	NMUC	1	0.3		0.0		0.0	1	0.3		0.0		0.0	2		
	Cladophora	BF		0.0		0.0		0.0		0.0		0.0	1	0.3	1		
	Coelastrum	COL	6	2.0	2	0.7	3	1.0	1	0.3		0.0		0.0	4		
	Cosmarium	NMUC	7	2.3		0.0	2	0.7		0.0	1	0.3		0.0	3		
	Eudorina	MCOL		0.0		0.0		0.0	1	0.3		0.0	1	0.3	2		
	Golenkinia	NMUC	1	0.3	8	2.7	3	1.0	1	0.3		0.0		0.0	4		
	Hydrodictyon	COL		0.0		0.0		0.0		0.0		0.0	1	0.3	1		
	Microspora	UBF	1	0.3	3	1.0		0.0		0.0		0.0		0.0	2		
	Oedogonium	UBF		0.0		0.0		0.0	2	0.7	1	0.3		0.0	2		
	Oocystis	NMUC	8	2.7	5	1.7	3	1.0		0.0	1	0.3		0.0	4		
	Pandorina	MCOL	2	0.7		0.0		0.0	1	0.3		0.0		0.0	2		
	Pediastrum	COL	**24**	8.0	**31**	10.3	11	3.7	**19**	6.3	6	2.0	10	3.3	6	3	
	Rhizoclonium	UBF		0.0		0.0		0.0		0.0		0.0		0.0	0		
	Scenedesmus	COL	**31**	10.3	**27**	9.0	5	1.7	9	3.0	13	4.3	16	5.3	6	2	
	Selenastrum	NMUC	4	1.3	12	4.0	7	2.3	4	1.3		0.0	2	0.7	5		
	Sorastrum	NMUC		0.0	3	1.0	4	1.3		0.0	1	0.3		0.0	3		
	Staurastrum	NMUC	17	5.7	3	1.0	**28**	9.3	6	2.0	4	1.3	6	2.0	6	1	
	Tetraedron	COL		0.0	4	1.3		0.0		0.0		0.0		0.0	1		
22	TOTAL		13	**36**	12	**34**	11	**27**	12	**18**	9	**11**	8	**13**			3 GENERA IN TOP 5 TAXA

APPENDIX 1. Cell Counts of Planktonic Algal Genera from Upper St. Croix Lake, Douglas County, WI, 2008 by phylum and sampling date.

PHYLUM	GENUS	MORPH	05/16 CT	05/16 %	07/08 CT	07/08 %	08/04 CT	08/04 %	08/31 CT	08/31 %	10/03 CT	10/03 %	10/31 CT	10/31 %	FRE	TIMES IN TOP 5 TAXA
Cyanobacteria	Anabaena	UBF-HC	1	0.3	3	1.0	1	0.3		0.0		0.0	5	1.7	4	
	Aphanizomenon	UBF-HC		0.0		0.0		0.0		0.0	2	0.7	11	3.7	2	
	Aphanocapsa	COL		0.0	2	0.7	3	1.0	2	0.7		0.0		0.0	3	
	Aphanothece	COL	2	0.7	1	0.3		0.0		0.0	3	1.0		0.0	3	
	Arthrospira	UBF-NHC		0.0		0.0	4	1.3	2	0.7		0.0	3	1.0	3	
	Chroococcus	COL	1	0.3		0.0		0.0		0.0	2	0.7	5	1.7	3	
	Coelosphaerium	COL	3	1.0	15	5.0	9	3.0	**19**	6.3	**21**	7.0	**33**	11.0	6	3
	Cylindrospermum	UBF-HC		0.0		0.0		0.0		0.0	4	1.3	7	2.3	2	
	Eucapsis	COL		0.0		0.0	2	0.7		0.0	2	0.7		0.0	2	
	Gloeotrichia	TUBF-HC	7	2.3	23	7.7	6	2.0	**21**	7.0	**45**	15.0	**51**	17.0	6	3
	Gomphosphaeria	COL		0.0		0.0		0.0	4	1.3	3	1.0	2	0.7	3	
	Lyngbya	UBF-NHC		0.0		0.0	2	0.7	1	0.3		0.0		0.0	2	
	Merismopedia	COL	2	0.7		0.0		0.0		0.0		0.0		0.0	1	
	Microcystis	COL		0.0	5	1.7	2	0.7	7	2.3	13	4.3	12	4.0	5	
	Nodularia	UBF-HC	3	1.0	12	4.0	8	2.7	**36**	12.0	**33**	11.0	**27**	9.0	6	3
	Oscillatoria	UBF-NHC	4	1.3		0.0		0.0		0.0		0.0	1	0.3	2	
	Phormidium	UBF-NHC		0.0		0.0		0.0	4	1.3		0.0		0.0	1	
	Plectonema	FBF-NHC		0.0		0.0	1	0.3		0.0	1	0.3	3	1.0	3	
	Pseudoanabaena	UBF-HC	1	0.3		0.0		0.0		0.0		0.0		0.0	1	
	Snowella	COL		0.0		0.0		0.0	2	0.7	5	1.7		0.0	2	
	Tolypothrix	FBF-HC		0.0		0.0		0.0		0.0		0.0	8	2.7	1	
	Woronichinia	COL	4	1.3	8	2.7	14	4.7	11	3.7	13	4.3	**18**	6.0	6	1
22	TOTAL		10	**9**	8	**23**	11	**17**	11	**36**	13	**49**	14	**62**		4 GENERA IN TOP 5 TAXA

nutrients are available then adding even small amounts of phosphorus is like stepping on the algal growth accelerator.

Over time nutrients accumulate ("run up to tipping point"), this alters the water chemistry and eventually nuisance organisms get established that outcompete other organisms for the available nutrients ("tipping point"). Since the algae are microscopic they can be accumulating over time for quite a while but at levels not perceived by the naked eye. Then, as the nuisance organisms really take hold and begin to reach higher densities earlier in the season, humans begin to notice. This is what seems to be happening in Upper St. Croix Lake.

Upper St. Croix Lake is basically a flattened, horizontal cylinder – long and narrow, flattened on one side. Of all the basic geometric shapes the cylinder has the greatest surface area to volume ratio. It's also fairly shallow and the long expanses of cylinder sidewall (shoreline) with shallow depths makes for a very high proportion of the lake being euphotic (the fancy word for getting enough light to make algae happy). A lake basin that is circular with steep sides (essentially the opposite of Upper St. Croix Lake) provides the smallest surface area to volume ratio. These bodies present much less surface area for algal growth and are generally beset with much less algae. Additionally, Upper St. Croix Lake run largely north-south, this allows the prevailing westerly winds to stir up internal nutrient pools and drive algal material to the very long eastern shore of the lake where it finds lots of shallow, nutrient-rich, well-light habitats.

The problems took a long time to develop and the solutions will be equally slow to take effect. Various nutrient abatement strategies are possible. They vary widely in effectiveness and cost. They include, in no particular order, but are not limited to:

- Upstream diversion of water into the constructed/natural wetlands to reduce sediment and nutrient load prior to water entering Upper St. Croix Lake.
- Planting of vegetation buffer strips along the shoreline and the reduction/elimination of excessive fertilizer use in the residential landscapes around Upper St. Croix Lake.
- Alum treatment of the sediments to seal off the resuspension of nutrients for several years.
- Removal of sediments.

In closing, Upper St. Croix Lake shows signs of moderate nutrient enrichment and a movement towards dominance by less desirable cyanobacterial taxa. You can't control drought, geological conditions, or basin morphology. Urban land use practices and local anthropomorphic inputs can be improved but will be slow to show significant visual improvements and could therefore be hard to initiate and sustain. Each of these drivers contributes to the problem and some by themselves might be overcome but in the aggregate the problem of algal blooms and the potential of fish-killing oxygen depletion will likely continue to increase.

middle two sample periods ((08/04, 08/31), and was on the top 5 most common genera list in 5 of the 6 samples.

Euglenophytes are closely related to the green algae but have a very different cell covering composed of internal protein strips that slide along each other to provide a flexible but easily penetrated covering. They have good nutritional values and moderate growth rates but prefer somewhat cooler waters. No euglenoid genus was present in all six samples but two genera – Phacus and Trachelomonas, were identified in 5 of the 6 cell counting periods and Phacus was on the list of 5 most abundant genera three times (early and late season when the water was a bit cooler), and the only euglenoid on the list. Two others – Euglena and a different species of Phacus were found in 4 of the 6 counting periods.

The dinoflagellates (Dinophyta) are ecologically similar to the euglenoids in their preference for cooler waters. They also share with the euglenoids a being unicellular and having a thin, internal, and easily disrupted cell covering. One dinoflagellate genus – the small, unwalled organism called Amphidinium, often used as a fish food supplement, was present in all 6 counting periods. A genus of larger unicells – Peridinium, was a minor component of the Upper St. Croix algal community and was present in 4 of the 6 samples.

Basin Issues. The circumstances that pushed the algal community in Upper St. Croix Lake towards cyanobacteria is an unfortunate, and largely unavoidable combination of several things –drought, urban land use nutrient inputs, local geological conditions (leaching of naturally occurring nutrients from the basal material), shoreline and near-shoreline anthropomorphic inputs (fertilizing of lawns, septic systems, surface runoff), and perhaps most important of all – basin morphology.

First, it's important to remember that all bodies of water, no matter how pristine or protected, will eventually support the growth of algae. Once a body of nutrients is introduced to a lake system it is very difficult to manage or eliminate. These nutrients undergo a season change in location and form. The spring overturn of the lake resuspends available inorganic nutrients from the sediments. The algae assimilate these nutrients and consequently they are incorporated into organic molecules (DNA, protein) or are stored ("luxury storage") in excess of their current need. As algae are eaten their organic and inorganic matter is echoed through the food web and becomes organic material within the various levels of consumers. Consumer waste, consumer death, and algal death all contribute abundant inorganic and organic matter to the sediments throughout the year but particularly in the fall/winter when most algae and aquatic plants die back. In the fall and winter the decomposing bacteria in the sediments metabolize these mostly organic forms of nitrogen and phosphorus back to inorganic forms that are once again available in the following spring during lake overturn.

The soft-water nature of Upper St. Croix Lake also seems to contribute to its sensitivity to inputs of phosphorus. The algae need phosphorus in much smaller amounts than nitrogen (the other potentially limiting nutrient). If sufficient amounts of other lipid (oil) rather than starch, increasing their nutritional value. These organisms are mostly small unicells or easily fragmented chains of cells. Size, nutrition, easy ingestion and digestion make for another preferred food item for many aquatic animals. There are a handful of marine diatom species that have been shown to produce neurotoxins but no freshwater types have yet to be shown capable of do so.

Diatoms are capable of heterotrophic nutrition (eating stuff) and also produce hardy overwintering stages. This generally provides them with strong starting stock of cells in the spring. A typical pattern for diatoms in temperate lakes is to start with moderate abundance in the early season (second most abundant cell types counted in our first two samples) before rising in abundance into the summer (most common cell types counted in early August counts, second most common for rest of season). Often there is a marked reduction in abundance in late summer due to silica depletion (required for cell walls) but wind, wave action, and a shallow basin can circumvent this decline as it did in Upper St. Croix Lake in 2008. Fall turnover (resuspending silica) often leads to a late season diatom spike in deeper lakes. Some diatom species can become nuisance organisms and some taxa are used as bioindicators of "clean" versus "polluted" waters. A number of the taxa found in this study are commonly associated with eutrophic waters.

Among the ochrophyte taxa identified in the 2008 samples, one genus, the diatom Asterionella, was present in all six samples. This genus was twice in the 5 most common taxa counted. This very common taxon has widespread distribution in freshwater lakes. Two diatom genera, Navicula (with two species) and Fragilaria, were present in five of the six sample periods and each made at least one appearance in the five most commonly counted genera list (Table 3). Three diatom genera were also very common epiphytes in the periphyton samples (Table 4). Cocconeis, Diatoma, and Epithemia were nearly universal inhabitations of submerged surfaces, especially the large green algal filaments of Cladophora and Oedogonium. Four other diatoms – Cyclotella, Fragilaria 2, Synedra, Tabellaria – all very common taxa, were found in four of the six sample periods. Six other diatom genera and the chrysophyte Dinobryon were present in half the samples. The remaining genera were less common (6 genera in two samples, 1 genus in one sample).

Other Phyla. The other three phyla (Dinophyta-dinoflagellates, Euglenophyta-euglenoids, and Cryptophyta-cryptophytes) present in 2008 cell counts were of varying but mostly minor significance across the sampling period with occasional exceptions (Table 1, Table 3). The euglenoids and cryptophytes contributed about 10% of all cells counted over the survey period while the dinoflagellates represented 3% of cells counted.

The cryptophytes are small unicellular organisms with no wall or a thin wall, high nutritional value and a high growth rate. The cryptophyte genus Cryptomonas, often used as a fish food supplement, was a very common member of the Upper St. Croix Lake algal community in 2008 and perhaps the most abundant taxon across the sample period. It was present in all six sample periods, was the most common genus counted in the

Twenty-two genera of green algae were present over the 2008 sampling period. Three genera – Pediastrum, Scenedesmus, and Staurastrum – were present in all six cell counts. These taxa are fairly ubiquitous, where there's water you'll usually find these three. They are all (along with Selenastrum and others to follow) common prey items; gut analysis of zooplankton, insect larvae, tadpole guts, snails, and small fish reveal them to be significant diet components. Pediastrum and Scenedesmus are colonies composed of small cells, easily fragmented and penetrated. Staurastrum is somewhat larger but easily in the realm of ingestion by all the above-mentioned animals plus it has a sugary extracellular envelope that would be like getting dessert before the main course. All three can use excess nutrients to fuel high growth rates but this is typically balanced by higher predation rates.

These three genera, plus Selenastrum, were the only green algal genera among the five most abundant taxa in any sample (Table 3). Scenedesmus was the most commonly counted organism in the first sample (05/16) and the others made early season appearances in the top 5 counted taxa as well. All faded out of the top 5 by early August, except Pediastrum. Many temperate zone lake studies have shown a similar pattern. The greens grow well in the early season with cooler temperatures and lake turnover nutrient fluxes, typically dominating cell counts early, often with serial flushes of one genus dominating then another and another until late summer. Higher temperatures and lower nutrients usually reduce green algal growth rates but not predation rates so their relative abundance is reduced for the rest of the growing season.

The small unicellular/colonial genus Selenastrum (see above paragraph0, often used as a fish food supplement, was present in five of six cell count periods. This organism has a very high growth rate, probably one of the highest in this group but it is preyed upon very heavily. Five other green algal genera were present in four of the six sample periods (Ankistrodesmus, Botryococcus, Coelastrum, Golenkinia, Oocystis). All are very common and all share the characteristics of being unicellular or colonies of small cells with thin walls. They are all commonly consumed in aquatic systems. The other 13 green algal genera identified were much less common, 2 genera were present in half the samples, 6 genera found in two samples, and 4 genera found in only one sample.

Ochrophyta. The ochrophytes are a large and diverse group that was the third most abundant phylum present in the algal community of Upper Lake St. Croix during 2008. This phylum has many subgroups and in freshwater the most common groups are the diatoms, tribophytes (yellow-green algae), chrysophytes, and synurophytes (together often called the golden algae). There were 21 genera of ochrophytes (and two genera with two species each) present in the 2008 cell counts. Seventeen of these 21 were diatoms, 2 were chrysophytes, and 1 each were tribophytes and synurophytes.

Diatoms are the most common and successful group of organisms within the phylum Ochrophyta. These unique organisms collect silica from the water and polymerize it into intricate glass cases called frustules that they use in place of a more traditional, organically-derived cell covering. Many diatoms store extra photosynthetic product as

Some Cyanobacteria are capable of "blooming" (massive population explosions) and in the bloom state may produce toxins that can harm aquatic life, pets, and potentially humans. Recent research has hinted at the possibility of these organisms producing toxins at sub-bloom densities as well. There are three basic types of toxins produced by blue-green algae: cytotoxins (or endotoxins), hepatotoxins, and neurotoxins.

The cytotoxins are various lipopolysaccharides (polymers of sugar-backbones with fatty acid side chains) that can kill cells in a fashion similar to pathogenic bacteria like Salmonella but with less toxic effects. Some strains of both Anabaena and Microcystis have been shown to produce cytotoxins.

Hepatotoxins are cyclic peptides that irreversibly inhibit liver-cell protein phosphatase enzymes. Their effects on the liver vary based on the amount of exposure. Strains of some common blue-green algal genera from Upper St. Croix Lake have been associated with hepatotoxin production including Microcystis, Anabaena, Nodularia, and Oscillatoria.

Neurotoxins are potent membrane sodium-channel blockers that disrupt neuromuscular activity. These very rapid-acting and high-potency toxins have been associated with the most critical animal and human pathologies including several documented human fatalities. The only blue-green genus from Upper St, Croix Lake that has been documented to have strains capable of producing neurotoxins is Anabaena.

Of all the known toxin-producing taxa found in Upper St. Croix Lake only Nodularia approached bloom conditions (9 -12% of all cells counted) in the 08/31, 10/03, and 10/31 samples (Table 3). At present this cyanobacterium does not appear to be a toxin-producing threat but it and other seasonally-dominant blue-green taxa should be monitored in the future, especially in light of the significant component of Nodularia and other cyanobacteria in the 2008 sampling season.

Chlorophyta. Green algae (Chlorophyta) were the second most common phylum in Upper St. Croix Lake during the 2008 sampling season (Table 1). Ecologically the greens are very versatile and can rival the cyanobacteria for metabolic diversity and tolerance of variable and harsh environmental conditions. These eukaryotic algae, the ancestors of land plants, are very diverse with many more taxa and morphologies than the prokaryotic blue-green algae. For most taxa in this phylum growth rates can be relatively high under optimal conditions of light, temperature, and nutrients but rarely can they match the maximum growth rates achieved by the blue-green algae under similar conditions. Green algae do not produce toxins.

Compared to the aforementioned characteristics of the blue-green algae (hard to ingest, hard to digest, moderate nutritional value), many green algal taxa are unicellular or small colonies (easy to ingest), many have no cell wall or a thin cellulose cell wall (easy to digest), and most have good nutritional value. Thus when given the choice of eating a green alga or a cyanobacterium most little critters take the former. The green algae, at least some taxa, are a preferred food item for many aquatic consumers.

nitrogen (in the form of long chains of nitrogen-rich amino acids like aspartate and arginine) and phosphate (in the form of linear polyphosphate molecules). These substantial cell-storage reservoirs allow the blue-greens to continue to grow during periods of nutrient deprivation in the water column.

These photosynthetic prokaryotes are also largely indigestible due to their cell wall. This complex outer covering includes an inner matrix of peptidoglycan (polymer of sugar backbone with amino acid side chains) overlain with a layer of lipopolysaccharide as seen in Gram-negative bacteria. Nearly every genus of blue-green identified in Upper St. Croix Lake also has an outer mucilage layer (polysaccharide) called the sheath. The sheath is a sticky and difficult-to-digest matrix that can be quite extensive. The cell wall and sheath make the blue-green algae hard to both ingest and digest; as a result they are generally avoided by consumers like zooplankton (microscopic animals) and planktivorous fishes. The unfortunate combination of versatile metabolism, ecological tolerance, luxury nutrient storage, high growth rate, and indigestibility make for formidable nuisance organisms that are very difficult to control and even more difficult to eradicate.

Of the 71 total genera found over the sampling season there were 22 cyanobacterial genera. Ten genera of the 71 (14%) were present in all six cell counting samples (Appendix 1). Four of these ten genera were cyanobacterial taxa. The filamentous blue-green genera Gloeotrichia and Nodularia were present in all sampling periods and Gloeotrichia was the most common organism in the cell counts of 10/03 and 10/31 (late season). Nodularia was one of the three most common organisms in the final three periods sampled (Table 3, Figure 5). The colonial genera, Coelosphaerium and Woronichinia were also present in every sample. They both produce significant sheaths that render them basically inedible. All four of these taxa are cosmopolitan and their abundance is generally associated with inorganically-enriched (especially phosphorus) waters.

In addition to the general metabolic and ecological advantages of cyanobacteria discussed above, Gloeotrichia and Nodularia have another metabolic advantage that makes them more of a nuisance, harder to control, and even harder to eradicate. These organisms can produce specialized cells called heterocysts (or heterocytes) that enable them to enzymatically fix atmospheric nitrogen gas into inorganic and useable forms of nitrate or ammonium. Thus, even if you can limit nitrogen availability in the water column they can make their own!

The colonial blue-green genus Microcystis was present in five of the six sample counts. This organism forms large amorphous colonies with substantial and diffuse sheaths. The only other cyanobacterial genus found in more than half the samples was the filamentous and heterocyst-producing genus Anabaena. The 16 remaining blue-green algal genera were found in at most half the samples (6 genera) or less (6 genera found in two samples, 4 genera found in only one sample).

TABLE 4. Most Common Periphytic and Benthic Algal Genera from Upper St. Croix Lake, Douglas County, WI, 2008.

PHYLUM	GENUS	MORPHOLOGY
Cyanobacteria	Gloeotrichia	Tapered Heterocystous Filament with Sheath
	Nodularia	Heterocystous Filament with Sheath
	Tolypothrix	Branched Heterocystous Filament with Sheath
Chlorophyta	Bulbochaete	Sparsely Branched Filament
	Cladophora	Densely Branched Filament
	Oedogonium	Unbranched Filament
Ochrophyta	Cocconeis	Monoraphid Pennate Diatom
	Diatoma	Araphid Pennate Diatom
	Epithemia	Biraphid Pennate Diatom

IV. DISCUSSION

Phytoplankton community dynamics is controlled by three broad categories of factors – the physical environment, nutrients, and biotic factors. The physical environment included such things as temperature, light, turbulence, stratification, and other hydrodynamic factors. Nutrients, from internal and external sources, determine community structure and can limit physiological responses in some taxa. Together, hydrodynamic/physical factors and nutrient factors are considered "bottom-up" controls of algal communities. Biotic factors like competition, toxic inhibition, parasitism, disease, and predation are typically considered to be "top-down" mechanisms that exert their influence down through a food web. Each algal phylum, genus, and species fits into this continuum of characteristics at some specific spot but that spot can change as the combination of characteristics changes. The dynamic nature of climate, season, and microhabitats in the continuously-changing water column make predictions very difficult.

The following sections present expanded discussions of the algal community components and the development of algal communities.

Cyanobacteria. The Cyanobacteria (or blue-green algae) are prokaryotic (bacteria-like) organisms with very wide metabolic and ecological tolerances coupled with potentially high growth rates under good conditions. This confers on them the ability to withstand conditions that are harmful to other types of algae. They can quickly respond to changes in their environment and take advantage of any available excess nutrients. All blue-green algae store nutrients beyond their immediate metabolic needs when such nutrients are present. Particularly, they generate intracellular storage granules of

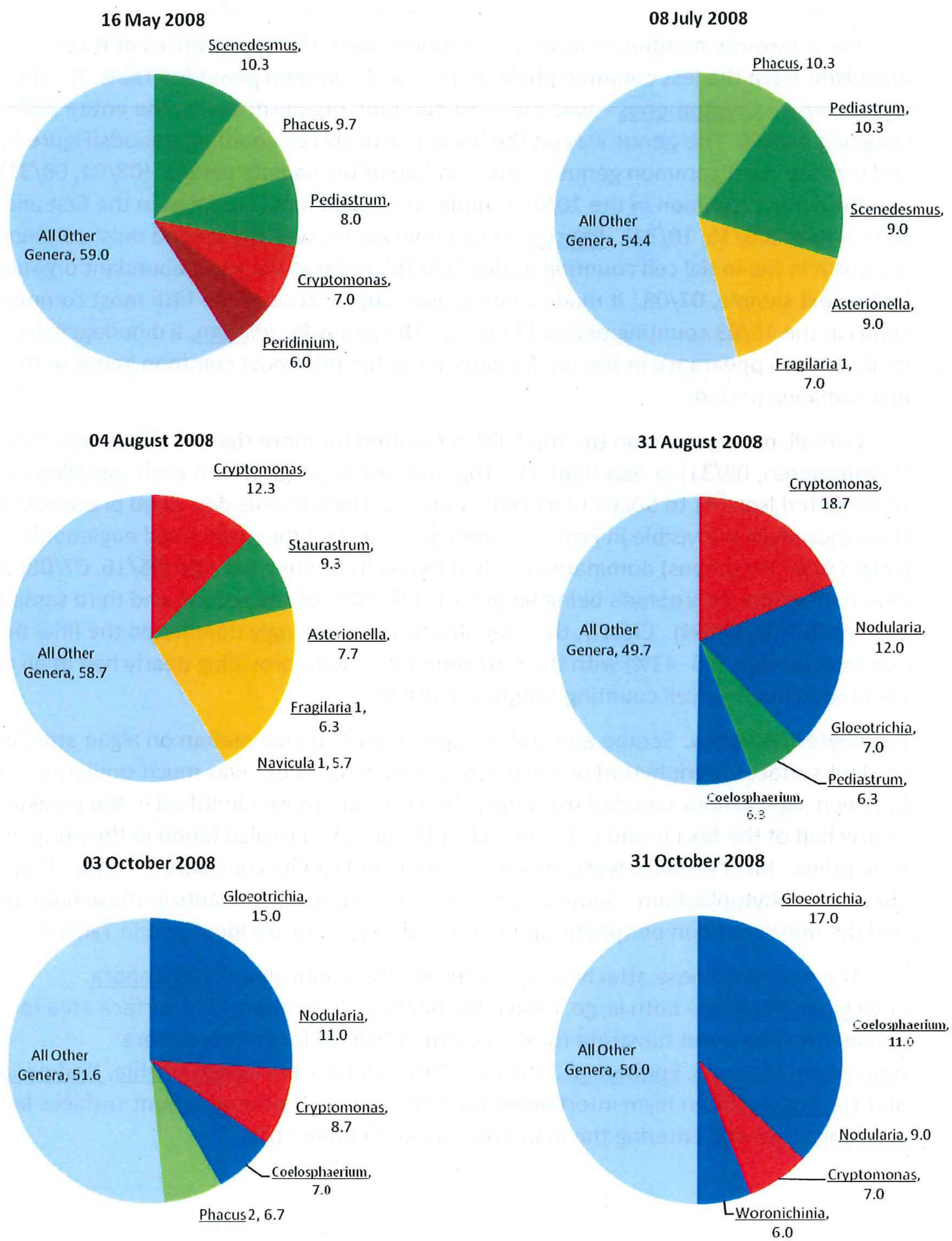
FIGURE 5. Five Most Common Planktonic Algal Genera (% of total cells counted) in Upper St. Croix Lake, Douglas County, WI, 2008 by Sampling Date.

The previously mentioned notable exceptions were the appearances of three organisms from the less common phyla on the most common genus list Table 3). The cryptophyte – Cryptomonas – was the most common organism during the entire 2008 sampling period. This genus was on the list in five of six cell counting periods(Figure 5) and was the most common genus counted in two of the sample periods (08/04, 08/31). It was third most common in the 10/03 sample and fourth most common in the first and last samples (05/16, 10/31). Phacus, a euglenoid genus, was the second most common organism in the initial cell counting period (05/16) and was the most abundant organism in the next sample, 07/08. It made a late season appearance as the fifth most common genus in the 10/03 counting period (Table 3). The genus Peridinium, a dinoflagellate, made a lone appearance in the top 5 genus list as the fifth most common genus in the first sampling period.

Overall, no organism on the top 5 list accounted for more than 18.7% of cells counted (Cryptomonas, 08/31) or less than 6%. Together the top 5 genera in each sampling period represented from 41 to 50.3% of all cells counted. The patterns described previously for the major phyla are visible in Figure 5 where genera from the greens and euglenoids (relatives of the greens) dominated the first two cell counting periods (05/16, 07/08) with genera from the Ochrophyta being large parts (18-20%) of the second and third sampling periods (07/08, 08/04). Clearly, the cyanobacteria increasingly dominated the final three sampling periods (25 -43%) with the four common genera providing nearly half of all cells counted in the final cell counting sample (Figure 5).

Periphyton/Benthos. Scrape and grab samples provided information on algae attached to plant surfaces (periphyton) or the bottom (benthos). There was much similarity between algal genera sampled from these habitats and those identified in the plankton. Nearly half of the taxa found in the plankton (32 of 71) were also found in the periphyton or benthos. Most of these were very uncommon and can be considered "trapped" or "beached" phytoplankton. Some organisms, however, are dominants in these habitats and the most common periphytic and benthic algal genera are identified in Table 4.

The largest of these attached organisms are the green algae. Cladophora and Oedogonium are both large, robust filaments and provide ample surface area for, and are the preferred substrate for the common unicellular diatom genera (Cocconeis, Diatoma, Epithemia). The cyanobacterial genera – Gloeotrichia, Nodularia, and Tolypothrix often form intertwined mats that adhere to the sediment surfaces before breaking loose and entering the planktonic habitat (Table 4).


16 May 2008
Scenedesmus, 10.3
Phacus, 9.7
Pediastrum, 8.0
Cryptomonas, 7.0
Peridinium, 6.0
All Other Genera, 59.0
08 July 2008
Phacus, 10.3
Pediastrum, 10.3
Scenedesmus, 9.0
Asterionella, 9.0
Fragilaria 1, 7.0
All Other Genera, 54.4
04 August 2008
Cryptomonas, 12.3
Staurastrum, 9.3
Asterionella, 7.7
Fragilaria 1, 6.3
Navicula 1, 5.7
All Other Genera, 58.7
31 August 2008
Cryptomonas, 18.7
Nodularia, 12.0
Gloeotrichia, 7.0
Pediastrum, 6.3
Coelosphaerium, 6.3
All Other Genera, 49.7
03 October 2008
Gloeotrichia, 15.0
Nodularia, 11.0
Cryptomonas, 8.7
Coelosphaerium, 7.0
Phacus 2, 6.7
All Other Genera, 51.6
31 October 2008
Gloeotrichia, 17.0
Coelosphaerium, 11.0
Nodularia, 9.0
Cryptomonas, 7.0
Woronichinia, 6.0
All Other Genera, 50.0

10/03	Gloeotrichia	Cyanobacteria	15.0	Heterocystous Filament
	Nodularia	Cyanobacteria	11.0	Heterocystous Filament
	Cryptomonas	Cryptophyta	8.7	Motile Unicell
	Coelosphaerium	Cyanobacteria	7.0	Colonial
	Phacus 2	Euglenophyta	6.7	Motile Unicell
			48.4	
10/31	Gloeotrichia	Cyanobacteria	17.0	Heterocystous Filament
	Coelosphaerium	Cyanobacteria	11.0	Colonial
	Nodularia	Cyanobacteria	9.0	Heterocystous Filament
	Cryptomonas	Cryptophyta	7.0	Motile Unicell
	Woronichinia	Cyanobacteria	6.0	Colonial
			50.0	

Genera of ochrophytes, all diatom taxa, had a brief appearance in the top 5 genera in the second and third sample periods (07/08, 08/04), similar to the pattern seen at the phylum- and number of genera-levels. Asterionella and Fragilaria were fourth and fifth most common in the July sample and third and fourth most common in the early August sample. Another diatom genus – Navicula, was the fifth most common genus in the early August samples. Only Asterionella and Fragilaria occurred more than once (2 each) and there were no other occurrences from this phylum in the five most common genera (Table 3).

Three of the six most common genera were from the Cyanobacteria (Table 3). Genera from this phylum were absent from the most common genera listings during the first three periods only to dominate the top 5 genera in the final three cell counting periods (08/31, 10/03, 10/31). This reinforces the patterns seen in the previous results for phylum-level and number of genus-level analyses. Gloeotrichia was the most common genus in the 10/03 and 10/31 cell counts after being the second most common genus in the 08/31 counting period (Table 3). Nodularia was the second most common genus in 08/31 and 10/03 samples and then dropped to third in the final sampling period. Coelosphaerium was also common, with a pattern of increasing abundance over time. Its first appearance, in the 08/31 counting period was as the fifth most common genus. It rose to fourth most common genus in the next period (10/03) and then to the second most common genus in the final period, 10/31. The only other blue-green algal genus to appear in the top 5 was Woronichinia; it was the fifth most common genus in the final cell counting period (Table 3). Of thirty slots in the top 5 list (five/sample period x 6 sample periods) the Cyanobacteria occupied 10 (33%), all in the final three periods (Figure 5).

TABLE 3. Most Common Planktonic Algal Genera from Upper St. Croix Lake, Douglas County, WI, 2008 by Sampling Date.

DATE	GENUS	PHYLUM	% TOT	MORPHOLOGY
05/16	Scenedesmus	Chlorophyta	10.3	Colonial
	Phacus	Euglenophyta	9.7	Motile Unicell
	Pediastrum	Chlorophyta	8.0	Colonial
	Cryptomonas	Cryptophyta	7.0	Motile Unicell
	Peridinium	Dinophyta	6.0	Motile Unicell
			41.0	
07/08	Phacus	Euglenophyta	10.3	Motile Unicell
	Pediastrum	Chlorophyta	10.3	Colonial
	Scenedesmus	Chlorophyta	9.0	Colonial
	Asterionella	Ochrophyta	9.0	Pennate Diatom
	Fragilaria 1	Ochrophyta	7.0	Pennate Diatom
			45.6	
08/04	Cryptomonas	Cryptophyta	12.3	Motile Unicell
	Staurastrum	Chlorophyta	9.3	Non-motile Unicell
	Asterionella	Ochrophyta	7.7	Pennate Diatom
	Fragilaria 1	Ochrophyta	6.3	Pennate Diatom
	Navicula 1	Ochrophyta	5.7	Pennate Diatom
			41.3	
08/31	Cryptomonas	Cryptophyta	18.7	Motile Unicell
	Nodularia	Cyanobacteria	12.0	Heterocystous Filament
	Gloeotrichia	Cyanobacteria	7.0	Heterocystous Filament
	Pediastrum	Chlorophyta	6.3	Colonial
	Coelosphaerium	Cyanobacteria	6.3	Colonial
			50.3	

second or third most numerous during the first four samples before increasing most numerous during the final two periods, 10/03 (13 genera) and 10/31 (14 genera). Of the average number of genera per sample (40) there were never more than 6 genera of euglenoids, cryptophytes, and dinoflagellates, combined (15% of total genera).

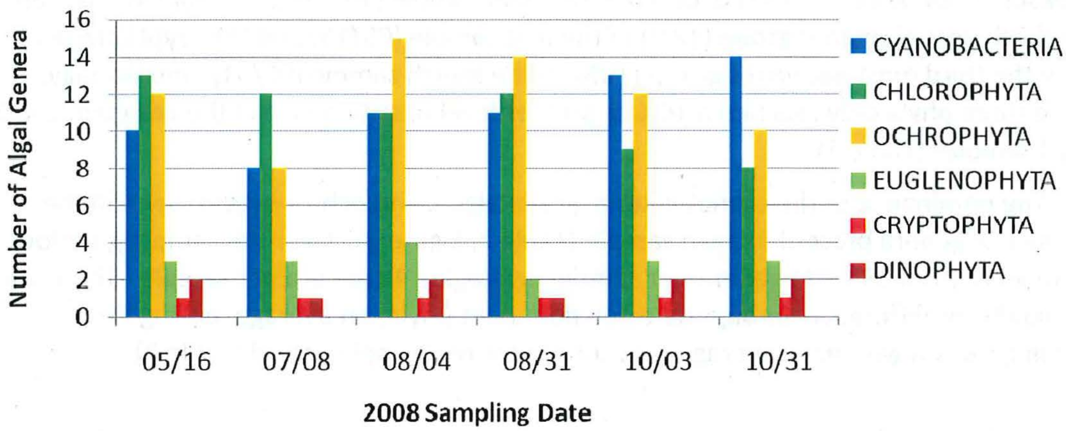


FIGURE 4. Number of Planktonic Algal Genera in Upper St. Croix Lake, Douglas County, WI, 2008 by Phylum and Sampling Date.

At the individual genus level only a handful of the 71 genera were ever very abundant in the cell counts (Appendix 1). The five most common genera in each sample period are listed in Table 3. With a couple of notable exceptions, the dominance of the three most common phyla is seen in these results as in the phylum-level and number of genera-level results summarized previously (Figure 2, Table 2).

The green algae were in the top 5 most common genera 20% of the time (Table 3) and in a pattern similar to the one seen in the two previous results. This phylum had the first (Scenedesmus) and third most common genus (Pediastrum) in the first sample (05/16) and the second and third most common genus (Pediastrum and Scenedesmus, respectively) in the second sample (07/08). A different green algal genus – Staurastrum, was the second most common genus in the next period (08/04) and Pediastrum was the third most common genus in next period (08/31). There were no green algal genera present in the top 5 genera in the last two sample periods, 10/03 and 10/31 (Table 3). Only Pediastrum was among the most common genera in at least half (3) of the cell counting periods.

cells counted, more than four times more abundant than either of the other two most common phyla. Averaged over the six samples, the cyanobacteria represented a third of all cells counted (Table 1).

The euglenoids, cryptophytes, and dinoflagellates combined to represent 23% of all cells counted over the entire sampling period (Table 1). In the first sample period (05/16) these phyla comprised 33% of all cells counted (Figure 3) before dropping to 18-26% of cells counted for the next four sample periods (07/08, 08/04, 08/31, 10/03) and reaching a seasonal low of 11% of cells counted in the final sample (10/31). The euglenoids were the third most abundant group (18%) in the first sample (05/16) and the cryptophytes were the third most abundant group (19%) in the fourth sample (08/31). Individually, these three phyla only reached a 10% or greater level of abundance in the cell counts in 5 of 18 samples (Table 1).

The dominance of the cyanobacteria, green algae, and ochrophytes is seen in the number of genera present in each sample (Table 2, Figure 4). Over the sampling period there were from 33 to 44 genera per sample, averaging 40 genera per sample. There was no significant difference among the three dominant phyla, on average, during the growing season with each averaging 11-12 genera per sample period (Table 2).

TABLE 2. Planktonic Algal Genera from Upper St. Croix Lake, Douglas County, WI, 2008 by Phylum and Sampling Date.

PHYLUM	05/16	07/08	08/04	08/31	10/03	10/31	MEAN
Cyanobacteria	10	8	11	11	13	14	11.2
Chlorophyta	13	12	11	12	9	8	10.8
Ochrophyta	12	8	15	14	12	10	11.8
Euglenophyta	3	3	4	2	3	3	3.0
Cryptophyta	1	1	1	1	1	1	1.0
Dinophyta	2	1	2	1	2	2	1.7
TOTAL	41	33	44	41	40	38	39.5

The patterns of abundance seen at the phylum level were also echoed here but less obviously. The green algae had the most numerous genera early (first two sample periods) and then steadily declined. Ochrophyte genera were the second most numerous group during the two early samples and were the most numerous genera during the middle two periods (08/04, 08/31) before settling back into the second most represented genera in the final two samples (Figure 4). Genera from the cyanobacterial lineage were

The Ochrophyta, mostly diatom taxa, was the second most abundant phylum during in the first two samples and then reached peak abundance in the early August sample (08/04) at 34% of cells counted (Table 1). They declined in all later sample periods (08/31, 10/03, 10/31) but were the second most common phylum in the cell counts for those periods (Figure 3). The ochrophytes represented 14% of cells counted at the end of the season and averaged 22% of cells counted for the entire sampling period (Table 1).

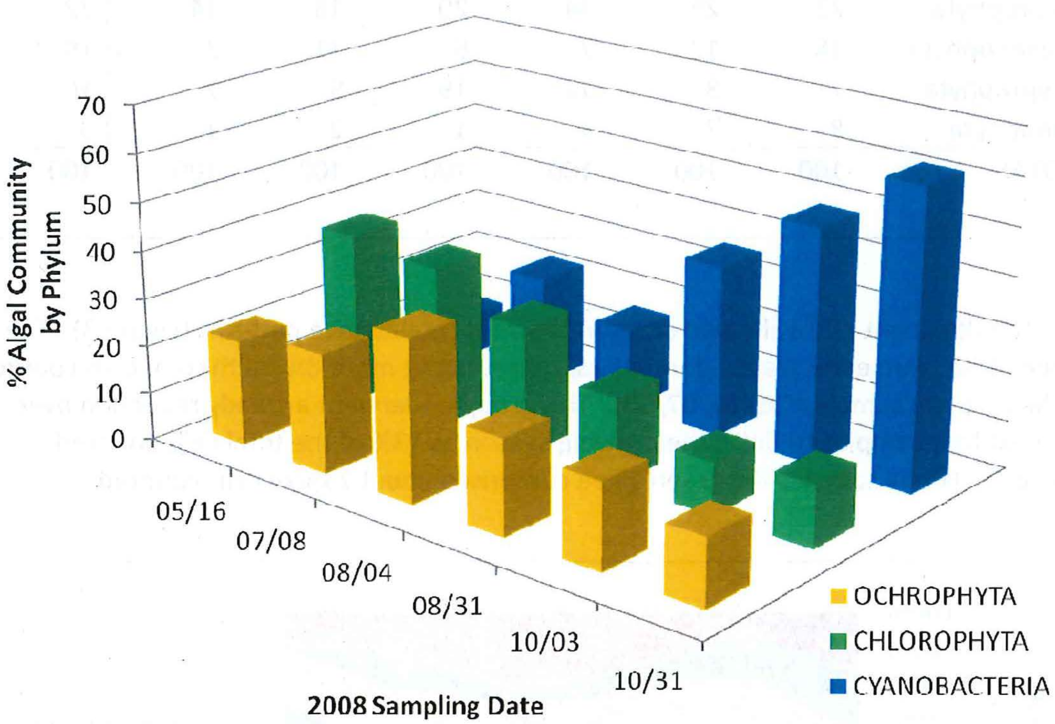


FIGURE 3. Algal Community Composition (%) in Upper St. Croix Lake, Douglas County, WI, 2008 by Three Most Common Phyla and Sampling Date.

Blue-green algae or Cyanobacteria were only 9% of cells counted in the first sample period (05/16) but their abundance ramped up steadily and at times quickly over the sampling season (Figure 3). In the first sample this phylum was the fourth most common group, it rose to third most common in the next two periods, 07/08 (23%) and 08/04 (17%). In less than four weeks the population more than doubled to 36% of cells counted (08/31) and was twice as common as either the green algae or ochrophytes. A month later (10/03) cyanobacterial cells counts were up another 50% and representing 49% of all cells counted. By the final sample period (10/31) the blue-green algae made up 62% of all

TABLE 1.	Percent Algal Community Composition from Upper St. Croix Lake, Douglas County, WI, 2008 by Phylum and Sampling Date.					

PHYLUM	05/16	07/08	08/04	08/31	10/03	10/31	MEAN
Cyanobacteria	9	23	17	36	49	62	33
Chlorophyta	36	34	27	18	11	13	23
Ochrophyta	22	25	34	20	18	14	22
Euglenophyta	18	13	7	6	11	3	10
Cryptophyta	7	3	12	19	9	7	10
Dinophyta	8	2	3	1	2	1	3
TOTAL	100	100	100	100	100	100	100

The dominant phyla showed different seasonal abundance patterns (Figure 3). The green algae were early season dominants, representing more than a third of cells counted in the first two samples (05/16, 07/08). This group underwent a steady reduction over the next four samples to finish the growing season as 13% of the total cells counted (Table 1). For all samples the green algae comprised about 23% of cells counted.

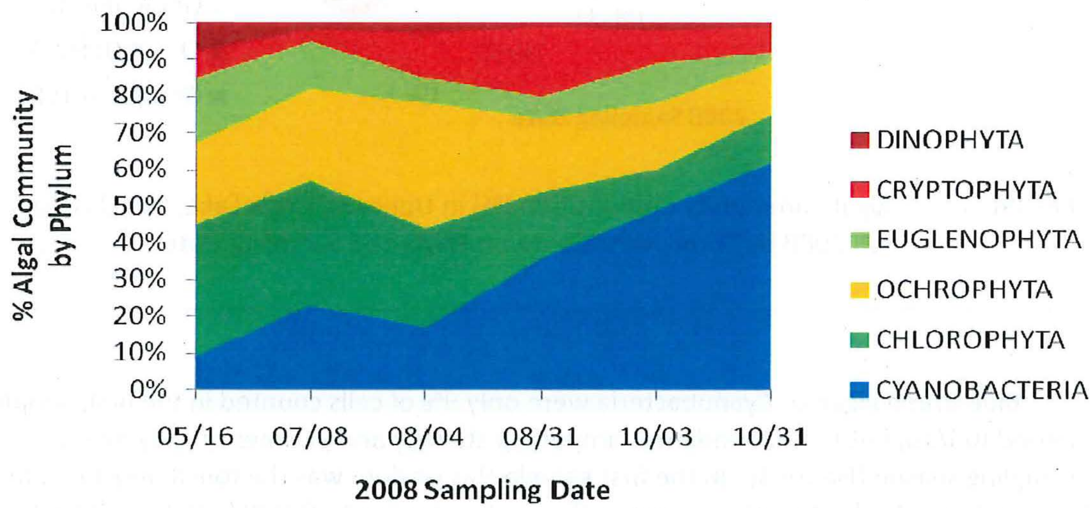


FIGURE 2. Algal Community Composition (%) in Upper St. Croix Lake, Douglas County, WI, 2008 by Phylum and Sampling Date.

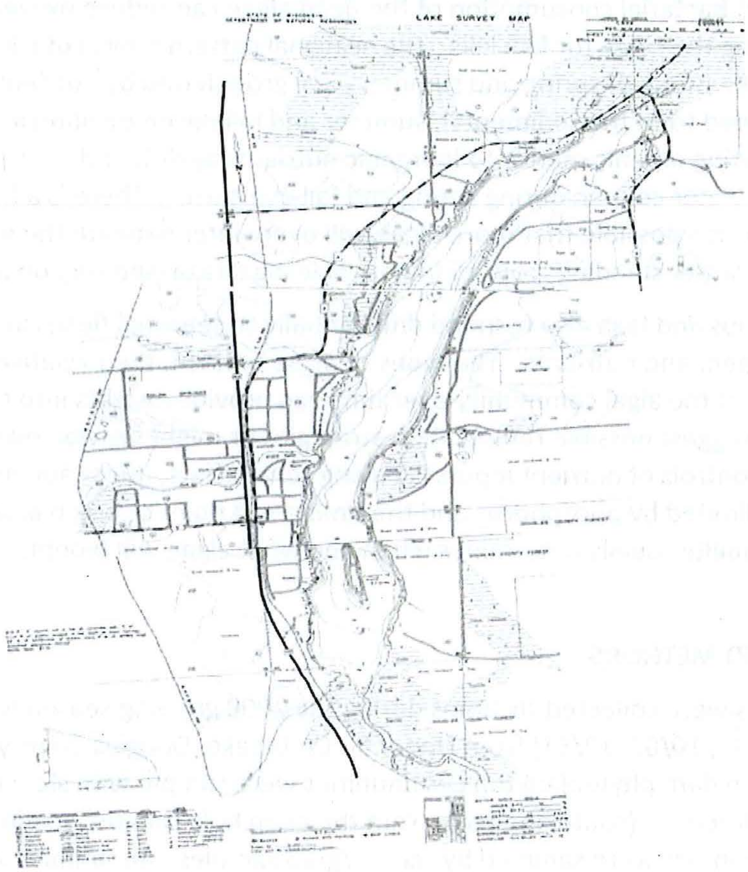


FIGURE 1. Upper St. Croix Lake, Douglas County, WI.

III. RESULTS

Phytoplankton. Organisms that swim or drift in the water column, are referred to as plankton. Phytoplankton are the algal components of the plankton. Representatives of six algal phyla waxed and waned in the phytoplankton during the sampling period (Table 1, Figure 2). Seventy-one genera of planktonic algae were identified during the counting process in Long Lake (Appendix 1). Sixty-five of the 71 algal taxa from Upper St. Croix Lake were from three phyla – the Cyanobacteria or blue-green algae (22 genera), the Chlorophyta or green algae (22 genera), and the Ochrophyta including the diatoms (21 genera). These are the dominant phyla in most lakes. The other three phyla represented in cell counts were the Euglenophyta or euglenoids, the Cryptophyta or cryptomonads, and the Dinophyta or dinoflagellates.

The microbial decomposition loop (detritivorous) is fed largely by the algae. It is in the sediments that bacterial consumption of the dead algae can reduce oxygen content to anoxic levels setting the stage for fish kills. The seasonal pattern typical of lakes like Upper St. Croix Lake is one of spring and summer algal growth (fed by nutrients either input or resuspended from the sediments); summer and fall decomposition in the sediments (converting organic matter to inorganic nutrients again); and resuspension of nutrients into the water column during spring and fall overturn. If there is a flux of nutrients in the fall it's possible that more algae will overwinter beneath the ice. This can lead to increasing larger standing crops of undesirable algal taxa (see section above).

Different groups and taxa also respond differentially to seasonal fluxes in temperature, oxygen, and nutrients. The types of algae present, their relative abundance, and the dynamics of the algal community over time can provide insights into trophic status and might suggest possible remediation strategies or might provide evidence that watershed-level controls of nutrient inputs is having some effect. Most aquatic algal communities are limited by phosphorus and the timing and point of origin around phosphorus availability usually determines when and what algae will bloom.

II. MATERIALS AND METHODS

Algae samples were collected six times during the 2008 growing season (05/16, 07/08, 08/04, 08/31, 10/03, 10/31) from Upper St. Croix Lake, Douglas County, Wisconsin (Figure 1). On each date phytoplankton communities were sample with slow plankton net tows in two directions (south and east) from the deep hole sample location and periphyton communities were sampled by scrape/grab samples. All samples were returned to UWSP for analysis as soon as possible.

At UWSP, algal samples were fractionated into fresh and iodine-preserved aliquots. Initial evaluations revealed general homogeneity between samples and consequently all samples were pooled for analysis. Fresh samples were surveyed immediately to provide the most accurate genus list. Preserved samples were stored, cold, until counting.

For planktonic algae counting analysis, 1ml aliquots of preserved material were placed into a Sedgewick-Rafter counting cell and allowed to settle for 1hr. Random fields were counted at 400X under an Olympus ZH20 Inverted Microscope with long working distance lenses. Colonial and filamentous organisms were counted as a single unit if intact. Counts were conducted until the sample total reached 300 per date.

Scrape/Grab algae samples were systematically surveyed to determine the generic composition of the samples but cell counts were not conducted.

Generic identification was from standard freshwater reference texts including (but not limited to) "Freshwater Algae of the United States (G.M. Smith), Freshwater Algae of the Western Great Lakes Area (G. Prescott) and "Freshwater Algae of North America (R. Sheath, et al.).

I. INTRODUCTION

Algae need carbon dioxide, water, sunlight, and a variety of inorganic nutrients, all in adequate amounts. The term algae is very general, this group of organisms encompasses both prokaryotic (like bacteria) and eukaryotic (like us) cell types. The algae range from single-celled to many meters long, some swim with flagella while others float or alter their buoyancy via physiological alterations. These organisms can be motile or non-motile unicells, unbranched or branched filamentous, motile or non-motile colonies, tubular, sheet-like, and about every shape in between. They can be blue-green, green, yellow, black, brown, gold, pink, red, or orange.

There are 9 or more major lineages or phyla of algae. Each phylum has a unique set of photosynthetic pigments, anatomical features, and physiological adaptations. Individual taxa (like a genus) are grouped in a phylum based on shared characteristics such as pigments, cell type, and reproduction. Within that phylum groups are further subdivided based on more specialized shared and distinct characteristics relative to the other members of that division. These subgroups are called classes, orders, families, and genera. In this study I identified algae to genus and phylum. While algae within the same phylum generally respond in a similar manner to seasonal and nutrient changes (since they're related to each other) such generalizations are weak. Each algal genus responds differently to changing environmental conditions. Seasonal changes in the composition of the algal community in Upper St. Croix Lake were traced via changes in the relative abundance of algae at the genus and phylum level.

Algae are considered primary producers (see diagram on title page) in most aquatic food webs (along with macrophyte vegetation). They are responsible for capturing solar energy via their photosynthetic pigments and using that trapped energy to convert inorganic carbon dioxide into organic sugars. These sugars store some of the captured solar energy in their chemical bonds. The algae use the sugars to make other new organic matter (proteins, carbohydrates, nucleic acids, lipids) as they grow and divide. Consumers and decomposers also use these sugars for energy and recycle much of the other organic matter as well. Algae are critically important components of the aquatic food web as many zooplankters (microscopic animals) as well as many larger consumers (snails, planktivorous fishes) have a diet based largely on algae.

Net growth rates of algae are determined by the difference between growth (production of new algae via asexual and sexual reproduction) and death (consumption, parasitism, natural death). Algae differ in their digestibility (shape, size, production of sticky mucilage) and nutrient value (proteins, lipids, carbohydrates) to consumers and consequently some taxa are preferentially removed from the community by predation while others are largely ignored by consumers and continue to expand their biomass during the growing season. The algae present at any point in time are frequently based more on what hasn't been eaten than what is growing the fastest. It's often these "not eaten" algal taxa, especially the Cyanobacteria (or blue-green algae) that become persistence bloom formers in ever earlier and longer cycles.

SUMMARY

The algal community in Upper St. Croix Lake, Douglas County, Wisconsin was sampled six intervals over the 2008 growing season from 16 May through 31 October. Algal material was collected, on each date, via several plankton net tows and periphyton/grab sampling. Algae in the phytoplankton community were identified to genus and phylum, and enumerated by cell count. Periphyton/grab samples were identified to genus and phylum.

The algal community in Upper St. Croix Lake from May to October 2008 was fairly typical of similar regional lakes with moderate eutrophication. The lake was dominated by organisms from three algal phyla – Cyanobacteria, Chlorophyta, and Ochrophyta. Additionally, several taxa – Phacus (Euglenophyta) and Cryptomonas (Cryptophyta) made significant contributions to the algal community during the observation period.

During the 2008 sampling season, one phylum – the Cyanobacteria, expanded rapidly from early July through the end of the season, contributing 62% of all cells counted in the final period. In this group there were several dominant genera (Gloeotrichia, Nodularia, Coelosphaerium) that represented from 25-35% of all cells counted in the final half of the sampling season. These very commonly occurring, nuisance taxa are not preferred food items, they respond quickly to excess nutrient availability with high growth rates, have high winter survival rates, and several have toxin-producing potential. The dense populations they form during the growing season are aesthetically displeasing and may alter higher-level food web dynamics. Their winter decomposition in the sediments will deplete under-ice oxygen levels with the potential for fish kills.

Once established at these levels these organisms are difficult to control and nearly impossible to eliminate. Several factors likely contributed to the development of these dense blue-green algal populations including drought cycles and water level, basin morphology, and both natural and cultural eutrophication.

ACKNOWLEDGEMENTS

Many thanks go to Jim Heim and the other volunteers from Upper St. Croix Lake that made the timely collecting and processing of algae possible. Thanks to Joe Richards, UWSP undergraduate, for assistance with algal identification and enumeration. Thanks to all groups and agencies that funded and facilitated this study. Special thanks to Nancy Turyk for her energy, inspiration, and insightful discussion of this project.

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ALGAL COMMUNITY COMPOSITION AND SUCCESSIONAL TRENDS
UPPER ST. CROIX LAKE, DOUGLAS COUNTY, WISCONSIN
MAY – OCTOBER, 2008

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