C*ladophora* and Water Quality of Lake Michigan: A Systematic Survey of Wisconsin Nearshore Areas

Steve Greb and Paul Garrison, DNR Integrated Science Services
Shaili Pfeiffer, DNR Office of the Great Lakes
December 8, 2004

Introduction

In recent years *Cladophora* has increased along Lake Michigan and been deposited in large quantities on Lake Michigan beaches. The presence of rotting *Cladophora* on Lake Michigan beaches presents aesthetic and odor problems that impairs recreational use of Lake Michigan. In addition, the rotting algae may provide adequate conditions for bacterial growth and crustaceans deposited on the beach with the decaying *Cladophora* may attract large flocks of gulls resulting in increased *E. coli* concentrations from gull fecal material.

In the spring of 2004 the Wisconsin DNR initiated a working group to address the nuisance algal problem on Lake Michigan. The working group includes representatives from the DNR Northeast Region, Southeast Region, Integrated Science Services, and Central Office. The group's objectives include researching environmental factors causing the algal blooms to assist with developing long term management plans, identifying short term beach clean up and odor mitigation options, and addressing public information needs. The *Cladophora* working group is addressing these objectives by working in conjunction with others around the state including DNR programs, UW Extension, UWM WATER Institute, UW Sea Grant, Wisconsin Coastal Management Program, county health departments, and Centerville Cares – a citizen organization in Manitowoc County.

The working group developed a monitoring program for the summer of 2004 to observe the density, distribution, and associated water quality of *Cladophora* along Wisconsin's Lake Michigan shoreline. This investigation was intended to test sampling techniques and inform long term monitoring plans and research needs.

Methods

Sampling sites were systematically chosen along Wisconsin's Lake Michigan shoreline at every other township boundary, 12 miles apart (See Figure 1). These 16 sites were sampled in June and late August/early September. At each location, water samples were taken at the 2 m and 10 m depth contour. At the 2 m depth contour samples were taken 1 m below the surface. At the 10 m depth contour samples were taken 1 m below the surface and 1 m above the bottom. Samples were analyzed for chlorophyll-a, total Kjehldahl nitrogen, ammonia, nitrate, total suspended solids, total phosphorus, total dissolved phosphorus, and soluble reactive phosphorus. These data were compared with historic nearshore water quality data from EPA monitoring in 1963 and 1974 and Milwaukee Metropolitan Sewage District monitoring from 1980 to present.

In addition to water quality sampling, a survey of *Cladophora* distribution and density was conducted. In June at each sampling location at 2 m, 4 m, 6 m, 8 m, and 10 m depth contours the bottom substrate, percent cover, and zebra mussel presence were noted. At most locations an underwater video camera was used to observe the bottom. Initially Door and Kewaunee sampling locations were observed using an aquascope, which proved to be inadequate for bottom observation. Two sites, in Door and Kewaunee counties, were revisited in mid July and resurveyed using an underwater video camera. In September, the distribution and density survey was repeated at 2 m and 10 m, and a 15 m depth contour survey was added. Alga samples were

also collected as part of the September monitoring at each sampling location and identified to determine what taxa other than *Cladophora* were present.

Beach monitors, as part of their monitoring of E. coli concentrations in beach water for the federal BEACH Act, noted *Cladophora* accumulation on Lake Michigan beaches for all except Kenosha County beaches and three Milwaukee County beaches. Beach monitors recorded data from a fixed sampling location 1-5 times per week between Memorial Day and Labor Day. They rated *Cladophora* accumulations on a scale of none, low, moderate and high using a picture scale distributed by the DNR prior to the 2004 beach monitoring season. These observations of alga accumulation were analyzed to determine the percentage of days with moderate and high alga accumulation on monitored Lake Michigan beaches.

Results

Minimum, maximum, median concentrations and percent of samples below the detection limit for each water quality variable are reported in Table 1. In June, total phosphorus ranged between <0.005 and 0.018 mg L^{-1} with a median of 0.009 mg L^{-1}. In September, total phosphorus ranged between <0.005 and 0.046 mg L^{-1} with a median of 0.006 mg L^{-1}. One outlying total phosphorus concentration measured in 2004, 0.046 mg L^{-1}, was from a sample off northern Sheboygan County south of Hika Bay during the algae sloughing period in early September. This higher concentration, in relation to other values observed, is likely due to the abundance of decomposing algae present in the water. The corresponding elevated SRP (0.025 mg L^{-1}) is consistent with this hypothesis.

	TSS	**Chlor-a**	**TKN**	**NH_3-N**	**NO_3-N**	**TP**	**TDP**	**SRP**
				--June--				
Min	<2	<0.28	<0.14	<0.015	0.155	<0.005	<0.005	<0.002
Max	7	4.58	0.97	0.042	0.368	0.018	0.012	0.005
Median	<2	0.70	0.23	<0.015	0.270	0.009	0.005	<0.002
% Non-detect	89	9	19	69	0	27	40	81
				--September--				
Min	<2	<0.28	<0.14	<0.015	0.183	<0.005	<0.005	<0.002
Max	17	1.80	0.34	0.129	0.327	0.046	0.026	0.025
Median	<2	0.56	<0.14	<0.015	0.249	0.006	<0.005	<0.002
% Non-detect	56	32	54	74	0	18	85	74

Table 1. Lake Michigan nearshore nutrient concentrations measured 6/22/04 – 6/29/04 and 8/25/04-9/2/04. All concentrations are reported in mg L^{-1}.

Paired signed rank tests for significant different between the surface samples at 2 m and 10 m depth contours, between the surface and bottom samples at the 10 m depth contour, and between the June and September were conducted (see Table 2). These results show higher concentrations of particulate related water quality variables, i.e. total phosphorus, Kjeldahl-nitrogen, total suspended solids, in the shallower water. No significant difference was observed between the surface and bottom samples at 10 m except for nitrate-nitrogen. Higher concentrations of nitrogen species and total dissolved phosphorus were observed in June than in September. Total phosphorus was also found to be higher in June than in September when compared between samples taken from the Illinois border to Kewaunee.

Comparison	TSS	Chlor-a	TKN	NO_3-N	TP	TDP
2 m surface vs. 10 m surface	**0.0003 (2 m)**	0.076	**0.03 (2 m)**	**0.008 (10 m)**	**0.001 (2 m)**	0.11
10 m surface vs. 10 m bottom	0.62	0.25	0.17	**0.048 (bottom)**	0.86	0.56
June sampling vs. Sept. sampling	**	0.077	**0.0001 (June)**	**0.0001 (June)**	0.059 Illinois	**0.038 (June)**

Table 2. Paired signed rank test for Lake Michigan nearshore water chemistry concentrations measured 6/22/04 – 6/29/04 and 8/25/04-9/2/04. Values in bold are considered significant ($P \leq 0.05$). The grouping with the statistically greater value is listed below the P value. **indicates insufficient data. NH_3 and SRP are not included because of insufficient data.

The subsequent analysis of the water chemistry results focuses on nitrate-nitrogen and total phosphorus, because these variables had low rates of non-detection. Figures 1 and 2 display the nitrate-nitrogen and total phosphorus concentrations measured at each sampling location along Lake Michigan.

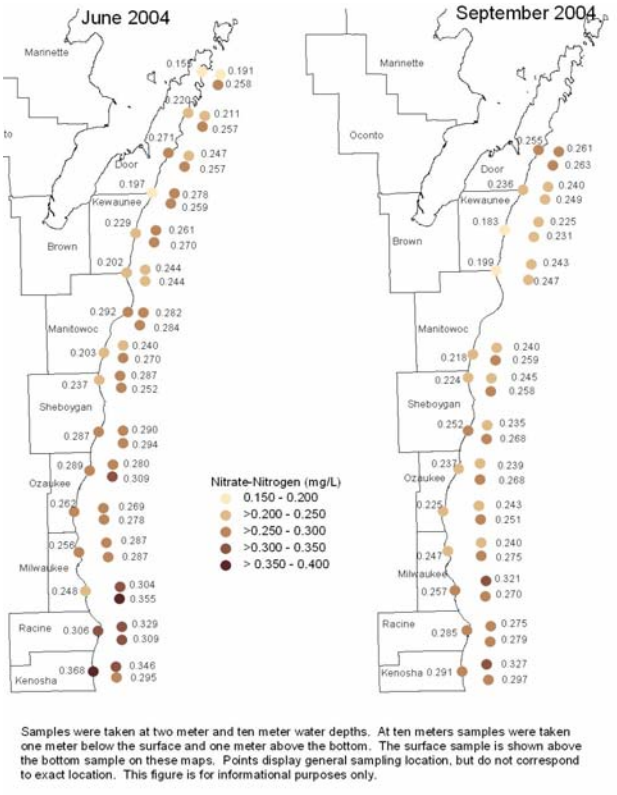

Figure 1. Geographic distribution of nitrate-nitrogen concentration reported as mg L^{-1} in June and September 2004.

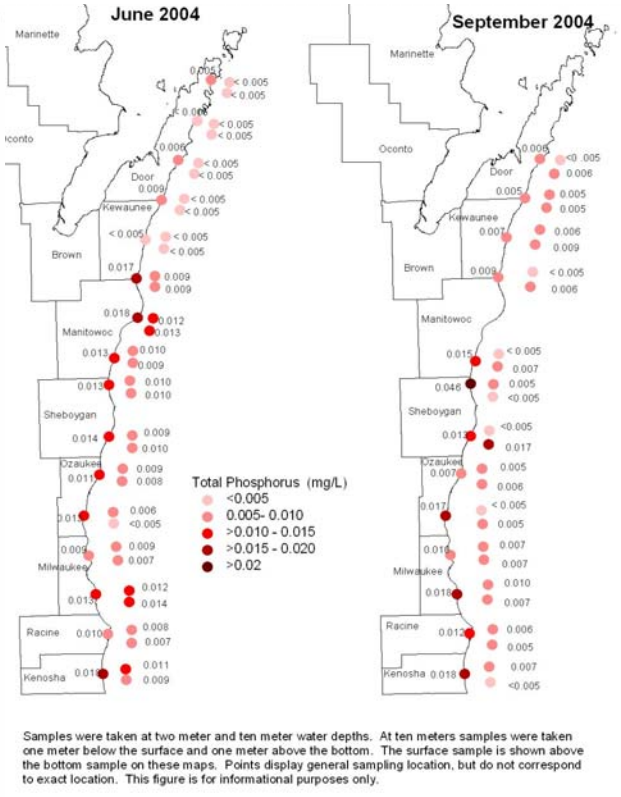

Figure 2. Geographic distribution of total phosphorus concentrations reported in mg L^{-1} in June and September 2004.

Nitrate-nitrogen and total phosphorus showed decreasing trends from south to north (Figure 3).

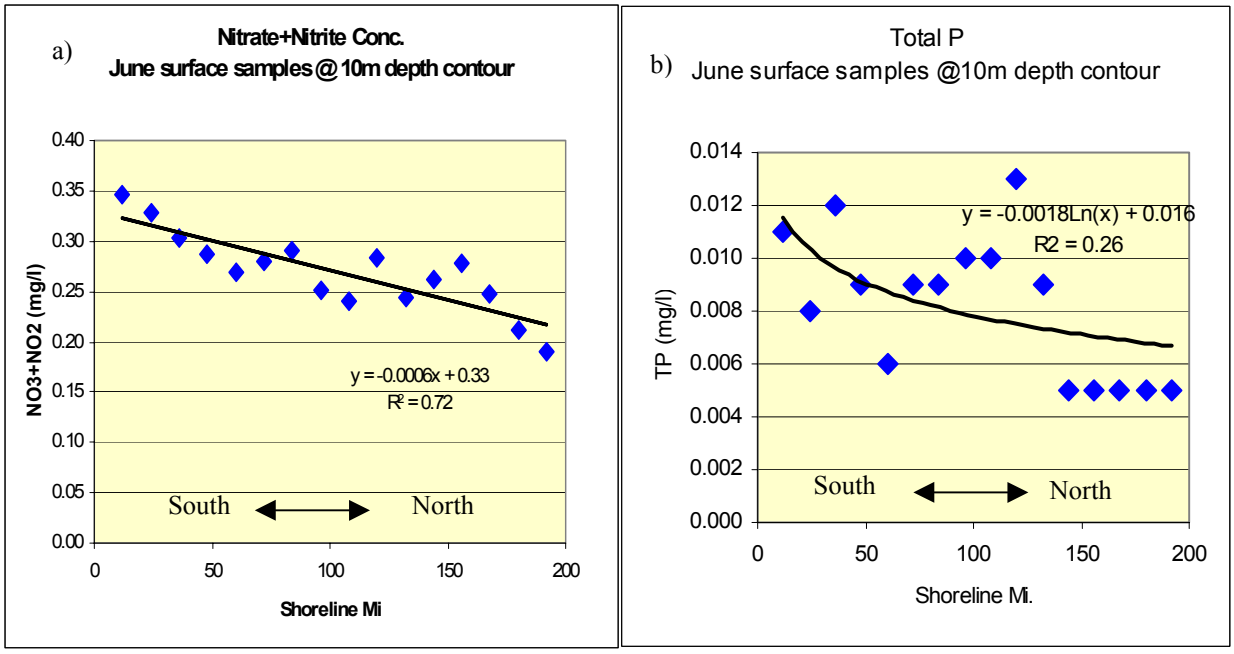

Figure 3. a) Nitrate-nitrogen shows a decreasing trend from south to north in the June surface samples at the 10 m depth contour. June and September results from the 2 m, 10 m surface, and 10 m bottom samples all show a similar trend. b) Total phosphorus shows a decreasing trend from south to north in the June surface sample at the 10 m depth contour. June samples from 2 m, 10 m surface, and 10 m bottom samples and September samples from 2 m and 10 m surface samples all show the same trend. The September 10 m bottom sample shows no trend.

A comparison of nitrate-nitrogen and total phosphorus concentrations observed in 2004 with historic data from Ozaukee, Milwaukee, Racine and Kenosha counties show no increasing or decreasing trends (Figure 4).

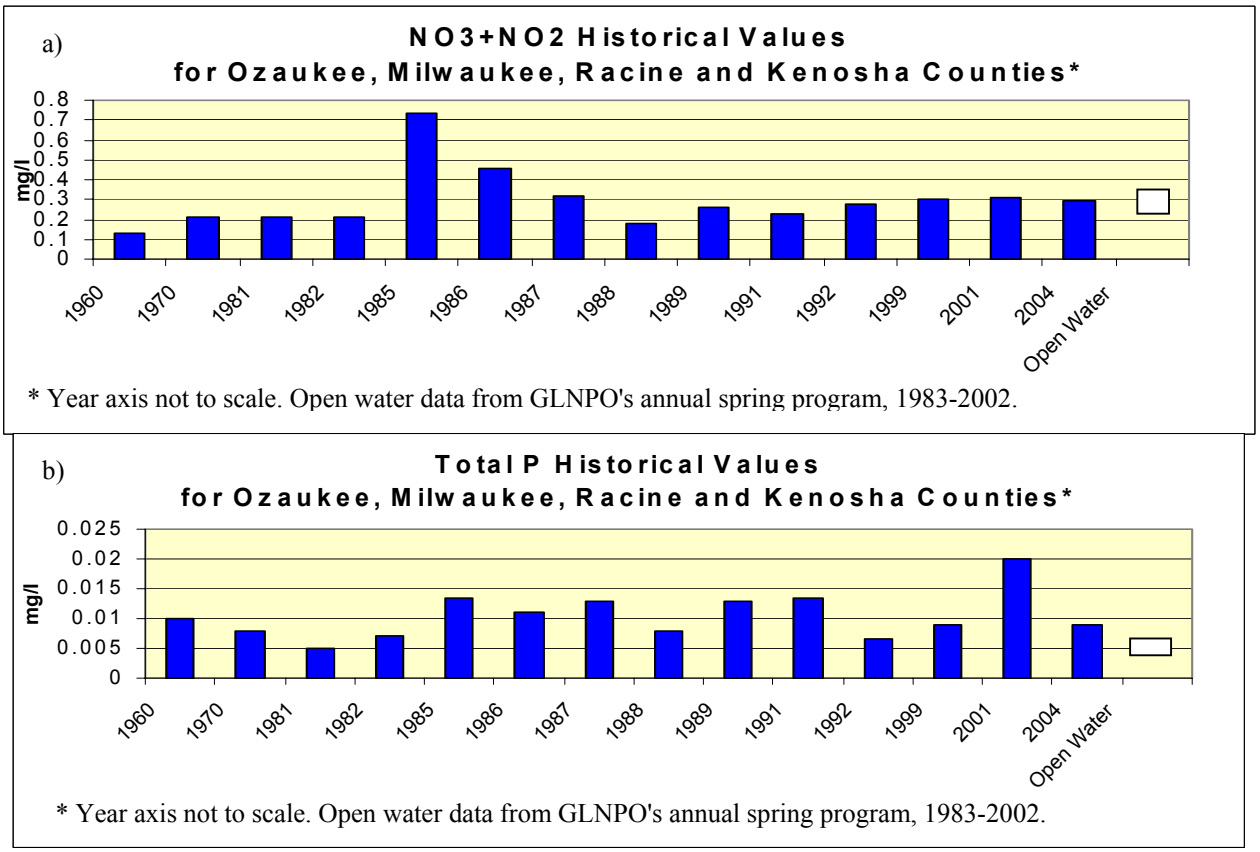

Figure 4. a) Historic nitrate-nitrogen concentrations. b)Historic total phosphorus concentrations. Data from USEPA STORET, MMSD, and 2004 DNR Lake Michigan sampling.

The distribution of *Cladophora* observed during the survey is reported in Figure 5. *Cladophora* coverage is dependent on substrate, with greater than 80% coverage in areas with rock substrate and less than 10% coverage in areas with sand substrate.

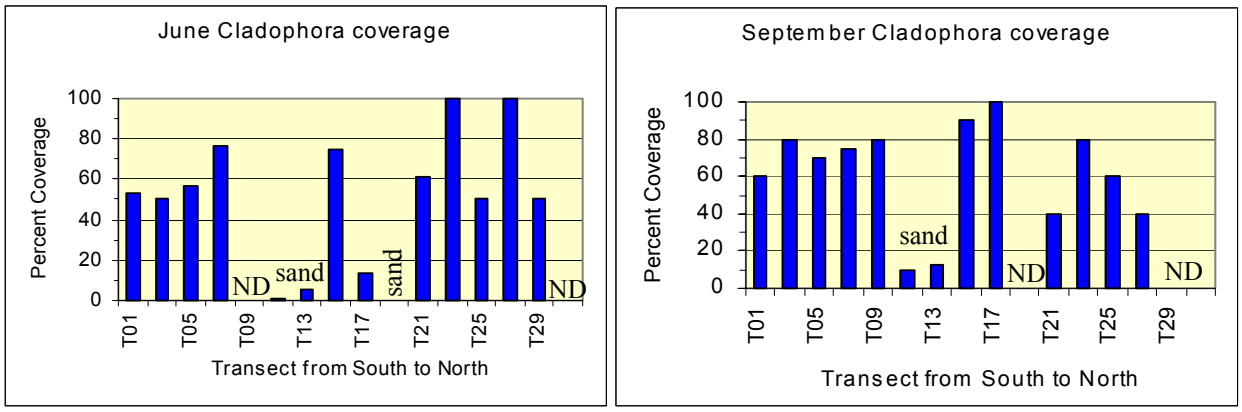

Figure 5. Average percent coverage of *Cladophora* on transects conducted along Wisconsin's Lake Michigan shoreline in June and September. (ND = no data)

Identification of the algae samples collected with the September monitoring indicated that *Cladophora* was the predominant filamentous algae at most survey sites. *Dichotomosiphon*

and *Tolypella* were also identified as important filamentous algae at a few sites. While hard substrate is critical for *Cladophora* growth, in Door County *Tollypella* was observed growing abundantly in some locations (such as Lily Bay) in soft sediment. Taxa other than *Cladophora* appear to be a significant component of the nuisance alga problem in Door County, however green algae growth in soft sediment was not observed outside of Door County. Zebra mussel presence or absence was often difficult to note using an underwater video camera due to complete coverage of hard surfaces by algae growth.

Analysis of the monitoring data from the BEACH ACT program shows that 45 of 66 Wisconsin Lake Michigan beaches had moderate to high accumulations of *Cladaphora* on the beach less than 20 percent of days monitored between Memorial Day and Labor Day. Two beaches in Milwaukee County and one in Door County had moderate to high accumulations more than 60% of days monitored (Table 3).

Percentage of Season Affected by Moderate to High to Algae Onshore	**Number of Beaches**	**Beach Locations and Names**
> 60	3	McKinley Beach, Bradford Beach - Milwaukee; Newport Bay Beach - Door
>40 – 60	5	Door (4) and Kewaunee (1)
>20 – 40	13	Ozaukee (1), Milwaukee (1), Manitowoc (1), Kewaunee (1), Door (7), Brown (2)
≤ 20	45	All Counties

Table 3. Percentage of summer monitoring season nuisance algae was present in moderate to high quantities on Wisconsin's Lake Michigan beaches.

Discussion

The results of the survey conducted by the DNR indicate that *Cladophora* growth is abundant along Wisconsin's entire Lake Michigan shoreline. Local differences in *Cladophora* abundance appear to be most likely due to differences in percentage of hard substrate. The 2004 nearshore phosphorus and nitrogen species concentrations are low. Median phosphorus concentrations were 0.009 mg L^{-1} in June and 0.006 mg L^{-1} in September. By comparison the long term (1988 – present) median total phosphorus concentrations in Lake Michigan tributaries Kewaunee River, Manitowoc River, Sheboygan River and Milwaukee River are 0.090, 0.168, 0.120, and 0.140 mg L^{-1}, respectively. This comparison shows that the nearshore concentrations are an order of magnitude lower than the tributary concentrations. Examination of the historic data from 1963, 1974, and 1980-present collected along Wisconsin's southern nearshore area shows no distinct trend over time for total phosphorus and nitrate-nitrogen concentrations. The 2004 nearshore phosphorus and nitrogen species concentrations are within the range of variability observed in historic data sets. Not surprisingly, because of near-shore particulates, the total phosphorus concentrations are slightly lower, approximately 0.004 mg L^{-1}, in the open water region of the lake.

Generally a decreasing trend from south to north in June and September of total phosphorus and nitrate concentrations was observed at 2 m and 10 m surface sample sites,

however observations of *Cladophora* density did not follow this trend. In fact, the results of the BEACH Act program beach monitoring suggest that moderate to high accumulations of *Cladophora* were most frequently found on Door County and Milwaukee beaches. Note that the BEACH Act monitoring ends on Labor Day, yet *Cladophora* sloughing at the end of August make September a time of potentially high algae accumulation on beaches that is not captured by the beach monitoring data set. Further exploration of the hypothesis that *Cladophora* distribution is based primarily on the availability of hard substrate (rather than on local nutrient availability) is merited. In addition, analyses of alga tissue nutrient concentrations in future surveys are also recommended to further determine if there are distinct differences in nutrient availability along the Lake Michigan coastline that was not captured in the 2004 summer sampling. These results will be used to develop monitoring plans for 2005.

DNR *Cladophora* Work Group
Mary Gansberg, NER
John Masterson, SER
Jim Baumann, OGL
Linda Talbot, OGL
Gina LaLiberte, ISS
Shaili Pfeiffer, OGL
Steve Greb, ISS
Paul Garrison, ISS

Collaborators
DNR Northeast Region
DNR Southeast Region
DNR Integrated Science Services
Centerville Cares
DNR Beach Monitoring Program

Funding provided in part by Wisconsin DNR. Financial assistance for this project was also provided by the Coastal Zone Management Act 1972, as amended, administered by the Office of Ocean and Coastal Resource Management, National Oceanic and Atmospheric Administration pursuant to Great #NA03NOS4190106 and the Wisconsin Coastal Management Program.