Cladophora Abundance and Physical/Chemical Conditions in the Milwaukee Region of Lake Michigan

Overview - May 2005

Introduction

In the Milwaukee region of Lake Michigan there has been a recent resurgence of nuisance blooms of benthic algae, dominated by the filamentous green alga, *Cladophora glomerata*. Negative impacts of the excessive growth of this algae include unsightly and foul smelling beaches, potential health risks from bacterial growth, clogging of water intakes, impaired drinking water quality, decline in lakeshore recreational quality, and property depreciation (Figure 1). There may be additional ecological impacts within the lake, though these have not been well documented.

Figure 1. *Cladophora* accumulation along the north shore of Bradford Beach - 2004

In response to nuisance algal blooms, including *Cladophora* blooms, in the Great Lakes between the 1950s and 1980s, phosphorus reduction programs were put in place. The decline in *Cladophora* that followed the reduction of phosphorus inputs suggested that phosphorus control was the key to algal control, and that nutrient abatement measures

This summary is derived from research conducted by Dr. H Bootsma and colleagues of the University of Wisconsin-Milwaukee Great Lakes WATER Institute. Support and funding of this research was from the Milwaukee Metropolitan Sewerage District (MMSD Contract # M03002P15)

were having the desired effect. However, the fact that *Cladophora* abundance has recently increased, while phosphorus inputs have reportedly continued to decrease, raises uncertainties about whether the phosphorus limitation paradigm remains applicable. The cause(s) of the current resurgence in *Cladophora* abundance are not obvious.

Purpose of Cladophora Study

The Milwaukee Metropolitan Sewerage District (MMSD) is in the midst of a Facilities Planning effort for the year 2020. This planning effort is utilizing a comprehensive watershed-based approach to evaluate questions and provide answers regarding the impacts to water quality and the benefits of potential improvements to the MMSD's wastewater collection, conveyance, treatment and watercourse systems. The 2020 Facilities Planning effort will need answers to questions that deal with a broad range of water quality issues, including those of nuisance algal growth in area waterways. Currently there is public concern regarding nuisance growth of the filamentous green alga, *Cladophora sp*., along Milwaukee's lakeshore. Excessive growth of this algae results in aesthetic degradation of beaches and other shorelines, potential health risks, clogging of water intakes, and alteration of the Lake Michigan nearshore ecosystem. In order to assess the magnitude of the *Cladophora* problem in the Milwaukee region, and to determine potential causes of the problem, a field study was conducted from October 2003 to October 2004. The primary objective of this study was to collect baseline data on the abundance and distribution of *Cladophora* in the Milwaukee region of Lake Michigan, and to gain insight into the potential factors responsible for the recent increase in *Cladophora* abundance.

Specific objectives of the study were:

1. To obtain quantitative data on the in-lake biomass and nutrient composition of *Cladophora,* and the influence of nutrient (nitrogen and phosphorus) inputs on these properties.

2. To evaluate the role of nearshore currents as a potential factor influencing the distribution of nutrients and *Cladophora*.

3. To assess the potential role of the zebra mussel (*Dreissena polymorpha*) in promoting *Cladophora* growth.

4. To provide a database on *Cladophora* abundance and nutrient content that will both facilitate the development of management targets and allow for an assessment of the efficacy of any implemented management strategies.

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Preliminary Findings

The Temperature Effect - The results of this study provide strong evidence that *Cladophora* growth in the Milwaukee region of Lake Michigan is phosphorus limited. However, light and temperature are also major factors influencing *Cladophora* growth. Prior to May and after October, nearshore lake temperatures are too low for *Cladophora* to grow. Between July and September, temperatures are frequently optimal for *Cladophora*, although temperatures fluctuate greatly as a result of lake internal waves.

An analysis of historic temperature records indicates that the average nearshore temperature has risen by approximately 3^{o}C in the past 30 years (Figure 2). As a result, the duration of time during which nearshore temperatures are optimal for *Cladophora* growth has increased.

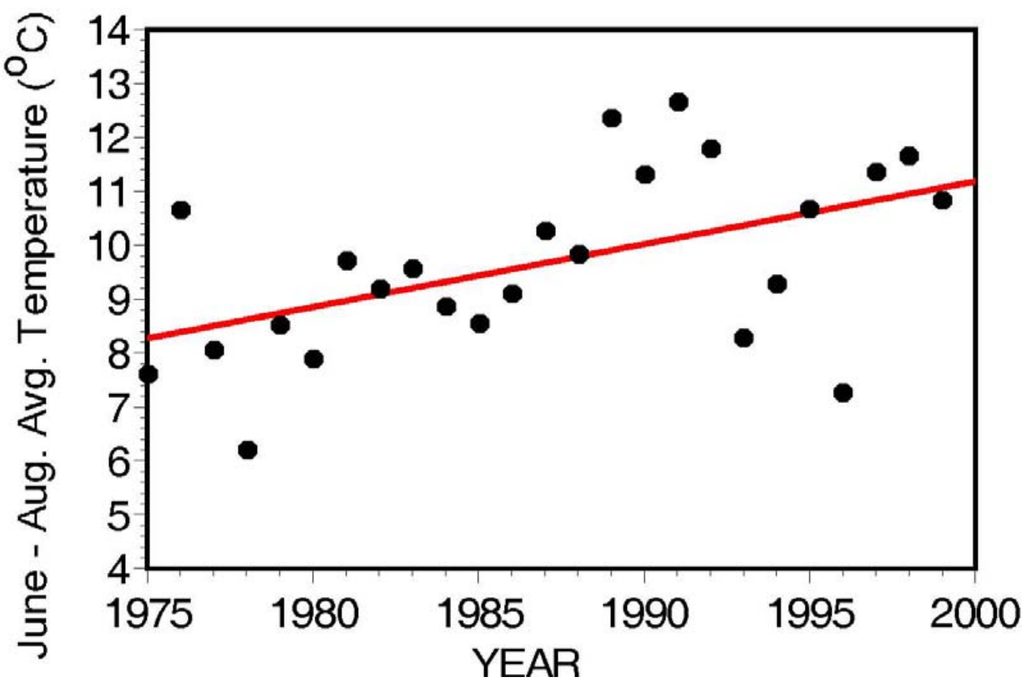

Figure 2. Temperature trend increase for the Milwaukee nearshore area from 1975 to 2000 (data provided by Milwaukee Water Works - Linnwood Water Filtration Plant). Data are for measurements of water drawn from a depth of ~15 m.

The Effect of Water Clarity - Historic analysis reveals that nearshore water clarity has also increased, most likely due to the filtration of water by zebra mussels (Figure 3). Data collected in 2003 indicate that water clarity has a strong influence on light levels on the lake bottom, where *Cladophora* grows. *Cladophora* is currently found in large quantities to depths of at least 10 meters (33 feet). While there are little historic

Cladophora data, a comparison of underwater light levels with *Cladophora* light requirements indicates that the depth range of *Cladophora* is currently about twice what it was in the early 1990s. In addition, *Cladophora* that was always present at shallower depths can now grow at faster rates, due to increased light availability.

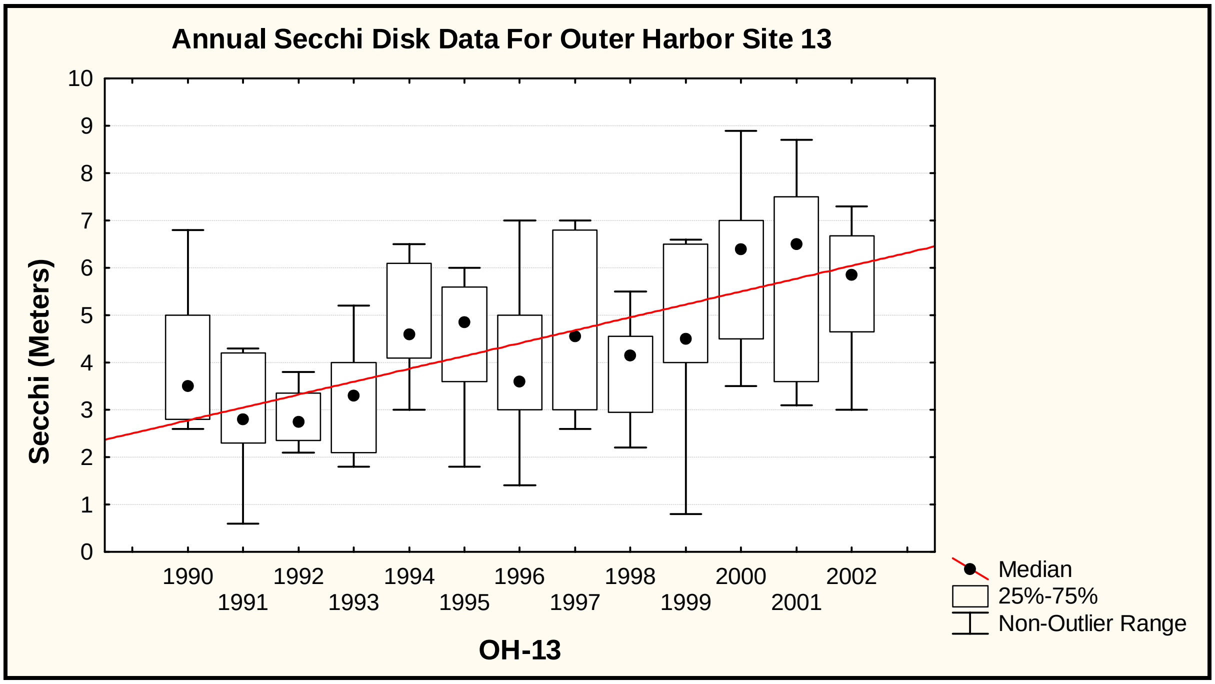

Figure 3. Temporal trend of secchi disk depths measured just south of Milwaukee, 2km offshore (Z_{max} = 10 m). Water transparency has increased since the early 1990's (data provided by Milwaukee Metropolitan Sewerage District).

The Effect of Phosphorus - A comparison of *Cladophora* abundance and nutrient content with ambient dissolved nutrient concentrations in the Lake Michigan nearshore area suggests that dissolved phosphorus concentrations are not sufficient to support the observed biomass of *Cladophora*. This suggests that there is a benthic (lake bottom) source of phosphorus. The results of both in-lake studies and experimental work suggest that zebra mussels are the likely source of this phosphorus. From a management perspective, an important question to answer is whether zebra mussels ultimately derive their phosphorus from the lake's internal pool in the form of plankton, or from suspended particulate material delivered to the lake from rivers. Mass balance calculations indicate that both of these sources are potentially important, depending on the time of year.

Spatial patterns of nearshore currents, phosphorus distribution, and *Cladophora* nutrient content indicate that the discharge of phosphorus from rivers through Milwaukee Harbor likely has some influence on *Cladophora* growth. However, estimated *Cladophora*

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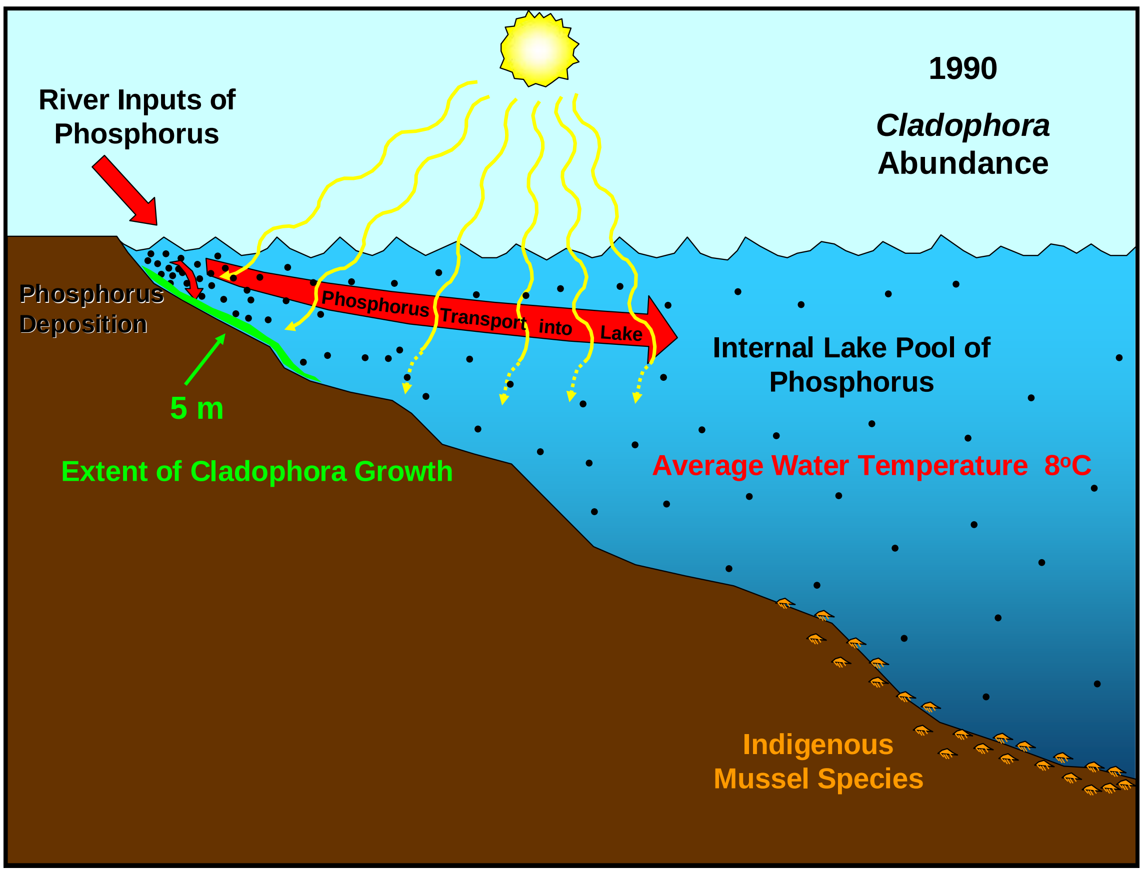
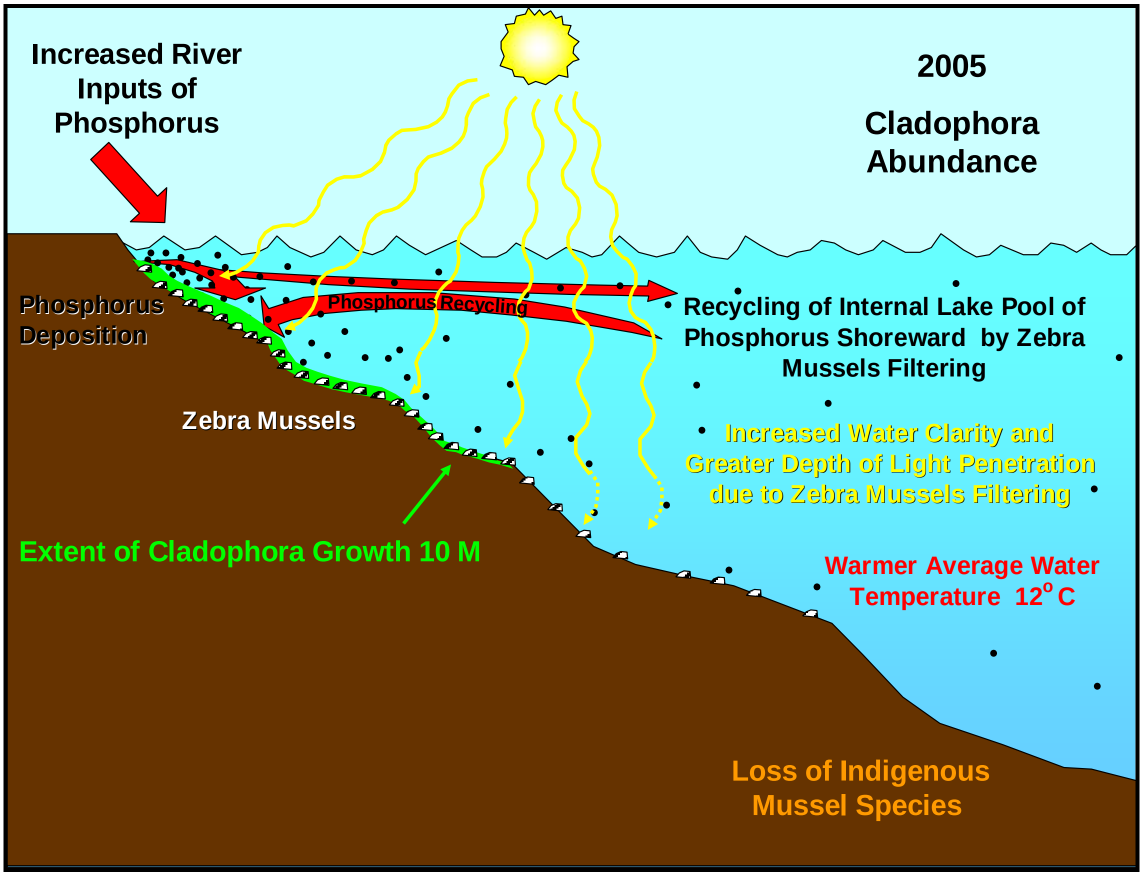
phosphorus demand is greater than phosphorus input from rivers, and therefore a substantial portion of *Cladophora* production must be supported either by the in-lake phosphorus pool or by efficient nearshore recycling of phosphorus delivered by rivers.

Based on the results of this study, the recent resurgence of *Cladophora* in the Milwaukee area of Lake Michigan appears to be a result of the combined effect of increased light availability, increased summer nearshore temperatures, and increased phosphorus availability; possibly related to the colonization of the nearshore waters by the invasion zebra mussels to the Great Lakes. The connection between *Cladophora* growth, the increase in light availability and water temperatures together with the appearance of zebra mussels in the mid-1990's has changed both the nutrient dynamics and ecology of the nearshore lake zone. These interactions and relationships are illustrated in Figures 4 and 5.



***Cladophora* growth in early-1990's**

Figure 4. A depiction of factors influencing *Cladophora* growth in early-1990's in the absence of large numbers of zebra mussels. It is hypothesized that a significant fraction of phosphorus inputs from the river system became part of the Lake's internal pool of phosphorus and unavailable for *Cladophora* growth.



***Cladophora* growth in 2005**

Figure 5. A depiction of factors influencing *Cladophora* growth in 2005. The influence of large numbers of zebra mussels are seen in increased water clarity and light availability. It is hypothesized that a significant fraction of phosphorus inputs from the river system that was part of the Lake's internal pool of phosphorus is now being recycle shoreward by zebra mussels filtering and excretion thereby becoming available for *Cladophora* growth.

Because it is not possible to control light or water temperature, any management strategy to control *Cladophora* growth must focus on managing sources of phosphorus. The two most likely sources of phosphorus that fuel *Cladophora* growth are direct river inputs and phosphorus recycled by dreissenid mussels (zebra and quagga mussels). The relative importance of these two sources of phosphorus must be quantified in order to develop effective management strategies.

Current concentrations of phosphorus found in *Cladophora* tissues indicate that further increases in phosphorus availability could result in even more *Cladophora* growth. Conversely, small reductions in phosphorus availability may result in significant reductions in *Cladophora* growth as indicated by the growth response curve to internal phosphorus content shown in Figure 6.

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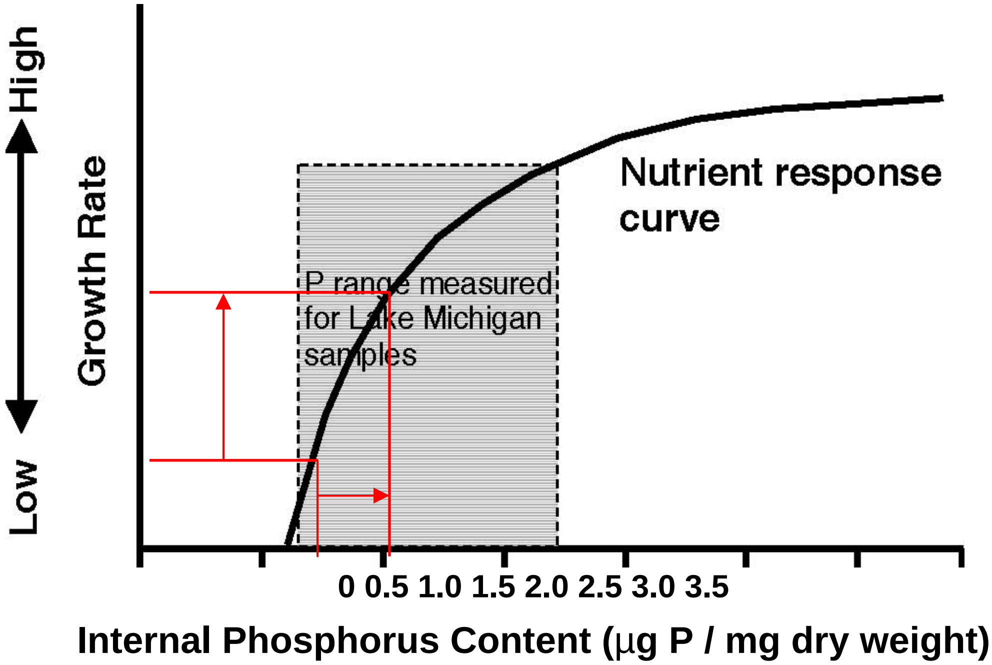

Figure 6. Phosphorus content of Lake Michigan *Cladophora* as measured in this study (shaded) compared with experimentally determined relationship between *Cladophora* phosphorus content and growth rate (Auer and Canale 1982b). Further increases in phosphorus availability could result in even higher *Cladophora* growth rates as illustrated above by distance between the red lines along the nutrient response curve.

Next Steps - Critical information required for the formulation of a *Cladophora* management strategy includes a quantitative evaluation of the relative importance of river-borne versus in-lake phosphorus sources for zebra mussels (which in turn provide phosphorus to *Cladophora*), and an evaluation of the potential impact resulting from the on-going establishment of quagga mussels (another invasive mussel species), which have the potential to cover larger areas of lake bottom than zebra mussels.

In addition, a revision of a previously developed *Cladophora* growth / abundance model, to account for phosphorus inputs from zebra mussels, will allow for a quantitative assessment of the relative importance of light, temperature and phosphorus as factors promoting *Cladophora* growth. Such a model will also help to predict the benefits of various management options. In the short term, a better understanding of the mechanisms causing *Cladophora* sloughing (detachment from the lake bottom) will allow for better prediction of the times and locations of *Cladophora* accumulation on beaches. This information will also improve the accuracy of a *Cladophora* growth / abundance model.

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