Cladophora in the Great Lakes: State of the Research

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Presentation Abstracts

Linking *Cladophora* research to public outreach and action

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As nuisance algae continue to foul Lake Michigan shorelines, citizens and interest groups have stepped up calls for mitigation. Considerable ongoing research provides new insights about the causes and consequences of prolific algae production. Transferring research results to affected property owners, resource managers, and decision-makers is critical to public understanding and the development of effective mitigation strategies and policies. Current *Cladophora* outreach in Wisconsin and future needs will be reviewed in preparation for discussion sessions during the workshop. Reducing phosphorus loading to nearshore zones and removing algal mats from affected shores are the present focus of management plans and actions. For example, a Fox River basin Total Maximum Daily Load (TMDL) allocation for total phosphorus (TP) and total suspended solids (TSS) is underway to remediate eutrophication in lower Green Bay and reduce the single largest tributary source of TP to Lake Michigan by 40%. Results from this TMDL and other watershed plans reveal that TP reductions in the Great Lakes basin are feasible but will require concerted efforts to address multiple point and nonpoint sources from numerous watersheds.

Linking *Cladophora* growth to mussel metabolism and nearshore hydrodynamics

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The resurgence of *Cladophora* in Lake Michigan has coincided with the establishment of dreissenid mussels in the lake, and it has been hypothesized that mussels have been instrumental in promoting *Cladophora* growth. We evaluate this hypothesis by using a numerical model to simulate *Cladophora* growth under pre- and post-mussel conditions. Model simulations suggest that the primary cause of increased algal production is the increase in water clarity resulting from filtration by dreissenids. However, *Cladophora* are only able to take advantage of increased water clarity because of the supply of dissolved P from mussels. To better understand the relationship between mussels and *Cladophora*, we have developed a mussel model that simulates P excretion as a function of food supply, mussel population structure, and temperature. Simulations with the linked *Cladophora* and mussel models indicate that mussel P excretion results in a higher optimal growth temperature for *Cladophora*. Ultimately, mussel P excretion is limited by food supply, which is driven to a large extent by nearshore-offshore mixing. Better measurements of horizontal mixing are required to assess the impact of mussels on *Cladophora* growth in the nearshore zone and plankton abundance in offshore waters.

Can algal community structure within washed up *Cladophora* masses be used to determine the source and size of future events?

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Mats of *Cladophora* sp. and associated algae have become a nuisance by washing onto swimming beaches along the Great Lakes. We looked at the algal community structure of several large *Cladophora* "wash-up" events along beaches in Door County (Wisconsin, USA). Each "wash-up" event was sampled each day for three days. Each day 5 composite samples were taken across the extent of the beach. Each sample was homogenized and examined under a microscope. Parameters measured include, average *Cladophora* length, frequency of *Cladophora* branches, the amount of epiphytes attached to *Cladophora* cells, the "health" of *Cladophora* chloroplasts, the relative abundance of other filamentous algae, and the species composition of the epiphytic diatoms. Using Correspondence Analysis we will determine which factors (if any) are best for identifying discreet *Cladophora* wash-up events. These indices could then be used to identify the source of these algal mats and therefore help us predict their occurrence and size. Preliminary data will be discussed.

Spatial and temporal variability of bacterial content in *Cladophora* mats in Lake Erie beach waters of Presque Isle State Park

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In recent years, frequent closings of the twelve public beaches of Presque Isle State Park in Erie, Pennsylvania have negatively impacted the use of these beaches for recreational use. While it is known that the cause for the beach closings are high bacterial levels in the beach water, the cause of high bacterial concentrations on certain days and beaches has remained elusive. To test the idea that *Cladophora* mats may be involved in harboring and/or transporting bacteria to the beach waters of Presque Isle State Park, we monitored *Bacteroides* content using quantitative PCR in *Cladohpora* mats over nine days in July and August of 2007. Consistent with previous analysis of *Cladophora* mats, we found that all the samples analyzed were able to harbor bacteria. Interestingly, the spatial and temporal distribution of bacterial content in the mats were not random, but instead were higher in samples obtained from the western beach waters, which traditionally harbor more bacteria compared to the eastern beach waters. We also found temporal variability in bacterial content in *Cladophora* mats that correlated with the bacterial concentration in the beach waters tested. Together, our data presents a model that implicates *Cladophora* as a source of bacterial pollution and/or transport in this aquatic ecosystem.

Impact of *Cladophora* mats on *E. coli* concentrations in beach water in Door County, WI

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Large mats of the green alga, *Cladophora*, have made a resurgence in the past few years along the shores of Lake Michigan, and recent research suggests that these mats may harbor large amounts of the microbial water quality indicator, *E. coli.* If mats of *Cladophora* are able to provide conditions suitable for the increased survival of *E. coli*, it is possible that pathogens associated with the presence of fecal material are able to persist as well, posing an increased risk to swimmers in affected areas. While there are several researchers investigating questions related to the presence of *Cladophora* in the Great Lakes, this presentation will discuss both field and laboratory research projects being conducted by researchers at the University of Wisconsin - Oshkosh. The preliminary results from a new 3-year field study, undertaken in 2007, investigating the spatial impacts of *Cladophora* on surrounding beach water will be presented. Additionally, the results from a laboratory microcosm study on the survival of *Salmonella*, *Shigella*, and *Campylobacter* in the presence of *Cladophora* will also be presented. Laboratory microcosm research suggests that the potential for *Cladophora* to prolong the survival of *E .coli* may be much greater than its ability to prolong the survival of some associated pathogens. Field research indicates that while *Cladophora* mats may harbor large amounts of *E. coli* in the mat proper, in calm weather these mats may not be contributing greatly to surrounding beach water *E. coli* concentrations. In addition, bacterial pathogens may not be harbored within *Cladophora* mats in nature, placing *E. coli's* role as an indicator organism in question.

Genetic relatedness of *E. coli* and enteric bacterial pathogens (*Salmonella, Campylobacter*) associated with *Cladophora* in Lake Michigan

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The macrophytic green alga, *Cladophora,* harbors high levels of the fecal indicator bacteria, *E. coli* and enterococci, in nearshore water of Lake Michigan. The main objective of this study was to determine (a) the population structure and genetic relatedness of *Cladophora*-borne *E. coli* and (b) the potential enteric bacterial pathogens associated with *Cladophora. E. coli* isolates (*n*=879) were collected from *Cladophora* mats growing on rocks from a breakwater located between Lake Michigan and the Burns Ditch embayment at Ogden Dunes beach in Ogden Dunes, Indiana. The horizontal, fluorophore-enhanced rep-PCR (HFERP) DNA fingerprinting technique was used to determine the genetic relatedness of the isolates to each other and to those in a library of *E. coli* DNA fingerprints comprising wild and domesticated animals and humans. *E. coli* isolates from *Cladophora* showed a high degree of genetic relatedness (≥92% similarity); however, in most cases, the isolates were genetically distinct. Isolates collected from 2002 were different from those obtained in 2003. *E. coli* isolates associated with *Cladophora* represented a unique group, distinct from other *E. coli* isolates in the DNA fingerprint library tested. Bacterial pathogens, such as shiga toxin-producing *E. coli* and *Shigella,* were associated with *Cladophora* mats, but their numbers were low compared to *Salmonella* and *Campylobacter*. Furthermore, while genotypically-identical *Salmonella* isolates were associated with geographically and temporally-distinct *Cladophora* algae, *Campylobacter* isolates were genetically diverse. These results suggest that *E. coli* strains associated with *Cladophora* may be a recurring source of indicator bacteria to nearshore beaches and *Cladophora* is a likely secondary habitat for some pathogenic bacteria in Lake Michigan. The association of these enteric bacteria with *Cladophora* warrants additional studies to assess the potential health impacts to beach users.

Western Lake Michigan Nearshore Survey of Water Chemistry and Cladophora Distribution, 2004-2007

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The Wisconsin Department of Natural Resources has been sampling the Western Lake Michigan nearshore for the last 4 years. Samples have been collected two times a year, once during late summer and secondly, either spring or early summer. Samples were generally collected at 17 sites from Kenosha to the Fayette Peninsula of the UP. Four additional sites were sampled in central and northern Green Bay. Surface and bottom samples were generally collected at 10 m water depth for nutrients, water clarity, chlorophyll, light, dissolved oxygen, temperature, and a few other parameters. Samples were also analyzed for the productivity of the *Cladophora* community as well as its distribution. At a few sites biomass was estimated on a seasonal basis.

The phosphorus species concentrations generally decline from south to north to Washington Island and then are similar in the northern portion of the lake. In contrast, total nitrogen levels are generally similar from south to north, or perhaps decline slightly. The nitrate levels decline from south to north, but levels are similar from Door Peninsula and northern portion of the lake. These trends may reflect the extent of agricultural activity in the eastern watersheds of the state. The concentrations of total nitrogen and phosphorus are higher in Green Bay than on the lake side. The *Cladophora* productivity south/north trend doesn't seem to be related to nutrient trends. Unlike *Cladophora* in the eastern Great Lakes and Green Bay, the Lake Michigan population has a significant diatom community associated with it.

Algal Blooms on Lake Michigan – Implications for Beach Management

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Algal blooms have been implicated as contributing fecal indicator bacteria (FIB) to nearshore waters and harboring potentially pathogenic micro-organisms. The importance of these contamination sources and their relationship to beach closings must not be overlooked when devising beach management protocols.

Previous studies of *Escherichia coli* concentrations in algal mats at Racine, WI revealed counts capable of exceeding 25,000 cfu/g. Therefore, in 2004, a study was designed to correlate algal presence to the concentration of *E. coli* isolated from bathing waters. When the *E. coli* concentration was categorically ranked relating to *Cladophora* presence (low, moderate or high prior to next day removal) and subjected to independent group analysis no significant difference in the amount of bacteria was seen, regardless of the amount of algae noted at the beach ($p = 0.64$). Based on this analysis it would appear that algal presence, in the context of this study, may not have influenced *E. coli* content in surface water. This analysis was limited by the small sample number ($n = 27$) and better correlation may have been noted if the degrees of freedom were higher, i.e. more samples collected, or if the algal mats were allowed to remain and were repeatedly measured.

In 2007, intensive sampling (32 samples per day) was performed on a single algal mat over a period of four consecutive days, from formation to decay. *E. coli* concentrations were significantly higher in the algal mat and the surrounding water on day four than on day one, representing an increase of two orders of magnitude ($p < 0.001$). One presumptive isolate of *Salmonella* was identified. Allowing algal mats to remain in nearshore waters until the point of decay may have implications for beach management as well as explaining the previous lack of correlation between algal presence and FIB concentration in Racine.