

Discussion Forum: Reaching a Consensus on What is Known, and Setting Future Research Priorities

Erica B. Young and John A. Berges

Department of Biological Sciences, University of Wisconsin-Milwaukee

Introduction

Examining research into and management of *Cladophora* problems in the Great Lakes is complicated by the diversity of organizations and people involved, and the many different levels at which the issues can be approached. At the December 8, 2004 workshop, we closed the day with a relatively informal discussion session in order to survey and consolidate our present understanding of the problems, and to see if we could reach consensus about future research directions.

The discussion was organized around six major questions. In this summary, we provide a brief overview of the discussions and major points of consensus or dispute. In some cases, where points were raised by particular workshop participants, we have included their names in order to facilitate follow-up by readers of this report. In other cases, we have made reference to individual workshop presentations.

We have also provided a brief, annotated bibliography of sources in print and available on the web that are of potential use to readers.

1. What are impacts of *Cladophora* on ecosystem and human health?

Participants generally agreed that it is the aesthetics of the blooms that draws most attention, especially the odors from the rotting material, and the appearance on the shore and in the nearshore water. Such problems clearly have effects on property values, but they also affect tourism and recreational uses. While the effects of large quantities of *Cladophora* on the shore are obvious, much of the *Cladophora* probably settles deeper in the lakes; the effects of this biomass on the lake benthos are not known. It is also not clear if the decay of *Cladophora* blooms can affect oxygen levels and whether it is therefore implicated in fish kills.

Additional risks are posed by the tendency of blooms to clog water intakes. Such events can be quite serious. There have been power outages caused by fouling of power plants in Wisconsin, and shut-downs of nuclear power plants in Lake Ontario have been caused by *Cladophora* blooms (Hecky).

In terms of direct effects on human health, there is some evidence of increases in botulism due to decreases in O₂ levels in Lake Ontario, which may be related to *Cladophora* decay. It is clear that the moist, protected environment created by *Cladophora* mats could aid in survival of some pathogens on recreational beaches, though the real importance of this process is not known (Kleinheinz talk). The ability of *Cladophora* to take up and sequester heavy metals was noted (Sandgren talk) and there was speculation about the degree to which decaying *Cladophora* might release these toxic metals. This could also pose a problem for disposal of *Cladophora* after clean-operations. Curiously, there has also been interest in looking for bioactive compounds in marine *Cladophora* species (Ref. 10).

On the other hand, abundant *Cladophora* growth may have the potential to increase biomass of invertebrates by providing habitat and refuges. In turn, this may provide better resources for vertebrate predators. There is relatively little evidence of this, but some studies have demonstrated large increases in invertebrates associated with *Cladophora* growth (Pillsbury talk).

2. What is the magnitude of the current *Cladophora* problem relative to the past?

Participants agreed that this was difficult to assess and largely subjective. Lake Ontario had huge problems in the late 60's-70's, and Lake Erie problems peaked in the 1970's. In Lake Michigan, problems received considerable media attention in the 1960's. Wisconsin DNR files detail homeowners' and fishermen's concerns and include photographs of *Cladophora*-laden front-end loaders on beaches (circa 1968).

Current problems in Lake Michigan may be worse than in the past because they seem less localized to point sources (Auer). Effects of fouling on nuclear plants on Lake Ontario appear to be worse judging by increased frequency and intensity of breakdowns in the last few years (Hecky). In Lake Huron, problems seem to have become much worse since the dreissenid mussel invasions.

3. What do we know about the spatial distribution of *Cladophora* in Lake Michigan and other Great Lakes?

Large scale distributions of *Cladophora* are not known, and the correlation between regions of high *Cladophora* growth and shore deposition has not been established. The availability of a suitable, hard substratum for *Cladophora* is probably important, and might help explain why the Michigan shores of Lake Michigan are generally much less affected than the Wisconsin side. However, south-western Wisconsin and Lake Co. Illinois share similar substrata, yet Illinois's *Cladophora* problems are apparently less severe. Water clarity also plays a role; in Green Bay problems are much worse in the clearer northern part of the bay, as opposed to the southern areas where sediment loads are higher and there is more sediment resuspension. There are fewer obvious connections between nutrient point sources and areas of heavy *Cladophora* growth. Recently, aerial photography of shorelines has been attempted in Lake Michigan and this may provide a means to establish distributions on a wider scale (Janssen & Bootsma).

4. Is there evidence for the causes of the problems? Is it the same for all the Great Lakes?

In the past, nutrients, especially phosphorus were identified as the critical variable controlling *Cladophora*. Stoichiometric data does indicate that *Cladophora* in Lake Michigan is phosphorus-limited in most cases (Bootsma talk), and this may indicate that increased availability of phosphorus is the cause of recent problems. The source of this phosphorus is not clear. Budgets of P-loading to the lakes provides some evidence for higher P inputs by some Wisconsin rivers in the short-term, but it seems unlikely that rivers can provide all the P necessary to drive the blooms (Bootsma talk). It is important to recognize that there are large reserves of phosphorus in Great Lakes sediment, and

particular chemical processes control P-availability in Lake Michigan (Brooks); the extent to which these are driving the problems is unknown.

Another cause of the problems seems likely to be the dreissenid mussels (the zebra mussel, *Dreissena polymorpha*, and the quagga mussel, *D. bugensis*), now well-established in all the Great Lakes except Superior. Mussels filter-feed on plankton, increasing water clarity which favors growth of benthic algae. For example, there were large increases in Secchi depth on the western side of Green bay due to mussels in 1993-4 (Harris). In addition, by filtering P-containing particulate matter from the whole water column and excreting P near the bottom, they may effectively be enriching P in the benthic regions where *Cladophora* grows (Maybruck, Stankovich and Higgins talks).

It is also important to recognize that *Cladophora* growth by itself may not be the only cause of problems. From the late 1980's-1990's when the problems of shoreline *Cladophora* deposition apparently disappeared in Lake Michigan there is no evidence that *Cladophora* growth and biomass distributions changed. Instead, it may be that it is the mechanisms that control *Cladophora* losses and wash-ups on the shore that are relevant. Basic questions remain unanswered such as the factors that cause *Cladophora* to detach (physical stress, nutrient deprivation, substratum characteristics), and the best ways to assess the state of health of *Cladophora* populations (Young talk). There are reports of growth associated with dolomite and limestone substrate (Colorado streams), and in places such as Waukegan where bedrock dominates, algae are bleached-looking and easy to pull off. Because *Cladophora* attaches to mussels, detachment may relate to the state of the mussels as well as the algae (Davis-Foust & Janssen talk).

There is clear evidence of differences in *Cladophora* problems between lakes, for example, in seasonal patterns of growth and loss. A late summer die-off in *Cladophora* beds in Lake Ontario (Higgins) has not been clearly observed in Lake Michigan populations (Bootsma, Young, Berges). Moreover, epiphyte loads (mostly diatoms) on growing *Cladophora* are markedly higher in Lake Michigan (Bootsma, Young talks) than in Lake Ontario and Lake Erie.

5. What management strategies are possible and which are being applied?

Manual cleaning of washed-up *Cladophora* from the shore has been attempted in several cases (Stauffer talk), but it is labor intensive, and impractical on a large scale; the Lakes contain vast biomasses of *Cladophora*. There has been local success at harvesting from the shallow water by essentially 'corralling' the algae and using hydraulic pumping to remove it (Harris).

Other suggestions range from identifying beds from which *Cladophora* might detach and putting in some form of containment (e.g. 'snow-fence'-like netting; Pillsbury), or harvesting algae from the lake bottom using commercially-available machinery, as is done to prevent blooms in some marine systems (e.g. Po River estuary, Italy; Berges). Anecdotal evidence from fishermen suggests that trawl nets are effective in collecting *Cladophora*.

Use of chemical compounds was also discussed. Algaecides such as copper sulphate were used in the 70's in Lake Ontario but were not very successful. Participants doubted whether chemical treatment would be effective in large bodies of water and questioned whether environmental regulations would permit it in any case. Alternatively,

researchers at Clemson University (SC) are using test plots to examine whether application of enzymes could help to speed *Cladophora* degradation once on the shore and help avoid odour problems. In South Africa, there have also been attempts to find biological agents (bacteria, fungi) that could decrease growth or speed decomposition (Ref. 3).

Another strategy that might be effective would be to characterize the hydrodynamics of susceptible regions and use computer models to predict where detached *Cladophora* is likely to end up. With predictions, warnings could be given and clean-up efforts could be better organized and targeted (Ref. 5).

6. What are the priorities for future research?

Concerns were raised about the identity of the organisms responsible for the blooms. Macroscopically, *Cladophora* can be confused with other green algae such as *Ulothrix* and *Spyrogira* species. The current taxonomy of *Cladophora* itself is problematic, and we do not have a clear idea of which species (or even how many species) we are dealing with (Muller talk, Ref. 6). Since species can differ markedly in physiology, it is an open question whether differences observed between lakes and over time might relate to taxonomic differences.

More work is needed to assess P-inputs to lake systems, and the relative importance of point sources versus non-point sources. It is troubling that recent estimates of river P loading (USGS, Lake Michigan Mass Balance Program, Bootsma talk) to Lake Michigan differ by such large amounts. River discharges should be the simplest to quantify, but there may be autochthonous offshore sources of P as well. Deep waters may serve as a reservoir of P which can be introduced/regenerated in spring and thus feed the algal growth for the summer. One approach that has not been well-explored is the use of detailed comparisons of 'then vs. now' nutrient budget estimates to determine whether there have been changes over time that can be related to changes in *Cladophora* problems. It would also be wise to determine whether the existing water-treatment infrastructure is adequate for treating effluents and whether improvements to these systems (e.g. addition of storm-water treatment) are feasible and cost-effective.

In terms of benthic processes and the role of dreissenid mussels, it will be important to understand how P is incorporated in and regenerated from the benthos. We need clearer estimates of P excretion and cycling rates from dreissenids, and in particular whether the more recent invaders, quagga mussels, differ substantially from the zebra mussels in terms of processes such as excretion and production of pseudofaeces.

There is a clear need for better mapping of the spatial distribution of *Cladophora* between sites and within different lakes. Methods such as sonar mapping (Ref. 9) and spectral remote sensing (Ref. 8) should be considered in addition to aerial photography. Global Information System techniques could then be applied to determine relationships with substratum and known nutrient sources.

In terms of management options, better information about lake hydrography, coupled with hydrodynamic modeling will be essential in order to identify likely places for *Cladophora* to accumulate on shores, and thus to provide early warning and direct clean-up efforts effectively.

Participants felt strongly that coordinated work that uses similar approaches to study different lakes and lake/stream environments will be needed to improve our understanding of factors controlling *Cladophora*. For example, it may be significant that there are regular die-offs of *Cladophora* in August in Lake Ontario, but apparently not in Lake Michigan. Moreover, studies of *Cladophora* in river systems have significant advantages in terms of our ability to make manipulations.

Selected sources for further information on *Cladophora* and nuisance algal blooms

- (1) The U. Wisconsin Milwaukee-Great Lakes Water Institute *Cladophora* site. Basic overview and discussion of Lake Michigan issues. <http://www.uwm.edu/Dept/GLWI/cladophora/>
- (2) Ontario Water Works Consortium. Discussion of *Cladophora* issues in Lake Ontario and U. Waterloo research efforts.. <http://www.owwrc.com/AA.htm>
- (3) The Potential Biological Control Agents of *Cladophora glomerata* that Occur in Irrigation Schemes in South Africa Report No 669/1/99. Discussion of possible application of fungi and bacteria to reduce blooms in irrigation waters. <http://www.fwr.org/wrcsa/669199.htm>
- (4) Centre for Aquatic Plant Management, UK. Notes on chemical control of algae, including *Cladophora*. <http://www.rothamsted.bbsrc.ac.uk/pie/JonathanGrp/InformationSheets/Chemical%20control%20of%20algae.pdf>
- (5) Use of modeling for algal bloom prediction. Green algal blooms in Ortobello lagoon, Italy. http://www.iemss.org/iemss2002/proceedings/pdf/volume%20tre/355_marsilii.pdf
- (6) AlgaeBase website. Taxonomic overview of *Cladophora*, including nomenclature and literature references. http://www.algaebase.org/generadetail.lasso?genus_id=37&-session=abv3:44F904F21daa007C40yVi152753B
- (7) Bioaccumulation of metals in *Cladophora* in a refinery waste lagoon in Bratislavia, eastern Europe. http://jagor.srce.hr/ccaaa/CCA-PDF/cca2001/v74-n1/cca_74_2001_135-145_Chmielewska.pdf
- (8) Efforts to apply remote sensing: hyperspectral imaging of *Cladophora* in Lake Ontario . A. Vodacek, Rochester Institute of Technology. <http://www.cis.rit.edu/research/dirs/pages/embayment/>
- (9) National Oceanic and Atmospheric Administration's (NOAA) Delaware's experience with marine green algal blooms (in this case, largely *Ulva* species). Comments and protocols for benthic mapping using side-scan sonar. http://www.csc.noaa.gov/crs/rs_apps/issues/sb_ulva.htm
- (10) Possibility of bioactive compounds in algae (including *Cladophora*) being developed for pharmaceuticals. <http://chapmanlab.lsu.edu/digitalalgae/GulfAlgae/MMSBiotech.html>
- (11) Lake Ontario Algae Cause and Solution Workshop Proceedings. <http://www.monroecounty.gov/documentView.asp?docID=2351>

