The Interaction of Two Nuisance Species in Lake Michigan: *Cladophora glomerata* and *Dreissena polymorpha*

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The filamentous green algae *Cladophora glomerata* (L.) Kutz. and the zebra mussel *Dreissena polymorpha* (Pallas) are two of the most obvious nuisance species along the Milwaukee, WI portion of the Lake Michigan shoreline, as well as throughout much of the Laurentian Great Lakes. The biology of *C. glomerata* and *D. polymorpha* make them excellent coinhabitants of North American freshwater systems, including the littoral zone of Lake Michigan. *C. glomerata* reached nuisance levels along the Milwaukee, WI shoreline during the 1990's, soon after the introduction of zebra mussels into the Laurentian Great Lakes in 1985. Zebra mussels modify the benthic ecosystem through their filter feeding activity, which transfers nutrients from the water column to the benthos, and thereby promote changes that include altering the benthic flora and fauna. In order to determine if zebra mussels influence the growth of *Cladophora* by concentrating nutrients in the benthos, a laboratory experiment was initiated.

Past studies have not provided evidence of a mechanism for a direct link between zebra mussels and *Cladophora* growth. This study was designed to determine if the recent increase in *C. glomerata* growth in Lake Michigan is linked to enhanced nutrient availability caused by *D. polymorpha*. The objective of this study was to observe the affect of zebra mussel pseudofeces/feces, as well as soluble zebra mussel secretions/excretions, on the growth of *Cladophora*.

Live zebra mussels and *Cladophora* filaments were collected from the Milwaukee, Wisconsin shoreline, cleaned, and then maintained under laboratory condition of 18˚C and 35 µM photon•m^{-2}•s^{-1} of light. *Cladophora* filaments were incubated in the above conditions for 14 days in one of four treatments, each with nine replicates. The first treatment consisted of *Cladophora* in DYM algal growth (DYM) media that mimicked the chemical composition of Lake Michigan. This was used as the control when observing the affects of the ZMDYM treatment. The second treatment, Zebra Mussel DYM (ZMDYM), contained soluble zebra mussel secretions/excretions. The third treatment consisted of *Cladophora* in filtered *Chlorella* DYM (CHLDYM), and was used as the control when observing the affects of the PFDYM treatment. CHLDYM contained any soluble materials that may be found in DYM containing chlorella, which was used for zebra mussel feeding. Treatment 4 was *Cladophora* in Pseudofeces DYM (PFDYM), which was DYM that was supplemented with zebra feces and pseudofeces.

Cladophora biomass, tissue nutrients, and median nutrients were measured before and after the incubation to provide the following results.

Experiment determined that *Cladophora* grown in DYM media supplemented with soluble zebra mussel secretions and excretions grew at a faster rate than did *Cladophora* grown in straight DYM media (figure 1). This shows that in a small, closed environment, the presence of zebra mussels can increase the growth of *Cladophora*.

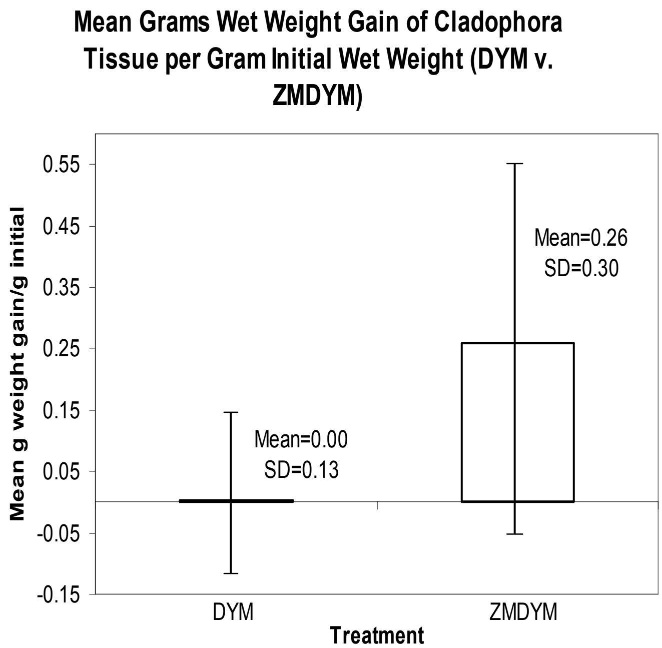

Figure 1. Mean grams wet weight gain of *Cladophora* tissue per gram initial wet weight over 14 days (DYM v. ZMDYM)

The nutrient analysis of the initial medium shows that the ZMDYM contains nearly twice the level of nitrate/nitrite as the straight DYM (22µM N vs. 14µM N, respectively) (table 1), and 11 times the level of SRP (11µM P vs. 1µM P, respectively) (table 2). This suggests that both the higher nitrate/nitrite concentration and higher soluble reactive phosphorus (SRP) concentration in the ZMDYM may have contributed to the increased growth.

Table 1. Concentration of nitrate/nitrite in media before experiment (µM)

	DYM	ZMDYM	CHLDYM	PFDYM
N of cases	3	3	3	3
Mean	14.526	22.078	15.060	15.504
Standard Dev	0.574	0.776	0.071	0.468

Table 2. Concentration of SRP in media before experiment (µM)

	DYM	ZMDYM	CHLDYM	PFDYM
N of cases	3	3	3	3
Mean	1.009	11.085	5.841	1.232
Standard Dev	0.008	0.149	0.006	0.071

In a broader view, these results suggest that in an open system, such as Lake Michigan, the presence of zebra mussels may increase the biomass of *Cladophora* in close proximity to mussel beds by increasing concentration of both available nitrogen and available phosphorus.

It was also determined that *Cladophora* grown in medium that was fertilized with pseudofeces/feces grew at a faster rate than *Cladophora* grown in medium which contained nutrients that may have solubalized from dried *Chlorella* as it was soaked in DYM (figure 2). This shows that under laboratory conditions such as those described here, the presence of zebra mussel pseudofeces/feces can increase the growth of *Cladophora*, even after correction for nutrients that may have been derived from un-ingested *Chlorella* in the container.

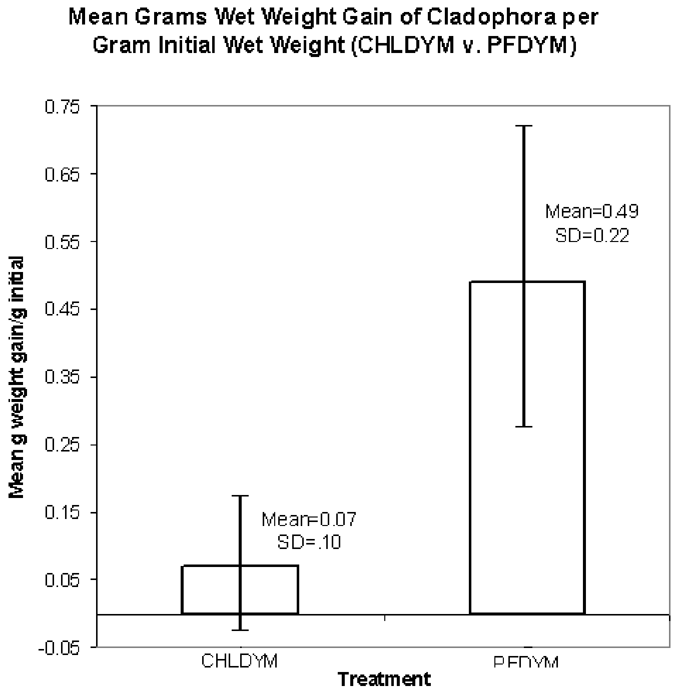

Figure 2. Mean grams wet weight gain of *Cladophora* tissue per gram initial wet weight over 14 days (DYM v. ZMDYM)

The nutrient analysis of the media showed that the initial PFDYM and CHLDYM contained similar levels of nitrate/nitrite (15 µM N each) (table 1), and the initial CHLDYM medium contained a higher level of SRP than did the PFDYM (5µM P vs. 1µM P) (table 2). These data do not suggest a reason for the increased growth in the PFDYM treatment versus the CHLDYM treatment, since the PFDYM media contained similar or lower levels of the nutrients analyzed.

These data suggest that in an open system, zebra mussel pseudofeces/feces can contribute to a fertilization effect on *Cladophora* in close proximity. At this time it is unclear as to which compounds from the pseudofeces/feces contributed by the zebra mussel are responsible for the observed affect. Nutrient analysis showed that dried *Chlorella* and pseudofeces/feces contained similar levels of carbon and nitrogen per unit mass (approximately 165 mg carbon/g sample and 82 mg nitrogen/g sample, respectively), although the dried *Chlorella* contained nearly twice the level of phosphorus as did the pseudofeces/feces (204 mg phosphorus/g sample v. 123 mg phosphorus/g sample, respectively). This suggests that the mucus that holds the pseudofeces together may contain high levels of carbon and nitrogen, and/or that the mussels could be assimilating a larger proportion of phosphorus than the other nutrients from the dried *Chlorella*, decreasing the proportion of phosphorus in their feces.

Analysis showed that the carbon and nitrogen levels in *Cladophora* were not significantly different between the straight DYM treatment and the treatment with DYM media supplemented with soluble zebra mussel secretions, or between the *Cladophora* grown in media that was fertilized with pseudofeces/feces and *Cladophora* grown in media which contained nutrients that may have solubalized from dried *Chlorella* as it was soaked in DYM. This can be explained by the fact that nitrogen levels in each of the treatments, 14.52 to 22.08 μM N, are near or above the 16 μM concentration of nitrate/nitrite that would limit the growth of *Cladophora* (Gerloff and Fitzgerald, 1976). *Cladophora* within each treatment was able to take up as much nitrogen as needed from the respective media.

In contrast to the carbon and nitrogen levels, tissue phosphorus levels were significantly higher in the ZMDYM treatment than the DYM treatment, and higher in the *Chlorella* DYM treatment than the PFDYM treatment. The levels found in the ZMDYM treatment versus the DYM treatment can be explained by the fact that the ZMDYM media, before addition to the experimental beakers, contained 11 times the SRP levels of the DYM. Some reasons for this can be phosphorus present in any of the secretion or excretions of the zebra mussels, or a slight contribution from the *Chlorella* used to feed the zebra mussels. Higher tissue phosphorus levels in the CHLDYM treatment versus the PFDYM can be explained by the fact that the initial CHLDYM media contained 5 times the level of SRP as the PFDYM. The reason for this could be that the zebra mussels integrated a higher proportion of phosphorus than the other nutrients from the dried *Chlorella*, and so there was less phosphorus in the pseudofeces/feces to contribute to a high media concentration of SRP.

Cladophora C:N:P ratios were also determined from the tissue nutrient analyses. The *Cladophora* grown in straight modified DYM media had a C:N:P ratio of 90:5:1, the *Cladophora* grown in DYM supplemented with zebra mussel excretions/secretions had a ratio of 50:3:1, *Cladophora* grown in DYM supplemented with solublized Chlorella nutrients had a ratio of 54:3:1, and the *Cladophora* grown in DYM fertilized with zebra mussel pseudofeces/feces had a ratio of 82:5:1. This indicates that *Cladophora* grown in DYM was able to integrate less phosphorus than the *Cladophora* grown in ZMDYM, although nitrogen levels were similar, and *Cladophora* grown in CHLDYM was able to integrate more phosphorus than did the *Cladophora* grown in PFDYM, although the tissue from these two treatments also contained similar levels of nitrogen. These tissue nutrient ratios appear to indicate that nitrogen may have been limiting in this experiment

These experiments have shown that, in a small, closed system, the presence of zebra mussel pseudofeces/feces and soluble secretions and excretions cause an increase in *Cladophora* biomass. This suggest that in a large, open system, such as near-shore regions of Lake Michigan, the introduction of zebra mussels during the late 20th century may have contributed to the increase in *Cladophora* biomass by concentrating nutrients in the benthos, in contrast to the period of high *Cladophora* during the 1960's, which was attributed to high phosphorus levels in the lake during that time. The results of the current study support the work of Lowe and Pillsbury (1995), who found that the presence of zebra mussels does increase benthic algal biomass in the Laurentian Great Lakes. As of 2004, no known control method has been developed to solve the *Cladophora* problem along the Milwaukee shoreline, and at this point, it is difficult to suggest any suitable mechanism to control *Cladophora* in a large water body such as Lake Michigan. Unless a control method is developed, the *Cladophora* problem is not expected to wane at any time in the near future.

References

Gerloff, G.C. and G.P. Fitzgerald. 1976. *The Nutrition of Great Lakes Cladophora*. United States Environmental Protection Agency report number EPA-600/3-76-044.

Lowe, R.L. and R.W. Pillsbury. 1995. Shifts in Benthic Algal Community Structure and Function Following the Appearance of Zebra Mussels (*Dreissena polymorpha*) in Saginaw Bay, Lake Huron. *J. Great Lakes Res*. 21(4):558-566.