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Impacts of *Dreissena polymorpha* on vertical mobility of *Campeloma* decisum, and susceptibility on shell morhphology

Abstract

Dreissena polymorpha, zebra mussel is an invasive species that alter aquatic ecosystem and can indirectly cause extinction in native invertebrate populations. As a result, they cause a lot of ecological and economic damage to the environment. The mussels recently appeared in Douglas Lake, MI. *Campeloma decisum*, a snail that is native to the lake, is getting colonized very rapidly. The purpose of this study was to figure out whether some snail characteristics make them susceptible to zebra mussels and to re-examine zebra mussel's influence over *Campeloma* mobility. Two random samples of *Campeloma* were collected on different days at the same site. The statistical analysis failed to yield the same result in two groups, and restriction on *Campeloma* movement by zebra mussels is clearly visualized; however it still remained unclear whether the shell morphology determines alteration of burrowing depth or the presence of zebra mussels do.

Introduction

Dreissena polymorpha, commonly known as zebra mussel, is an exotic species of bivalve, living byssally attached to any kinds of hard substrates including live invertebrates (Mackie, 1991). Since it was introduced into the U.S. in 1980s, it has appeared throughout environment today (Bossenbroek, 2006). Zebra mussels are highly prolific that their fecundity ranges from 30,000 to 40,000 per one female annually, and it seems to be enough drive away other species (Mackie, 1991). Recent surveys show the disappearance of native *Unionid* species at lower Great Lake region and the sudden decline in native bivalve species population at the Hudson River estuary as a result of competition with zebra mussels (Bowers, 2007; Strayer, 2007; Casagrandi, 2007). The invasion of zebra mussels does not only alter the aquatic ecosystem but it is also causing the economic loss on the waterworks and electric power generation facilities (Connelly, 2007; Marcus, 1994).

Douglas Lake in Michigan is also not free from those zebra mussels, and the native invertebrate species including *Campeloma decisum* are suffering from the invasion. Zebra mussels are known as selective filter-feeders that prey mostly on high quality phytoplankton resulting in the disturbance of planktonic foodweb (Naddafi, 2007; Miller 2007). Schwalb(2007) and Appledorn et al.(2007) reported the slower movement of *Unionid* mussels and *C. decisum* in the presence of zebra mussels as well as the burrowing depth of each species (Schwalb, 2007; Appledorn, 2007). Then it became clear that zebra mussels influence in the survivorship of *C. decisum* based on the facts that *C. decisum* is also a filter-feeder species that requires soft substrate to burrow (Bovbjerg, 1952). However, it was hard to find the studies about the relationship between the amount of zebra mussels attached and the intensity of restriction on the mobility. Finally, it was not clear whether the alteration in movement is the result of zebra mussels load.

Therefore we hypothesized that:

1. *C. decisum* shell morphology is more susceptible to attachment by *D. polymorpha*.
2. *D. polymorpha* alters the burrowing ability of *C. decisum*, and the heavier load will decrease the vertical mobility even further.

Methods

We collected *C. decisum* twice on July 25, 2007, and Aug 2, 2007 at the same site on East Point in Douglas Lake, MI. The sample site on East Point had fairly shallow water level that varied from 10 inches to 30 inches deep, and the water temperature was about 25℃ to 30℃. There existed no vegetations at the spot, and the bottom of lake was very soft sand. For the first group of our sample, we looked for signs of zebra mussels to detect *Campeloma* beneath the surface, and we gathered *Campeloma* sitting on the surface without zebra mussels.

For the second sampling, we scooped the surface and looked for *Campeloma* without using zebra mussel as an indicator. As a result, we collected 103 *Campeloma* without zebra mussels and 65 with zebra mussels for first group, and 46 with zebra mussels and 35 without zebra mussels for second group.

We had labeled each *Campeloma* with permanent marker right after sampling, and provided aquariums filled in water and sand from Douglas Lake. First group of the sample had been kept in three separate aquariums for three days before the measurement, and second group of sample had been kept for a day before the measurement and experiment. For each group, wet weight of *Campeloma*, overall length, overall width, aperture length, aperture width, age, shell thickness, number of whorls, wet weight of total zebra mussels per *Campeloma*, and number of zebra mussels per *Campeloma* were measured, and shell shape (shell width/shell length), shell volume ($(\pi r^2 h)/3$), aperture area (πab), area to volume ratio (aperture area/shell volume), whorl tightness (shell width/number of whorls), and growth rate (shell width/age) were calculated from measured data.

We distributed 29 *Campeloma* of the second group with zebra mussels and 30 without of second group evenly into four 10-gallon aquariums, each with 15cm of natural substrate and 15cm of lake water. The burrowing depth was measured after three hours. The same experiment about the burrowing ability was not performed with the first group of the sample.

One-way ANOVA was performed on data of both groups to analyze whether the measurement variables greatly vary depending on the presence of zebra mussels. Regression between the burrowing depth and every other variable was also performed to examine what alters the burrowing ability the most. Another regression was done between zebra mussel load in grams and every other variable to see the correlation between the amount of load and intensity of restriction. At last, factor analysis was performed and each component was extracted with principal component analysis to see the impact of variables as a group on the presence of zebra mussels.

Results

For the first group of the sample, 7 variables showed significant difference depending on the presence of zebra mussels ($F > 1$, $p < 0.05$, Table 1). *Campeloma* with zebra mussel had longer overall length and aperture width, thicker shells, more number of whorls, larger aperture size, lower area to volume ratio, and less tighter whorls (Fig. 1). In the second group of the sample, *Campeloma* with zebra mussels were older, burrowed shallower, and grew slower ($F > 1$, $p < 0.05$, Table 2, Fig. 2).

There was no evidence of strong correlation between the load of zebra mussels per *Campeloma* and the rest of the variables that showed r^2 value less than 0.3 ($F > 1$, $p < 0.05$ Table 3). The regression against the burrowing depth also showed that none of the regressed variables are in strong correlation with the burrowing depth ($F > 1$, $p < 0.05$ Table 4).

Principal component analysis showed that four components were extracted in the first group, namely physique (weight, overall length, overall width, aperture length, aperture width, shell volume, and aperture area), area to volume ratio (aperture shape and area to volume), volume size (age, area to volume ratio, whorl tightness, shell shape, and aperture shape), and tightness of shell (whorl tightness, growth rate, and shell shape). The physique and area to volume ratio showed fairly strong correlation (average c-value = 0.951, 0.711), on the other hand, ones of volume size and tightness of shell were relatively weak (avg. c-value = 0.458, 0.491, Table 5).

In the second group, six components were extracted; physique (weight, shell volume, overall width, overall length, aperture width, and shell thickness), aperture size (aperture length and aperture area), shell growth (growth rate), number of whorls, shell shape, and burrowing depth. Strong correlations were observed on physique, aperture size, shell growth, and number of whorls (avg. c-value = 0.845, 0.941, 0.882, 0.807) while shell shape and burrowing depth showed again relatively weak correlation. (avg. c-value = 0.682, 0.515, table 6).

Discussions

The statistical analysis on shell morphology of *C. decisum* gave some features that seem to be responsible for the attachments of *D. polymorpha*; overall length, aperture width, shell thickness, number of whorls, aperture shape, area to volume ratio, whorl tightness, age, and growth rate. Even though those features are strongly supported by the statistics and previous studies showing 50% decrease of growth rate (Table 1, Table 2, Appledorn, 2006), comparing two separate groups of *Campeloma* from same population and habitat, those numbers become meaningless. First and second group of sample drew completely different outcomes that not even single variable overlaps in the result. Therefore it is hard to discuss whether zebra mussels are more susceptible to certain type of *Campeloma*'s shell morphology. Also factor analysis produced the result that only physique in terms of size and volume was drawn as significant group feature in both groups (Table 5, Table 6); however it does not seem to be consistent with previous study saying that zebra mussels do not exhibit substrate or sizr preference (Mackie, 1991). If more samples can be collected from the same population at East Point and studied in the same way, it will have more credibility in the statistical analysis.

It is clear that zebra mussels restrict the movement of *Campeloma* resulting in decrease of burrowing depth (Table 2). Burrowing depth does not seem to decrease proportionately with the amount of zebra mussels in terms of weight, however, values were close to being significant. This may suggest a trend that the more zebra weight attached, then the stronger effect it had on vertical mobility(Table 4). We drew the same conclusion as the previous workers (Appledorn, 2006); however there could be many untested factors that alter the burrowing ability other than the presence of zebra mussels. The reproductive activity, velocity of water flow, water temperature, day length, and nutrient conditions are the factors influencing burrowing ability as well (Schwalb, 2007). Even though we maintained every condition same for each *Campeloma* sample with and without zebra mussels, we were not concerned about abiotic factors concerning zebra mussel colonization, such as temperature, or water flow.

Our experiment and statistical analysis failed to examine which factors alter the vertical mobility of *Campeloma*, shell morphology or the presence of zebra mussels (Table 4). If we run more experiments only with *Campeloma* that do not have zebra mussels but vary greatly in shell morphology, it will be possible to investigate the influence of shell morphology on burrowing depth.

Figures and Tables

	df	F-value	p-value
Overall Length	1	4.070	0.045
Aperture Width	1	6.307	0.013
Shell Thickness	1	108.962	0.000
Number of Whorls	1	19.251	0.000
Aperture Shape	1	10.954	0.001
Area-Volume Ratio	1	71.760	0.000
Whorl Tightness	1	5.494	0.020

Table 1 – One-way ANOVA on first group of sample depending on the presence of *D. polymorpha*. Only significant features included.

a) Modified for $F > 1$, $p < 0.05$

	df	F-value	p-value
Age	1	5.847	0.019
Depth	1	9.896	0.003
Growth Rate	1	6.152	0.016

Table 2 – One-way ANOVA on second group of sample depending on the presence of *D. polymorpha*. Only significant features included.

a) Modified for $F > 1$, $p < 0.05$

Variables	R Square	F-value	p-value
Weight	0.161	5.188	0.031
Overall Length	0.226	7.862	0.009
Overall Width	0.099	2.980	0.096
Aperture Length	0.001	0.017	0.896
Aperture Width	0.256	9.304	0.005
Shell Thickness	0.035	0.967	0.334
Age	0.000	0.011	0.917
Number of Whorls	0.002	0.042	0.840
Burrowing Depth	0.131	4.087	0.053
Shell Shape	0.086	2.526	0.124
Aperture Shape	0.061	1.766	0.195
Shell Volume	0.187	6.203	0.019
Aperture Area	0.036	0.994	0.328
Area-Volume Ratio	0.064	1.845	0.186
Whorl Tightness	0.049	1.378	0.251
Growth Rate	0.002	0.041	0.841

Table 3 – Regression against total wet weight of *D. polymorpha*.

a) Significant values have very low R^2

Variables	R Square	F-value	p-value
Weight	0.000	0.011	0.919
Overall Length	0.001	0.060	0.807
Overall Width	0.000	0.000	0.997
Aperture Length	0.023	1.332	0.253
Aperture Width	0.001	0.034	0.855
Shell Thickness	0.005	0.284	0.596
Age	0.033	1.938	0.169
Number of Whorls	0.007	0.429	0.515
Shell Shape	0.004	0.241	0.625
Aperture Shape	0.022	1.289	0.261
Shell Volume	0.000	0.006	0.938
Aperture Area	0.008	0.488	0.488
Area-Volume Ratio	0.019	1.079	0.303
Whorl Tightness	0.004	0.209	0.649
Growth Rate	0.062	3.780	0.057
Zebra mussel weight	0.131	4.087	0.053
Zebra #	0.049	1.389	0.249

Table 4 – Regression again burrowing depth of *C. decisum*.

	Component			
c-value	Physique	Area-Volume Ratio	Volume Size	Tightness of Shell
Weight	**.970**	-.091	-.134	.038
Overall Length	**.983**	-.038	-.132	-.011
Overall Width	**.974**	-.123	-.017	.158
Aperture Length	**.946**	-.053	-.088	.092
Aperture Width	**.861**	.422	.272	.016
Age	.504	-.563	**.483**	-.360
Shell Thickness	.586	.007	-.207	-.133
Number of Whorls	.691	.073	-.473	-.251
Shell Shape	-.391	-.294	**.420**	**.577**
Aperture Shape	.531	.650	**.492**	-.051
Shell Volume	**.971**	-.100	-.101	.082
Aperture Area	**.950**	.253	.106	.042
Area-Volume Ratio	-.265	**.772**	**.508**	-.171
Whorl Tightness	.681	-.222	**.411**	**.448**
Growth Rate	-.143	**.600**	-.607	**.449**

Table 5 – Factor Analysis on first group of *C. decisum*

a) Extraction Method: Principal Component Analysis.

b) c-value = component value

c) Variables in bold are responsible for component

	Component					
c-value	Physique	Aperture Size	Growth	Number of Whorls	Shell Shape	Burrowing Depth
Weight	**.915**	.236	.037	.117	.003	.085
Overall Length	**.789**	.229	-.187	-.251	-.453	.067
Overall Width	**.895**	.058	.230	.194	.086	.156
Aperture Length	.029	**.988**	-.010	.032	.088	.010
Aperture Width	**.794**	-.050	.055	.033	.247	-.209
Shell Thickness	**.727**	-.129	.165	.379	.159	.238
Age	.324	-.109	-.843	-.117	.344	.153
Number of Whorls	.367	.061	-.276	**.807**	-.214	-.247
Burrowing Depth	-.333	.118	-.079	.358	-.447	**.515**
Shell Shape	-.241	-.194	.369	.514	**.682**	-.048
Aperture Shape	.382	-.916	.021	.017	-.047	-.025
Shell volume	**.949**	.132	.109	.027	-.149	.118
Aperture Area	.348	**.894**	.036	.042	.190	-.094
Area-Volume Ratio	.450	-.879	.027	.015	-.123	.038
Whorl Tightness	.377	-.006	.462	-.639	.290	.374
Growth Rate	-.194	.069	**.882**	.135	-.349	-.080
Zebra mussel Weight	.545	-.025	.078	-.341	-.152	-.588

Table 6 – Factor Analysis on second group of *C. decisum*

a) Extraction Method: Principal Component Analysis.

b) c-value = component value

c) Variables in bold are responsible for component

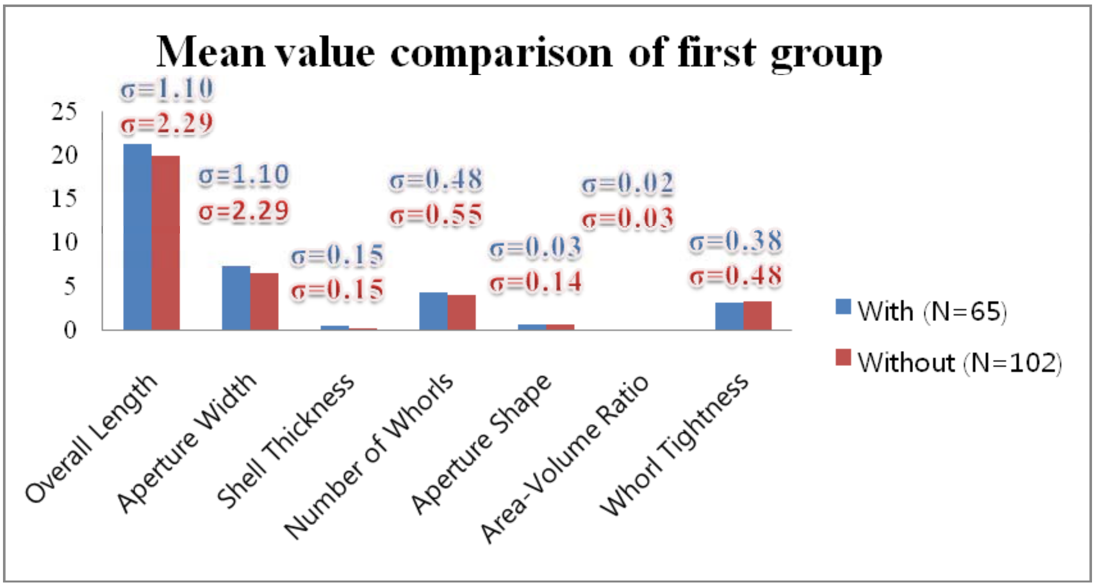

Figure 1 – Mean value comparison of first group

a) Modified for $F > 1$, $p < 0.05$

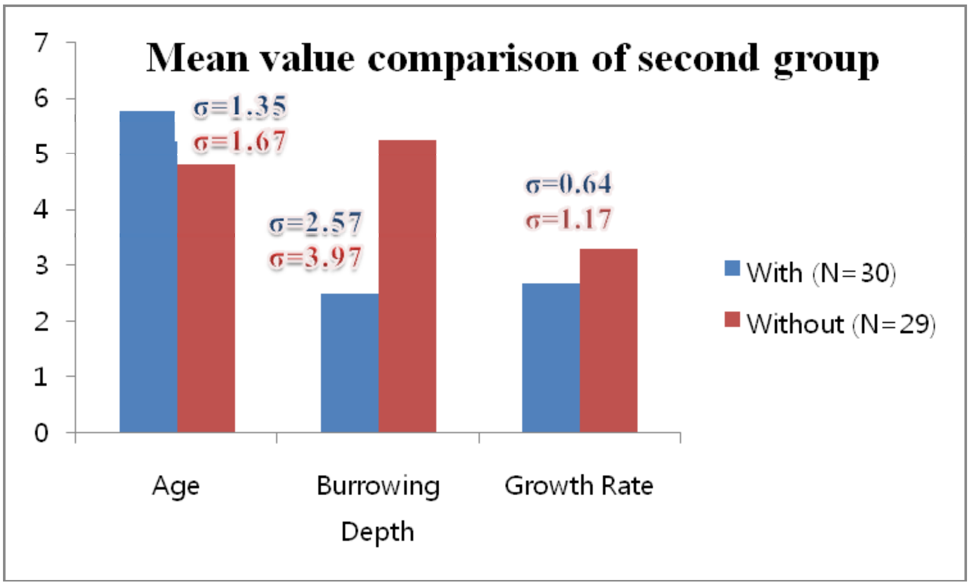

Figure 2 - Mean value comparison of second group
a) Modified for $F > 1$, $p < 0.05$

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