Item 20

LRA ER Reference 2.3-8
Haynes, L. M., Zebra Mussels and Benthic Macroinvertebrate Communities of Southwestern Lake Ontario and Selected Tributaries: Unexpected Results?, Great Lakes Research Review 3(1), April 1997

Great Lakes Research Review
Volume 3, No. I, April 1997

Zebra Mussels and Benthic Macroinvertebrate Communities of Southwestern Lake Ontario and Selected Tributaries: Unexpected Results?

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Abstract - Since the zebra mussel *(Dreissena polymorpha)* colonized the Great Lakes ecosystem, ecologists and managers have expressed concern about potential impacts it would have on native benthic macroinvertebrate communities in lakes and streams. We compared post- *Dreissena* invasion data (1991-1992) with pre-invasion *data (1983)* from the same sites in Lake Ontario. *Dreissena* was the overwhelmingly dominant taxon in 1991-1992. Nevertheless, the overall abundance of other benthic macroinvertebrates, and the number of taxa collected, were greater following establishment of *Dreissena.* Our study failed to provide evidence that *Dreissena* has induced a population decline in any non-bivalve taxon that was present in 1983. The invasion of *Dreissena* and other recent environmental changes appear to have created conditions more favorable for most benthic macroinvertebrate taxa in the nearshore region of Lake Ontario. We also asked why zebra mussels have not colonized many creeks in western New York. some with apparently ideal habitat, that are fed partially by water from the Erie Canal which is a source of *Dreissena* larvae. Counts of *Dreissena* larvae and concentrations of chlorophyll a were much higher in the canal than in our study creek, yet water quality, current velocity, and particulate organic carbon concentrations in the creek and the canal were very similar. Four factors appear to limit colonization of creeks by the zebra mussel: 1) Retention of larvae by wetlands through which discharges from the canal often flow, 2) Filtering of phytoplankton and larvae by dense beds of adult zebra mussels often found at the beginning of channels connecting the canal to creeks, 3) Inappropriate food quality (e.g., lack of small-diameter phytoplankton with important fatty acid constituents) reaching creeks from the canal, or 4) Muddy substrates inappropriate for attachment and filter feeding by *Dreissena.*

INTRODUCTION

First reported in the Great Lakes in 1988, the zebra mussel *(Dreissena polymorpha)* has colonized many portions of the Great Lakes basin and connected watersheds. The spread of *Dreissena* has generated concern among ecologists for several reasons, particularly their ability to: 1) Completely cover and change the physical structure of hard substrates and 2) Reduce open lake phytoplankton biomass by filter feeding which likely impacts pelagic food webs dependent upon microscopic algae (e.g., zooplankton, alewives, stocked salmon). Since 1990, researchers at State University of New York at Brockport have studied the effects of zebra mussels on benthic macroinvertebrate communities associated with bottom substrates in southwestern Lake Ontario and in several western New York creeks connected to the Erie Canal and Lake Ontario.

STUDIES IN SOUTHWESTERN LAKE ONTARIO

Because *Dreissena* and other benthic macroinvertebrate taxa are fairly immobile, often occupy the same substrates, and in some instances may consume similar foods, changes in previously established benthic macroinvertebrate communities following *Dreissena* invasion are possible. However, scarcity of pre-invasion data has made assessment of *Dreissena* impacts on pre-established macroinvertebrate taxa difficult. In 1991-1992, we used the same location, study design and sampling methods as those of Bader (1985), who quantified abundances of benthic macroinvertebrate taxa in 1983, seven years before the establishment of *Dreissena* in Lake Ontario. Full details are in Stewart and Haynes (1994) and Stewart (1993).

In 1991-1992, zebra mussels comprised up to 93% of the macroinvertebrates (insects, crustaceans, worms, snails, etc.) collected, replacing the amphipod, sideswimmer *(Gammarus fasciatus)* which was the numerically dominant taxon in 1983. However, the total abundance *of non-Dreissena* macroinvertebrates was significantly greater, in 1991-1992 (range: 1,316 + 170 to 5,267 + 523 $/m^2$) than in 1983 (range: 127 + 41 to 1,159 + 107 $/m^2$). Taxa showing me greatest increases in abundance included the annelid worms *(Manayunkia speciosa, Spirosperma ferox)* and unidentified tubiticids; the gastropod snails *(Helisoma anceps, Physa heterostropha, Stagnicola catascopium, Valvata tricarinata, Goniobasis Livescens, Amnicola limosa)*; the sideswimmer *(Gammarus fasciatus); the* trichopteran insect *(Polycentropus* sp.); and the decapod crayfish *(Orconectes propinquis)*. No taxon was less abundant in 1991-1992 than in 1983, and comparisons of macroinvertebrate community similarity in 1983 and 1991-1992 (range: 50 to 99% similarity) indicated that previously established taxa did not change substantially between 1983 and 1991-1992. The number of taxa collected was significantly greater in 1991-1992 (maximum: 32 per sample) than in 1983 (maximum: 15 per sample). While taxa of numerical importance in 1983 remained important in 1991-1992, some taxa of little numerical importance in 1983, such as the oligochaete worms *(Stylaria lacustris, Potamothrix vejdovskyi, S. ferox)*, and the snail *(Amnicola limosa)*, were of increased importance in 1991-1992. No taxon exhibited a significant population decline between 1983 and 1991-1992.

Population changes of some taxa are similar to those reported by other researchers who have studied impacts of *Dreissena* on benthic macroinvertebrate communities in Lakes Erie and St. Clair (Dermott *et al.* 1993, Griffiths 1993). Although other factors may have contributed to the changes observed, our results support theories that *Dreissena* is facilitating the transfer of energy to bottom organisms by pseudofecal/fecaldeposition, that mussel colonies are providing habitat for additional invertebrate taxa, and that predicted disasterous changes in native benthic

Parameter	Erie Canal	Salmon Creek	Significant?
Temperature (°C)	19.6	19.4	No
PH	7.9	8.0	No
Calcium (mg/L)	62.9	72.5	No
POC (mg/L)	21.5	21.6	No
Veligers (#/L)	14.3	0.2	Yes
Chlorophyll a (mg/L)	7.9	4.6	Yes
Velocity (m/sec)	0.09	0.05	No
Discharge (m^3/sec)	0.07	0.08	No

Table 1. Comparison of mean physical, chemical and biological conditions most relevant to zebra mussel biology in the Erie Canal and Salmon Creek.

Parameter	Tolerated Range	Optimum Range	Makarewicz (1989)	Salmon Creek
Temperature (°C)	0 - 3 0[a]	20 - 25 [a]	1- 27	9 - 27
pH	4.6 - 9.5 [b]	8.2 - 8.6 [b]	7.5 - 8.5	7.3 - 8.3
Calcium (mg/L)	> 40 [a,c]	> 50 [a,c]	61 - 68	49 - 118
Current (m/sec)	> 0 - 2.5 [d,e]	0.1 - 1 [d,e]	< 1	0.03 - 0.16
Food Particle Size (μm)	1 - 450 [b,f,g]	15 - 45 [b,f,g]	not reported	not examined

[a]Kovalalc 1989, [b]Morton 1971; Sprung 1993, [d]Smirnova and Vinogradov 1990, [e]O'Neill and MacNeill 1991, [f]Sprung and Rose 1988, [g]Ten Winkel and Davids 1982

Table 2. Tolerated and optimal ranges of important environmental parameters for zebra mussels. Makarewicz reported water quality data for nearby Larkin, Buttonwood and Northrup Creeks.

macroinvertebrate communities (except for freshwater clams) have yet to occur in Lake Ontario.

Dreissena may facilitate transfer of nutrients to benthic macroinvertebrates by filter-feeding on open water phytoplankton and subsequently depositing wastes on the bottom. *Dreissena* feces and pseudofeces are important in diets of benthic macroinvertebrates that eat detritus (dead organic material). Facultative or obligatory detritivores with population increases in our study were *S. ferux* and other tubificid worms, the snails *(P. heterosrostpha, V. tricarinata),* the amphipod *(G. fasciatus),* and the insect *(Polycentropus* sp.). Other researchers have found the abundance and biomass of many benthic invertebrates, including detritivorous oligochaete worms and midgefly (chironomid insect) larvae, to be greatest among clumps of *Dreissena* where feces and pseudofeces accumulate.

Enhanced substrate complexity also may contribute to increased abundance and diversity of macroinvertebrates. By creating an interstitial network that may increase refugia available to other benthic organisms, Dermott *et al.* (1993) suggested that *Dreissena* was responsible for increases in *Gammarus* sp. observed on bedrock substrates colonized by *Dreissena*. Griffiths (1993) likewise attributed population increases of leeches, snails, sideswimmers, *(Polycentropus)* and the midgefly *(Polypedilum* sp.) in Lake St. Clan to increased substrate heterogeneity provided by *Dreissena.* Of these taxa, only leeches and *Polypedilum* failed to show significant population increases at our study sites between 1983 and 1991-1992.

Dreissena may indirectly create benthic habitat as well. Filter-feeding improves water clarity through removal of suspended particles. The resulting increase in the lighted water zone, in combination with increased transfer of nutrients to the lake bottom by *Dreissena,* may promote growth of benthic vascular plants (aquatic weeds). Positive relationships between benthic algae and populations of nematode round worms, naidid oligochaete worms, leeches, snails *(Gyraulus* sp., *Helisoma* sp., *Physa* sp., *Valvata* sp., *Goniobasis* sp., *Amnicola* sp.), sideswimmers, mayfly (ephemeropteran insect) larvae and midgefly larvae have been reported from the Great Lakes in the past (Cook and Johnson 1974, Barton and Hynes 1978). Griffiths (1993) believed that increased densities of submerged vascular plants and benthic algae following colonization of Lake St. Clair by *Dreissena* contributed to the observed increase in macroinvertebrate populations there. A variety of filamentous green algae were present at our study sites in 1983 and in 1991-1992, and macroinvertebrates, especially the sideswimmer *(G. fasciatus)*, were associated with the algae.

While most macroinvertebrate population changes observed in our study may be attributable to *Dreissena*, these changes may also reflect changes in water quality or habitat conditions that are unrelated to the *Dreissena* invasion. Phosphorus abatement programs have contributed to declines in total phosphorus concentrations throughout Lake Ontario since the mid-1970s but assessing the effects that phosphorus abatement has had and will continue to have on benthic macroinvertebrate populations is problematic. Johnson and MacNeil (1986) attributed declines in the abundances of some oligochaete worm, sphaeriid clam and isopod/scud taxa in the Bay of Quinte to reductions in phosphorus loading to Lake Ontario. Barton (1986) observed declines in total benthic macroinvertebrate abundance in areas undergoing rapid deeutrophication, but noted that species diversity often increased under such conditions. Increased overall abundance of benthic macroinvertebrates, including at least one worm taxon *(S. ferox)* known to inhabit nutrient-rich habitats, suggest nutrient deposition by *Dreissena* has more than compensated for oligotrophication processes in Lake Ontario between 1983 and 1991-1992. Increased water clarity resulting from declining phosphorus concentrations, in combination with *Dreissena* filter-feeding, also may lead to a deeper and warmer epilimnion (Mazumder 1990) which may further increase benthic production.

Other studies conducted within the Great Lakes strongly suggest *Dreissena* is threatening clams of the family Unionidae by settling on their shells and possibly inhibiting their ability to feed, respire, and reproduce (cf. Mackie 1991). Our study did not focus on freshwater clams and failed to show that *Dreissena* is negatively affecting other benthic macroinvertebrate taxa. Our data suggest that *Dreissena* has thus far had a positive impact on many benthic macroinvertebrate species in southwestern Lake Ontario.

STUDIES IN WESTERN NEW YORK CREEKS

The New York State Erie Barge Canal, with a direct connection to Lake Erie, was colonized by zebra mussels in 1989. Many of the creeks and rivers crossed by the canal receive water from it from April through November. Dense colonies of zebra mussels were observed at canal water outfalls to these creeks as early as 1990, but none of six creeks examined in Monroe County, New York, has zebra mussels more than 100 m downstream from where canal discharges enter.

Salmon Creek was chosen for study (see Miller and Haynes 1997 and Miller 1994 for full details of methods and results) because there was no apparent reason why zebra mussels should not successfully colonize the creek. Rocky substrates suitable for attachment are abundant, and invertebrate and fish communities indicate a reasonably healthy environment. Aside from agricultural and suburban run-off common to all streams in the region, there is no evidence of point source pollution in the watershed. We examined water quality (temperature, pH, calcium carbonate concentration), physical conditions (current, substrate), and biological conditions (food supply, predation) to learn why zebra mussels have not become established.

Water temperature, pH, calcium carbonate concentration, and current velocity in the Erie Canal and Salmon Creek did not differ significantly during the sampling period (Table l), and they can be eliminated as factors reducing zebra mussel abundance in the creek. In fact, physical and chemical conditions in the creek were generally in the optimal ranges for the survival, growth and reproduction of zebra mussels (Table 2).

Fish of 11 species were collected from Salmon Creek and the canal outfall channel, but only one zebra mussel was found in the stomach of one fish. Although crayfish abundance in Lake Ontario increased after colonization by the zebra mussel (Stewart 1993), and predation on zebra mussels by crayfish has been observed in controlled settings, the abundance of crayfish in Salmon Creek does not appear to have changed. Predation also does not appear to be a likely factor limiting zebra mussel abundance in Salmon Creek

Initially, we hypothesized that food supplies for zebra mussels (measured as particulate organic carbon. POC, in the water) would decrease as canal water moved over the existing zebra mussel colony in the outfall channel and was diluted by Salmon Creek, but POC did not differ between the canal and the creek (Table 1). Thus, food quantity, as measured by POC, was eliminated as a factor limiting zebra mussel colonization of Salmon Creek.

The abundance of veligers and the concentration of chlorophyll a dropped sharply after water left the Erie Canal (Table 1). In fact, veliger counts dropped 50% or more and chlorophyll a levels dropped by an average of 87% less than 15 m down the channel leading from the canal to the creek. Maximum densities of *Dreissena* larvae were 55/L in the canal and 2.3/L in the creek Maximum chlorphyll a levels were 21.7 mg/L in the canal and 7.3 mg/L in the creek.

What reduced veliger counts and chlorophyll a concentration after the canal outfall?

Near the base of the canal outfall channel to Salmon Creek is a dense colony of adult zebra mussels and a small wetland. Part of the water flowing out of the canal forms a back eddy that flows through the wetland. Adult zebra mussels were observed attached to vegetation in the wetland, suggesting that some veligers become trapped and settle in the wetland. That this may occur in Salmon Creek was supported by sampling in Brockport Creek. The canal discharge to Brockport Creek meanders through a wetland before reaching the creek No adult zebra mussels were found in the creek, but chlorophyll a levels were much higher after water passed through the wetland than they were in the canal. This suggests that the wetlands associated with canal outfall channels produce phytoplankton but prevent veligers from reaching the creeks.

Literature published before 1993 indicated that food particle size, not composition, is the critical aspect of diet for zebra mussels; 15 to 45 m is the preferred size range, but 1 to 450 m particles can be filtered and ingested (Ten Winkel and Davids 1982). Later studies suggest that food quality also is important. Stoeckman and Gerton (Ohio State University, Columbus, Ohio, personal communication) found better survival among cultured zebra mussels using a commercial diet of marine algae higher in fatty acids than the control diet: Vanderploeg *et al.* (1996) reported that the key to raising *Dreissena* in culture is providing the right algae, particularly freshwater *Chlorella minutissima* and marine *Rhodomonas minuta,* both about 3m in diameter and rich in long chain polyunsaturated fatty acids. However, Wright *et al.* (1996) reported that two *Dreissena* species survived and grew better on small phytoplankton high in saturated fatty acids. Clearly, small food size is important to veligers, but more work is needed to precisely define key components of the *Dreissena* diet and how diet requirements may influence where mussels can colonize successfully.

The Erie Canal has many of the physical and biological properties of a lake, among which is the presence of phytoplankton and bacteria suitable for zebra mussel feeding. Chlorophyll a levels in the canal were consistently higher than levels in Salmon Creek. The high abundance of zebra mussels in the canal is undoubtedly related to its rich food supply. Because phytoplankton do not readily occur in streams and 87% of canal phytoplankton (measured as chlorophyll a) is filtered by adult *Dreissena* before reaching the creek, it is quite likely that the POC of Salmon Creek does not meet the qualitative nutritional requirements of zebra mussels.

Just as adult zebra mussels at the base of the canal discharge to Salmon Creek appear to filter most phytoplankon out of the water, it is likely they are also feeding on the larvae (Smirnova and Vinogradov 1990) coming from the canal and create the 60% reduction in numbers observed.. The dense population of adult *Dreissena* in the discharge channel appears to be a "biotic sponge" which removes veligers and phytoplankton from the canal water flowing into Salmon Creek, thus depriving the creek of appropriate quality food (phytoplankton) and a source of larvae to support colonization of the creek

Why have zebra mussels not colonized other creeks in the region? The wetland between the canal and Brockport Creek apparently prevents veligers from reaching the creek. Near their outfalls, Allens and Northup Creeks have predominately muddy bottoms unsuitable for zebra mussel attachment and filter feeding. Thus, it appears that zebra mussels are having a difficult time colonizing streams fed by the Erie Canal in Monroe County, New York

CONCLUSION

By occurring in large clumps and filter-feeding intensively, *Dreissena* may benefit other macroinvertebrate taxa in Lake Ontario by increasing the complexity of benthic substrate and by increasing the flow of energy to benthic environments. While some factors (e.g., increased water clarity due to *Dreissena* biofiltration and phosphorus abatement programs) may be acting synergistically to favorably impact benthic organisms, biodeposition by *Dreissena* may keep benthic food resources at high levels despite overall declines in fertility of the Lake Ontario ecosystem. Given the appropriate physical habitat and water quality conditions and an abundant source of veligers, four factors appear to limit colonization of regional creeks by zebra mussels: 1) Partial retention of zebra mussel veligers by wetlands through which the canal discharges often flow, 2) Filtering of phytoplankton and veliger larvae by adult *Dreissena* often found at the beginning of outfall channels from the canal to creeks, 3) Inappropriate food quality (e.g., lack of small-diameter phytoplankton with important fatty acid constituents) reaching creeks from the canal, or 4) Muddy substrates inappropriate for attachment and filter feeding by *Dreissena.* Considering the many dire warnings of impending ecological disaster after invasion by zebra mussels, these results are encouraging. Our research team continues to monitor for potential longer term changes. but so far it appears that the Zebra mussel has not greatly changed benthic communities in lakes and streams in our part of the Great Lakes basin.

ACKNOWLEDGMENTS

I thank Timothy W. Stewart and Steven J. Miller who wrote the M.S. theses upon which this paper is based.

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