Honors Program

Angela J. Bergo

Macro-invertebrate assemblages among wild rice (Zizania palustris) in Lake Bemidji, Beltrami County, Minnesota

Aquatic Biology

05 May 2014

Macro-invertebrate assemblages among wild rice (Zizania palustris) in Lake Bemidji, Beltrami County, Minnesota

Angela J Bergo

Bemidji State University

Aquatic Biology

May 5, 2014

Abstract

One of the principal goals of ecology is to describe and understand the factors that shape and influence community composition. Even though they far outnumber most other organisms on the planet, invertebrates are often overshadowed by more charismatic organisms. Macro-invertebrates play a variety of roles in ecosystems, including nutrient cycling, decomposition, and primary production. Not only do they perform essential ecological tasks, macro-invertebrates are an invaluable resource for interpreting ecosystem health. By collecting and identifying macro-invertebrates from a particular site, it is possible to monitor the health and stresses being placed on that site. In this study, macro invertebrates were sampled and identified in late fall among wild rice (*Zizania palustris*) beds from Lake Bemidji, a northern meso-eutrophic lake in Beltrami County, Minnesota.

Introduction

The biologist Edward Wilson wrote: “If human beings were to disappear tomorrow, the world would go on with little change. Gaia, the totality of life on Earth, would set about healing itself and return to the rich environmental states of a few thousand years ago. But if invertebrates were to disappear, I doubt that the human species could last more than a few months. Most of the fishes, amphibians, birds, and mammals would crash to extinction about the same time” (Wilson, 1987).

Among multicellular organisms, invertebrates are an often overlooked group. Roughly 80% of all described species are invertebrates (Cardarso, Erwin, Borges, and New, 2011). Nearly every corner of our planet has been colonized by invertebrates, they can be found in fresh and saline waters as well terrestrial habitats. Invertebrates fill many varied niches in food webs: feeding on decaying matter, living plants, living in symbiotic or parasitic relationships, or even taking the role of top predator.

Invertebrates play a critical role in freshwater ecosystems by contributing to a variety of ecosystem services, including nutrient cycling, energy flow, and sediment mixing (Wallace and Webster, 1996). Freshwater invertebrates have a significant task in decomposing detritus, it has been estimated that benthic invertebrates process between 20 and 73% of leaf litter that ends up in headwater streams (Covich, Palmer, and Crowl, 1999). In doing so they contribute to releasing bound nutrients back into the water in a form usable by fungi, plants, and bacteria which leads to increased growth. The chain of energy flow continues, with these organisms being consumed by others. Freshwater invertebrates are also predators whose feeding habits affect the density, size, and locations of their prey. On the other end of the feeding spectrum, freshwater invertebrates are prey for both terrestrial and aquatic consumers. In some cases, invertebrates account for over 80% of the gut content of smaller fishes (Zimmer, Hanson, Butler and Duffy, 2001).

Amphipods are benthic, epibenthic or subterranean crustaceans. There are 1,870 species recognized from freshwater, which accounts for 20% of amphipod diversity. Of all subterranean animal groups, amphipods are among the most diverse (Vainola et al., 2008). Amphipods are significant contributors to the flow of energy by decomposing dead organic matter and constituting a major part of many fish species (Grabowski, Bacela, and Konopacka, 2007). Gammarids (members of the amphipod genus *Gammarus*) belong to the largest and most diverse family of amphipods. They are important nutrient cyclers in ecosystems and many species prefer relatively high water quality. Their sensitivity to pollutants makes them ideal candidates for bioindication (Postaski, Capelli, and Chambers, 2013), although in Europe, some non-native species of Gammarids are outcompeting native amphipods (Grabowski et al., 2007).

The order Odonata is a relatively small group of insects that play an essential role in aquatic and terrestrial habitats. As both larvae and adults, Odonates are excellent predators. Many of these are habitat specialists and are sensitive to habitat structure. As larvae, they consume aquatic prey items, while as adults they devour terrestrial prey (Seifert and Scheu, 2012). Coupled with their habitat preferences, this makes them helpful in evaluating changes in environmental health both above and below the water's surface (Kalkman et al., 2008).

Another member of the underappreciated invertebrate community is the humble mollusk. There are two important classes in the phylum Mollusca, the bivalves and the gastropods. Non-marine mollusks are one of the most imperiled and diverse groups in the animal kingdom. According to the 2007 International Union for Conservation of Nature (IUCN), mollusks are a group that is most affected by extinction (Regnier, Fontaine, and Bouchet, 2009). Flowing fresh water is one of the most endangered ecosystems on earth, and this habitat degradation affects freshwater mollusks in particular, because of their restricted habitat requirements and inability to flee (Regnier et al., 2009). The superfamily Unionoidea is a group of bivalves that reach the peak of diversity in North America. 189 of the 200 unionid species listed the IUCN *red list* reside within the United States (Lydeard et al., 2004). In some parts of the U.S. as much as 65% of unionid species have been lost (Lydeard et al., 2004).

Invertebrate communities are an invaluable tool when monitoring and assessing ecosystem health. An Index of Biotic Integrity (IBI) uses invertebrate and plant communities to assess the human impact on watersheds. IBIs often use invertebrate communities as their indicators because pollution and water quality affect the diversity and abundance of invertebrates (Bhatt and Pandit, 2010).

Scientists can use IBIs to detect disturbances and identify their causes, enabling them to find the best management practices to limit or protect the habitat from further degradation (Uzarski, Burton, and Genet, 2004). The effects of anthropogenic pollution vary by taxa depending on each individual taxa's resilience (Gray and Harding, 2012). An important part of conservation is understanding. When ecosystems are altered, an unpredictable cascade of effects can play out. It has been shown that distinct populations can exist on different sides of the same island, and if one of those populations disappear, a single side's ecosystem may become drastically different and less diverse than the other (Page, Mitchell, and Hughes, 2012). Invertebrate communities are easily affected by changes that to us might seem small. For instance, particulate matter settling on substrate affects grazers' ability to find food. Often, an IBI can be tailored for a specific problem. Uzarski (2004) developed an IBI specifically to deal with fringing wetlands around Great Lakes, and Gray and Harding (2012) developed an IBI to monitor effects of acid mine drainage in New Zealand.

IBIs work because of the relationship between an organism's biological traits and environmental constraints (Menezes, Baird and Soares, 2010). Traits can either be related to the biology of the organism, to the ecology of the organism, or to the function of the organism. For instance, predation by other organisms can have a dramatic effect on size distributions of invertebrates (Zimmer, Hanson, Butler and Duffy, 2001). The distribution of organisms can be linked to horizontal and vertical location within vegetation (Marklund, Blindlow, and Hargeby, 2001). Functional traits influence organisms' performance which in turn can affect ecosystem functioning. Physical environmental variables (such as temperature, hydroperiod, canopy type, and total area), pH, and predators account for much of variation in species richness (Dingemanse and Kalkman, 2008) (Hoverman et al., 2011) (Hassall, Thompson, French and Harvey, 2007). Menezes, Baird, and Soares (2004) claim that these traits can be studied and used for biomonitoring. Unlike using taxonomic tools alone, studying these traits make it possible to create a functional model of the ecosystem enabling scientists to identify causes of impairment rather than simply identifying the presence of degradation.

Sediment loading is becoming one of the most pressing forms of pollution in the US. Excess sediments can affect everything from primary producers to those who occupy the top of the food chain. Sedimentation lower algal growth and composition, it can also clog and reduce feeding efficiency, which can reduce growth rates or cause death (Kent and Stelzer, 2008). Because of many invertebrates' position at the base of the food web, small changes in their abundance can have cascading effects on the entire system.

Physical habitat doesn't just affect animals. Physical conditions also affect the plants that are present in an ecosystem. Wild Rice (*Zizania palustris*) production and genetic characteristics are heavily influenced by the type and amount of sediment and plant litter that is present (Sims, Pastor, Lee and Dewey, 2012) (Walker, Pastor and Dewey 2006) (Lee, 2002). Water flow also has an effect on wild rice. Eule-Nashoba, Biesboer, and Newman (2012) found that seeds from plants growing in lacustrine habitats had larger seeds. Water velocity also determines how populations of rice plants grow in relation to each other: groups that grew in high flow grew in clumps, whereas plants growing in more stagnant water grew in a much more spread out, random pattern (Asaeda, Fujino and Manatunge, 2005).

Ecology is a complex and nuanced study. Even the smallest member of a community plays an integral role and even the smallest changes can have a cascading effect. Invertebrates in particular are able to provide scientists with an abundant, easily collectable source of ecological information. By studying invertebrates and the habitats they inhabit, scientists are provided with a wealth of information about our world and how best to protect it. It is for this reason that in this study, macro-invertebrates were sampled at various rice beds in and around Lake Bemidji, Beltrami County, Minnesota.

Method

Samples were taken at the following locations in and around Lake Bemidji in Beltrami county Minnesota: (R1) 47 27’59” N, 94 52’44” W (R2) 47 29’32” N, 94 48’44” W and (L1) 47 27’49” N, 94 53’35” W. Six samples were taken at each site: Three benthic grabs, and three net sweeps. Samples were taken at the bow, side, and stern of the boat at each site. Samples were rinsed through a 0.5 mm sieve and placed in sample bottles covered with 90% alcohol.

Samples were rinsed with water through a 0.59 mm sieve, allowing invertebrates to be extracted, classified, and counted. Most samples contained large amounts of thick, organic matter rendering the sieve largely useless. For those samples, specimens were extracted under a microscope by hand. Organisms that were less than 1mm in size were ignored, as were empty, bleached, or severely fragmented shells. Organisms were classified to the lowest possible taxonomic level.

Samples were also scored using tolerance values from Hilsenhoff’s 1988 Family Biotic Index and calculated using:

$$\text{FBI} = \frac{\sum[(TV_i)(n_i)]}{N}$$

where: TV_i = family tolerance value, n_i = number of individuals in family, and N = total number of specimens.

Results

Specimens collected represented 4 phyla, and 7 classes. 14 families were identified and 5 were classified down to genus (Table 1). The most abundant family by far was Gammaridae, constituting 58.49% of all specimens collected and were found at each sample site. Physidae, the next most abundant family, comprised just 12.64% of total specimens (Figure 1 and Table 2).

The lake site had fewest overall specimens than either of the river sites, with 25.66%. Lake Site 1 also had the lowest overall diversity, with only 8 families represented. Gammaridae was most abundant at lake site 1, accounting for 86.03% of all organisms sampled there. River site 1 had the highest total specimens, accounting for 40.38% of all organisms but had the lowest percentage of gammarids, 40.65%. River site 2 had the highest overall diversity, with 13 different families (Table 3).

Class	Order	Family	Genus
Hydrozoa	Anthomedusae	Hydridae	*Hydra*
Gastropoda		Physidae	*Physa*
Gastropoda		Valvatidae	*Valvata*
Gastropoda		Planorbidae	*Planorbella*
Gastropoda		Ancylidae	
Bivalvia	Unionoida	Unionidae	
Hirudinea			
Hirudinea		Glossiphoniidae	
Insecta	Ephemeroptera	Baetidae	
Insecta	Odonata	Lestidae	
Insecta	Trichoptera	Phryganeidae	
Insecta	Trichoptera	Leptoceridae	*Leptocerus*
Insecta	Hemiptera	Pleidae	
Insecta	Diptera	Chironomidae	
Malacostra	Amphipoda	Gammaridae	
Ostracoda			

Table 1: Represented taxa

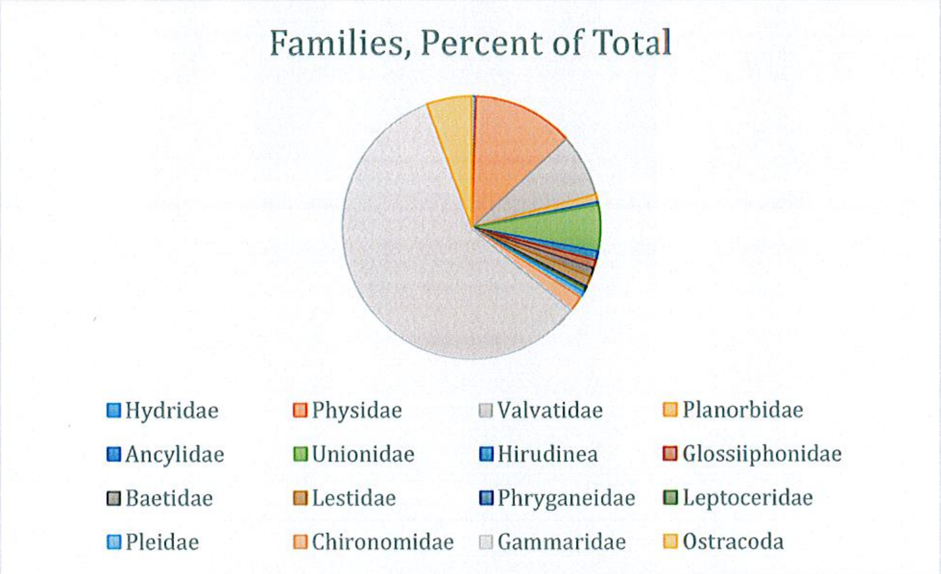

Figure 1: Represented families shown as percent of total.

Family	% Total
Hydridae	**0.57%**
Physidae	**12.64%**
Valvatidae	**7.74%**
Planorbidae	**0.94%**
Ancylidae	**0.38%**
Unionidae	**5.66%**
Hirudinea	**1.13%**
Glossiiphonidae	**0.94%**
Baetidae	**1.13%**
Lestidae	**1.32%**
Phryganeidae	**0.19%**
Leptoceridae	**0.57%**
Pleidae	**0.75%**
Chironomidae	**1.89%**
Gammaridae	**58.49%**
Ostracoda	**5.66%**

Table 2: Families as percent of total.

	(L1 NA)	(L1 NB)	(L1 NC)	(L1 BA)	(L1 BB)	(L1 BC)	(R1 NA)	(R1 NB)	(R1 NC)	(R1 BA)	(R1 BB)	(R1 BC)	(R2 NA)	(R2 NB)	(R2 NC)	(R2 BA)	(R2 BB)	(R2 BC)	Sum
Hydra	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	**3**
Physa	0	0	0	2	3	0	0	2	0	18	21	16	1	0	0	0	4	0	**67**
Valvata tri	0	0	0	0	0	0	0	0	0	10	14	13	0	0	0	0	3	1	**41**
Planorbel	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	1	2	**5**
Ancylidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	**2**
Unionidae	0	0	0	0	1	0	0	0	0	9	2	3	0	0	0	5	6	4	**30**
Hirudinea	0	0	0	0	1	2	0	0	0	0	3	0	0	0	0	0	0	0	**6**
Glossipho	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	1	1	**5**
Baetidae	0	2	0	0	0	0	1	0	0	0	0	0	0	1	0	2	0	0	**6**
Lestidae	0	0	0	1	0	1	0	0	0	0	0	0	0	1	3	1	0	0	**7**
Phryganei	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	**1**
Leptoceru	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	**3**
Pleidae	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	**4**
Chironom	0	0	1	0	0	0	0	1	0	2	5	0	0	0	0	1	0	0	**10**
Gammaric	16	13	22	23	27	16	24	23	35	4	1	0	68	22	13	1	2	0	**310**
Ostracoda	0	0	2	0	0	0	0	0	0	0	0	0	0	24	4	0	0	0	**30**
Sum	**16**	**15**	**25**	**27**	**34**	**19**	**28**	**26**	**35**	**43**	**47**	**35**	**74**	**48**	**20**	**10**	**19**	**9**	
% Total	**3.02%**	**2.83%**	**4.72%**	**5.09%**	**6.42%**	**3.58%**	**5.28%**	**4.91%**	**6.60%**	**8.11%**	**8.87%**	**6.60%**	**13.96%**	**9.06%**	**3.77%**	**1.89%**	**3.58%**	**1.70%**	

Table 3: All specimens listed by site.

Using Hilsenhoff's pollution tolerance values (Table 4), a biotic index was calculated and each site was scored (Table 5). River site 1 had the worst score, 6.9 which is considered poor, with a severe degree of organic pollution. River site 2 was slightly better, at 6.45 which falls in the fair category. This rating still indicates substantial organic pollution. Lake Site 1 had the best score, 6.07. This score is still well within the fair category, indicating substantial organic pollution.

Family	**Tolerance Value**
Hydridae	5
Physidae	8
Valvatidae	8
Planobidae	7
Ancylidae	6
Unionidae	6
Hirudinea	7
Glossiphonidae	6
Baetidae	5
Lestidae	6
Phryganeidae	4
Leptoceridae	4
Pleidae	
Chironomidae	7
Gammaridae	6
Ostracoda	8

Table 4: Pollution tolerance values.

Biotic Index	Water Quality	Degree of Pollution
<3.75	Excellent	Organic pollution unlikely
3.76 - 5.0	Good	Some organic pollution
5.1 - 6.5	Fair	Substantial pollution likely
6.6 - 10	Poor	Sever organic pollution likely

Table 5: Biotic index values.

Discussion

There are a wide range of biotic indices, each specific to a particular region or set of circumstances. Uzarski, Burton, and Genet developed an IBI specifically for fringing wetlands found on Lakes Huron and Michigan (2004). Gray and Harding developed an index designed for assessment of acid mine drainage (2012). The index used in this project was a very basic rapid field assessment based on family. An index based on species would be much more accurate (Hilsenhoff, 1988). An IBI specifically for lacustrine waters may be more appropriate as most IBI's are based on stream systems.

The Gammaridea are often found to be the dominant group in littoral zones (Grabowski, et al. 2007) so it is not surprising that they make up a dominant portion of the specimens. Their abundance also probably has an effect on the overall biotic score.

While it makes sense for a lake surrounded by an urban environment to be affected by organic pollution, such a small sample size over such a short period of time makes it impossible to draw any meaningful conclusions. To obtain a more accurate and useful score, more samples should be taken over a greater period of time, through different seasons. Physical and chemical parameters of the water should also be measured.

Using an Ekman dredge for the benthic grabs is perhaps not the best method for obtaining benthic samples. The amount of vegetation and organic matter makes extraction difficult. Rinsing did not dislodge most organisms, so it had to be picked by hand, inevitably leaving some specimens behind (Figures 2 and 3).

Figure 2: Benthic sample from river site 1, before rinsing

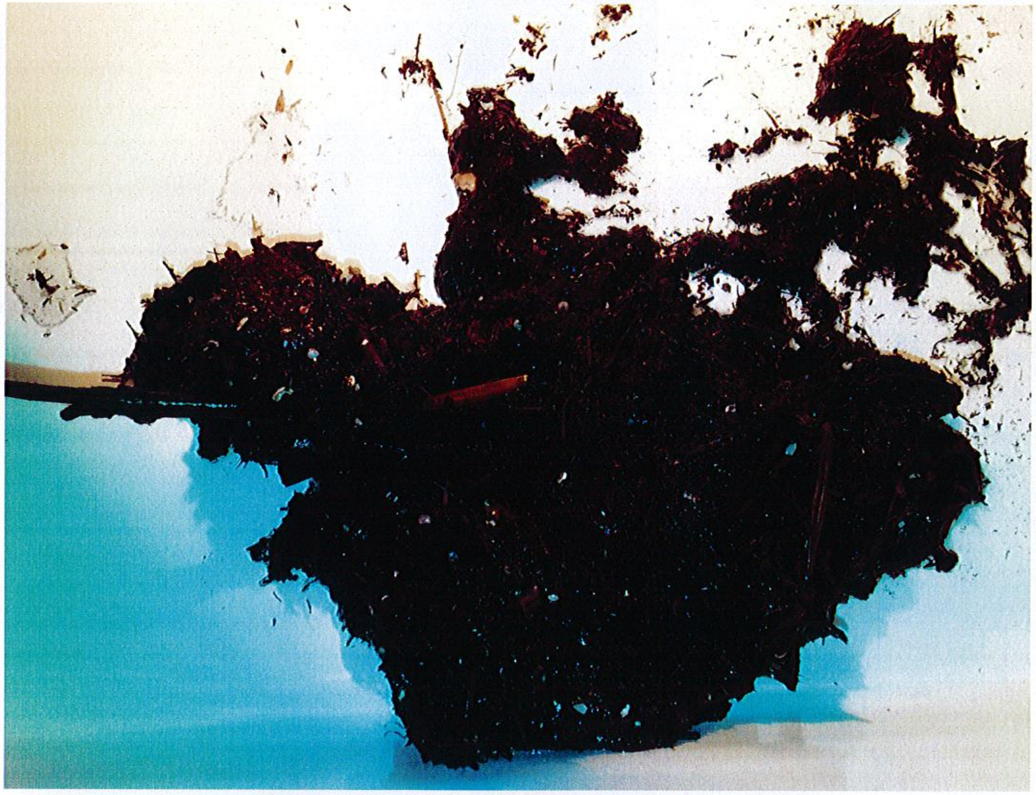

Figure 3: Benthic sample from river 1, after rinse.

Small organisms were hard to identify confidently beyond family, due to size. Even with higher magnification, it is difficult to manipulate such small organisms to make visible or count such things as setae or tarsal claws. Ostracods could only be identified to class, and only 5 specimens were able to be identified to genus.

Invertebrates are often overlooked outside of entomology despite their importance to ecosystem function. There is a wealth of information to be gained through the study of macro-invertebrate assemblages and abundances. While this study was short with few samples, it added to the growing accumulation of invertebrate data, and increased data specifically about wild rice beds in Lake Bemidji, Minnesota.

References

Asaeda, T., Fujino, T. and Manatunge, J. "Morphological adaptations of emergent plants to water flow: a case study with Typha angustifolia, Zizania latifolia and Phragmites australis." *Freshwater Biology* 50 (2005): 1991-2001.

Bhatt, J.P. and Pandit, M.K. "A macro-invertebrate based new biotic index to monitor river water quality." *Current Science* 99.2 (2010): 196-203.

Cardarso, P., Erwin, T.L., Borges, P.A.V., and New, T.R. "The seven impediments in invertebrate conservation and how to overcome them." *Biological Conservation* 144 (2011): 2647-2655.

Covich, A.P., Palmer, M.A. and Crowl, T.A. "The role of benthic invertebrate species in freshwater ecosystems." *BioScience* 49.2 (1999): 119-127.

Dingemanse, N.J. and Kalkman, V.J. "Changing temperature regimes have advanced the phenology of Odonata in the Netherlands." *Ecological Entomology* 33 (2008): 394-402.

Eule-Nashoba, A.R., Biesboer, D.D. and Newman, R.M. "Seed size in lacustrine and riverine populations of wild rice in northern Minnesota and Wisconsin." *Botany* 90 (2012): 27-33.

Grabowski, M., Bacela, K., and Konopacka, A. "How to be an invasive gammarid (Amphipoda: Gammaroidea)-comparison of life history traits." *Hydrobiologia* 590 (2007): 75-84.

Gray, D.P. and Harding, J.S. "Acid mine drainage index (AMDI): a benthic invertebrate biotic index for assessing coal mining impacts in New Zealand streams." *New Zealand Journal of Marine and Freshwater Research* 46.3 (2012): 335-352.

Hassall, C., Thompson, D.J., French, G.C. and Harvey, I.F. "Historical changes in the phenology of British Odonata are related to climate." *Global Change Biology* 13 (2007): 933-941.

Hilsenhoff, W.L. "Rapid field assessment of organic pollution with a family-level biotic index." *Journal of North American Benthological Society* 7.1 (1988): 65-68.

Hoverman, J.T., Davis, C.J., Werner, E.E., Skelly, D.K., Relyea, R.A. and Yurewicz, K.L. "Environmental gradients and the structure of freshwater snail communities." *Ecography* 34 (2011): 1049-1058.

Kalkman, V.J., Clausnitzer, V, Dijkstra, K.B., Orr, A.G., Paulson, D.R. and van Tol, J. "Global Diversity of dragonflies (Odonata) in freshwater." *Hydrobiologia* 595 (2008): 351-363.

Kent, T.R. and Stelzer R.S. "Effects of deposited fine sediment on life history traits of Physa integra snails." *Hydrobiologia* 596 (2008): 329-340.

Lee, P.F. "Ecological relationships of wild rice, Zizania spp. 10. Effects of sediment and among-population variations on plant density in Zizania palustris." *Canadian Journal of Botany* 80 (2002): 1283-1294.

Lydeard, C., Cowie, R.H., Ponder, W.F., Bogan, A.E., Bouchet, P., Clark, S.A., Cummings, K.S., Frest, T.J., Gargominy, O., Herbert, D.G., Hershler, R., Perez, K.E., Roth, B., Seddon, M., Strong, E.E. and Thompson, F.G. "The global decline of mollusks." *Bioscience* 54.4 (2004): 321-330.

Marklund, O., Blindlow, I., and Hargeby, A. "Distribution and diel migration of macroinvertebrates within dense sumberged vegetation." *Freshwater Biology* 46 (2001): 913-924.

Menezes, S., Baird, D.J. and Soares, M.V.M. "Beyond taxonomy: a review of macroinvertebrate trait-based community descriptors as tools for freshwater biomonitoring." *Journal of Applied Ecology* 47 (2010): 711-719.

Page, T.J., Marshall, J.C. and Hughes, J.M. "The world in a grain of sand: evolutionarily relevant, small-scale freshwater bioregions on subtropical dune islands." *Freshwater Biology* 57 (2012): 612-627.

Postaski, L.L., Capelli, G.M., Chambers, R.M. "Occurence and distribution of the freshwater amphipods Gammarus pseudolimnaeus and Gammarus fasciatus in Southeastern Virginia." *Northeastern Narualist* 20.4 (2013): 609-623.

Regnier, C., Fontaine, B. and Bouchet, P. "Not knowing, not recording ,not listing: numerous unnoticed mollusk extinctions." *Conservation Biology* 23.5 (2009): 1214-1221.

Seifert, L.I. and Scheu, S. "Linking aquatic and terrestrial food webs - Odonata in boreal systems." *Freshwater Biology* 57 (2012): 1449-1457.

Sims, L., Pastor, J., Lee, T. and Dewey, B. "Nitrogen, phosphorus, and light effects on reproduction and fitness of wild rice." *Botany* 90 (2012): 876-883.

Uzarski, D.G., Burton, T.M., and Genet, J.A. "Validation and performance of an invertebrate index of biotic integrity for Lakes Huron and Michigan fringing wetlands." *Aquatic Ecosystem Health and Management* 7.2 (2004): 269-288.

Vainola, R., Witt, J.D.S., Grabowski, M., Bradbury, J.H., Jazdzewski, K., and Sket, B. "Global diversity of amphipods (Amphipoda; Crustacea) in freshwater." *Hydrobiologia* 595 (2008): 241-255.

Walker, R.D., Pastor, J., Dewey, B.W. "Effects of wild rice (Zizania palustris) straw on biomass and seed production in northern Minnesota." *Canadian Journal of Botany* 84 (2006): 1019-1024.

Wallace, J.B. and Webster, J.R. "The role of macroinvertebrates in stream ecosystem function." *Annual Review of Entomology* 41 (1996): 115-139.

Wilson, E.O. "The little things that run the world (the importance and conservation of invertebrates." *Conservation Biology* 1.4 (1987): 344-346.

Zimmer, K.D., Hanson, M.A., Butler, M.G., and Duffy, W.G. "Size distribution of aquatic invertebrates in two prairie wetlands, with and without fish, with inplications for community production." *Freshwater Biology* 46 (2001): 1373-1386.