Current Status of *Dreissena polymorpha* and Biodiversity of Littoral Macroinvertebrates in Geneva Lake, Wisconsin

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Introduction

Geneva Lake is a beautiful glacial lake located in southeastern Wisconsin. It was created during the Late Wisconsin Glaciation between 50,000 to 100,000 years ago when the Laurentide ice sheet covered a large portion of North America. When the margin of the Delavan Lobe (a sub-lobe of the Lake Michigan Glacier) reached southeastern Wisconsin, meltwater carved the tunnel valley in which Geneva would form. When the lobe retreated, terminal and recessional moraines where left behind. These moraines give Geneva Lake its unique hydrology (Addig and Dott 2004). Due to these moraines Geneva Lake has a relatively small ratio of acres of watershed to acres of lake surface-area. There are only 2.48 acres of land for every 1 acre of surface water. Geneva's shoreline is 20.1 miles long and it has a maximum depth of 141 feet (GLEA, 2008).

Geneva Lake supports a healthy and diverse ecological system. It bounces between being a mesotrophic and oligotrophic lake. The Trophic Standard Index values for each year are determined by averaging Secchi depth, total phosphorous, and chlorophyll "a" values (Figure 1). These conditions allow the lake to host various flora and fauna. A majority of the fish in Geneva are panfish such as bluegill and pumpkinseed, but others include smallmouth and largemouth bass, northern pike, brown trout, and walleye. However, most of the larger game fish such as Walleye are not native to the lake; stocking has occurred since the late 1950s (Southeastern Wisconsin Regional Planning Commission 2008). According to a 2001 study about 22 species of zooplankton were found in Geneva Lake, the most abundant being *Eubosmina coregoni* (cladoceran), *Tropocyclops prasinus* (copepod), *Cyclops (Diacyclops) thomasi* (copepod), and *Daphnia longiremis* (cladoceran) (SWRPC 2008). In the same study 29 different species of aquatic macrophytes were documented in the lake. The most abundant macrophytes were wigeon grass, muskgrass, and eel grass (SWRPC 2008). Although Geneva is home to various native species, it is also susceptible to the threats of invasives.

Currently there are no documented species of invasive fish in Geneva (outside of stocked fish), but some prevalent invasives found in the Great Lakes of Wisconsin include the sea lamprey and round goby. Another invasive not yet found in Geneva, but in the Great Lakes, would be the zooplankton called the spiny water flea (*Bythotrephes longimanus)*. This larger zooplankton preys on other zooplankton such as Daphnia that helps keep waters clear by feeding on green algae (New Scientist 2016). Geneva has also been invaded by macrophytes such as curly-leaf pondweed and Eurasian water milfoil, the latter being the most detrimental due to its aggressive proliferation that increases competition for resources with native plants (SWRPC 2008). However, one of the most notorious and prolific invasive species to inhabit Geneva's waters is the macroinvertebrate *Dreissena polymorpha*, the zebra mussel.

The zebra mussel is native to the Caspian Sea in Eastern Europe. However, it was carried via ships through canals to the Black Sea where it spread throughout central and western Europe. Eventually it was transported by trans-Atlantic ships to North America (Karatayev et al. 2014). Veligers of zebra mussels are planktonic until they mature and become sessile by attaching to hard substrates with byssal threads. It is when the mussels are in their veliger life stage that they are most easily transported. Once zebra mussels enter a system, their short reproductive cycle allows them to proliferate at high rates and dominate the littoral zone where they are well adapted to thrive. Zebra mussels physically change the littoral zone by forming druses, which are "reef-like structures" that provide shelter from predation for some macroinvertebrates like amphipods, isopods, and some species of chironomids (Karatayev et al. 2014). The zebra mussel likes calcareous water to develop its shell, which makes Geneva Lake a suitable habitat with its limestone bedrock. They are aggressive filter feeders that non-selectively consume organic matter, digest only what they need, and ejest the rest. Zebra mussels are capable of filtering up to 1 liter a day (USGS, 2014). This habit means that there is a large amount of organic matter not being incorporated into their bodies and being released as pseudofeces. This process allocates nutrients from the pelagic zone into the benthic zone, which has multiple consequences (Botts et al. 1996). By removing large quantities of zooplankton and phytoplankton from the pelagic zone, the mussels are competing with fish for a food source while simultaneously increasing water clarity. Clearer water can increase light penetration, causing an increase in macrophyte populations (USGS 2014). Although some organisms benefit from the presence of zebra mussels, these invasives tend to have a dramatic impact on an ecosystem that can leave it permanently altered.

Zebra mussels were first discovered in Geneva Lake by the Geneva Lake Environmental Agency (GLEA) in the fall of 1995 (Schmalz 1996). Every four years, GLEA conducts a study to document how populations of zebra mussels and aquatic macroinvertebrates have changed. Zebra mussels were assessed using artificial substrates that were placed off of three piers. Macroinvertebrate populations were observed by collecting benthic samples from the littoral zone. Through these procedures the GLEA was able to observe how zebra mussel and macroinvertebrate populations have changed within the past four years.

Methods

The primary component of this study required the obtainment of benthic macroinvertebrate samples from the littoral zone. Two rounds of benthic samples were taken; one on July 12 and a second on August 16. Seven benthic sampling stations were established. Station descriptions and GPS coordinates are in Table 4 and represented in Figure 2. At each site three grabs were obtained with a 6” x 6” Ekman dredge. The grab was carefully lowered to the bottom and a diver ensured that the sampler was sitting flat. The diver used a sieve pail to catch any debris that may have fallen out due to improper closure of the grab from plants or rocks. The material captured from the three grabs was then placed into one labeled plastic container (two containers were used if necessary) and preserved with 70% ethyl alcohol. These samples were transported to the lab at George William’s College where large debris and plants were cleaned and removed. The remaining sediment was viewed under a dissecting microscope and macroinvertebrates were removed and placed into scintillation vials. Organisms were identified to the family level (when possible) at the taxonomy lab at UW-Superior. The equation for volumetric abundance provided below was used to calculate densities:

$$\textbf{Volumetric Abundance} = \frac{(n/36\ in2)\ (36\ in2/232\ cm2)\ (10{,}000\ cm2/1\ m2)}{3} = n/m^2$$

There was a discussion about altering how the equation was represented, but ultimately the results were the same for both versions.

Three artificial substrates were deployed to document populations of zebra mussels. The substrates consisted of four squares of plexiglass stacked on top of each other. From bottom to top, the squares’ dimensions were 12” x 12”, 10” x 10”, 8” x 8”, and 6” x 6”. Substrate sampler 1 (SS1) was located on Gordy’s lighthouse pier in Fontana. Substrate sampler 2 (SS2) was deployed at the Hillside Road boat launch in Linn. The third substrate sampler (SS3) was placed off of the Riviera Pier in Lake Geneva. All three substrates were deployed on June 16, 2016. Thirty-four days later on July 20 2016 the samplers were pulled and zebra mussels were counted and recorded. The substrates were completely cleaned and redeployed. Twenty-eight days later on August 17 2016 the substrates were checked again, cleaned, and redeployed. . The samplers were processed and removed from the lake sixty-five days later by Ted Peters on October 21 2016. Parameters such as time of deployment, water depth, sampler depth, temperature, Secchi depth, and weather conditions can be found in Table 1. We counted the number of mussels on the top and bottom of each square for each substrate. These numbers are recorded in Table 2. The densities of zebra mussels on the top, bottom, top and bottom combined, and on the entire sampler were calculated and are recorded in Table 3. The densities were calculated by dividing the total number of mussels counted one/both sides of a single plate or the entire sampler by the area in square meters. Below is a conversion table (Table 5) used to determine the area in square meters.

Plate	Area For One Side (in^2)	Area One Side (m^2)	Area Both Sides (m^2)	Area for Whole Sampler (m^2)
6" x 6"	36	0.0231	0.0462	0.0462+0.0826+0.129+0.186 = 0.4338
8" x 8"	64	0.0413	0.0826	
10" x 10"	100	0.0645	0.129	
12" x 12"	144	0.0929	0.186	

Table 5. Conversion table for aid in calculating densities of zebra mussels on artificial substrates.

Results

Table 6. BS1

Date	Class	Order	Family	Count	Density (n/m^2)
7/12/2016	Malacostraca	Amphipoda	Gammaridae	40	**574.7**
	Malacostraca	Amphipoda	Hyallelidae	2	**28.7**
	Malacostraca	Isopoda	Asellidae	28	**402.3**
	Hexapoda	Trichoptera	Hydroptilidae	25	**359.2**
	Hexapoda	Ephemeroptera	Caenidae	1	**14.4**
	Hexapoda	Diptera	Chironomidae	71	**1020.1**
	Hexapoda	Odonata	Coenagriondiae	1	**14.4**
	Hydracarina*			1	**14.4**
	Bivalvia	Veneroida	Dreissenidae	194	**2787.4**
	Gastropoda		Pleuroceridae	1	**14.4**
	Gastropoda		Hydrobiidae	9	**129.3**
	Gastropoda		Physidae	4	**57.5**
	Oligochaeta			28	**402.3**
	Hirudinea	Rhynchobdellida	Glossiphonidae	3	**43.1**
	Turbellaria	Tricladida		3	**43.1**
Date	**Class**	**Order**	**Family**	**Count**	**Density (n/m^2)**
8/16/2016	Malacostraca	Amphipoda	Gammaridae	4	**57.5**
	Malacostraca	Amphipoda	Hyallelidae	2	**28.7**
	Hexapoda	Trichoptera	Hydroptilidae	6	**86.2**
	Hexapoda	Trichoptera	Leptoceridae	7	**100.6**
	Hexapoda	Ephemeroptera	Caenidae	12	**172.4**
	Hexapoda	Diptera	Chironomidae	82	**1178.2**
	Hexapoda	Odonata	Libellulidae	2	**28.7**
	Hydracarina			12	**172.4**
	Bivalvia	Veneroida	Dreissenidae	140	**2011.5**
	Gastropoda		Pleuroceridae	2	**28.7**
	Gastropoda		Hydrobiidae	93	**1336.2**
	Gastropoda		Physidae	2	**28.7**
	Gastropoda		Valvatidae	8	**114.9**
	Gastropoda		Viviparidae	1	**14.4**
	Gastropoda		Planorbidae	3	**43.1**
	Hirudinea	Rhynchobdellida	Glossiphonidae	4	**57.5**

*Hydracarina is a super tribe classification for mites. The nomenclature for orders under the class Gastropoda is in a state of flux and uncertainty, therefore order names for snails were not included in this report. Class Insecta was replaced with class Hexapoda; Insecta is considered a subclass.

Table 7. BS2

Date	Class	Order	Family	Count	Density (n/m^2)
7/12/2016	Malacostraca	Amphipoda	Gammaridae	124	**1781.6**
	Malacostraca	Amphipoda	Hyallelidae	232	**3333.3**
	Malacostraca	Isopoda	Asellidae	302	**4339.1**
	Malacostraca	Decapoda	Cambaridae	5	**71.8**
	Hexapoda	Trichoptera	Hydroptilidae	5	**71.8**
	Hexapoda	Trichoptera	Leptoceridae	3	**43.1**
	Hexapoda	Ephemeroptera	Caenidae	3	**43.1**
	Hexapoda	Diptera	Chironomidae	210	**3017.2**
	Hexapoda	Odonata	Libellulidae	1	**14.4**
	Hydracarina			8	**114.9**
	Gastropoda		Pleuroceridae	5	**71.8**
	Gastropoda		Hydrobiidae	8	**114.9**
	Gastropoda		Physidae	17	**244.3**
	Gastropoda		Planorbidae	1	**14.4**
	Gastropoda		Valvatidae	2	**28.7**
	Oligochaeta			21	**301.7**
	Bivalvia	Veneroida	Dreissenidae	613	**8807.5**
	Pelecypoda		Sphaeriidae	1	**14.4**
Date	**Class**	**Order**	**Family**	**Count**	**Density (n/m^2)**
8/16/2016	Malacostraca	Amphipoda	Gammaridae	14	**201.1**
	Malacostraca	Amphipoda	Hyallelidae	108	**1551.7**
	Malacostraca	Isopoda	Asellidae	1	**14.4**
	Hexapoda	Trichoptera	Hydroptilidae	7	**100.6**
	Hexapoda	Trichoptera	Leptoceridae	18	**258.6**
	Hexapoda	Ephemeroptera	Caenidae	12	**172.4**
	Hexapoda	Ephemeroptera	Baetidae	1	**14.4**
	Hexapoda	Diptera	Chironomidae	121	**1738.5**
	Hydracarina			9	**129.3**
	Bivalvia	Veneroida	Dreissenidae	48	**689.7**
	Gastropoda		Hydrobiidae	44	**632.2**
	Gastropoda		Physidae	20	**287.4**
	Gastropoda		Valvatidae	2	**28.7**
	Gastropoda		Viviparidae	2	**28.7**
	Gastropoda		Planorbidae	20	**287.4**
	Oligochaeta			31	**445.4**

Table 8. BS3

Date	Class	Order	Family	Count	Density (n/m^2)
7/12/2016	Malacostraca	Amphipoda	Gammaridae	48	**689.7**
	Malacostraca	Amphipoda	Hyallelidae	29	**416.7**
	Hexapoda	Trichoptera	Hydroptilidae	11	**158.0**
	Hexapoda	Trichoptera	Leptoceridae	1	**14.4**
	Hexapoda	Ephemeroptera	Caenidae	28	**402.3**
	Hexapoda	Diptera	Chironomidae	62	**890.8**
	Hydracarina			12	**172.4**
	Gastropoda		Hydrobiidae	28	**402.3**
	Gastropoda		Physidae	9	**129.3**
	Gastropoda		Planorbidae	1	**14.4**
	Gastropoda		Valvatidae	9	**129.3**
	Oligochaeta			41	**589.1**
	Hirudinea	Rhynchobdellida	Glossiphonidae	15	**215.5**
	Bivalvia	Veneroida	Dreissenidae	221	**3175.3**
	Pelecypoda		Sphaeriidae	11	**158.0**
Date	**Class**	**Order**	**Family**	**Count**	**Density (n/m^2)**
8/16/2016	Malacostraca	Amphipoda	Gammaridae	162	**2327.6**
	Malacostraca	Amphipoda	Hyallelidae	11	**158.0**
	Hexapoda	Trichoptera	Hydroptilidae	12	**172.4**
	Hexapoda	Trichoptera	Leptoceridae	16	**229.9**
	Hexapoda	Ephemeroptera	Caenidae	47	**675.3**
	Hexapoda	Diptera	Chironomidae	175	**2514.4**
	Hexapoda	Odonata	Libellulidae	1	**14.4**
	Hydracarina			7	**100.6**
	Bivalvia	Veneroida	Dreissenidae	234	**3362.1**
	Pelecypoda		Sphaeriidae	5	**71.8**
	Gastropoda		Hydrobiidae	111	**1594.8**
	Gastropoda		Physidae	7	**100.6**
	Gastropoda		Valvatidae	22	**316.1**
	Gastropoda		Planorbidae	8	**114.9**
	Oligochaeta			14	**201.1**
	Hirudinea	Rhynchobdellida	Glossiphonidae	8	**114.9**

Table 9. BS4

Date	Class	Order	Family	Count	Density (n/m^2)
7/12/2016	Malacostraca	Amphipoda	Gammaridae	7	**100.6**
	Malacostraca	Amphipoda	Hyallelidae	10	**143.7**
	Malacostraca	Isopoda	Asellidae	82	**1178.2**
	Hexapoda	Trichoptera	Hydroptilidae	4	**57.5**
	Hexapoda	Trichoptera	Leptoceridae	10	**143.7**
	Hexapoda	Diptera	Chironomidae	100	**1436.8**
	Hydracarina			8	**114.9**
	Gastropoda		Hydrobiidae	10	**143.7**
	Gastropoda		Physidae	22	**316.1**
	Gastropoda		Planorbidae	6	**86.2**
	Oligochaeta			12	**172.4**
	Hirudinea	Rhynchobdellida	Glossiphonidae	2	**28.7**
	Bivalvia	Veneroida	Dreissenidae	87	**1250.0**
Date	**Class**	**Order**	**Family**	**Count**	**Density (n/m^2)**
8/16/2016	Malacostraca	Amphipoda	Gammaridae	25	**359.2**
	Malacostraca	Amphipoda	Hyallelidae	2	**28.7**
	Malacostraca	Isopoda	Asellidae	5	**71.8**
	Hexapoda	Trichoptera	Hydroptilidae	13	**186.8**
	Hexapoda	Trichoptera	Leptoceridae	33	**474.1**
	Hexapoda	Ephemeroptera	Caenidae	1	**14.4**
	Hexapoda	Diptera	Chironomidae	450	**6465.5**
	Hexapoda	Odonata	Coenagriondiae	1	**14.4**
	Hexapoda	Coleoptera	Curculionidae	1	**14.4**
	Bivalvia	Veneroida	Dreissenidae	172	**2471.3**
	Pelecypoda		Sphaeriidae	8	**114.9**
	Gastropoda		Pleuroceridae	1	**14.4**
	Gastropoda		Hydrobiidae	55	**790.2**
	Gastropoda		Physidae	6	**86.2**
	Gastropoda		Planorbidae	5	**71.8**
	Oligochaeta			35	**502.9**
	Hirudinea	Rhynchobdellida	Glossiphonidae	1	**14.4**

Table 10. BS5

Date	Class	Order	Family	Count	Density (n/m^2)
7/12/2016	Malacostraca	Amphipoda	Gammaridae	122	**1752.9**
	Malacostraca	Amphipoda	Hyallelidae	86	**1235.6**
	Malacostraca	Isopoda	Asellidae	84	**1206.9**
	Malacostraca	Decapoda	Cambaridae	1	**14.4**
	Hexapoda	Trichoptera	Hydroptilidae	2	**28.7**
	Hexapoda	Ephemeroptera	Baetidae	1	**14.4**
	Hexapoda	Diptera	Chironomidae	57	**819.0**
	Hydracarina			3	**43.1**
	Gastropoda		Hydrobiidae	5	**71.8**
	Gastropoda		Physidae	4	**57.5**
	Gastropoda		Planorbidae	4	**57.5**
	Gastropoda		Valvatidae	6	**86.2**
	Gastropoda		Viviparidae	2	**28.7**
	Oligochaeta			11	**158.0**
	Bivalvia	Veneroida	Dreissenidae	155	**2227.0**
	Pelecypoda		Sphaeriidae	1	**14.4**
Date	**Class**	**Order**	**Family**	**Count**	**Density (n/m^2)**
8/16/2016	Malacostraca	Amphipoda	Gammaridae	46	**660.9**
	Malacostraca	Amphipoda	Hyallelidae	120	**1724.1**
	Malacostraca	Isopoda	Asellidae	35	**502.9**
	Hexapoda	Trichoptera	Hydroptilidae	6	**86.2**
	Hexapoda	Trichoptera	Leptoceridae	3	**43.1**
	Hexapoda	Ephemeroptera	Caenidae	10	**143.7**
	Hexapoda	Diptera	Chironomidae	39	**560.3**
	Hexapoda	Megaloptera	Sialidae	1	**14.4**
	Hydracarina			5	**71.8**
	Bivalvia	Veneroida	Dreissenidae	103	**1479.9**
	Pelecypoda		Sphaeriidae	1	**14.4**
	Gastropoda		Pleuroceridae	2	**28.7**
	Gastropoda		Hydrobiidae	227	**3261.5**
	Gastropoda		Valvatidae	1	**14.4**
	Gastropoda		Planorbidae	6	**86.2**
	Oligochaeta			8	**114.9**
	Hirudinea	Rhynchobdellida	Glossiphonidae	12	**172.4**

Table 11. BS6

Date	Class	Order	Family	Count	Density (n/m^2)
7/12/2016	Malacostraca	Amphipoda	Gammaridae	60	**862.1**
	Malacostraca	Amphipoda	Hyallelidae	8	**114.9**
	Malacostraca	Isopoda	Asellidae	181	**2600.6**
	Malacostraca	Decapoda	Cambaridae	2	**28.7**
	Hexapoda	Trichoptera	Hydroptilidae	3	**43.1**
	Hexapoda	Diptera	Chironomidae	13	**186.8**
	Hydracarina			3	**43.1**
	Gastropoda		Hydrobiidae	7	**100.6**
	Gastropoda		Planorbidae	6	**86.2**
	Gastropoda		Valvatidae	1	**14.4**
	Gastropoda		Viviparidae	1	**14.4**
	Oligochaeta			2	**28.7**
	Bivalvia	Veneroida	Dreissenidae	105	**1508.6**
Date	**Class**	**Order**	**Family**	**Count**	**Density (n/m^2)**
8/16/2016	Malacostraca	Amphipoda	Gammaridae	9	**129.3**
	Malacostraca	Amphipoda	Hyallelidae	37	**531.6**
	Hexapoda	Trichoptera	Hydroptilidae	8	**114.9**
	Hexapoda	Trichoptera	Leptoceridae	3	**43.1**
	Hexapoda	Ephemeroptera	Caenidae	43	**617.8**
	Hexapoda	Diptera	Chironomidae	52	**747.1**
	Hydracarina			1	**14.4**
	Bivalvia	Veneroida	Dreissenidae	30	**431.0**
	Gastropoda		Hydrobiidae	46	**660.9**
	Gastropoda		Physidae	4	**57.5**
	Gastropoda		Planorbidae	3	**43.1**

Table 12. BS7

Date	Class	Order	Family	Count	Density (n/m^2)
7/12/2016	Malacostraca	Amphipoda	Gammaridae	14	**201.1**
	Malacostraca	Amphipoda	Hyallelidae	1	**14.4**
	Malacostraca	Isopoda	Asellidae	188	**2701.1**
	Hexapoda	Trichoptera	Hydroptilidae	6	**86.2**
	Hexapoda	Trichoptera	Leptoceridae	3	**43.1**
	Hexapoda	Ephemeroptera	Caenidae	1	**14.4**
	Hexapoda	Diptera	Chironomidae	52	**747.1**
	Hydracarina			2	**28.7**
	Gastropoda		Hydrobiidae	9	**129.3**
	Gastropoda		Planorbidae	5	**71.8**
	Oligochaeta			12	**172.4**
	Bivalvia	Veneroida	Dreissenidae	86	**1235.6**
Date	**Class**	**Order**	**Family**	**Count**	**Density (n/m^2)**
8/16/2016	Malacostraca	Amphipoda	Gammaridae	32	**459.8**
	Malacostraca	Amphipoda	Hyallelidae	8	**114.9**
	Malacostraca	Isopoda	Asellidae	19	**273.0**
	Hexapoda	Trichoptera	Hydroptilidae	2	**28.7**
	Hexapoda	Trichoptera	Leptoceridae	5	**71.8**
	Hexapoda	Ephemeroptera	Caenidae	3	**43.1**
	Hexapoda	Ephemeroptera	Baetidae	1	**14.4**
	Hexapoda	Diptera	Empididae	1	**14.4**
	Hexapoda	Diptera	Chironomidae	76	**1092.0**
	Hydracarina			4	**57.5**
	Bivalvia	Veneroida	Dreissenidae	20	**287.4**
	Gastropoda		Hydrobiidae	116	**1666.7**
	Gastropoda		Physidae	3	**43.1**
	Gastropoda		Planorbidae	1	**14.4**
	Oligochaeta			3	**43.1**

Conclusion

I calculated the percent change in densities of taxa from 2012 to 2016 to see what general changes have occurred since 2012. I then took a broader look at all of the data going back to 1996 to see general trends in taxa densities. Overall, from 2012 to 2016 an increase was observed in the diversity and density of multiple taxa. I will first discuss each sampling station individually.

BS1 was located by pier 61 on the north shore, east of the narrows. Comparing the first sampling dates, July 11 2012 vs July 12 2016, there was in increase in the densities of the families Gammaridae (amphipod, by 90%), Asellidae (isopod, by 96%), Chironomidae (fly, by 94%), Dreissenidae (zebra mussel, by 21 %), and Hydrobiidae (snail, by 44%). Some taxonomic groups that were found in 2016, but not in 2012 during the first round of sampling are the class Oligochaeta (worm) and class Tricladida (flatworm). Comparing the second sampling dates, August 20 2012 vs August 16 2016, there was in increase in the densities of the family Gammaridae (25%), Chironomidae (99%), and Dreissenidae (78%). Regarding both sampling years (2012 vs 2016) there was a decrease in the snail families Physidae (60%), Valvatidae (100%), and Viviparidae (100%). This current year was the first time the families Libellulidae (dragonfly), Glossiphoniidae (leech), and the super tribe Hydracarina (mites) have been captured at BS1. The highest density recorded of Asellidae at BS1 was represented this year at 402 n/m^2.

BS2 was located in front of Stone Manor. There was an increase in the number of taxa found for both sampling dates. Comparing July 11 2012 vs July 12 2016, there was an increase in the Families Gammaridae (97%), Asellidae (99%), Chironomidae (99%), Libellulidae (51%), Pleuroceridae (snail, 90%), and Dreissenidae (54%). There was a decrease in the snail families Planorbidae (88%), Valvatidae (91%), and Viviparidae (100%). For the second sampling dates, August 20 2012 and August 16 2016, the number of taxa present increased from 4 to 16. There was in increase in the families Leptoceridae (caddisfly, 70%) and Chironomidae (93%). Dreissenidae decreased by 93%.

BS3 was located in front of Lake Geneva Country Club. For the first sampling dates there was an increase in the number of taxa represented from 10 to 15. There was in increase in Chironomidae (95%), Dreissenidae (71%), and Oligochaeta (98%). There was a decrease in the snail families Physidae (64%) and Valvatidae (23%). For the second round of sampling there was an increase in the families Gammaridae (97 %), Dreissenidae (23%), and Chironomidae (97%). The taxa represented increased from 8 to 16.

BS4 was located by the Chicago Club on the south shore near Fontana. For the first and second sampling dates the number of taxa represented increased from 9 to 13 and 11 to 17, respectively. For the first sampling dates, there was an increase in the families Chironomidae (97%), Asellidae (71%), and Physidae (54%). There was a slight decrease in the families Gammaridae and Glossiphoniidae, but a larger decrease in Dreissenidae (92 %). This site experienced the highest density of Dreissenidae in 2012 at 16,379 n/m^2. For the second sampling date, there was in increase in the families Gammaridae (84%), Dreissenidae (32%), Asellidae (81%), Chironomidae (95%), Hydrobiidae (98%), and Physidae (17%). The snail families Valvatidae and Viviparidae were not represented at this site in 2016. This is the first time that GLEA has captured a Curculionidae, or weevil beetle. This is a highly diverse family that is easily recognizable by the adult's elongate snout. Each species specializes in consuming a particular plant, and with the aid of my Aquatic Entomology professor Dr. Kurt Schmude we believe it to be the species *Euhrychiopsis lecontei* (Figure 5). This species specializes in consuming Eurasian milfoil (Jester et al 1997).

BS5 was located in front of George William's College in William's Bay. Taxa representation jumped from 2012 to 2016 from 6 to 16 for the first sampling dates and 6 to 17 for the second sampling dates. For the first sampling date, there was an increase in the family Asellidae (80%), but a decrease in the snail families Valvatidae (65%), Viviparidae (87%), Planorbidae (69%), and Dreissenidae (45%). For the second round of sampling there was an increase in Chironomidae (21%) and Dreissenidae (49%). This was the first time that GLEA has captured a member of the family Sialidae, or the alderflies. Sialidae is one of the two aquatic families from the order Megaloptera.

BS6 was located at Pier 229 on the East shore of William's Bay. For the first sampling dates, there was an increase in the families Gammaridae (41%), Asellidae (95%), and Hydrobiidae (86%). There was a decrease in Planorbidae (45%), Valvatidae (99%), Viviparidae (91%), Dreissenidae (84%), and Chironomidae (32%). For the second sampling dates, there was a decrease in the families Gammaridae (78%), Planorbidae (40%), Valvatidae (100%), Viviparidae (100%), and Dreissenidae (82%). Chironomidae increased by 82%.

BS7 was located on the north shore to the west of the narrows. For the first sampling dates there was an increase in the families Asellidae (95%) and Chironomidae (73%). There was a decrease in Gammaridae (60%), Dreissenidae (28%), Hydrobiidae (40%), and Planorbidae (91%). For the second sampling date, there was an increase in the family Gammaridae (40%), Asellidae (53%), and Dreissenidae (78%). The families Valvatidae and Viviparidae were not represented like they were in 2012. This is was the first time that GLEA captured a member of the family Empididae, or shore flies.

Overall, an increase was observed in the density and presence of multiple families. As literature suggests there has been a significant jump in the abundance of Gammaridae, Asellidae, and Chironomidae due to the presence of zebra mussels (Karatayev et al. 2014). In the 2004 and 2008 studies, Chironomidae was reported as being absent or present at low densities (between 50-150 n/m^2). In 2012 chironomids were found at each benthic sampling station at densities around 50-100 n/m^2. This year, chironomid densities increased back to 1996 and 2000 levels ranging from 700-7,000 n/m^2. The sudden drop in Chironomidae is unusual; chironomids are able to occur in a wide range of habitats at high densities (Hammond 2009). A previously unrecorded family of amphipods, Hyalellidae (genus *Hyalella*), was documented this year; it was found at all 7 sampling sites. The 2012 intern Brian Schmidt noted a jump in the caddis fly family Leptoceridae (Schmidt, 2012). Although the densities were not as great in 2012, Leptoceridae was found at all 7 sampling sites along with the caddisfly family Hydroptilidae and the may fly family Caenidae. Genera of Hydroptilidae identified were *Hydroptila, Agraylea, Orthotrichia,* and *Oxyethira.* Genera of Leptoceridae were *Oecetis, Nectopsyche,* and *Leptocerus.* There was no mention of Hydracarina (water mites) since 1996; this year they were found at all 7 sampling sites. The leech family Glossiphoniidae has not been mentioned since 1996, but was found at 4 of the sampling sites. Schmidt also mentioned an increase in some snail families such as Hydrobiidae, Planorbidae, Valvatidae, and Viviparidae (Schmidt, 2012). The family Hydrobiidae was definitely the most abundant and has maintained high densities. In most cases, however, there was a decrease in the snail families Planorbidae, Valvatidae, and Viviparidae. As Schmidt (2012) suggested, the emergence of some families may be due to the stabilization of Dreissenidae (densities of Dreissenidae increased and decreased at various sites). Another explanation for the increase in taxa this year could be due to a change in methodology for processing the samples. In previous studies, a hand lens was used to sort through the samples, whereas I used a dissecting microscope that allowed me to observe smaller organisms difficult to see without higher magnification.

For the artificial substrate samplers it seems that the mussels prefer to attach to the bottom side of the squares. The reason for this is uncertain; it may have something to do with photosensitivity, especially since water clarity has increased allowing for deeper light penetration. It is important to note that the samplers have not be deployed since 2009, so I cannot say how numbers have changed within the past few years directly. It is also important to note, however, that there were thousands of veligers on the substrates in 2016 that were too small to see with the naked eye. Unfortunately, the veligers were so small that it was difficult to identify them as zebra mussels and therefore they could not be included in the final density calculations. There is a picture of the veligers in Figure 4. One possible explanation for this is that in 2016 we counted earlier in the summer than in 2009; the veligers on the substrates may have just attached and did not have the same amount of time to grow. This is only a potential explanation based off of knowledge of the zebra mussel's lifecycle (zebra mussels typically reproduce during the spring (Knigge et al. 2015)) and has not been tested or verified in any way.

Acknowledgements

I would like to thank Ted Peters and the Geneva Lake Environmental Agency for giving me the opportunity to work for them this summer. It was an incredibly valuable experience, and I feel like I have improved professionally and gained tremendous experience conducting field work and analyzing data. I would also like to thank Dr. Kurt Schmude for lending me his expertise in aquatic entomology and macroinvertebrates and allowing me to use his taxonomy lab and resources at UW-Superior.

Figures and Tables

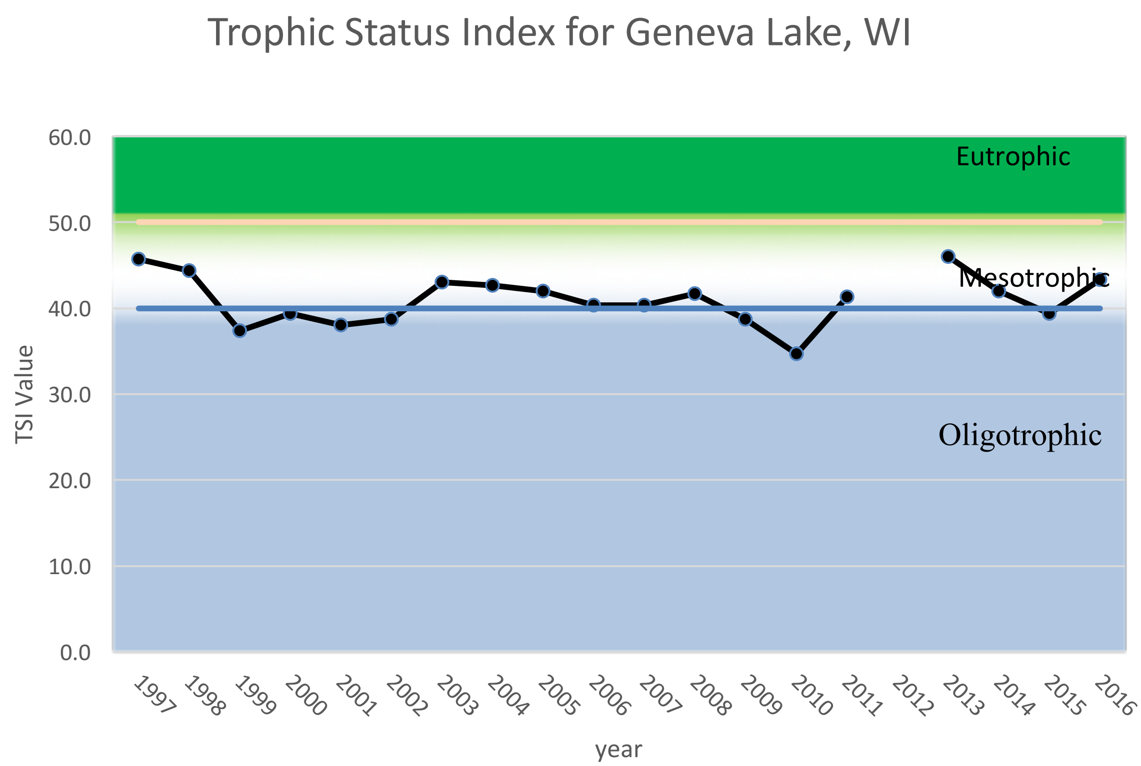

Figure 1. Trophic Status Index values for Geneva Lake from 1997-2016. Values determined by averaging Secchi disc, total phosphorous, and chlorophyll "a" values. Geneva is a borderline mesotrophic/oligotrophic lake.

Figure 2. Locations of the 7 benthic sampling stations.

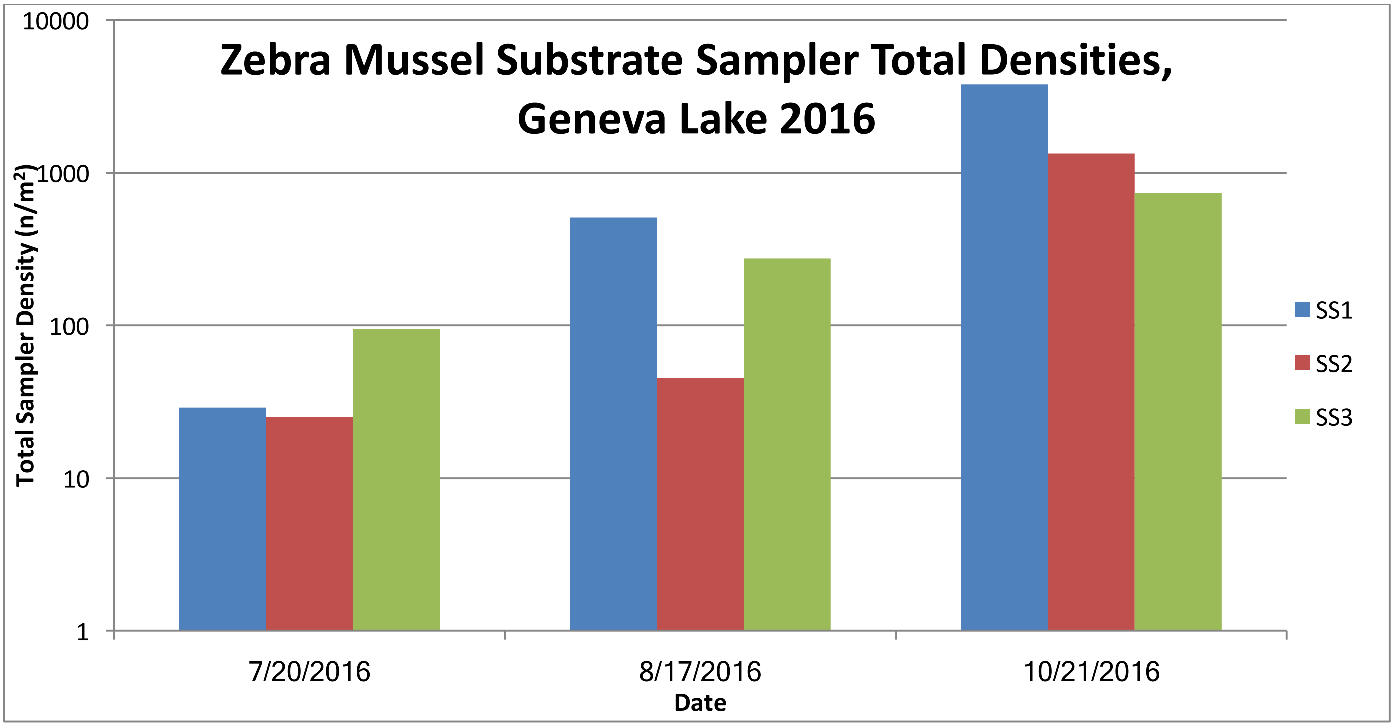

Figure 3. Total densities of zebra mussels on artificial substrate samplers at SS1(Fontana), SS2 (Linn), and SS3 (Lake Geneva) 2016.

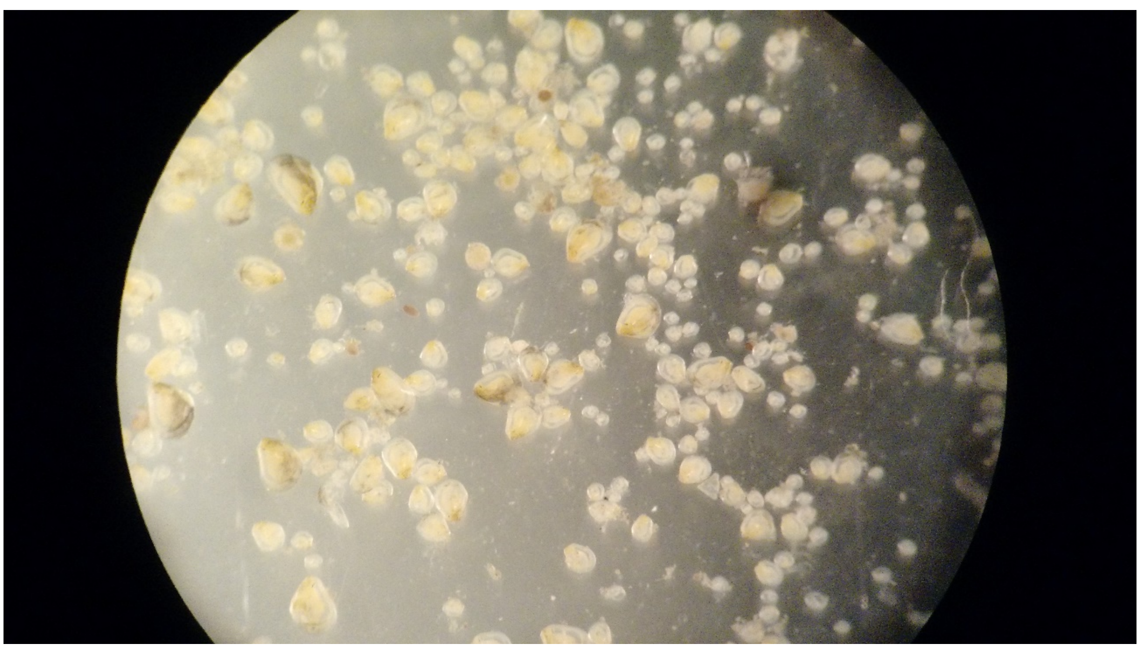

Figure 4. Unidentified mussel veligers from artificial substrates.

Figure 5. Curculionidae (weevil beetle), *Eurychiopsis lecontei*, that found at BS4.

Deployment: 6/16/	Location	Time	Water Temp (F)	Water Depth	Comments		
42^{0} 35' 21.14"N 88^{0} 26'	Riviera, LG	10:58	71	2 m	West end of piers		
42^{0} 33' 30.82" N, 88^{0} 27	Robinsin Hills	11:36	71	2 m	First horse to the W (left) at end of pier		
42^{0} 33' 1.66" N, 88^{0} 34'	Gordy's Fonta	12:50	70	2.5 m	Lighthouse pier, at end N next to light house		
Date: 7/20/2016	**Location**	**Time**	**Water Temp (F)**	**Depth (Sampler)**	**Secchi (m)**	**days**	**Comments**
42^{0} 35' 21.14"N 88^{0} 26'	Riviera, LG	10:35	80.6	1.17 m	1.75*	25	Mostly sunny, wind SW 5-7 mph, water choppy*
42^{0} 33' 30.82" N, 88^{0} 27	Robinson Hill	11:00	82.4	1.42 m	2.25*	25	Mostly sunny, calm, A 87.8 F*
42^{0} 33' 1.66" N, 88^{0} 34'	Gordy's, Font	11:30	83	1.78 m	2.15*	25	Sunny, light breeze SW, Air 87 F*
	Thousands of microscopic mussel veligers found on each substrate. Unable to identify as zebra mussels.						
Date: 8/17/2016	**Location**	**Time**	**Water Temp (F)**	**Depth (Sampler)**	**Secchi (m)**	**days**	**Comments**
42^{0} 35' 21.14"N 88^{0} 26'	Riviera, LG	13:18	80.6	1.17 m	1.75*	29	Sunny, Air 77.9 F, Light E breeze
42^{0} 33' 30.82" N, 88^{0} 27	Robinson Hill	14:12	80.6	1.42 m	2.25*	29	Sunny, Air 93.2 F, Light E breeze
42^{0} 33' 1.66" N, 88^{0} 34'	Gordy's, Font	10:30	77.9	1.78 m	2.15*	29	Sunny, Air 77 F, Light E breeze
	*Bottom						
	Thousands of microscopic mussel veligers found on each substrate. Unable to identify as zebra mussels.						
Date: 10/21/2016	**Location**	**Time**	**Water Temp (F)**	**Depth (Sampler)**	**Secchi (m)**	**days**	**Comments**
42^{0} 35' 21.14"N 88^{0} 26'	Riviera, LG	14:20	60	1.17 m	1.75*	65	80% cloudy, lt. NE wind,Air 50 F waves >4"
42^{0} 33' 30.82" N, 88^{0} 27	Robinson Hill	14:48	58	1.42 m	2.25*	65	90% Cloudy, lt NE wind, 7-10 mph. Air 50.0 Waves 6-9"
42^{0} 33' 1.66" N, 88^{0} 34'	Gordy's, Font	15:25	60	1.78 m	2.15*	65	100% Cloudy, lt. NE wind 7-5 mph, air 50.0F, waves 4-6"
	Still many small microscopic mussel velligers found on bottom of each substrate layer. However, they appear bigger than previous month.						
	Noticed many other small molluscs other than zebra mussels.						

Table 1. Parameters recorded during initial deployment of zebra mussel artificial substrate and subsequent counts. Water depths/Secchi depths estimated by meter markings on rope.

Date: 7/20/2016		# Mussels	
Location	**Square**	**Top**	**Bottom**
Lake Geneva	6" x 6"	0	9
	8" x 8"	2	2
	10" x 10"	0	8
	12" x 12"	3	18
Linn	6" x 6"	0	0
	8" x 8"	0	1
	10" x 10"	0	2
	12" x 12"	2	6
Fontana	6" x 6"	1	7
	8" x 8"	0	2
	10" x 10"	0	1
	12" x 12"	1	1

Date: 8/17/2016		# Mussels	
Location	**Square**	**Top**	**Bottom**
Lake Geneva	6" x 6"	17	19
	8" x 8"	28	9
	10" x 10"	21	3
	12" x 12"	21	4
Linn	6" x 6"	0	6
	8" x 8"	1	2
	10" x 10"	1	4
	12" x 12"	1	5
Fontana	6" x 6"	27	69
	8" x 8"	13	32
	10" x 10"	14	8
	12" x 12"	25	19

Date: 10/21/2016		# Mussels	
Location	**Square**	**Top**	**Bottom**
Lake Geneva 65 days	6" x 6"	5	61
	8" x 8"	29	26
	10" x 10"	27	130
	12" x 12"	17	30
Linn 65 days	6" x 6"	4	146
	8" x 8"	46	78
	10" x 10"	42	191
	12" x 12"	27	59
Fontana 65 days	6" x 6"	8	325
	8" x 8"	4	517
	10" x 10"	25	277
	12" x 12"	34	493

Table 2. Raw data of zebra mussel from artificial substrates processed on 7/20/2016, 8/17/2016, and 10/21/2016.

Date: 7/20/2016		Densities (n/m^2)			
Location	Square	Top	Bottom	Combined	Whole Substrate
Lake Geneva	6" x 6"	0	388	194	
	8" x 8"	48	48	48	
	10" x 10"	0	124	62	
	12" x 12"	32	194	113	95
Linn	6" x 6"	0	0	0	
	8" x 8"	0	24	12	
	10" x 10"	0	31	16	
	12" x 12"	22	65	43	25
Fontana	6" x 6"	43	302	172	
	8" x 8"	0	48	24	
	10" x 10"	0	16	8	
	12" x 12"	11	11	11	29
Date: 8/17/2016		**Densities (n/m^2)**			
Location	**Square**	**Top**	**Bottom**	**Combined**	**Whole Substrate**
Lake Geneva	6" x 6"	733	819	776	
	8" x 8"	678	218	448	
	10" x 10"	326	47	186	
	12" x 12"	226	43	135	275
Linn	6" x 6"	0	259	129	
	8" x 8"	24	48	36	
	10" x 10"	16	62	39	
	12" x 12"	11	54	32	45
Fontana	6" x 6"	1164	2974	2069	
	8" x 8"	315	775	545	
	10" x 10"	217	434	326	
	12" x 12"	269	205	237	511
Date: 10/21/2016		**Densities (n/m^2)**			
Location	**Square**	**Top**	**Bottom**	**Combinec**	**Whole Substrate**
Lake Geneva	6" x 6"	216	2,629	1429	
42^0 35' 21.14"N	8" x 8"	702	630	666	
88^0 26' 12.95" W	10" x 10"	419	2,016	1217	
	12" x 12"	183	323	253	732
Linn	6" x 6"	172	6,293	3247	
42^0 33' 30.82" N	8" x 8"	1,114	1,889	1501	
88^0 27' 44.86" W	10" x 10"	651	2,961	1806	
	12" x 12"	291	635	462	1,336
Fontana	6" x 6"	345	14,009	7208	
42^0 33' 1.66" N	8" x 8"	97	12,518	6308	
88^0 34' 19.70" W	10" x 10"	388	4,295	2341	
	12" x 12"	366	5,307	2833	3,792

Table 3. Calculated densities of zebra mussels on artificial substrates.

SITE INFORMATION FOR BENTHIC SAMPLING			**GPS**
Site ID	**Common Name**	**Depth(m)**	**Coordinates**
BS1	East of Pier #61, E. of Narrows N. shore, near LG	1.7	N 42 34.401' W 88 28.153'
BS2	In front of Stone Manor, East Shore of Geneva Bay	2.5	N 42 34.953' W 88 26.126'
BS3	In front of Lake Geneva Country Club, S. Shore, Linn	1.6	N 42 33.795' W 88 28.308'
BS4	In front of Chicago Club Estates, S. Shore, Fontana	1.2	N 42 33.029' W 88 31.886'
BS5	In front of George William's College, N. Shore	2.1	N 42 33.944' W 88 33.344'
BS6	In front of pier #229, E. Shore William's Bay	2.2	N 42 34.487' W 88 31.797'
BS7	In front of pier #130, W of The Narrows on N. Shore	2	N 42 34.469' W 88 30.142'

*GPS coordinates taken from study by Brian Schmidt in 2012.

Table 4. Descriptions of each benthic sampling station.

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