Pelecypod and Gastropod Communities at Pierce Cedar Creek Institute:

Variation in Understudied Organisms

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Abstract

Pelecypod (freshwater bivalves) and gastropod (freshwater snails) communities were studied at Pierce Cedar Creek Institute (PCCI, Barry County, Southwest Michigan) to determine the diversity and variation in and among riverine, wetland, and lake habitats. These faunal groups are two of the most understudied, least understood and most at risk of extirpation in North America. The mollusc communities were compared to the non-mollusc macroinvertebrate communities, quantified and documented indicators of overall water quality. The mollusc communities within PCCI were also compared to communities in three other water bodies (Kalamazoo, Looking Glass, and Thornapple Rivers). Cedar Creek was determined to be a pristine habitat for many Unionidae in the watershed and supported high abundance as well. One Cedar Creek site had a unionid density of 21.29 per m^2 which was a much greater density than other river sites studied during this research. The wetlands, depending on location, had a very large diversity and abundance of pelecypods and gastropods. This was also true in Brewster Lake and the unionid populations, for example site one has 31 *Pyganodon grandis* and one of the five sites had none. Aquatic invasive species like the zebra mussel, asian clam, and chinese mystery snails from the Thornapple River are a real threat to Cedar Creek. Responsible management of PCCI's waters is vital to maintain the pristine environment.

Introduction:

Freshwater Pelecypods (bivalves) range from tiny pea clams and fingernail clams in the family Sphaeriidae to bivalves that can grow greater than 150 mm long and are in the family Unionidae. Freshwater gastropods (snails) are a diverse group that consists of 842 named taxa in the USA and Canada (Lysne et al. 2008). More than 70% and 60%

of unionids and gastropods respectively are globally imperiled and Sphaeriidae have recently been found to be in decline, sometimes dramatically (Strayer et al. 2004, Lysne 2008, Wilson et al. 1995). The need for pollution-free environments is evident in the research of all of these molluscs and recent effects of water quantity, water quality and invasive species have caused dramatic declines in all of these groups (Strayer et al. 2004, Cope et al. 2008).

Both Sphaeriidae and Gastropods have a lifecycle that includes dispersal abilities that are limited to the flow and movement of water patterns as they release their larvae into the water columns. However, the Unionidae have a bizarre and unique lifecycle that includes a host fish for movement (Bauer and Wächtler 2001) during early life stages. Unionidae are longer lived than Gastropods and Sphaeriidae, with the former sometimes living over 60 years whereas the later living 1-5 years (Lysne et al. 2008; Bauer and Wächtler 2001). Research has shown that these mollusc groups are equivalent to a “canary in a coalmine” and are some of the most sensitive aquatic organisms in North America (Cope et al. 2008). With approximately 300 Unionidae species, approximately 40 species of Sphaeriidae, and more than 800 Gastropod taxa found in North America, it has been found that species vary in their sensitivity to water quality and habitat changes (Strayer et al. 2004). However, quite commonly, when macroinvertebrates are collected for water quality analyses Unionidae are not counted at all or placed in the broader category of Pelecypoda with the Sphaeriidae, and gastropods only counted as Class Gastropoda. Even at Pierce Cedar Creek Institute this has been the case with macroinvertebrate research in both lentic and lotic systems (e.g., Vander Hyde et al. 2009, Higgins and Bajema 2006, Balis and Bajema 2005). The

entire benthic macroinvertebrate community including all mollusc groups in the three aquatic ecosystem types represented at PCCI (lake, wetland, and river) was surveyed during this study. Data was collected using standardized quantitative methods so that it could be compared with sites off PCCI and help with determining management implications and help provide documentation about molluscs at PCCI. Management strategies for healthy and sustainable mollusc communities were suggested for the future of PCCI and extrapolated for other plans nationwide.

Our objectives were to determine whether there were differences among the molluscan communities sampled at rivers, lakes and wetlands. In addition, we were considering whether the molluscan communities differed from the PCCI sites to the sites in rivers off PCCI land. Finally, this was the first true molluscan survey at PCCI and all species collected were identified down to genus (Sphaeriidae) or species (Unionidae and Gastropoda).

Methods:

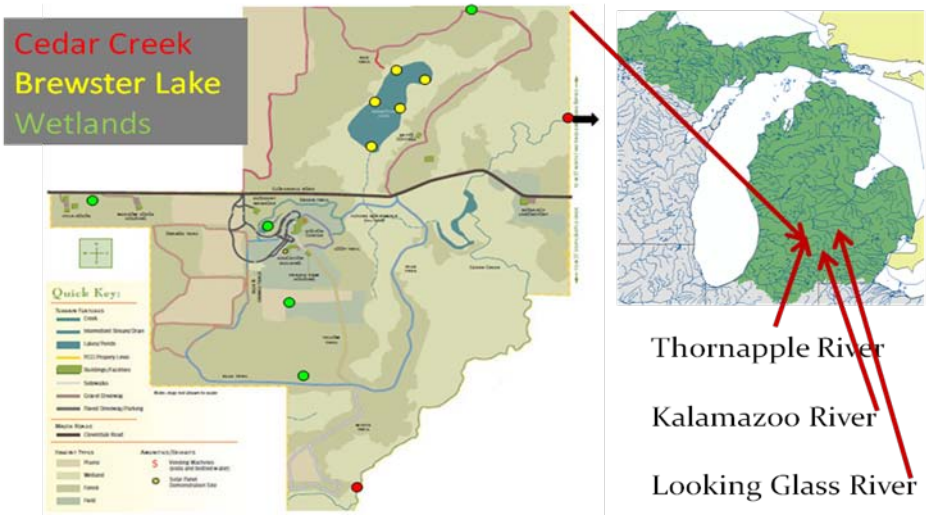
Lotic Sampling - Cedar Creek and the Kalamazoo, Looking Glass, and Thornapple Rivers prior to sampling had timed survey reconnaissance to determine the best sites for quantitative quadrat sampling (Figure 1). It was necessary to do a four person hour visual search to determine if the sites suggested are suitable for data collection. Wading and/or snorkeling was necessary to determine exact locations for sampling. Once sites were selected, an upstream and downstream site was determined for sampling. In each river, an extensive quadrat sampling method was used that locates all sizes of unionids (juvenile and adults) as indicators of reproduction (Strayer and Smith 2003). We

sampled approximately 20% of 400m^2. In Cedar Creek we used 0.25m x 0.25m quadrats due to the tremendous density of unionids initially found. For the other rivers we used a 1m x 1m quadrat. Unionids were identified, measured and had a small piece of tissue sampled (for DNA analyses in future projects) and returned alive to the river reach they were found. Global Positioning System (GPS) was used to record sampling location and abiotic habitat variables were recorded for each quadrat sampled (e.g., depth, flow, substrate composition).

Sphaeriidae and gastropods were also sampled using standard D-net kick sweep, triplicate sampling and other non-molluscan samples were collected using this same technique. Samples were taken from of live individuals in the field or lab and returned in ethanol (95%) for proper identification. All samples were returned to Central Michigan University and kept for future confirmation. Insects were identified down to the lowest possible taxonomic level (based on the Ontario Benthos Biomonitoring Protocol), with gastropods from D-net sampling were identified to species and Sphaeriidae identified to Genera (Merritt and Cummins 2008).

Lentic Sampling- For Brewster Lake unionid sampling, a timed survey (1.5ph) was used at 5 sites evenly distributed throughout the lake shoreline (Strayer and Smith 2003) (Figure 1). A boat provided by PCCI was used to travel from site to sites on Brewster Lake. Due to the long periods in the water, wetsuits were necessary for this sampling and unionids were collected by tactile and visual surveys of depths that snorkeling was possible (~50m^2 per site). Wetland sites did not have Unionids present therefore were not sampled for Unionidae.

Five Brewster Lake sites and wetlands (5 sites) were sampled for Sphaeriidae, Gastropods, and other non-molluscan macroinvertebrates were sampled using standard D-net sampling, collection and identification techniques noted above (Figure 1). Three replicates were collected at each site.



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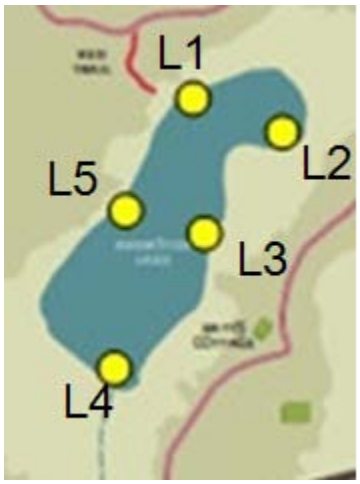

B

Figure 1. Sampling Sites- A) Green Sites= PCCI wetlands, Yellow=PCCI Lakes, Red Sites= Cedar Creek Sites- 1 end of White Trail (PCC1) and 1 at Broadway Rd (PCC2). B) Individual sampling sites on Brewster Lake.

Statistical Analyses

Quadrat sampling technique that were used for unionids were compared using standard t-tests statistics for between sites, within rivers and among river data. D-net data was analyzed using t-test statistics for species counts, species diversity and differences among sites and aquatic habitat (lake, river, wetlands).

A Principle Component Analysis (PCA) using PC-Ord^{TM} was used to compare all D-net data. This considered all non-unionid molluscan data and the non-molluscan data from all river, wetland and lake sites. The PCA used a correlation cross-products matrix from all sites from which eigenvalues were determined to explain the variation among the non-unionid molluscan data and then vectors from the non-molluscan data were added to determine which non-molluscan invertebrates correlated with the molluscs we found.

Results:

In total, a single genus of Sphariidae was found in wetlands, two in Brewster Lake and two in Cedar Creek with two genera found in the other rivers sampled. Also, in total ten species of Gastropoda were found in wetlands, eight in Brewster Lake and eleven in Cedar Creek with twelve species found in the other rivers sampled. Finally, no Unionidae were found in wetlands only one species (*Pyganodon grandis*) was found in Brewster Lake and seven live species with five more species with only shells in Cedar Creek and 12 species of Unionidae found in the other rivers sampled. These data can be found and are summarized in Appendix A.

Lakes and rivers had a greater number of Sphaeriidae genera than did wetlands. Cedar Creek and the other rivers had the same number of Sphaeriidae genera (Figure 2). Sphaeridae richness was greater in rivers than in lakes and greater in lakes than in wetlands. Cedar Creek and the other rivers had the same abundance of Sphaeriidae (Figure 3). *Musculium* were found in wetlands, *Musculium* and *Pisidium* were found in lakes, and *Sphaerium* and *Pisidium* were found in rivers. Lakes had the greatest number of Gastropoda species and rivers had a greater number of species than wetlands. Cedar Creek and the other rivers had the same number of Gastropoda species (Figure 4). Wetlands had ten total species with three to four main species per site. There were also two species, *Stagnicola petoskeyensis* and *Stagnicola caperatus*, were found in wetlands and not found in lakes or rivers. Lakes had eight total species with five main species per site. Lakes lacked species that were not found in rivers or wetlands. Rivers had eleven total species with five main species per site. There were three species found in the rivers and not found in lakes or wetlands. Lakes had the greatest number of Gastropoda species and rivers had a greater number of species of gastropods than wetlands. Cedar Creek and the other rivers had the same Gastropoda abundance (Figure 5). Richness and abundance of Sphaeriidae and Gastropoda data are presented in Appendix A.

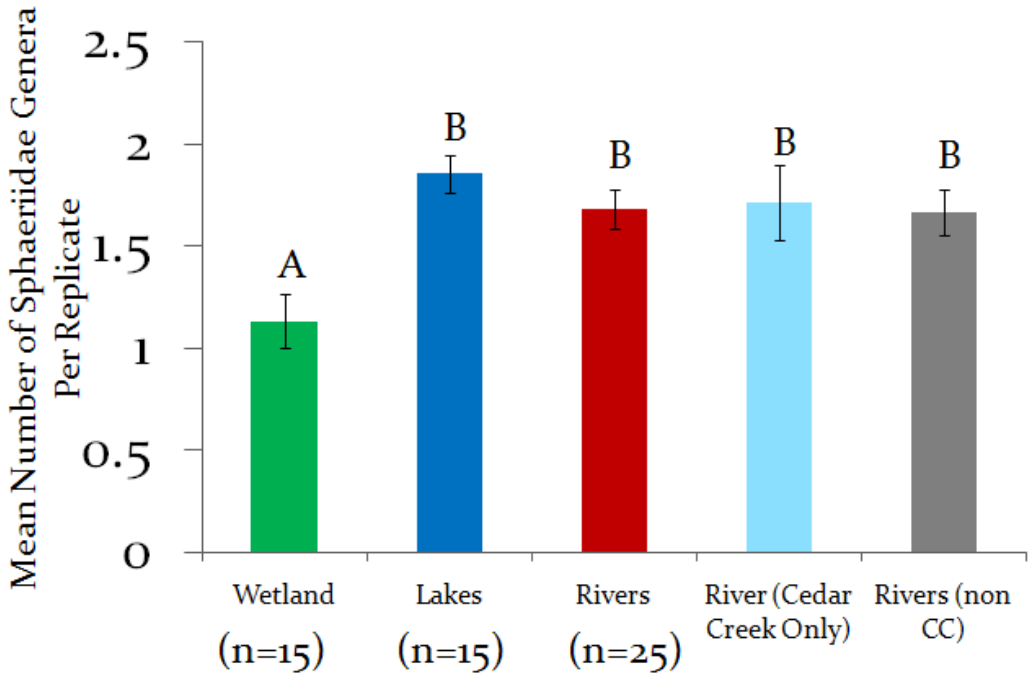

Figure 2. Mean Sphaeriidae richness found at sampling sites during 2010. Bars are standard error and A/B $p<<0.0005$. CC = Cedar Creek.

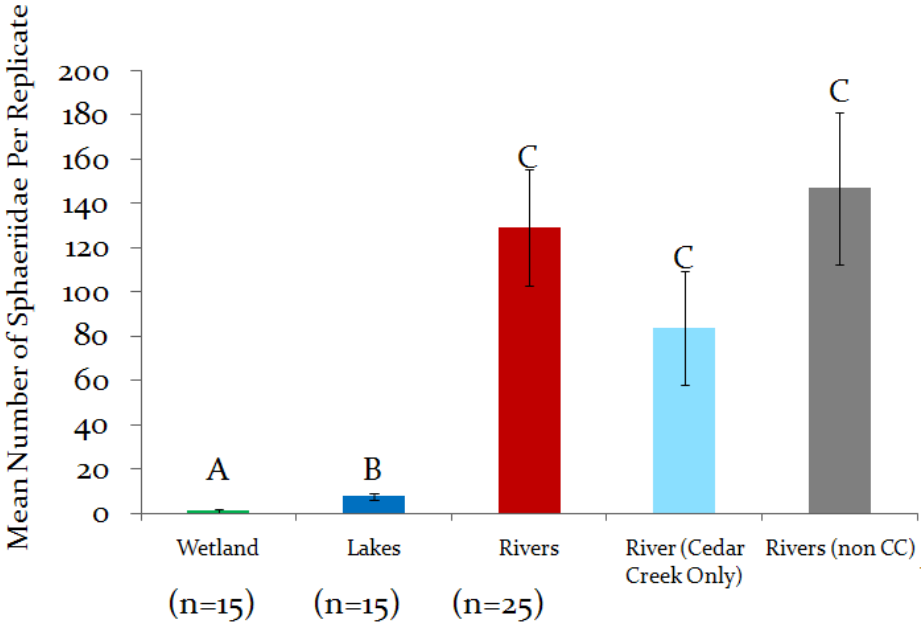

Figure 3. Mean Sphaeriidae abundance found at sampling sites during 2010. Bars are standard error. A/B *p=0.0038*, B/C p=0.00097, C/A *p<0.0008.* CC = Cedar Creek.

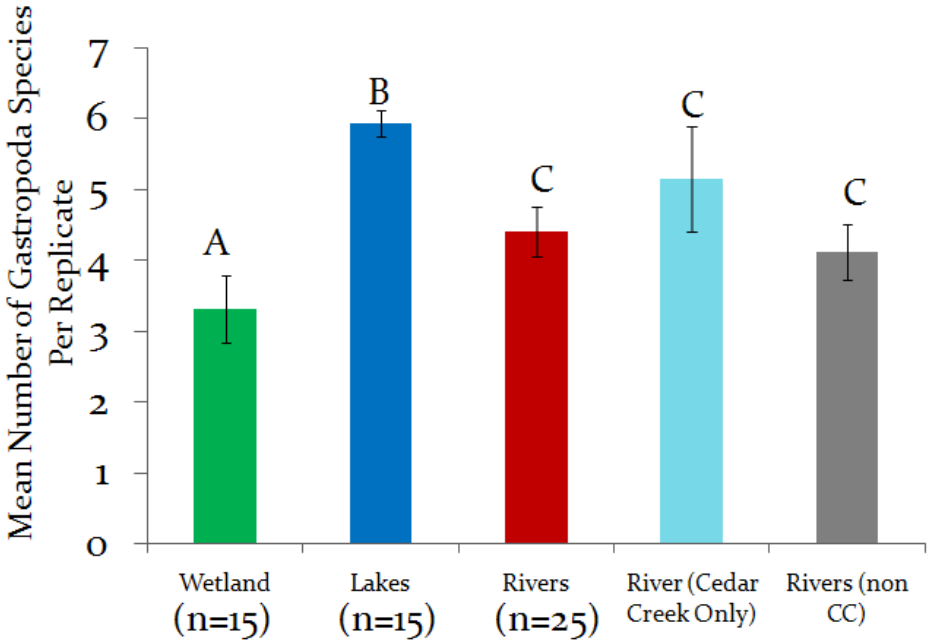

Figure 4. Mean Gastropoda species richness found at sampling sites during 2010. Bars are standard error. A/B $p<<0.0005$, B/C $p=0.0026$, C/A $p<0.01$. CC = Cedar Creek.

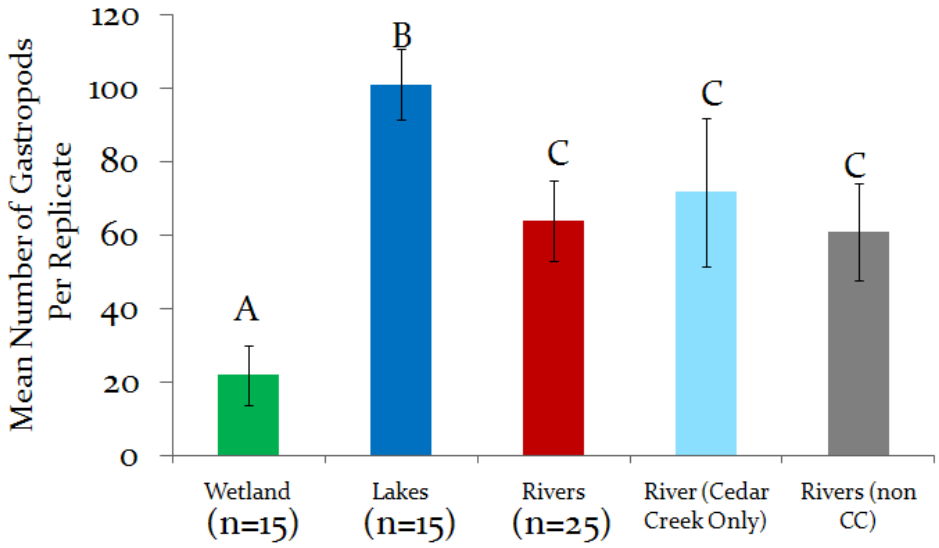

Figure 5. Mean Gastropoda abundance found at sampling sites during 2010. Bars are standard error. A/B $p<<0.0005$, B/C $p=0.025$, C/A $p<0.01$. CC = Cedar Creek.

According to Principle Component Analysis, non-Unionidae molluscan data for lakes are similar, for wetlands are similar, and for rivers, with the exception of Cedar Creek site 1, are similar. Cedar Creek site 1 (near the white trail) is grouped separately (Figure 6). Non-molluscan macroinvertebrate data from Principle Component Analysis shows Hirudinea, Oligochaeta, and Hemiptera found more in wetlands, Decapoda and Simuliidae found more in rivers, and Hydrachnida and Trichoptera found more in lakes (Figure 7).

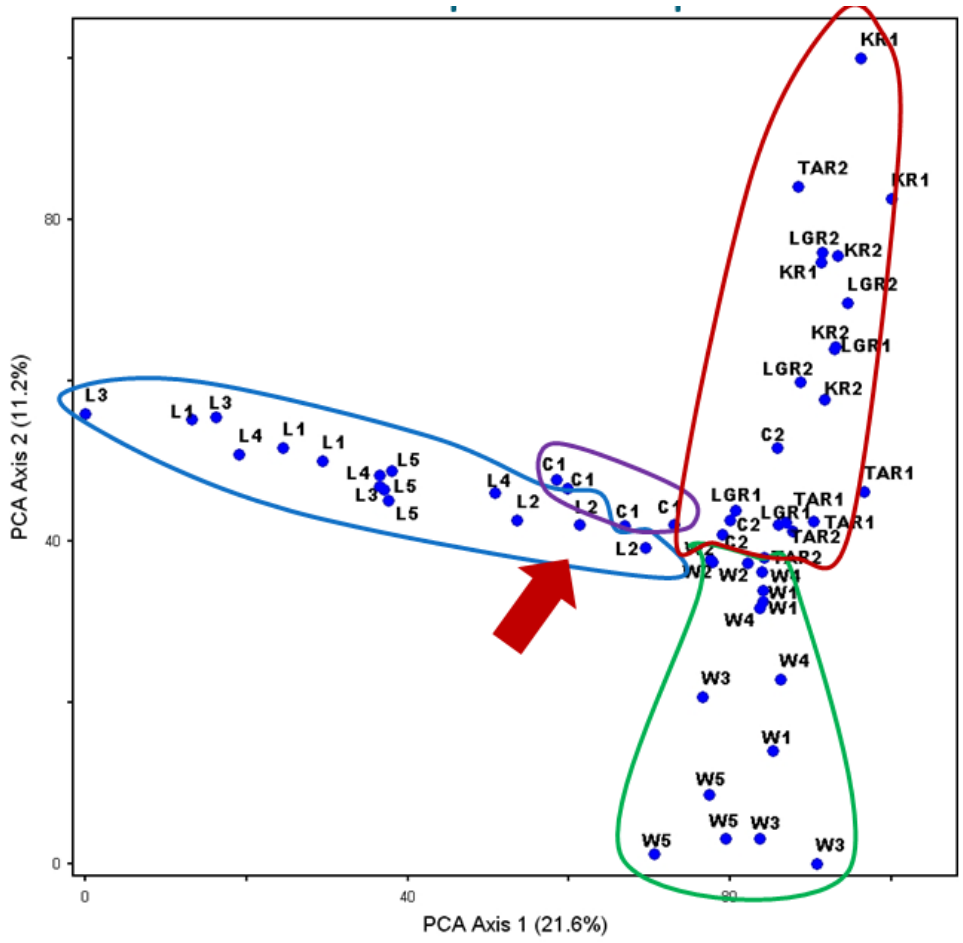

Figure 6. Principle Component Analysis (PCA) for all replicates sampled in 2010. PCA plots all non-unionid molluscan data by replicates. L= Lake sites, W= wetland sites, C=Cedar Creek Sites (C1=White trail, C2=Broadway), KR= Kalamazoo River, LGR= Looking Glass River, and TAR= Thornapple River.

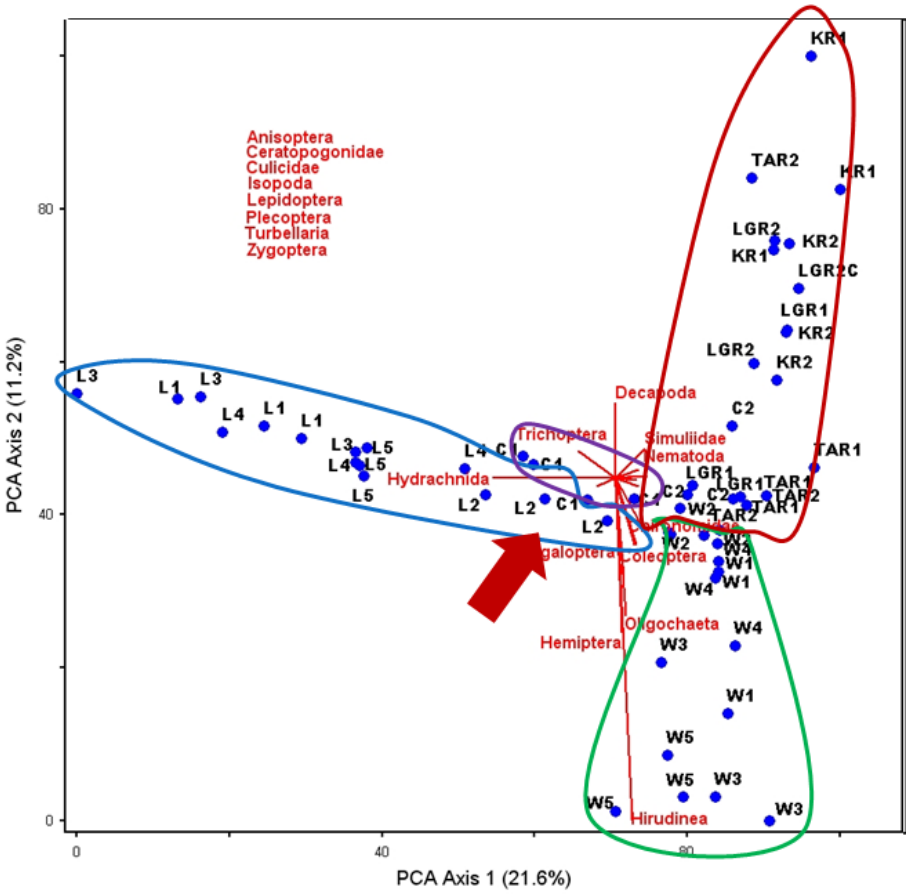

Figure 7. Principle Component Analysis (PCA) for all replicates sampled in 2010. PCA plots all non-unionid molluscan data by replicates with vectors of similar non-molluscan data from D-Net samples. L= Lake sites, W= wetland sites, C=Cedar Creek Sites (C1=White trail, C2=Broadway), KR= Kalamazoo River, LGR= Looking Glass River, and TAR= Thornapple River. List of invertebrate data in left corner corresponds with small vectors. Red arrow points to site L2- the unique site on Brewster Lake.

Seven total live species and shells of five additional species were found in Cedar Creek. Of those species, four (Elktoe, Round Pigtoe, Ellipse, and Rainbow) are listed as Special Concern in the State of Michigan and one (Slippershell) is listed as Threatened in the State of Michigan (Michigan Natural Features Inventory 2009). Five live species were found at PCC1 and seven species were found at PCC2. PCC2 had a

greater Unionidae abundance compared to PCC1. The most common Unionidae species found were Spike, Rainbow, and Plain Pocketbook (Figure 8).

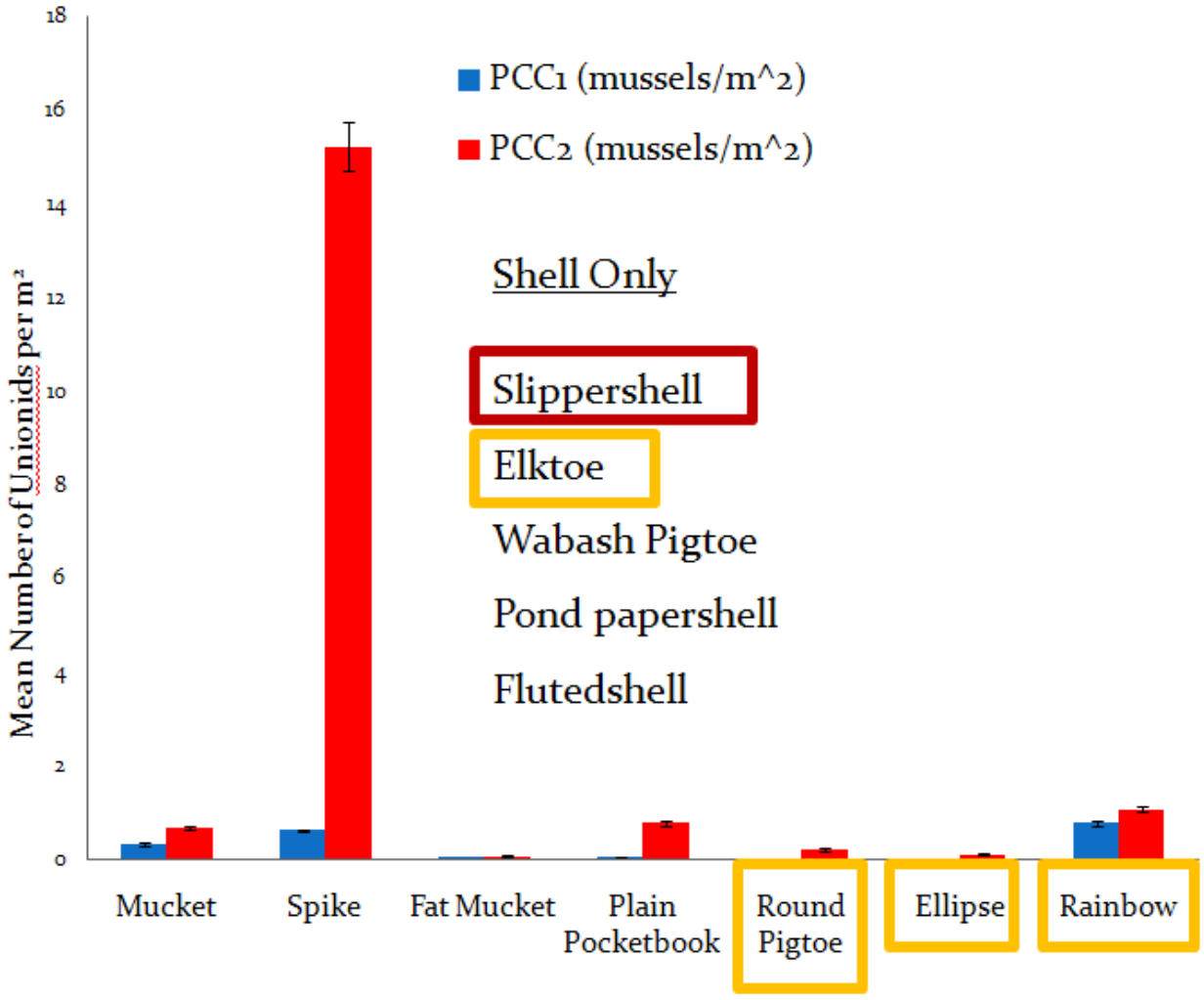

Figure 8. Unionidae density at Cedar Creek Sites. PCC1= white trail, PCC2= Broadway crossing. 5 species listed were found as shells only. Species with yellow boxes are listed as special concern in Michigan and in red is threatened in Michigan. Bars are standard error.

One species on Unionidae, *Pyganodon grandis*, was found in Brewster Lake at four out of the five sampling sites (Table 1). Site 1 and 3 had the largest numbers with

31 live *P.grandis* found at each site. Sites 4 and 5 had lower numbers of *P.grandis* found 10 and 2 respectively and site 2 had no live or shells of mussels found.

Table 1. Brewster Lake Unionidae diversity. Sites correspond to sites presented in Figure 1.

Site	*P.grandis*
1	31
2	0
3	31
4	10
5	2

Although there was only one species of unionid found in Brewster Lake, Cedar Creek sites had many more with 5 and 7 species found alive respectively. Overall density of the Cedar Creek White Trail site was comparable to many of the other rivers we sampled in the nearby area (Table 2). However, Cedar Creek Broadway Site had the largest density of mussels collected all summer. This density is dominated by *Elliptio dilatata* (~14 per m^2), but even without the Spike (*E. dilatata*) this site would be more densely populated than many of the other sites (Table 2). The number of species we found is comparable to the other rivers in the area. Zebra mussels, asian clam and chinese mystery snail which are all invasive species we found in the Thornapple River were not found in Cedar Creek.

Table 2. Unionid species richness and density as sampled at all sites throughout summer 2010.

Site	# of species	Density (per m^2)
Cedar Creek (C1- White Trail)	5	1.79
Cedar Creek (C2- Broadway)	7	21.29
Thornapple 1	6	1.32
Thornapple 2	10	2.90
Looking Glass 1	10	3.82
Looking Glass 2	12	9.4
Kalamazoo 1	5	1.13
Kalamazoo 2	9	8.33

Discussion

We found that macroinvertebrate and molluscan communities differed in wetlands, lake, and riverine habitats. This means that each type of habitat is unique and the communities found there are unlike the communities found in the other habitats. For example, the Sphaeriidae found in wetlands, *Musculium*, differed from that found in rivers, *Sphaerium* and *Pisidium*. We believe this is due to differences in water flow, substrate composition, water quantity, and water quality between wetlands, lake, and riverine habitats.

Macroinvertebrate and molluscan communities are statistically similar among Cedar Creek, Thornapple River, Kalamazoo River, and Looking Glass River. These rivers are all in the same or adjacent watersheds in southwest Michigan. This allows communities in these water bodies to interact with each other allowing the

macroinvertebrates and mollusks to move and populate the entire water body. This interaction will lead to the communities becoming similar to each other throughout the range of the watershed.

According to the Principle Component Analysis, certain macroinvertebrates were more likely to be found in certain habitats. For example, Hirudinea were found more often in wetlands and Hydrachnida were more often found in the lake (Figure 7). These findings are nothing too surprising, but this sort of comparison should be used in the future to see if the macroinvertebrate community composition for each habitat changes over time.

Our findings are very important because a study like this has never been done before. The studies that have been done on macroinvertebrate community composition have just focused on wetlands, lakes, or rivers, but have never compared all of them. This study is unique because it incorporates the communities from wetlands, lake, and riverine habitats that are in the same area, Pierce Cedar Creek Institute, and compares them to one another. It also compares other rivers in the same region, Thornapple, Kalamazoo, and Looking Glass Rivers, for further comparison.

Unique Findings at Pierce Cedar Creek Institute

One interesting finding was that the Broadway Site (C2) in Cedar Creek had a very high abundance of mussels. The density was 21.29 mussels/m^2 and this is the most mussels sampled in all Michigan rivers in the past two years by Central Michigan University. This high abundance is very good because it shows that Cedar Creek is a pristine environment and that the Broadway site has ideal conditions for mussels and

mussel reproduction. However, the majority of the mussels found were Spike (*Elliptio dilatata*) and the Unionidae composition at this site is dominated by this species (Figure 8). This should be monitored to ensure that biodiversity at the Broadway site is not lost.

In contrast to the Broadway Site, the Cedar Creek site off from the white trail (C1) had a density of 1.79 mussels/m^2. This is much lower and may be because the site is more similar to a lake. According to the Principle Component Analysis, C1 is grouped separately from rivers because the non-unionid mollusc community is more similar to that found in the lake, whereas C2 is grouped with the rivers and the non-unionid mollusk community is similar to that found in the other rivers (Figure 6). Therefore C1 is more like a lake than a river and this could account for the lower number of mussels. The reason C1 is more lake like may be because there is some sort of water flow between the lake and C1, which would account for the mollucan communities to be similar. Also, the substrate composition was mostly sand and woody debris at C1, whereas it was mostly gravel at C2. The difference in substrate composition could cause the difference in mussel abundance.

Brewster Lake Site 2 (L2) is unique and should be investigated further. From the Principle Component Analysis, L2 is closer to the wetlands on PCCI property in community composition then the rest of the Brewster Lake sites. The molluscan communities at L2 are more similar to wetlands then lakes. Another interesting possibility that was determined from the search of Brewster Lake came from where the *P.grandis* was found in the lake. In site 1, many *P.grandis* were found but the population was not evenly distributed throughout the site. Some locations had ground water intrusions leading to the surrounding water to be much colder. In these areas no

mussels were found leading to the possibility that *P.grandis* habitat selection is possibly linked to the flow of groundwater in the lake.

Invasive Species Threats to Pierce Cedar Creek Water Bodies

There are many aquatic invasive species threats to PCCI, the three main ones of concern are the zebra mussel (*Dreissena polymorpha*), asian clam (*Corbicula fluminea*), and the chinese mystery snail (*Cipangopaludina chinensis*). All of the following currently are found in large numbers in the Thornapple River which Cedar Creek is a tributary to. If one or all of these invasive species were to find their way into PCCI water bodies it could lead to some very serious consequences for the health of the pristine aquatic habitats on the property (Higgins and Vander Zanden 2010).

Management Implications

The control of invasive species into all water bodies at PCCI should be of great concern. There are some management steps that can be taken to lessen the spread of the zebra mussel, asian clam, and the chinese mystery snail. The current fishing regulations in effect at PCCI are a very effect way to stop the spread of invasive species. Allowing no outside boats, no bait buckets, and controlling fishing is a great policy to protect Brewster Lake. These steps should also be taken on Cedar Creek to also protect it from these threats. One regulation that is not in practice that might be one to consider is making sure the researchers over the summer are not spreading invasive species with their equipment. This could be resolved by whenever any equipment (buckets, waders, nets, YSI probes, etc.) is taken from one body of water to another all parts are washed with a bleach solution and allowed to dry before allowed to go into another body of water. If these techniques are applied the risk of invasive species could

be greatly decreased. Furthermore, PCCI should have a vested interest in the health and management of the Thornapple River. Controlling the invasive species here will also help protect Cedar Creek. For example, the destruction of dams would provide an unobstructed pathway for the spread of zebra mussels further up the Thornapple River and eventually into Cedar Creek.

The molluscan biodiversity should be monitored on a five year cycle in the wetlands, lake, and riverine habitats. It is not necessary to monitor every year because these organisms, especially Unionidae, are fairly long lived. For monitoring, a survey should be conducted in each type of habitat in order to determine molluscan biodiversity.

There is a large change in unionid density between the Cedar Creek White Trail and Cedar Creek Broadway Site and further research is needed to completely understand why this is such a dramatic change. One possible hypothesis to this is the large wetland like environment that separates the two sites. One is more of an open habitat and the other is a Cedar Swamp. This could limit the movement of fish consequently effecting the movement of the mussels. To determine the true cause of this change further research will need to be done to see how the creek changes between these two sites.

Acknowledgements

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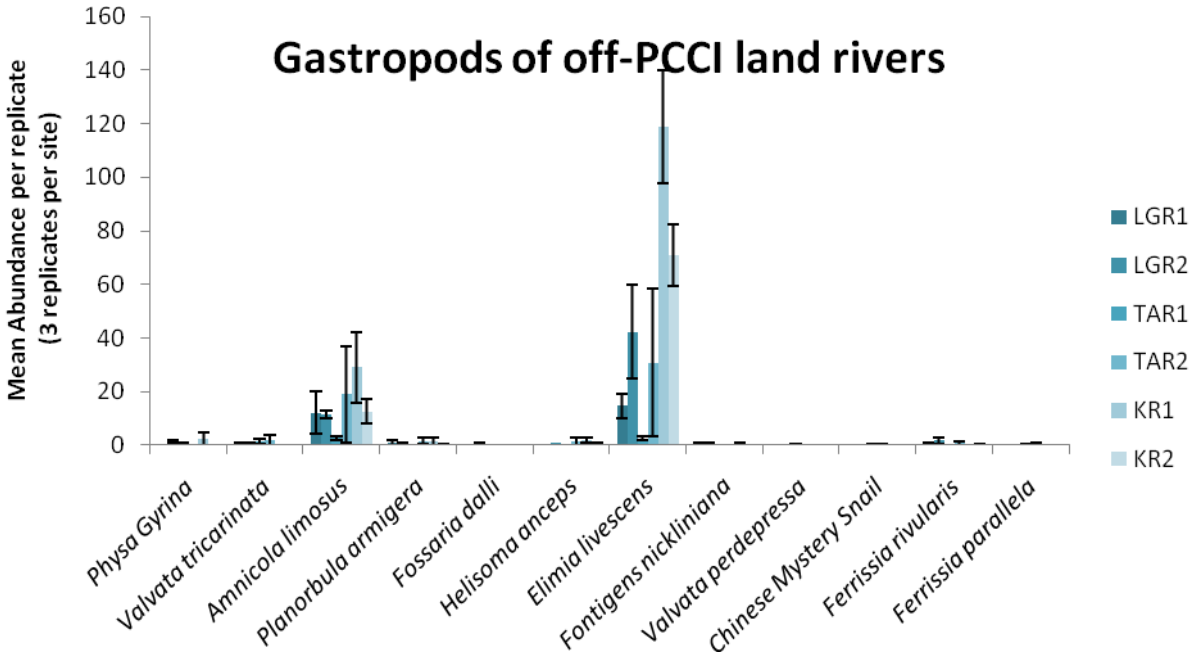
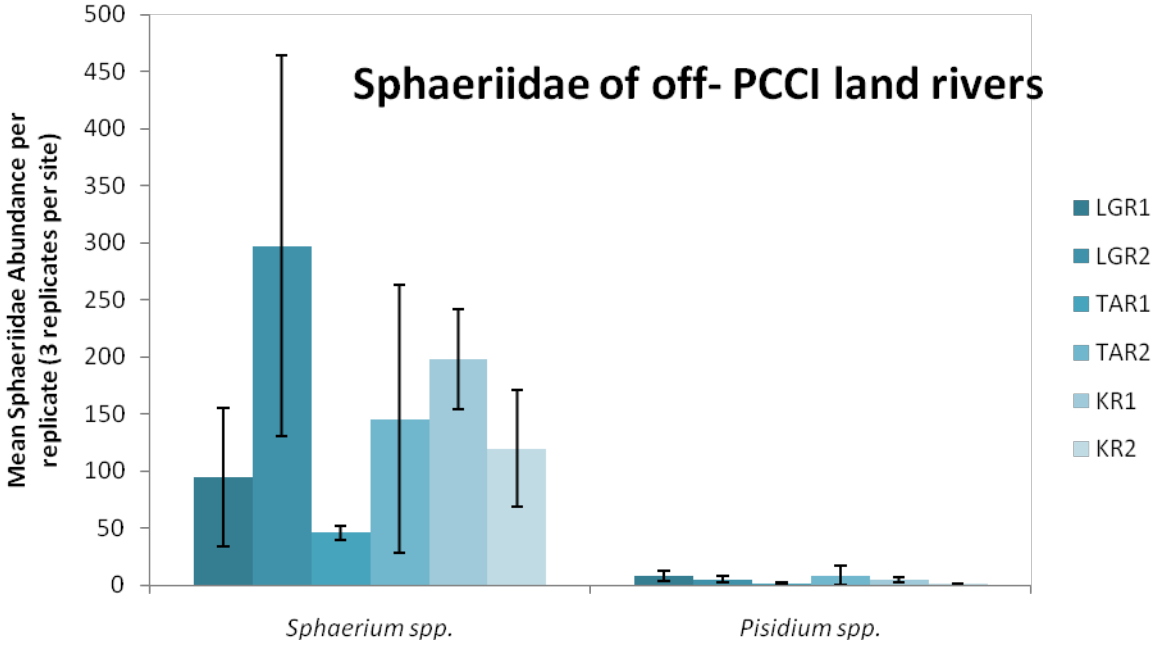
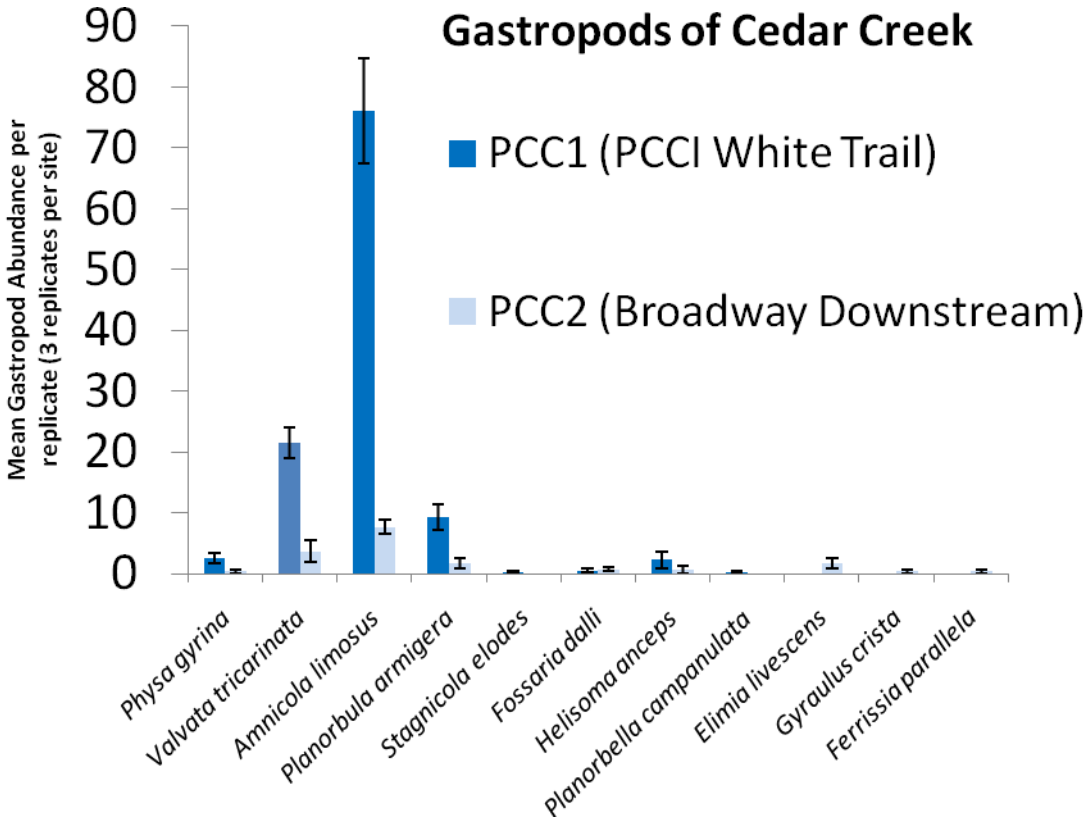
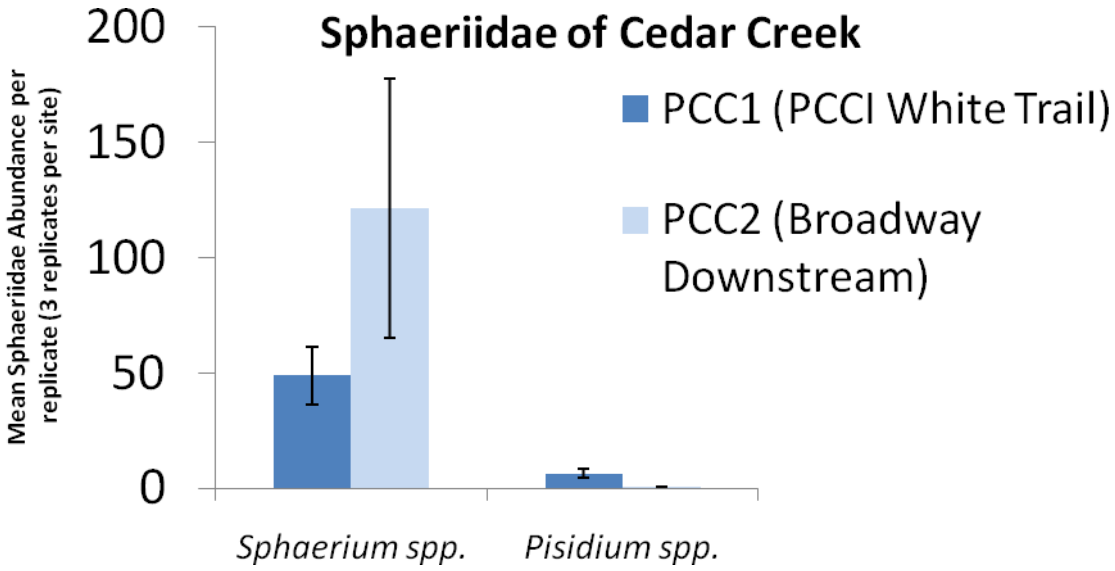
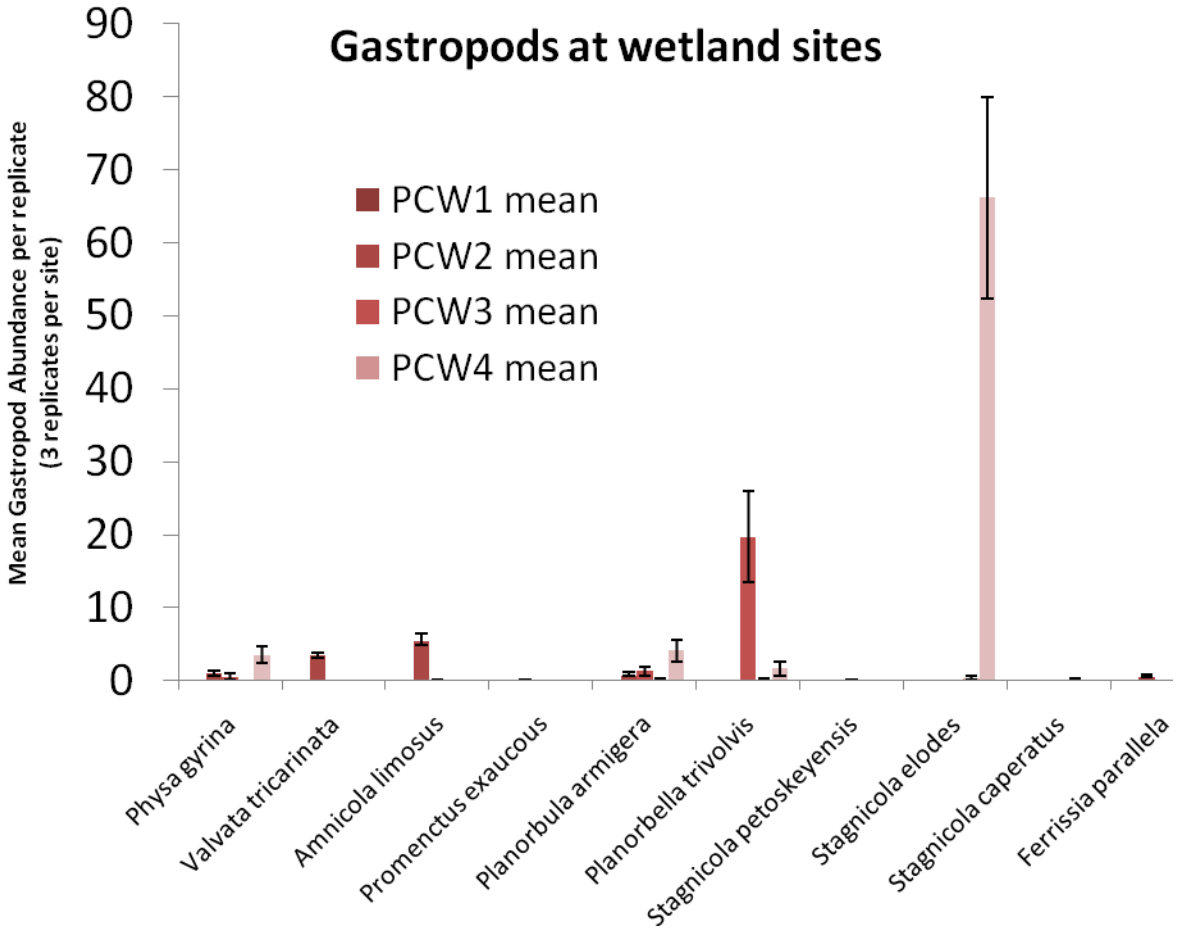
APPENDIX A

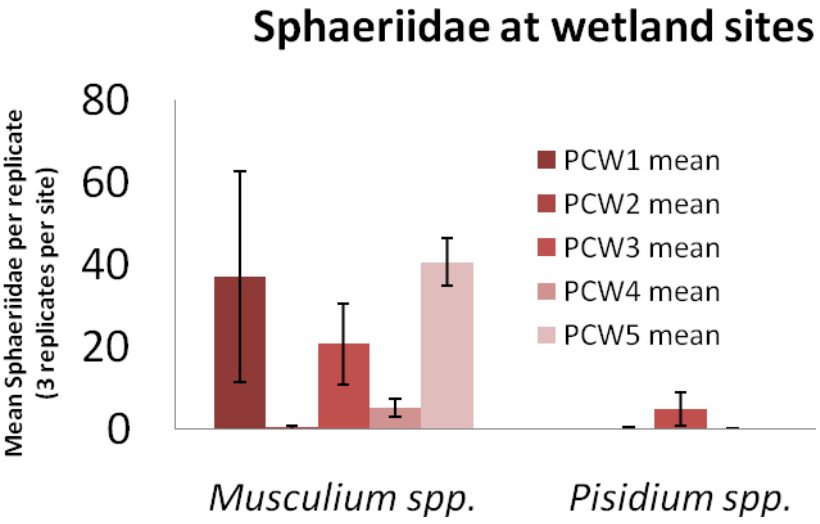

Gastropods of off-PCCI land rivers
Mean Abundance per replicate (3 replicates per site)
160
140
120
100
80
60
40
20
0
Physa Gyrina
Valvata tricarinata
Amnicola limosus
Planorbula armigera
Fossaria dalli
Helisoma anceps
Elimia livescens
Fontigens nickliniana
Valvata perdepressa
Chinese Mystery Snail
Ferrissia rivularis
Ferrissia parallela
LGR1
LGR2
TAR1
TAR2
KR1
KR2

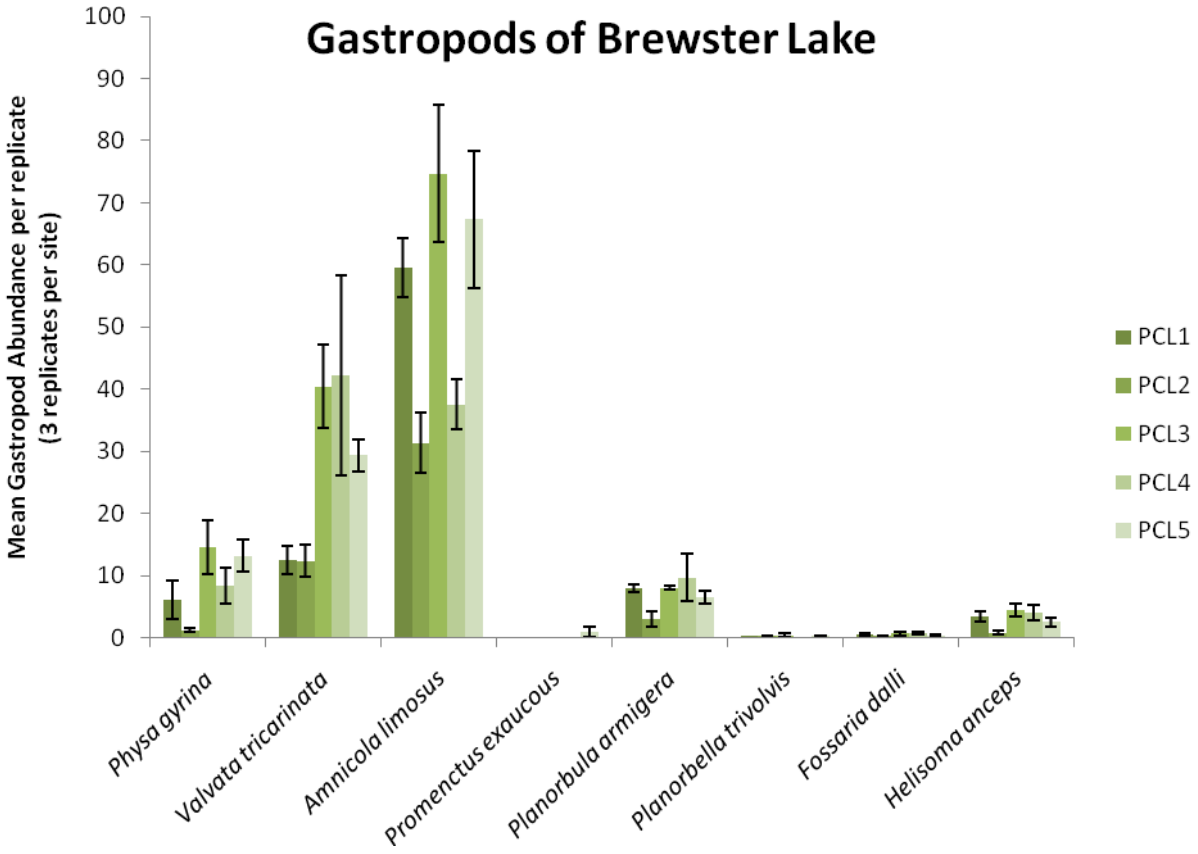

Sphaeriidae of off- PCCI land rivers
Mean Sphaeriidae Abundance per replicate (3 replicates per site)
500
450
400
350
300
250
200
150
100
50
0
Sphaerium spp.
Pisidium spp.
LGR1
LGR2
TAR1
TAR2
KR1
KR2

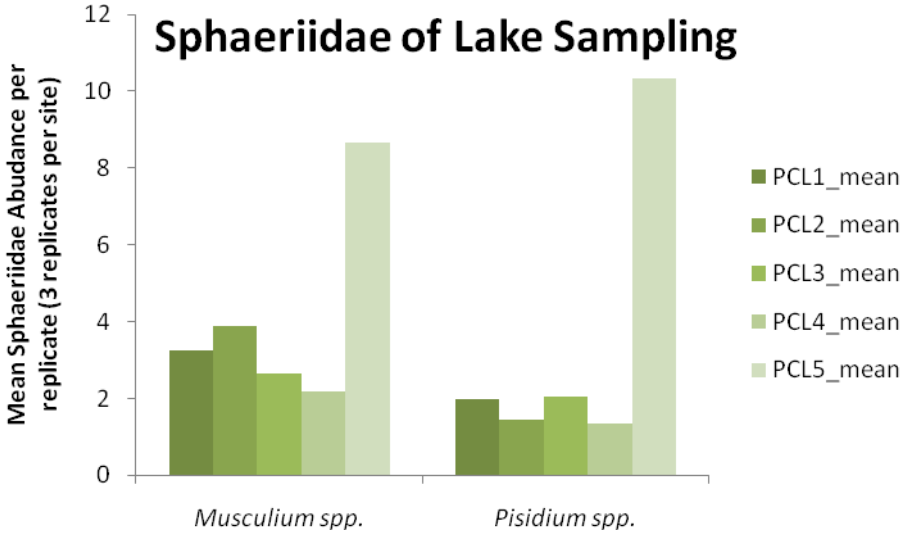

Gastropods of Cedar Creek
Mean Gastropod Abundance per replicate (3 replicates per site)
90
80
70
60
50
40
30
20
10
0
PCC1 (PCCI White Trail)
PCC2 (Broadway Downstream)
Physa gyrina
Valvata tricarinata
Amnicola limosus
Planorbula armigera
Stagnicola elodes
Fossaria dalli
Helisoma anceps
Planorbella campanulata
Elimia livescens
Gyraulus crista
Ferrissia parallela


Sphaeriidae of Cedar Creek
Mean Sphaeriidae Abundance per replicate (3 replicates per site)
200
150
100
50
0
PCC1 (PCCI White Trail)
PCC2 (Broadway Downstream)
Sphaerium spp.
Pisidium spp.


Gastropods at wetland sites
Mean Gastropod Abundance per replicate (3 replicates per site)
90
80
70
60
50
40
30
20
10
0
PCW1 mean
PCW2 mean
PCW3 mean
PCW4 mean
Physa gyrina
Valvata tricarinata
Amnicola limosus
Promenctus exaucous
Planorbula armigera
Planorbella trivolvis
Stagnicola petoskeyensis
Stagnicola elodes
Stagnicola caperatus
Ferrissia parallela


Sphaeriidae at wetland sites
Mean Sphaeriidae per replicate (3 replicates per site)
80
60
40
20
0
PCW1 mean
PCW2 mean
PCW3 mean
PCW4 mean
PCW5 mean
Musculium spp.
Pisidium spp.


Gastropods of Brewster Lake
Mean Gastropod Abundance per replicate (3 replicates per site)
100
90
80
70
60
50
40
30
20
10
0
PCL1
PCL2
PCL3
PCL4
PCL5
Physa gyrina
Valvata tricarinata
Amnicola limosus
Promenctus exaucous
Planorbula armigera
Planorbella trivolvis
Fossaria dalli
Helisoma anceps


Sphaeriidae of Lake Sampling
Mean Sphaeriidae Abudance per replicate (3 replicates per site)
12
10
8
6
4
2
0
PCL1_mean
PCL2_mean
PCL3_mean
PCL4_mean
PCL5_mean
Musculium spp.
Pisidium spp.

Non-molluscan D-Net sampling data from all 55 sites sampled Summer 2010 by CMU (Used in Principle Component Analysis)

	Coelenterata	Turbellaria	Nematoda	Oligochaeta	Hirudinea	Isopoda	Amphipoda	Decapoda	Hydrachnida	Ephemeroptera	Anisoptera	Zygoptera	Plecoptera	Hemiptera	Megaloptera
PCC1A	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0
PCC1B	0	0	0	0	0	0	3	0	1	2	0	0	0	0	0
PCC1C	0	0	0	0	1	0	1	0	1	0	0	0	0	0	0
PCC1D	0	0	0	0	0	0	3	0	0	3	0	0	0	0	0
PCC2A	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0
PCC2B	0	1	0	0	0	0	16	0	0	4	0	0	5	0	0
PCC2C	0	0	0	0	1	0	1	0	1	11	0	0	1	0	0
PCW1A	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
PCW1B	0	0	0	8	0	0	1	0	0	0	0	0	0	0	4
PCW1C	0	0	0	17	0	0	1	0	0	0	0	0	0	0	4
PCW2A	0	0	0	0	3	0	36	0	55	1	12	35	0	0	0
PCW2B	0	0	0	0	0	0	91	1	16	0	1	13	0	0	0
PCW2C	0	0	0	0	2	0	136	0	25	0	6	27	0	0	0
PCW3A	0	0	0	35	19	0	2	0	1	0	0	0	0	0	0
PCW3B	0	0	0	6	13	0	23	0	1	0	0	0	0	6	0
PCW3C	0	0	0	6	13	0	2	0	0	0	0	1	0	0	0
PCW4A	0	0	0	7	2	0	6	0	14	0	0	1	0	1	4
PCW4B	0	0	0	0	8	0	7	0	2	0	0	3	0	8	5
PCW4C	0	0	0	14	1	0	1	0	12	0	1	0	0	1	9
PCW5A	0	0	0	7	10	0	0	0	0	0	9	2	0	0	4
PCW5B	0	0	0	2	11	0	0	0	0	0	0	0	0	1	0
PCW5C	0	0	0	8	10	0	0	0	1	0	2	0	0	9	0
PCL1A	0	0	0	0	0	0	37	0	39	17	3	0	0	0	0
PCL1B	0	0	0	1	1	0	5	0	29	3	4	3	0	0	0
PCL1C	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0
PCL2A	0	0	0	2	0	0	2	0	5	0	0	0	0	0	0
PCL2B	0	0	0	0	0	0	7	0	5	1	12	5	0	0	0
PCL2C	0	0	0	0	0	0	13	0	20	2	4	0	0	1	0
PCL3A	0	0	0	0	0	0	1	0	2	0	0	0	0	0	0
PCL3B	0	0	0	0	0	0	0	0	7	0	1	0	0	0	0
PCL3C	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0
PCL4A	0	0	0	0	0	0	3	0	0	0	2	0	0	0	0
PCL4B	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0
PCL4C	0	0	0	1	1	0	6	0	4	4	1	0	0	0	0
PCL5A	0	0	0	1	1	0	10	2	27	5	5	1	0	0	0
PCL5B	0	0	0	1	0	0	10	2	37	4	4	7	0	0	0
PCL5C	0	0	0	0	0	0	30	1	25	21	7	8	0	0	0
TAR1A	0	3	0	0	0	0	6	1	0	4	0	0	0	0	0
TAR1B	0	1	0	0	0	0	1	0	0	6	0	0	0	0	0
TAR1C	0	0	1	0	0	2	17	0	0	1	0	0	0	0	0
TAR2A	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
TAR2B	0	0	1	2	0	0	0	0	0	20	0	0	0	0	0
TAR2C	0	0	2	0	0	0	11	1	0	102	0	0	0	0	0
LGR1A	0	0	0	0	0	1	0	0	0	8	0	0	5	0	0
LGR1B	0	0	0	0	0	1	0	0	0	1	0	0	2	0	0
LGR1C	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0
LGR2A	0	0	0	0	0	2	1	1	0	3	1	0	0	0	0
LGR2B	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
LGR2C	0	0	0	0	0	0	0	2	0	2	0	0	1	0	0
KR1A	0	0	0	0	0	0	59	0	0	0	0	0	0	0	0
KR1B	0	0	0	0	0	0	4	0	0	1	1	0	0	0	0
KR1C	0	0	0	0	0	0	45	1	0	14	1	0	0	0	0
KR2A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
KR2B	0	0	0	0	0	0	1	0	0	2	4	0	0	0	0
KR2C	0	0	0	0	0	0	5	1	3	22	2	0	0	0	0

Non-molluscan D-Net sampling data from all 55 sites (continued)

	Trichopte	Lepidopte	Coleopter	Chironom	Tabanidae	Culicidae	Ceratopog	Tipulidae	Simuliida	Misc. Dipt
PCC1A	1	0	0	5	0	0	0	0	0	1
PCC1B	29	0	2	1	0	0	0	0	0	0
PCC1C	5	0	0	0	0	0	0	0	0	0
PCC1D	8	0	0	1	0	0	0	1	0	0
PCC2A	3	0	1	0	0	1	0	0	0	0
PCC2B	9	0	7	0	0	0	0	0	0	1
PCC2C	0	0	0	4	1	0	0	0	0	1
PCW1A	5	0	4	34	0	0	0	0	0	0
PCW1B	8	0	3	84	0	0	0	0	0	0
PCW1C	11	0	0	118	0	0	0	0	0	0
PCW2A	4	0	10	4	0	0	0	0	0	0
PCW2B	1	0	0	6	0	0	7	0	0	0
PCW2C	4	0	1	7	0	0	5	0	0	2
PCW3A	0	0	17	1	0	0	7	0	0	0
PCW3B	1	0	4	0	0	0	0	0	0	2
PCW3C	2	0	1	6	0	0	0	0	0	0
PCW4A	80	0	9	109	0	13	4	0	0	1
PCW4B	89	0	5	25	0	5	0	0	0	0
PCW4C	26	0	5	6	0	1	0	0	0	1
PCW5A	5	0	5	0	0	0	0	0	0	12
PCW5B	11	0	2	0	0	0	0	0	0	3
PCW5C	3	0	8	0	0	0	0	0	0	5
PCL1A	64	0	1	0	0	0	0	0	0	0
PCL1B	42	0	7	0	0	0	0	0	0	0
PCL1C	24	0	0	0	0	0	0	0	0	0
PCL2A	21	0	8	0	0	0	0	0	0	0
PCL2B	1	0	8	0	0	1	0	0	0	0
PCL2C	6	0	6	0	1	0	1	0	0	0
PCL3A	93	0	0	0	0	0	0	0	0	0
PCL3B	50	0	0	0	0	0	0	0	0	0
PCL3C	14	0	0	0	0	0	0	0	0	0
PCL4A	12	0	0	0	0	0	0	0	0	0
PCL4B	29	0	1	0	0	0	0	0	0	0
PCL4C	16	0	0	2	0	0	0	0	0	0
PCL5A	53	0	0	0	0	0	0	0	0	0
PCL5B	13	0	7	1	1	1	0	0	0	1
PCL5C	51	0	2	0	0	0	0	0	0	0
TAR1A	56	0	14	8	0	9	0	0	0	0
TAR1B	23	0	1	6	0	0	0	0	0	0
TAR1C	4	0	1	0	0	0	0	0	0	0
TAR2A	38	0	0	0	0	0	0	0	0	2
TAR2B	18	0	0	7	0	1	0	0	1	0
TAR2C	31	0	18	10	0	2	0	0	0	0
LGR1A	43	1	2	0	1	0	0	0	0	0
LGR1B	46	0	1	0	3	0	0	0	0	0
LGR1C	14	0	0	0	0	1	0	0	0	0
LGR2A	28	1	4	5	1	4	0	0	3	4
LGR2B	14	0	1	0	0	0	0	0	0	0
LGR2C	6	0	4	2	0	0	0	0	1	0
KR1A	24	0	0	1	0	0	0	0	0	0
KR1B	12	0	2	0	0	0	0	0	0	0
KR1C	7	0	0	0	0	0	0	0	0	0
KR2A	12	0	0	0	0	0	0	0	0	0
KR2B	23	2	8	0	0	0	0	0	0	0
KR2C	106	0	3	3	0	0	0	0	1	0

Molluscan genera and species at each site per 1 min D-Net sampling time

	P. gyrina	*V. tricarinata*	*A. limosus*	*P. exacuous*	*P. armigera*	*P. trivolvis*	*S. petoskeyensis*	*S. elodes*	*S. caperatus*	*F. dalli*	*H. anceps*	*P. campanulata*	*E. livescens*	*Planorbe*	*G. crista*
PCC1A	4.00	26.00	78.00	0.00	10.00	0.00	0.00	0.00	0.00	1.00	5.00	0.00	0.00	0.00	0.00
PCC1B	3.00	25.00	93.00	0.00	11.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PCC1C	0.00	20.00	81.00	0.00	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PCC1D	3.00	15.00	52.00	0.00	13.00	0.00	0.00	1.00	0.00	1.00	4.00	1.00	0.00	0.00	0.00
PCC2A	0.00	5.00	6.00	0.00	2.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
PCC2B	1.00	6.00	10.00	0.00	3.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	3.00	0.00	1.00
PCC2C	0.00	0.00	7.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	2.00	0.00	0.00
PCW1A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PCW1B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PCW1C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PCW2A	1.50	3.50	3.50	0.25	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PCW2B	0.25	2.75	6.00	0.00	1.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PCW2C	1.25	4.25	6.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PCW3A	0.00	0.00	0.00	0.00	2.25	7.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PCW3B	1.33	0.00	0.00	0.00	1.67	27.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PCW3C	0.33	0.00	0.33	0.00	0.00	24.67	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PCW4A	0.00	0.00	0.00	0.00	0.20	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PCW4B	0.00	0.00	0.00	0.00	0.40	0.60	0.00	0.00	0.40	0.00	0.00	0.00	0.00	0.00	0.00
PCW4C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PCW5A	1.33	0.00	0.00	0.00	4.33	0.33	0.00	43.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PCW5B	4.33	0.00	0.00	0.00	1.33	1.00	0.00	63.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PCW5C	5.00	0.00	0.00	0.00	6.67	3.67	0.00	91.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PCL1A	7.50	8.75	50.25	0.00	6.75	0.25	0.00	0.00	0.00	0.50	3.75	0.00	0.00	0.00	0.00
PCL1B	0.00	16.33	65.67	0.00	8.00	0.00	0.00	0.00	0.00	1.00	1.67	0.00	0.00	0.00	0.00
PCL1C	10.67	12.33	63.00	0.00	9.00	0.00	0.00	0.00	0.00	0.00	4.67	0.00	0.00	0.00	0.00
PCL2A	1.00	17.33	40.67	0.00	5.33	0.00	0.00	0.00	0.00	0.00	1.33	0.00	0.00	0.00	0.00
PCL2B	1.00	8.67	24.67	0.00	1.33	0.00	0.00	0.00	0.00	0.00	0.67	0.00	0.00	0.00	0.00
PCL2C	1.67	11.00	28.67	0.00	2.33	0.33	0.00	0.00	0.00	0.33	0.33	0.00	0.00	0.00	0.00
PCL3A	6.00	49.50	91.50	0.00	8.50	1.00	0.00	0.00	0.00	0.00	3.00	0.00	0.00	0.00	0.00
PCL3B	20.00	27.33	53.67	0.00	8.00	0.00	0.00	0.00	0.00	1.00	4.00	0.00	0.00	0.00	0.00
PCL3C	17.50	44.50	79.00	0.00	7.50	0.00	0.00	0.00	0.00	1.00	6.50	0.00	0.00	0.00	0.00
PCL4A	8.00	12.50	32.50	0.00	3.00	0.00	0.00	0.00	0.00	1.00	3.00	0.00	0.00	0.00	0.00
PCL4B	13.50	46.00	45.50	0.00	16.00	0.00	0.00	0.00	0.00	0.50	6.50	0.00	0.00	0.00	0.00
PCL4C	3.50	68.00	34.50	0.00	10.00	0.00	0.00	0.00	0.00	0.50	2.50	0.00	0.00	0.00	0.00
PCL5A	9.50	30.50	75.00	2.50	4.50	0.00	0.00	0.00	0.00	0.00	4.00	0.00	0.00	0.00	0.00
PCL5B	18.00	33.00	45.50	0.00	8.00	0.50	0.00	0.00	0.00	0.50	1.50	0.00	0.00	0.00	0.00
PCL5C	12.00	24.50	81.50	0.00	7.00	0.00	0.00	0.00	0.00	0.50	2.00	0.00	0.00	0.00	0.00