Report as of FY2006 for 2006SD80B: "Development of an Optimal Macroinvertebrate Bioassessment Index for Prairie Lakes in Northeastern South Dakota"

Publications

- Other Publications:
    - Vander Vorste, Ross and David German. 2006. Development of an Optimal Macroinvertebrate Bioassessment Index for Prairie Lakes in Northeastern South Dakota, Eastern South Dakota Water Conference, WRI, South Dakota State University, Brookings, SD. Poster Presentation.
    - Vander Vorste, Ross and David German. 2006. Development of an Optimal Macroinvertebrate Bioassessment Index for Prairie Lakes in Northeastern South Dakota, South Dakota Academy of Science, South Dakota State University, Brookings, SD. Poster Presentation.
    - Vander Vorste, Ross and David German. 2006. Development of an Optimal Macroinvertebrate Bioassessment Index for Prairie Lakes in Northeastern South Dakota, Undergraduate Research Day, WRI, South Dakota State University, Brookings, SD. Poster Presentation.

Report Follows

Development of an Optimal Macroinvertebrate Bioassessment Index for Prairie Lakes in Northeastern South Dakota

INTRODUCTION

Monitoring biological communities can provide a good estimate of ecosystem integrity (i.e. chemical, physical, and biological integrity) in aquatic environments (Plafkin 1989). Biological communities are sensitive to stressors (i.e. domestic waste, agricultural runoff, and sedimentation) that pollute water bodies (Lewis 2001). Biological monitoring can be performed on algae, fish, and benthic macroinvertebrate communities. There are advantages of using benthic macroinvertebrates in biological monitoring. Macroinvertebrates are ubiquitous in aquatic systems throughout the world and they are good indicators of localized conditions due to limited migration ability. Benthic macroinvertebrates respond to short-term environmental disturbances and degraded conditions can be detected through taxa identification (Plafkin 1989). Long-term effects of stress can be seen through changes in community structure (Barbour et al 1999). Another advantage of biological monitoring is its relatively low cost when compared chemical and toxicity tests (Ohio EPA 1987, Karr 1993).

Metrics are measurable components of biological systems used to describe communities. They show predictable change in value along a gradient of human disturbance (Gronke 2004). Metric categories include community composition, richness, feeding, habit and tolerance measurements. A multimetric index approach to bioassessment encompasses all these types of descriptors in biological communities. Multimetric indexes quantify the biological effects of a broad array of human activities because they are sensitive to water quality, habitat structure, flow regime, energy source and biotic interactions (Karr and Chu 1999). Metrics are ranked based on discriminatory power and coefficient of variation. Metrics that are most sensitive to anthropogenic disturbances are combined to form an index of biotic integrity (IBI). An IBI scores sites based on impact of disturbance compared to a reference site. Reference sites will have highest IBI scores while more polluted water bodies should have a lower score.

Study Sites

Three different lakes were selected based on previous knowledge of water quality conditions. Enemy Swim Lake was used as a reference site because of its favorable water quality condition. Clear Lake and Lake Minnewasta were thought to progressively decrease in water quality condition. All the lakes were located in the Northern Glaciated Plains (NGP) ecoregion of northeastern South Dakota. Beneficial uses for all three lakes include:

(4) warm water permanent fish life propagation

(7) immersion recreation

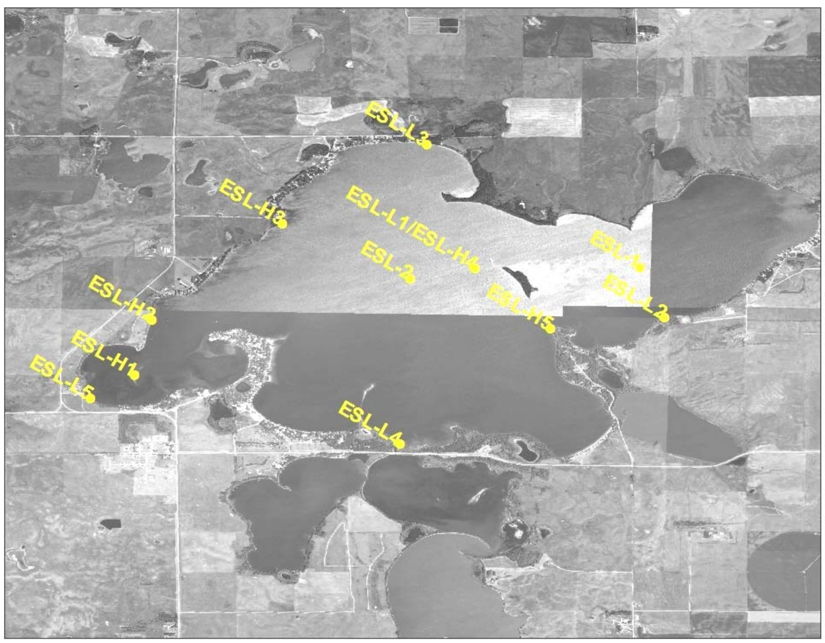
(8) limited contact recreation

(9) wildlife propagation and stock watering

Enemy Swim Lake

Enemy Swim Lake is located in Day County, South Dakota (Figure 1). It is a large (3.35 sq. mi.) and deep lake (26 ft. max.). It has a large immediate watershed (20.47 sq. mi.) with about ninety-five percent of the runoff entering the lake through an eastern tributary (State Lakes Preservation Committee 1977). The majority of the watershed (73%) consists of pasture and less intensive land use practices. In 1996-1998, only twelve percent of the watershed was utilized as cropland (Skadsen 2005). Fisheries personnel describe Enemy Swim "as one of a few South Dakota lakes having a complex basin with highly variable substrates including rock, boulders, gravel, cobble, sand, and silt." Enemy Swim Lake's Carlson's Trophic State Index (TSI) labels the lake as mesotrophic, containing moderate amounts of nutrients.

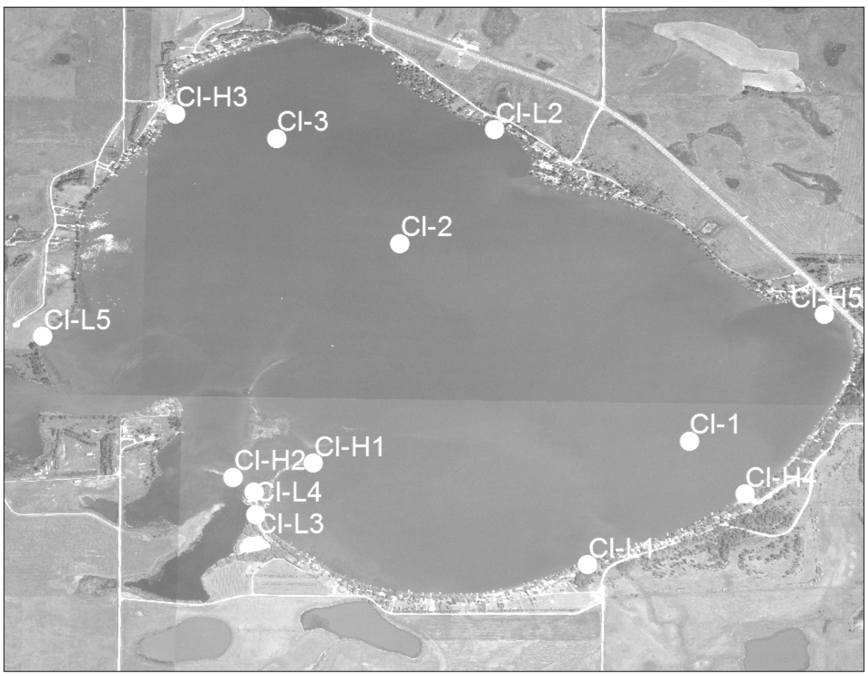
Figure 1: Site Map of Enemy Swim Lake, Day County, SD (1-3=basin/water quality sites, H1-5=Hester-Dendy sites, L1-5=sweep-net sites)



Clear Lake

Clear Lake is located in Marshall County, South Dakota (Figure 2). It has an area of 1.71 sq. mi. and a maximum depth 20 ft. Clear Lake has a small immediate watershed (4.05 sq. mi.) making sediment input less significant (State Lakes Preservation Committee 1977). It has been labeled a eutrophic lake based on its TSI value which ranged from 47-63 when sampled by the SD Department of Environmental and Natural Resources in 1989-1993 (Stewart and Stueven 1994).

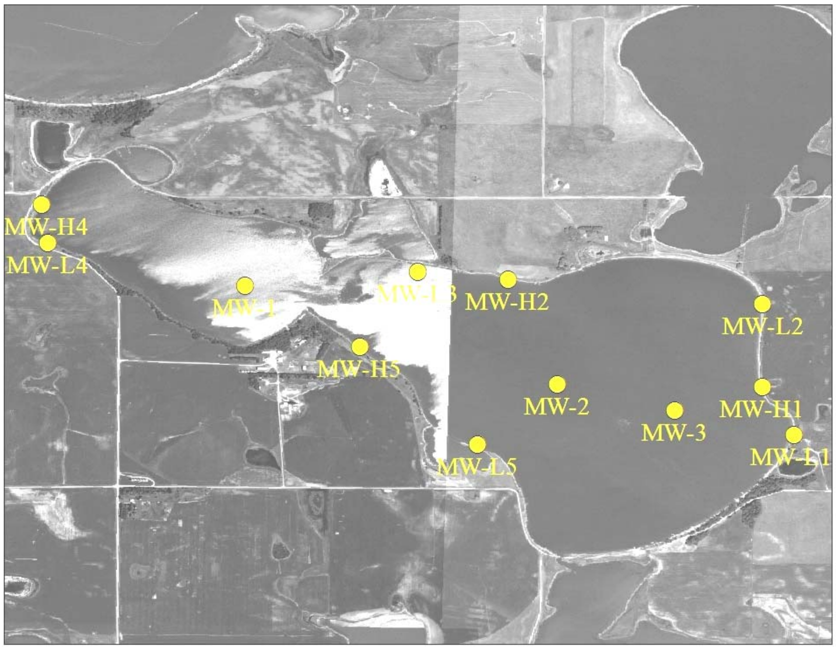
Figure 2: Site map of Clear Lake, Marshall County, South Dakota (1-3=basin/water quality sites, H1-5=Hester-Dendy sites, L1-5=sweep-net sites)



Lake Minnewasta

Lake Minnewasta is located in Day County, South Dakota (Figure 3). It is the smallest lake (0.95 sq. mi.) and the most shallow (14 ft. max.) of the study. Lake Minnewasta has an immediate watershed is 1.12 sq. mi. with 15% under cultivation in 1977. Current TSI values for Lake Minnewasta classify it as hyper-eutrophic, containing an excess amount of nutrients.

Figure 3: Site map of Lake Minnewasta, Day County, South Dakota (1-3=basin/water quality sites, H1-5=Hester-Dendy sites, L1-5=sweep-net sites).



Previous Work

This study was based on the work done by A. Gronke (2004). Gronke developed an index of biotic integrity for prairie pothole lakes in eastern South Dakota. The study examined the phytoplankton, macrophyte and macroinvertebrate communities of seven lakes. Sixty-four candidate invertebrate metrics were tested to find an optimized set for an IBI. Gronke (2004) sampled basin and littoral invertebrate habitats. A total of 86 invertebrate taxa were identified during the study. Reference sites from this study contained greater total taxa richness compared to study sites. Reference sites also had significantly higher percentage of intolerant taxa than study sites. A total of 10 optimized littoral invertebrate metrics were identified (Table 1). Gronke (2004) concluded that macroinvertebrate communities of other prairie pothole lakes need to be inventoried and the validity of metric sets must be tested further.

Table 1: Top 10 optimized littoral invertebrate metrics for prairie pothole lakes in Eastern South Dakota (Gronke 2004).

	Metric	Group
1	Hilenhoff's biotic index	Tolerance
2	Evenness	Richness
3	Percent dominant taxa	Composition
4	Percent collector gatherers	Feeding
5	Shannon-Wiener Index	Richness
6	Percent swimmers	Habit
7	Percent predators	Feeding
8	Tolerant taxa	Tolerance
9	Total taxa	Richness
10	Percent Hemiptera	Composition

Braskamp (2002) selected fourteen lakes in eastern South Dakota and characterized littoral invertebrate community structure, habitat and shoreline condition. A total of 179 macroinvertebrate taxa were identified during this study. Braskamp (2002) found differences in the invertebrate communities of two ecoregions, Northern Glaciated Plains (NGP) and the Northwestern Glaciated Plains (NWGP). There were also correlations identified between the invertebrate community and environmental conditions. This demonstrated the importance of optimizing metrics for specific ecoregions. Optimized invertebrate metrics for lake littoral zones are crucial to lake management (Braskamp 2002).

German (2005) surveyed the macrophyte and macroinvertebrate communities of Enemy Swim Lake and nearby Pickerel Lake. The study identified a more diverse community then what was expected based on previous studies on South Dakota lakes (German 2005). Enemy Swim Lake exhibited characteristics of lakes that are mesotrophic to early eutrophic in 2005. German (2005) stated that a shift to a slight eutrophic condition may be apparent in Enemy Swim Lake during recent years.

In 2001, a watershed improvement project was started on Enemy Swim Lake. During this project 1,444 acres of cropland in the watershed were converted to grassland using the Conservation Reserve Program. Cattle stream crossings, pasture renovation and cattle watering systems were also used to reduce sediment and nutrient loads to the lake. Activities from this improvement project resulted in a thirty-seven percent reduction of in-lake phosphorus concentrations. TSI values shifted from a eutrophic to a mesotrophic state and an increase in water clarity was seen through Secchi disk transparency readings (Skadsen 2005).

OBJECTIVES

This project was designed to gather baseline invertebrate data for Enemy Swim Lake, Clear Lake and Lake Minnewasta. Invertebrate research has not been performed on the latter two lakes. The current trophic state of the three lakes was determined and the macroinvertebrate communities were described. Another goal of this project was to proceed in developing a multimetric macroinvertebrate index for South Dakota prairie lakes. This will be done by testing metrics identified by Gronke (2004) on Enemy Swim Lake, Clear Lake and Lake Minnewasta.

METHODS

Water Quality

Water quality conditions of the three lakes were monitored during May, June, July, August and September. Samples were collected within six days of mid-month for the following parameters:

1. Total phosphorus
2. Total dissolved phosphorus
3. Organic nitrogen
4. Ammonia
5. Nitrate + nitrite
6. Suspended solids
7. pH
8. Air and water temperature
9. Dissolved oxygen
10. Secchi depth
11. Chlorophyll a (surface samples only)
12. Fecal coliform bacteria (surface samples only)

Undergraduate Student Ross Vander Vorste with Hester-Dendy Sampler used for invertebrate collection.

Water samples were collected with a Van-Dorn type water sampler from three mid-lake sites at surface and near bottom depths. Composite surface and bottom samples were made using equal water quantities from the three in-lake sites. Physical parameters were measured using methods and equipment similar to German (1997). Samples were sent to the South Dakota State University Water Quality Laboratory for chemical analysis.

Macroinvertebrate Collection

Three different sampling methods were used to collect macroinvertebrates. An Eckman dredge was used to collect basin invertebrates at three locations in each lake (Gronke 2004). Site locations corresponded to the sites used to collect water samples. Samples were sieved (250 µm) to wash away fine sediment and placed to coolers. Littoral invertebrates were collected at five sites in each lake using a three-minute sweep-net technique (Braskamp 2002). Modified Hester-Dendy multi-plate samplers were anchored at five littoral sites in each lake and allowed to colonize for approximately 30 days (Britton and Greeson 1987). Littoral invertebrate samples were rinsed into coolers to preserve living invertebrates.

Invertebrate specimens were picked from samples as soon as possible after collection to avoid preliminary preservation with 70% alcohol. The majority of samples were volumetrically subsampled to downsize the amount of specimens needed to be picked and identified. All samples were visually examined for large and rare invertebrate taxa. Invertebrate specimens were picked, sorted into vials and preserved with 70% alcohol or a 10% Formalin solution. Specimens were identified to family or genus if possible (Table 2). Habit guilds, feeding groups and tolerance values were obtained from Hilsenhoff (1987, 1988, 1998), DeShon (1995), Merrit and Cummins (1996) and Barbour et al. (1999).

Table 2: Literature sources used to identify invertebrate specimens.

Assemblage	Order	Sources
Invertebrate		
	Chironomidae	Wiederholm (1983), Mason (1973) Merrit and Cummins (1996)
	Tricoptera	Wiggins (1996), Merrit and Cummins (1996)
	Corixidae	
	Coleoptera	Merrit and Cummins (1996) Hilsenhoff (1975)
	Molluska	Pennack (1978)
	Hyrachnida	
	Others	Sawyer (1972), Thorp and Covich (2001)

RESULTS

Water Quality

Laboratory analysis of water quality samples collected in 2006 at Enemy Swim Lake , Clear Lake, and Lake Minnewasta are presented in Tables 3, 4, and 5, respectively.

Table 3.

Enemy Swim Lake							
Sample Location	Sample Date	Ammonia Nitrogen mg/L (ppm)	Nitrate Nitrogen mg/L (ppm)	Total Dissolved Phosphorus mg/L (ppm)	Total Phosphorus mg/L (ppm)	Total Kjeldahl Nitrogen (TKN) mg/L (ppm)	Total Suspended Solids mg/L (ppm)
SURFACE	5/16/2006	0.116	0.06	0.006	0.016	0.72	3.5
BOTTOM	5/16/2006	0.076	0.06	0.008	0.016	0.649	3
SURFACE	6/17/2006	0.047	0.04	0.061	0.026	0.729	4.33
BOTTOM	6/17/2006	0.061	0.04	0.009	0.026	1.1	4.75
SURFACE	7/17/2006	0.104	0.07	0.013	0.023	0.776	5.25
BOTTOM	7/17/2006	0.154	0.05	0.018	0.022	0.838	5.25
SURFACE	8/17/2006	0.199	0.05	0.012	0.027	0.998	4
BOTTOM	8/17/2006	0.164	0.04	0.011	0.028	1.2	5.25
SURFACE	9/20/2006	0.073	0.05	0.014	0.024	1.18	5.25
BOTTOM	9/20/2006	0.101	0.04	0.013	0.029	0.844	6.88

Table 4.

Clear Lake							
Sample Location	Sample Date	Ammonia Nitrogen mg/L (ppm)	Nitrate Nitrogen mg/L (ppm)	Total Dissolved Phosphorus mg/L (ppm)	Total Phosphorus mg/L (ppm)	Total Kjeldahl Nitrogen (TKN) mg/L (ppm)	Total Suspended Solids mg/L (ppm)
SURFACE	5/16/2006	0.17	0.06	0.027	0.039	1.31	1.75
BOTTOM	5/16/2006	0.138	0.07	0.018	0.037	0.868	1.75
SURFACE	6/15/2006	0.104	0.03	0.017	0.041	1.03	3.25
BOTTOM	6/15/2006	0.044	0.02	0.02	0.037	1.05	2.5
SURFACE	7/17/2006	0.063	0.06	0.026	0.054	1.03	3.75
BOTTOM	7/17/2006	0.127	0.08	0.043	0.046	0.948	4.25
SURFACE	8/17/2006	0.152	0.04	0.036	0.053	1.04	4.5
BOTTOM	8/17/2006	0.143	0.03	0.034	0.056	1.02	4
SURFACE	9/19/2006	0.115	0.03	0.024	0.055	0.927	4.75
BOTTOM	9/19/2006	0.076	0.04	0.022	0.057	0.971	5.5

Table 5.

Lake Minnewasta							
Sample Location	Sample Date	Ammonia Nitrogen mg/L (ppm)	Nitrate Nitrogen mg/L (ppm)	Total Dissolved Phosphorus mg/L (ppm)	Total Phosphorus mg/L (ppm)	Total Kjeldahl Nitrogen (TKN) mg/L (ppm)	Total Suspended Solids mg/L (ppm)
SURFACE	5/16/2006	0.173	0.06	0.042	0.097	1.77	10.2
BOTTOM	5/16/2006	0.138	0.05	0.043	0.106	1.87	11.4
SURFACE	6/15/2006	0.14	0.11	0.17	0.209	2.07	14
BOTTOM	6/15/2006	0.122	0.11	0.179	0.21	2.06	14.5
SURFACE	7/17/2006	0.243	0.07	0.15	0.266	2.95	17.7
BOTTOM	7/17/2006	0.198	0.06	0.15	0.236	2.72	18.2
SURFACE	8/17/2006	0.161	0.16	0.222	0.29	2.46	14.3
BOTTOM	8/17/2006	0.168	0.14	0.214	0.266	2.23	17.7
SURFACE	9/19/2006	0.186	0.15	0.219	0.295	2.44	28
BOTTOM	9/19/2006	0.18	0.14	0.223	0.296	2.52	32

Trophic status of the three lakes ranged from mesotrophic to hyper-eutrophic. (Figure 4, Figure 5) Enemy Swim Lake had the lowest TSI value (50.24) with Clear Lake (59.68) and Lake Minnewasta (82.92) falling below in water quality standards based on Phosphorus TSI values.

Biological

Overall species diversity was highest in Enemy Swim Lake with 23 families found. Clear Lake and Lake Minnewasta followed with 22 and 14 families respectively (Table 1). A Modified ASPT Index was used to rank the lakes based on invertebrate community's tolerance to pollution (Figure 4). Enemy Swim (5.17) had the highest ranking thus having more pollution intolerant species. Clear Lake (4.73) and Lake Minnewasta (4.50) contained invertebrate communities with more tolerant species. The Ephemoptera and Trichoptera (ET) Index was used to compare lakes. Enemy Swim Lake, 5 families, had the highest ET diversity while Clear Lake, 3 families, and Lake Minnewasta, 1 family, fell below (Figure 5)..

Figure 4.

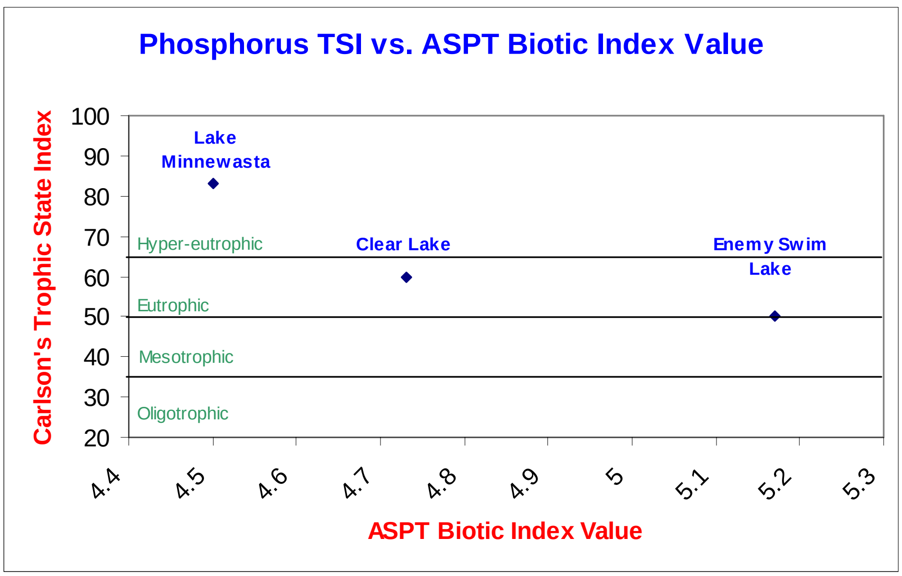


Figure 5.

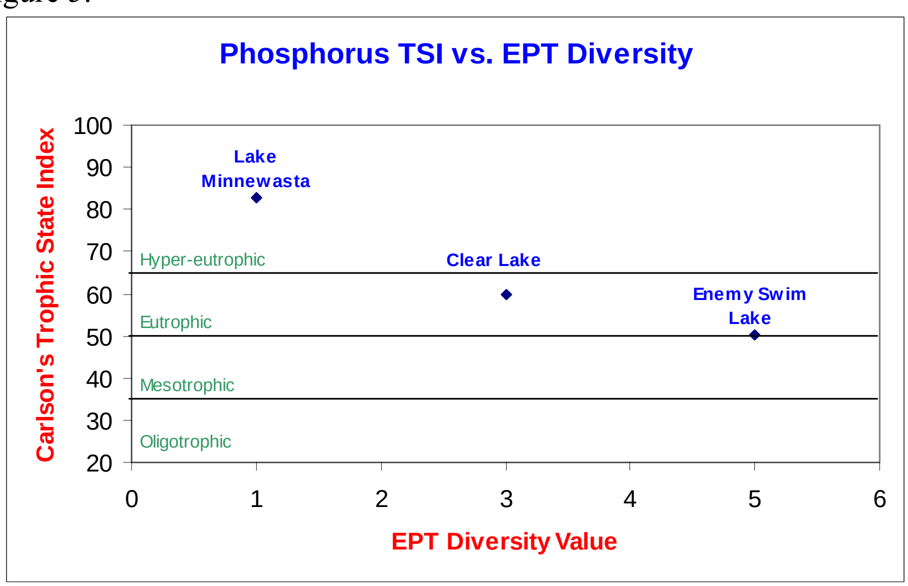
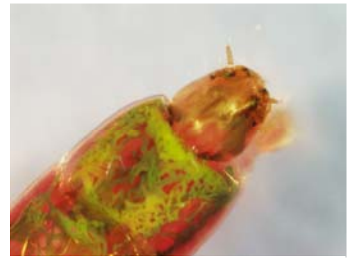


Table 6. Family List for Enemy Swim Lake (E), Clear Lake (C), Lake Minnewasta (M)

MAJOR GROUP	MINOR GROUP	FAMILY	LAKE
Annelida	Oligocheata	Tubificidae	E,C,M
	Hirudinoidea	Glossiphoniidae	E,C,M
Crustacean	Amphipoda	Gammaridae	E,C,M
		Talitridae	E,C,M
	Decapoda	Cambarinae	C
Insecta	Diptera	Chironomidae	E,C,M
		Ceratopogonidae	E,C,M
		Phychodidae	E
		Tipulidae	C
		Phoridae	C
	Hemiptera	Corixidae	E,C,M
	Trichoptera	Polycentropodidae	E,C,M
		Leptoceridae	E,C
		Helicopsychidae	E
		Limnephilidae	E
		Phryganeidae	E
		Hydroptilidae	C
	Ephemeroptera	Ephemeridae	E,C
		Caenidae	E,C,M
	Coleoptera	Haliplidae	E,C,M
		Curculiondae	E
		Dytiscidae	C
		Hydrophilidae	M
	Odonata	Coenagrionidae	E,C,M
Mollusca	Bivalvia	Sphaeriidae	E,C
	Gastropoda	Hydrobiidae	E,C
		Physidae	E,C,M
		Planorbidae	E,C,M
		Valvatidae	E



Chironomus sp.
"Bloodworm"

Chironomus sp.
"Adult Bloodworm"

Mystacides sp.
"Caddisfly"

SUMMARY

Statistical and metric analysis showed that Enemy Swim Lake was placed in a mesotrophic status during the sampling period. It was also found to contain the least pollution tolerant families and the highest ET family diversity. Clear Lake was found to be in the eutrophic status based on Phosphorus TSI values. Clear Lake fell in between Enemy Swim Lake and Lake Minnewasta in the ASPT Index and ET Diversity values. Lake Minnewasta was found to be hyper-eutrophic and also had the most pollution tolerant invertebrate communities and the least ET Diversity. This relationship corresponds with Gronke 2004 in which reference littoral sites had significantly higher percentages of intolerant species. Further taxonomic identification and water chemistry analysis should further show a relationship between water quality and invertebrate communities.

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