I. DETERMINING THE IMPACTS OF SAWMILL DEBRIS ON BENTHIC MACROINVERTEBRATE COMMUNITIES WITHIN MUSKEGON LAKE, MICHIGAN

A. State if the project was implemented and monitored as proposed. Describe activities completed during implementation and monitoring.

Ecological monitoring activities were implemented as proposed with adjustments to the timing of monthly sampling events and site locations. Based on survey information from Progressive AE and Russel Marine, the Muskegon Water Sports Park was selected as the location for the 2015 samples. The Muskegon Water Sports Park was sampled with a modified suction sampler as the presence of embedded wood debris prevented sampling with a PONAR. This location contained soft sediment that could be sampled by a PONAR. Sufficient mills debris were not found in Bear Lake or the area between the Bear Lake Channel and Snug Harbor. A second set of samples were collected in 2016 in northeastern Muskegon Lake by a submerged dock structure located in deeper water off the Muskegon Water Sports Park. We also attempted to sample deep water sites off the South Shore Bike Path and did not find soft sediment. Overall monitoring activities included sample of benthic macroinvertebrates that were separated from the sediment and identified to the lowest possible taxonomic level. Financially, actual expenses for ecological monitoring approximated projected expenses were less than budgeted due to AWRI being able to collect the 2016 using the Russel Marine boat. No sampling expenses for labor, boat time, and gasoline were recorded in 2016.

B. Describe the materials and methods used to complete project implementation and outreach tasks. Project implementation and public outreach was carried out by the West Michigan Shoreline Regional Development Commission. The initial partnership for the restoration project was initiated by the Muskegon Lake Watershed Partnership. As the MLWP staff support organization, WMSRDC convened the private landowners, City of North Muskegon and the County of Muskegon to develop a MDEQ/NOAA AOC land acquisition grant proposal for the purpose of restoration. A competitively selected ecological restoration consultant completed Engineering and Design (E&D) for the project under a previous WMSRDC NOAA Great Lakes Habitat Restoration grant. Under this grant, WMSRDC advertised the construction bid package and a construction contractor was selected. This phased approach worked well for a complex, multi-year project. This provided WMSRDC and other project partners with adequate time to present information about the project and to take input on the design at MLWP public meetings and at individual landowner and stakeholder meetings.

C. For projects with a monitoring plan, describe the methods used in data collection and data analysis, assumptions for data analysis, and key findings.

Data Collection Methods

The 2015 study was conducted along the north shoreline of Muskegon Lake, particularly within the North Muskegon Water Sports Park area (Figure 1). The two control transects were located next to a private boat launch and old wooden docks. The shallow littoral zones (0-2 m depth) within the impacted area were covered by sawmill debris and therefore, this area has been proposed for dredging and remediation. The sawmill debris consisted of wood planks (from one

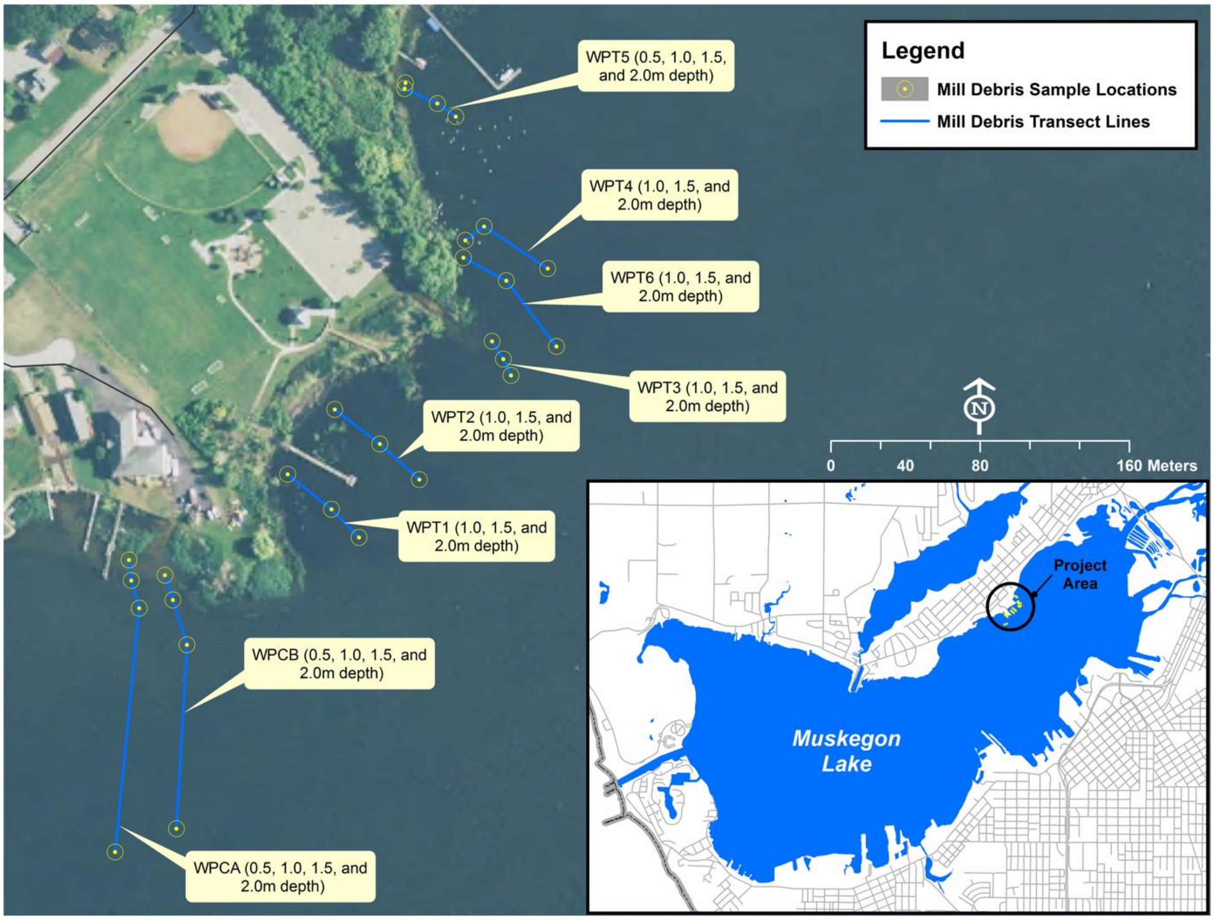

Figure 1. Muskegon Water Sports Park suction sampling locations for benthic macroinvertebrates (n=90). Sampling locations were conducted along transects at varying depths and included two control transects (WPCA and WPCB) and six mill debris transects (WPT1-6). Depths sampled were 0.5m, 1.0m, 1.5m, and 0.5m, although some 0.5m depths were not sampled due to over growth of plants and the inability to suction sample at these locations.

in length to five feet), wood chips (chips were no greater than one inch), and saw dust. All impacted sites had sawmill debris coverage of 50% or greater. Most of the shallower depths within the impacted area were overgrown with macrophytes (primarily Eurasian watermilfoil; *Myriophyllum spicatum*). This survey was used to obtain a pre-restoration base of knowledge of the macroinvertebrate community in the current conditions. This location could not be sampled using a PONAR dredge due to hardened substrates and larger sawmill debris, so alternative methods

Macroinvertebrate samples were collected from sites within the study area (Figure 1) using a portable, battery-operated suction device (area = 0.023 m^2; Taylor et. al, 1995) with a 0.5-mm, nitex-mesh bag. The sampling orifice was designed to be the same size as a petite PONAR. Six transects were located throughout a sawmill debris impacted area (WPT1-WPT6) while two transects were located outside of the impacted area for control samples (WPCa or Ca and WPCb or Cb). Due to geographical and time limitations, only two control transects were assessed. At both the sawmill debris impacted and control areas, samples for community structure analysis were collected during the months of August and September in 2015. Sediment samples containing benthic macroinvertebrates were collected along the eight transects at 0.5 m, 1.0 m, 1.5 m, and 2.0 m depths. Triplicate samples were taken at each depth, approximately 1 m apart. A total of 9 samples were collected randomly at different depths and transects for quality assurance purposes (these samples were not included in any analyses). While in the field, samples were placed within labeled plastic bags. Once in the lab, samples were place into labeled plastic jars and preserved in 10% buffered formaldehyde with rose bengal stain.

Along each transect, GPS coordinates were taken using a Thales/Magellan ProMark 3 GPS at each depth sampled. Field measurements for general water quality parameters (dissolved oxygen, turbidity, pH, temperature, redox potential, specific conductance, total dissolved solids, and chorophyll a) were made with a YSI 6600 Sonde at 0.1 m above the sediment at each sampling location prior to sample collection.

In the laboratory, preserved samples were sieved and placed in a glass pan where all organisms were collected and sorted into major taxonomic groups. Macroinvertebrates were identified down to the lowest taxonomic level possible (using Merrit, Cummins, & Berg, 2008; Peckarsky et al., 1990; McCafferty, 1981). Chironomids and oligochaetes were mounted onto slides using Permount mounting medium prior to identification.

The 2016 study (N=15) was conducted along the north shoreline of Muskegon Lake off shore of the North Muskegon Water Sports Park (Figure 2) on top of a submerged wooden dock. The two control transects were located at similar depths in soft sediment east and west of the submerged dock. Both the submerged dock area and the control locations contained sufficient soft sediment to be sampled with a Petite PONAR. Triplicate samples were taken at each location, approximately 1 m apart. While in the field, samples were placed within labeled plastic bags. Once in the lab, samples were place into labeled plastic jars and preserved in 10% buffered formaldehyde with rose bengal stain.

Along each transect, GPS coordinates were taken using a Thales/Magellan ProMark 3 GPS at each depth sampled. Field measurements for general water quality parameters (dissolved oxygen, turbidity, pH, temperature, redox potential, specific conductance, total dissolved solids, and chorophyll a) were made with a YSI 6600 Sonde at 0.1 m above the sediment at each sampling location prior to sample collection.

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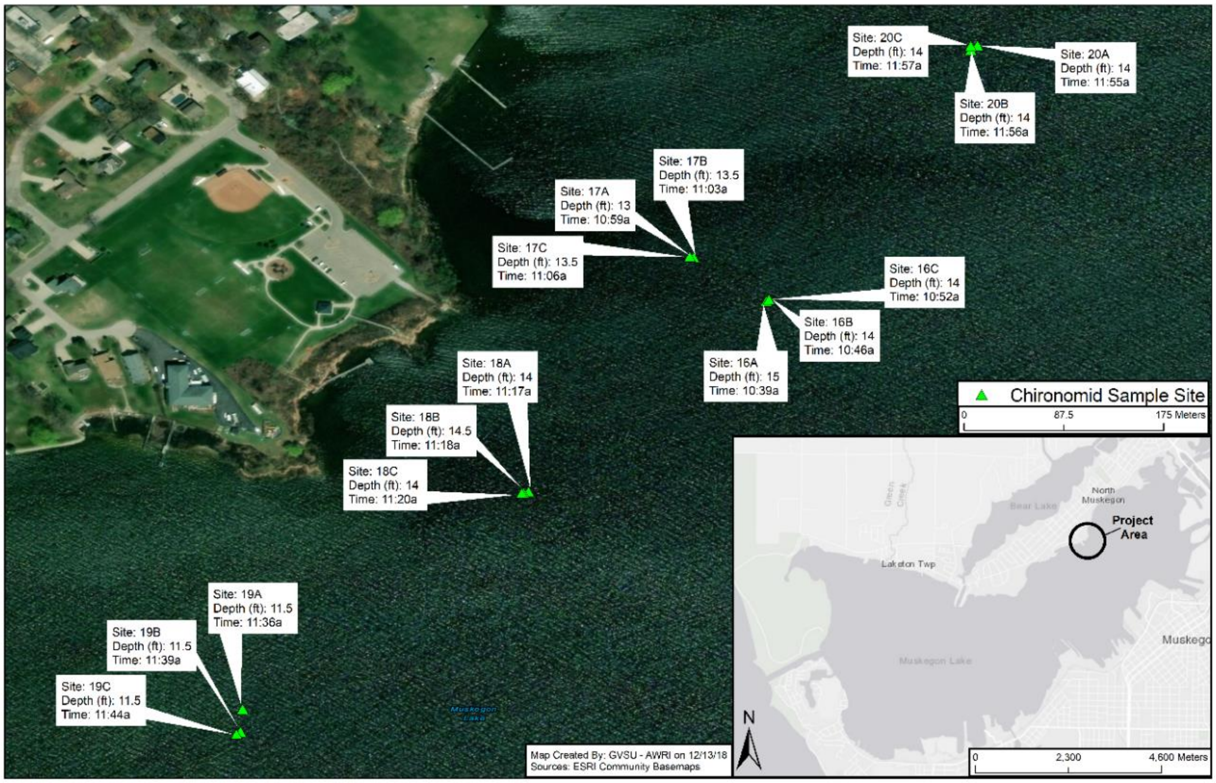

Figure 2. Muskegon Water Sports Park off shore locations suction sampling locations for benthic macroinvertebrates (n=90). Sampling locations were conducted along transects at varying depths and included two control transects (WPCA and WPCB) and six mill debris transects (WPT1-6). Depths sampled were 0.5m, 1.0m, 1.5m, and 0.5m, although some 0.5m depths were not sampled due to over growth of plants and the inability to suction sample at these locations.

Data Analysis Methods

2015 Samples North Muskegon Water Sports Park Near Shore

Macroinvertebrate counts were multiplied by 43.3 to convert samples from in^2 to m^2. Data were tested for normality with a Shapiro-Wilks test. Non-normal data were transformed to achieve a normal data set. All data remained non-normal, so statistical analyses for non-normal data were used.

Macroinvertebrate community data were evaluate with a Kruskal-Wallis (KW) analysis to determine if sampling depths along each transect were significantly different; each transect was tested separately. If the KW analysis produced a significant p-value, a Pairwise Wilcoxon Rank Sum (PWR) test (with a bonferroni p-value adjustment) was then used on the individual transect to determine which sampling depth(s) influenced the differences in benthic macroinvertebrate community structure. Then, a non-parametric similarity percentage analysis (SIMPER) was used on those same transects to determine what taxa were driving the differences between the differing depths. Mean number of most influential organisms was calculated to determine what patterns were occurring between these organisms and the depths they were collected at. KW was then used to examine differences in the major taxa between the sawmill debris and control sites. Major taxa of the sawmill debris transects were compared to the control transects to determine which taxa were different.

Using benthic community abundances, control and sawmill debris transects were then examined separately using non-metric multidimensional scaling (NMDS) to determine if patterns were present when depths were not combined. Spatial patterns in the benthic community abundances between the control and mill debris sites were examined using NMDS. A stress value equal to or less than 0.15 was deemed as acceptable. Any stress value equal to or above 0.2 was considered questionable. We grouped major taxa together in each transect and used a Bray-Curtis distance matrix to characterize the macroinvertebrate communities within the NMDS. The non-parametric analysis of similarity (ANOSIM) was then used to assess if the benthic assemblages between the two site types had significantly different species compositions. Both the major taxa and the water chemistry variables were then combined with the macroinvertebrate community abundance data using SIMPER. This was used to determine the cumulative sum of which major taxa or water chemistry variable influenced the differences between the control and sawmill debris sites. NMDS plots were then overlaid with either the major taxa or water chemistry data to show influences of the two data sets on the macroinvertebrate communities using ENVFIT. To help decipher which major taxa groups were contributing the most to the difference between sawmill debris and control transects, the mean, maximum, minimum, and standard error were calculated for all major taxa groups, for both types of transects. Using benthic community abundances, control and sawmill debris transects were then examined separately in NMDS to see what patterns were seen when depths were not combined.

To evaluate the sites using the habitat template model, individual species were assigned to functional trait niches, or trait states, based on their feeding guild/trophic habit and habitat trait group. Organisms were categorized into six functional feeding groups and five habit trait groups according to Merritt, Cummins, and Berg (2008) and Heino (2008). Functional feeding groups included shredders, gatherers, filterers, scrapers, herbivore-piercers, and predators. Habitat trait groups included burrowers, climbers, clingers, sprawlers, and swimmers (Table 1). Functional feeding groups refer to an individual's feeding mode and approximate food type, while habit trait groups refers to information on mobility and where food is obtained by the individual (see Table 2.1). Abundances of functional trait groups were then examined in NMDS to see what patterns the trait groups formed when associated with water chemistry data or site types.

Water chemistry data between sawmill debris and control sites were compared using the Wilcoxon Rank Sum test (WR). All statistical analyses were conducted using RStudio (version 3.3.1).

Table 1. Descriptions of functional feeding groups and habit trait groups of freshwater macroinvertebrates. Modified from Heino (2006).

Functional category	Ecological descriptions
Functional feeding group	*Feeding characteristics*
Gatherers	Feed on fine particulate detritus within and on the benthic floor
Filterers	Filter suspended material from water column and often build nets for capturing food, including small organisms
Herbivore-piercers	Feed on living vascular macrophytes and algae by piercing and sucking cells and tissue fluids
Predators	Attack and engulf other animals/prey, may suck body fluids
Scrapers	Feed on periphytic algae and associated material on mineral and organic substrates
Shredders	Feed on living or decomposing vascular macrophyte tissue, coarse particulate organic material, by chewing large pieces
Habit trait group	*Relative mobility and where food is obtained*
Burrowers	In habit fine sediments and may construct burrows with protruding tubes or ingest their way through sediments
Climbers	Live on macrophytes or coarse detrital debris, moving vertically on stem-type surfaces
Clingers	Possess behavioral or morphological adaptations for attachment to surfaces mainly on wave-swept shores
Sprawlers	Inhabit the surfaces of floating leaves of macrophytes or fine sediment
Swimmers	Adapted for short periods of swimming between benthic objects or swimming by rowing with the specially adapted hind legs.

2016 Samples North Muskegon Water Sports Park Off Shore

Macroinvertebrate counts were multiplied by 43.3 to convert samples from in^2 to m^2. Data were tested for normality with a Shapiro-Wilks test. Non-normal data were transformed to achieve a normal data set. All data remained non-normal, so the Mann- Whitney Rank Sum test was used to compare control and mill debris sites. Since the populations of the deep water sites were limited to chironomids, oligochaetes, amphipods, and gastropods, Shannon Weaver diversity was used for comparing populations and trait analysis was not conducted

Key Project Findings

- Population analyses did not indicate sawmill debris had negative effect on the macroinvertebrate communities. The results did show that sawmill debris lead to a difference in benthic macroinvertebrate community composition when present. This appeared to be a function of more macrophytes present in the saw mill debris areas and the resulting temperature and DO gradient.
- Sprawler and clinger abundances were similar between mill debris and control sites. Burrowers (clams, oligochaetes) were more evenly arranged throughout natural sediment. This functional feeding group includes *Dero digitate*, oligochaete immatures without hairs/chaetae, *Limnodrilus hoffmeisteri*, *Physa, Valvata tricarinata, Valvata piscinalis,* and *Leptophepiidae*.
- There was more variation seen within the gatherers (snails, caddisflies) of the macroinvertebrate communities of the sawmill debris impacted site
- Filterer-burrowers (clams), filterer-climber (midges, *Tanytarsus*), predators-sprawlers (midges, *Procladius*), and shredder-climbers (midges, *Polypedium*) were the most abundant functional trait groups within the control transects
- Predator-swimmers (*Lebertia*) were five times greater within the sawmill debris site.
- In the deeper zone where sufficient sediment was present on top of sawmill debris to obtain PONAR samples, there were no significant differences between benthic macroinvertebrate populations between debris influenced siites and control sites.

D. Describe results and outcomes.

2015 Samples Muskegon Water Sports Park

Analysis of major taxa between the two sites types found Amphipoda, Isopoda, Bivalvia, Gastropoda, Glossiphoniidae, and Lebertiidae to be significantly different between the sawmill debris and control sites (p-values= <0.00, <0.00, 0.01, 0.02, 0.05, 0.04, respectively. Chironomidae were close to being significant with a p-value of 0.06. When the major taxa data were analyzed using NMDS, a significant separation occurred between the sawmill debris and control transects (R=0.72, p=0.034; Figures 3 & 4). Gastropoda and Bivalvia were found in greater quantities within the control sites and were the most influential for those sites, while Amphipoda and Isopoda were found in higher numbers within the sawmill debris sites and were the most influential for the sawmill debris sites (Figure 4.3). Temperature, specific conductivity, and turbidity appeared to drive the differences when water quality data were analyzed with the major taxa (Figure 4).

Analyses performed on the major taxa indicated Bivalvia and Gastropoda to be the most statistically influential taxa when comparing sawmill debris sites to control sites showed cumulative contributions of 0.44 and 0.78, respectively. The same analysis done on the entire species data set resulted with *Dreissena polymorpha* (zebra mussels), *Amnicola limosus* (mud amnicola), immature Oligochaetae without hair chaetae, *Limnodrilus hoffmeisteri* (Limnodrilus worm), *Bithynia sp.* (freshwater snails), *Valvata piscinalis* (European stream valvata), and *Hyalella sp.* (a freshwater amphipod) being the most influential species (cumulative contributions=0.19, 0.31, 0.4, 0.47, 0.54, 0.6, 0.66, 0.71, respectively). Analysis of environmental data resulted in turbidity, specific conductivity, and temperature being the most influential when comparing sawmill debris and control sites (cumulative contributions=0.49, 0.74, and 0.84, respectively.

Calculation of the mean number of organisms per m^2 indicated Amphipoda, Isopoda, and Oligochaeta to be more prevalent in the sawmill debris transects, while Bivalvia and Gastropoda were more abundant in the control transects (Table 2, Figure 5). Chironomidae abundance also was significantly different between control and sawmill debris transects (mean #/m^2 = 3279

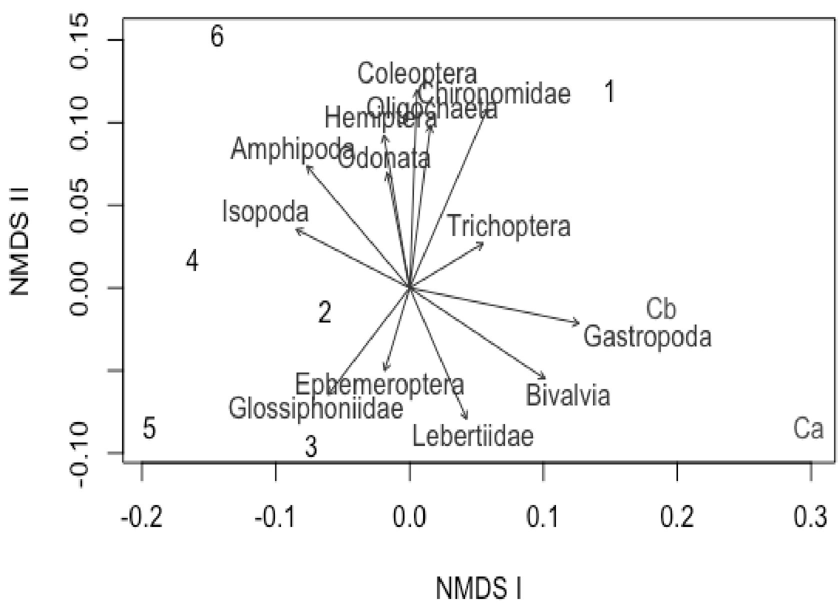

Figure 3. Non-metric multidimensional scaling (NMDS) plot of averaged benthic macroinvertebrate community taxa samples (n=8) from North Muskegon Water Sports Park in Muskegon Lake, Michigan. Each point represents an entire transect of data. Vectors represent the major taxa present and their influence on the macroinvertebrate community structure. The NMDS plot resulted with a stress value of 0.053 and an ANOSIM analysis with a significant difference between control and mill debris sites (R=0.71, p=0.03).

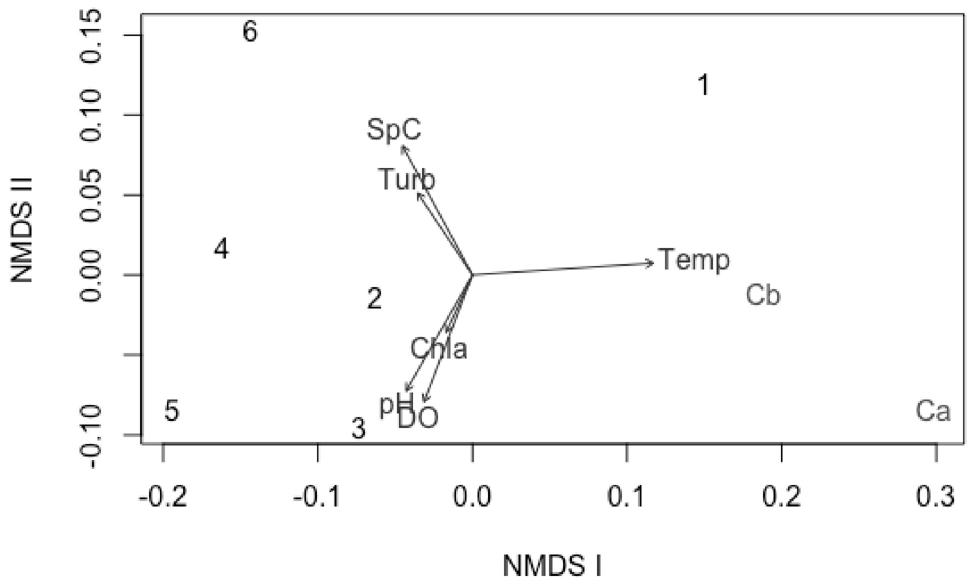

Figure 4. Non-metric multidimensional scaling (NMDS) plot of averaged benthic macroinvertebrate community taxa samples (n=8) from North Muskegon Water Sports Park in Muskegon Lake, Michigan. Each point represents an entire transect of data. Vectors represent averaged water quality data of each transect and their influence on the macroinvertebrate community structure. The NMDS plot resulted with a stress of 0.053 and an ANOSIM analysis with a significant difference between control and mill debris sites (R=0.71, p=0.03).

Table 2. Summary of benthic macroinvertebrate populations from major taxa group for control and mill debris sites collected within the North Muskegon Water Sports Park, Muskegon Lake, Michigan. Mean, maximum, minimum, and standard error (SE) calculations shown.

Location	Control				Mill Debris			
Metric	Mean	SE	Max	Min	Mean	SE	Max	Min
Units	#/m^2	#/m^2	#/m^2	#/m^2	#/m^2	#/m^2	#/m^2	#/m^2
Amphipoda	981	263	3940	43	2774	408	16973	0
Ephemeroptera	464	199	3421	0	501	87	2208	0
Odonata	38	13	173	0	68	13	433	0
Trichoptera	125	36	476	0	119	29	1126	0
Coleoptera	0	0	0	0	2	1	43	0
Bivalvia	22	79	13	87	57	82	24	0

	841	14	4317		50	1	811	
Gastropoda	22196	5389	73653	346	10066	1519	53476	130
Lebertiidae	67	22	303	0	33	12	563	0
Hemiptera	0	0	0	0	1	1	43	0
Isopoda	0	0	0	0	178	42	1299	0
Glossiphoniidae	7	4	43	0	38	8	260	0
Oligochaeta	9228	1214	27712	4763	12664	1424	63824	606
Chironomidae	3279	562	9006	736	2375	474	25720	130

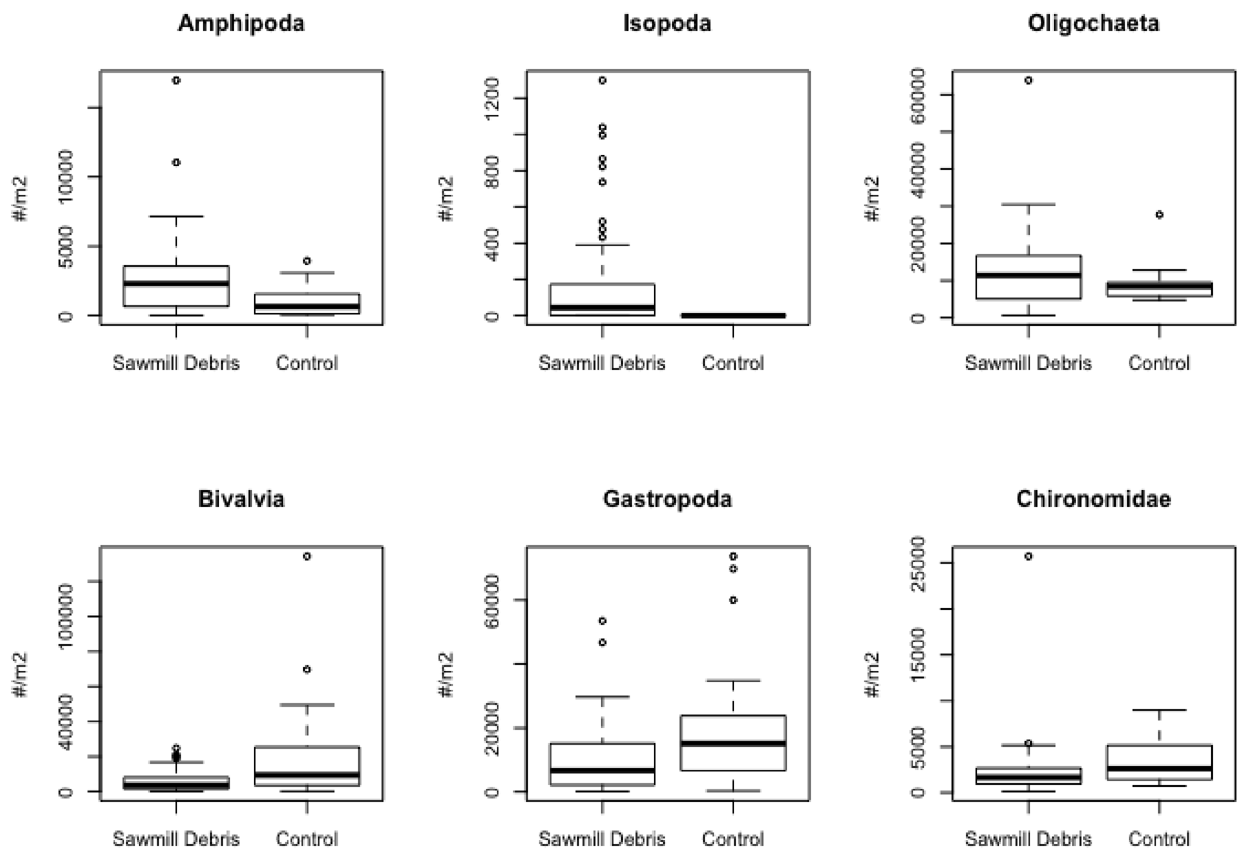

Figure 5. Boxplot of major taxa that were more prevalent within either the control or sawmill debris transects and had the greatest differences in abundances. The y-axis represents the number of organisms per m^2 and the x-axis indicates the site type the data were from.

Functional trait group analyses by site resulted in a clear pattern between sawmill debris and control sites (Figure 6). The control sites have less vertical variation than does the sawmill debris, while both sawmill debris and the control has equal horizontal variation. When this plot was overlaid with water quality measurements, temperature, dissolved oxygen, and specific conductivity are the most influential (represented by longest vectors; Figure 7). When the same plot is instead overlaid with the functional trait groups, overlapping traits made it hard to

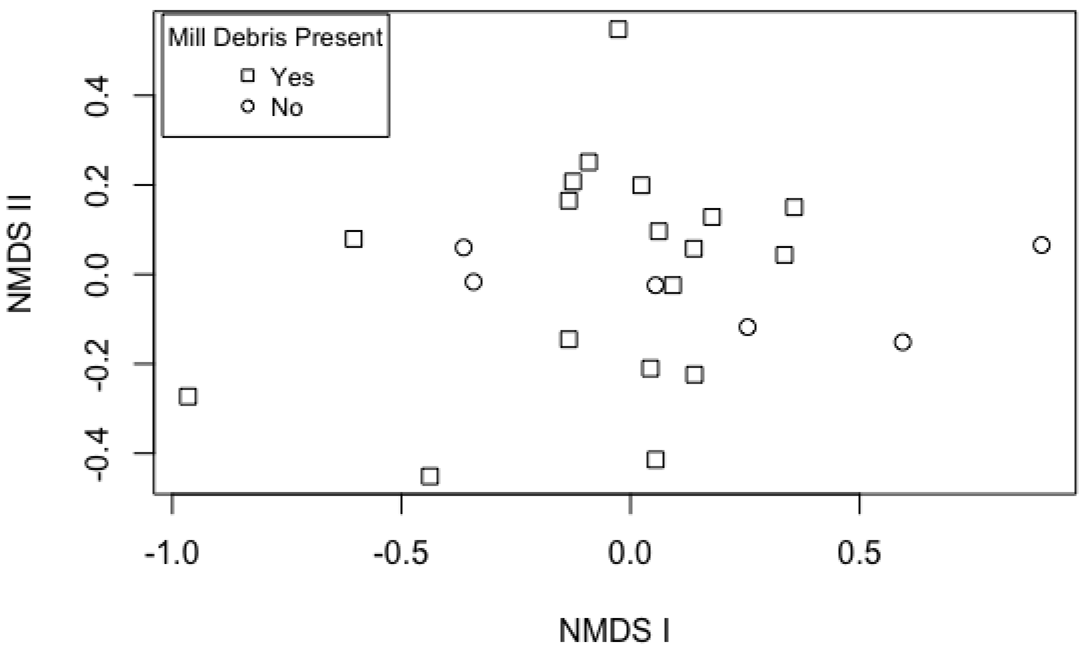

Figure 6. Non-metric multidimensional scaling (NMDS) plot of averaged benthic macroinvertebrate community taxa samples (n=8) from North Muskegon Water Sports Park in Muskegon Lake, Michigan. Each point represents an entire transect of data. Vectors represent averaged water quality data of each transect and their influence on the macroinvertebrate community structure. The NMDS plot resulted with a stress of 0.053 and an ANOSIM analysis with a significant difference between control and mill debris sites (R=0.71, p=0.03).

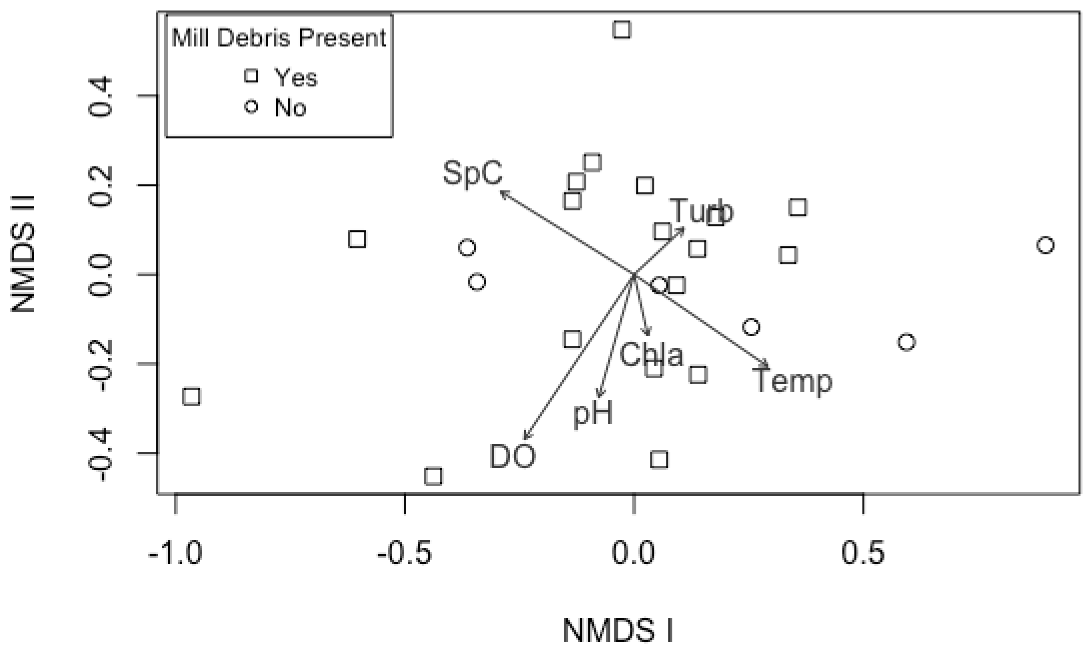

Figure 7. Non-metric multidimensional scaling (NMDS) plot of averaged benthic macroinvertebrate community taxa samples (n=8) from North Muskegon Water Sports Park in Muskegon Lake, Michigan. Each point represents an entire transect of data. Vectors represent averaged water quality data of each transect and their influence on the macroinvertebrate community structure. The NMDS plot resulted with a stress of 0.053 and an ANOSIM analysis with a significant difference between control and mill debris sites (R=0.71, p=0.03).

interpret any results (Figure 8). Therefore, functional feeding groups and functional habit groups were separated and the NMDS with overlaying parameters was redone. With just the functional habit groups overlaid on the plot, clingers, burrowers, and sprawlers are the most influential (represented by longest vectors; Figure 9). Within this plot, clingers and sprawlers are orthogonal to burrowers. When that same plot was overlaid with the functional feeding guilds, filterers, gatherers, and scrapers were the most influential (represented by longest vectors, Figure 10). This plot showed predators and collectors to be almost identical and scrapers and filterers to be similar to each other. When the NMDS was plotted with site names, a pattern can

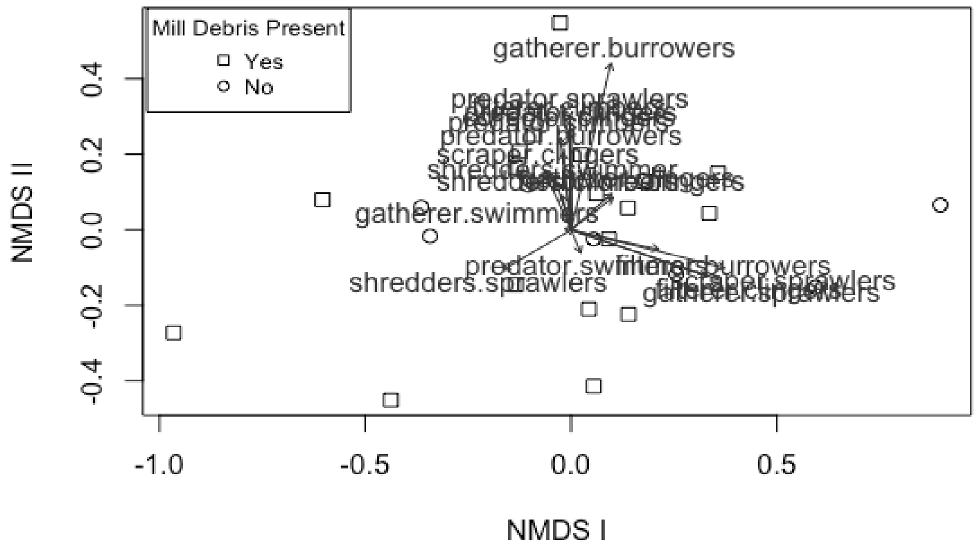

Figure 8. Non-metric multidimensional scaling (NMDS) plot of functional trait group of benthic macroinvertebrate samples (n=24) from North Muskegon Water Sports Park in Muskegon Lake, Michigan. Each point represents triplicate samples from one site along either sawmill debris transects (squares) or control transects (circles). Vectors represent the functional trait groups. The NMDS plot resulted with a stress value of 0.12.

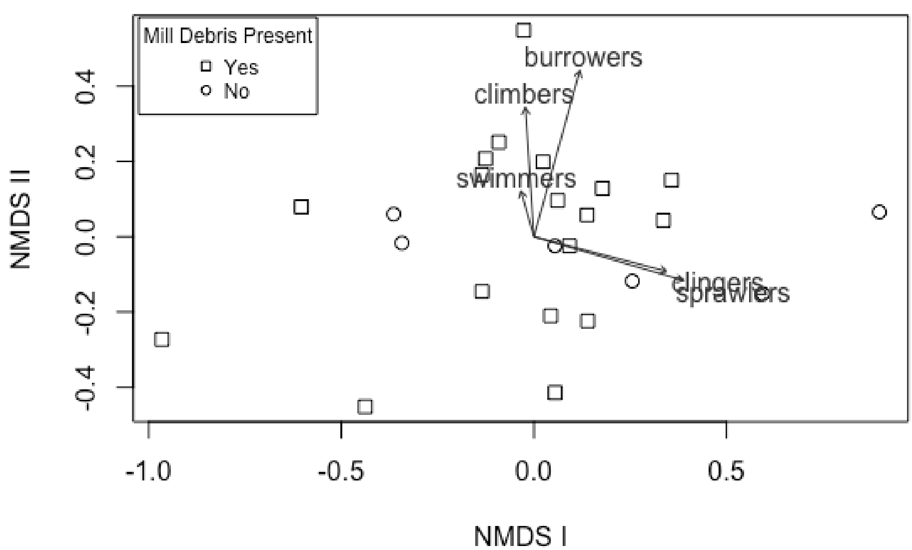

Figure 9. Non-metric multidimensional scaling (NMDS) plot of functional trait group of benthic macroinvertebrate samples (n=24) from North Muskegon Water Sports Park in Muskegon Lake, Michigan. Each point represents triplicate samples from one site along either sawmill debris transects (squares) or control transects (circles). Vectors represent the functional habit groups. The NMDS plot resulted with a stress value of 0.12.

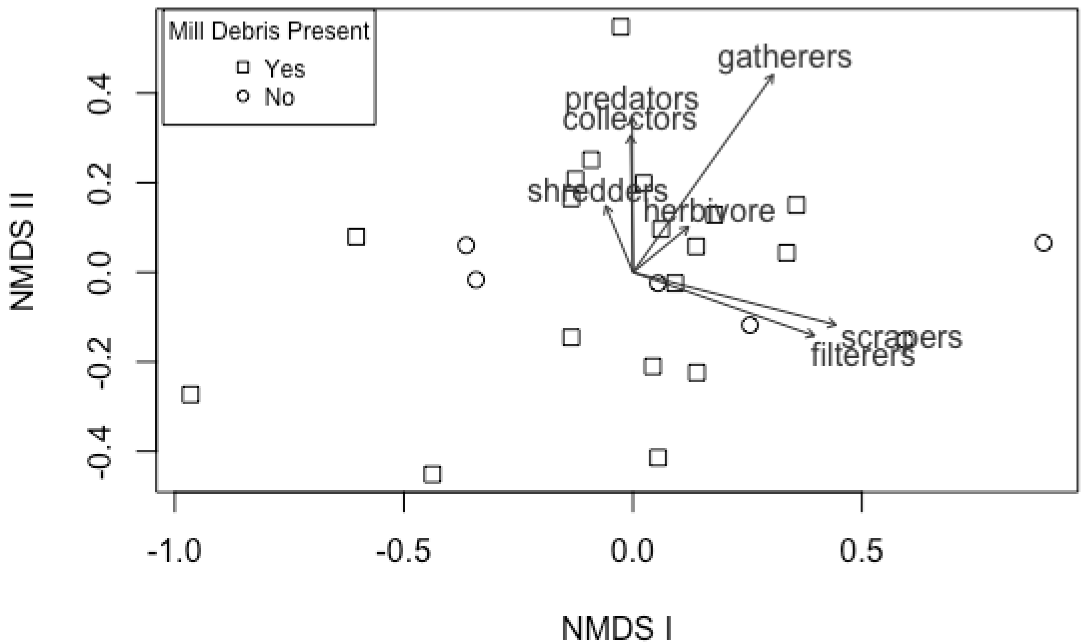

Figure 10. Non-metric multidimensional scaling (NMDS) plot of functional trait group of benthic macroinvertebrate samples (n=24) from North Muskegon Water Sports Park in Muskegon Lake, Michigan. Each point represents triplicate samples from one site along either sawmill debris transects (squares) or control transects (circles). Vectors represent the functional feeding groups. The NMDS plot resulted with a stress value of 0.12.

be seen within the control transects (Figure 11). Both control transects ordinated similarly along a depth gradient. Within the plot Caa and Cba represent the 1.0 m depths, Cab and Cbb represent 1.5 m, and Cac and Cbc represent the 2.0 m depths of the two transects. This pattern was not replicated within the sawmill debris impacted transects, and, in fact, there is no pattern at all with the varying depths where sawmill debris was present. This first group of NMDS plots all have the same stress value of 0.12.

Another NMDS analysis of the functional trait groups resulted in clustering (Figure 12). This cluster can be seen in expanded detail in figures 13 and 14. Figure 15 shows the same NMDS analysis with the points representing the functional feeding groups. No clear pattern can be seen. The same is true when the points represent just functional habit groups (Figure 16). This second group of NMDS plots all have the same stress value of 0.08.

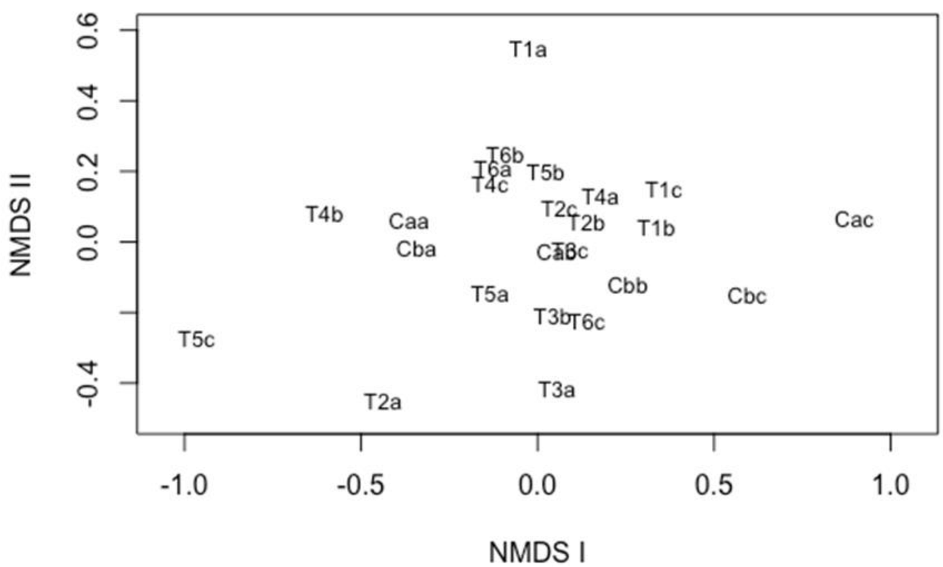

Figure 11. Non-metric multidimensional scaling (NMDS) plot of functional trait group of benthic macroinvertebrate samples (n=24) from North Muskegon Water Sports Park in Muskegon Lake, Michigan. Points labeled with 'T' correspond with sawmill debris impacted sites, while points labeled with 'C' represent control sites. The NMDS plot resulted with a stress value of 0.12.

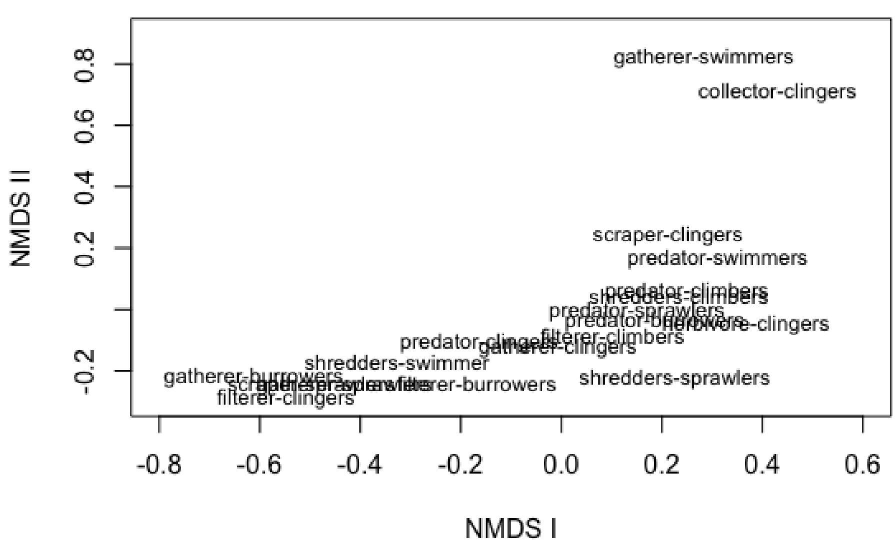

Figure 12. Non-metric multidimensional scaling (NMDS) plot of functional trait groups (n=19) present within the North Muskegon Water Sports Park area. The NMDS plot resulted with a stress value of 0.08.

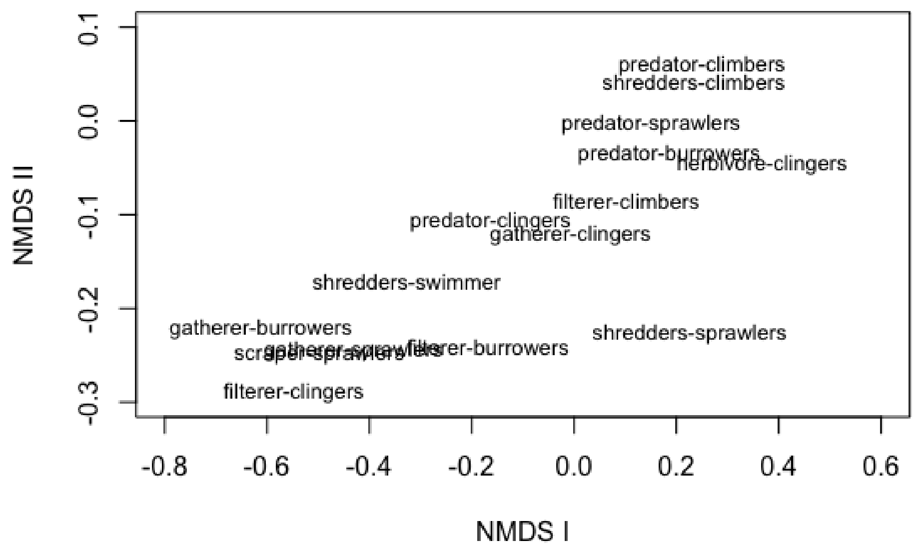

Figure 13. Non-metric multidimensional scaling (NMDS) plot of functional trait groups (n=19) present within the North Muskegon Water Sports Park area. The NMDS plot resulted with a stress value of 0.08.

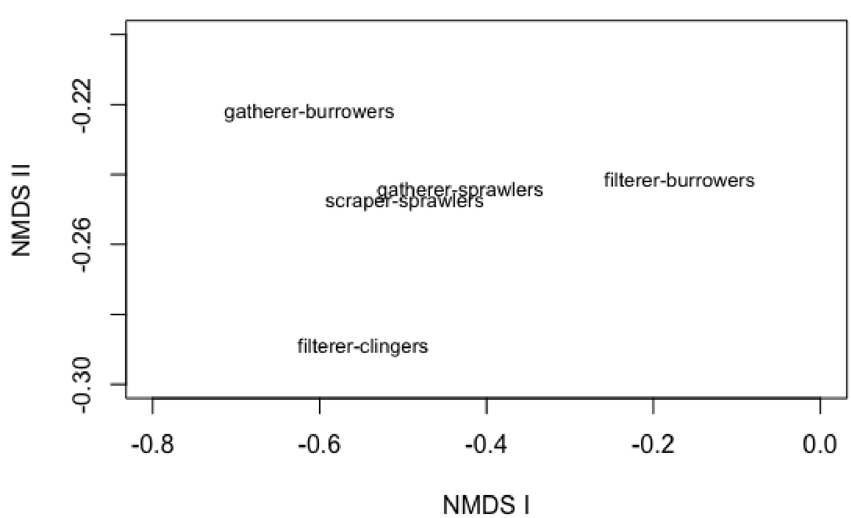

Figure 14. Non-metric multidimensional scaling (NMDS) plot of functional trait groups (n=19) present within the North Muskegon Water Sports Park area. The NMDS plot resulted with a stress value of 0.08.

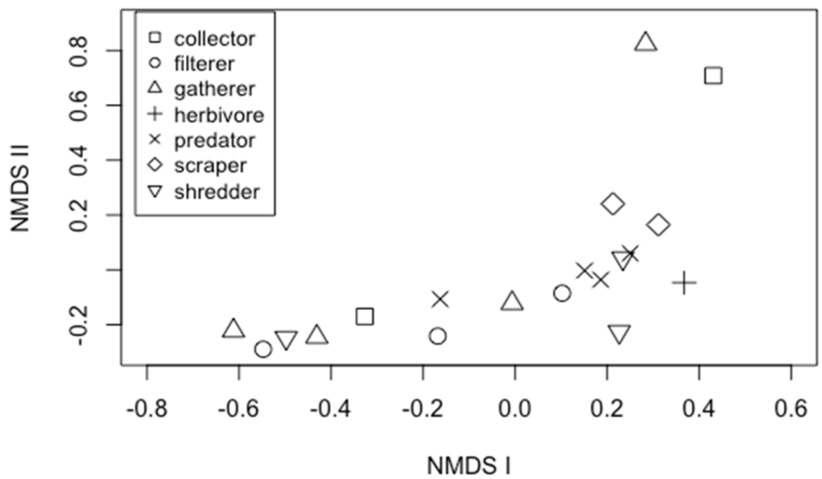

Figure 15. Non-metric multidimensional scaling (NMDS) plot of functional trait groups (n=19) present within the North Muskegon Water Sports Park area. Each point represents the functional feeding group of its corresponding functional trait. The NMDS plot resulted with a stress value of 0.08.

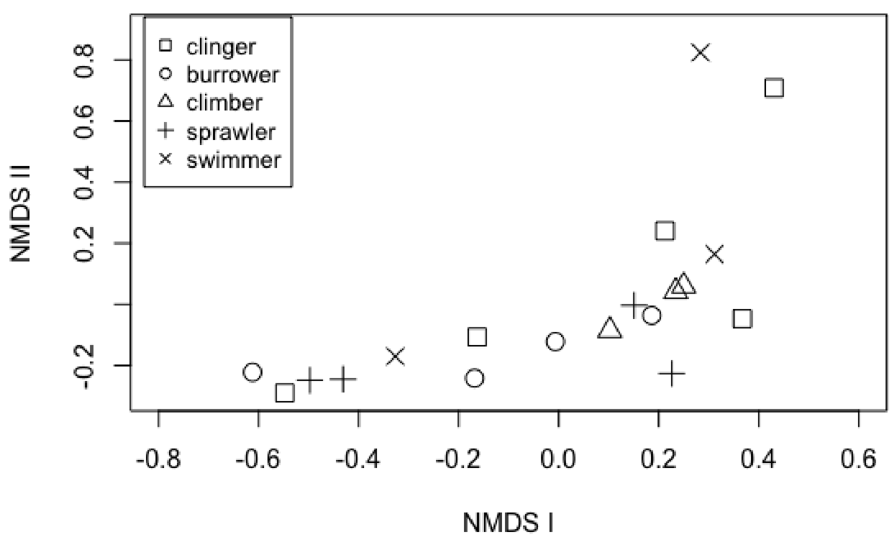

Figure 16. Non-metric multidimensional scaling (NMDS) plot of functional trait groups (n=19) present within the North Muskegon Water Sports Park area. Each point represents the functional habit group of its corresponding functional trait. The NMDS plot resulted with a stress value of 0.08.

Analyses of mean, minimum, and maximum abundance of functional trait groups showed filterer-burrowers (*Pisidium and Sphaerium*), filterer-clingers (*Dreissena polymorpha*), predators-burrowers (*Clinotanypus and Coelotanypus*), scraper-sprawlers (*Amnicola limosa*), and shredder-climbers (*Polypedium*) to be more abundant within the control transects than the sawmill debris affected ones (Table 3). These functional trait groups range from about two to five times greater in the control transects. Shredder-swimmers (*Asellota*) were only present within the sawmill debris transects. This was the only functional trait group within the sawmill debris impacted sites to be more than two times greater within the impacted area. The next three functional groups to be greater within the impacted area were gatherer-burrowers (*Dero digitata, Limnodrilus hoffmeisteri, and mmatures without hairs/chartae*), predator-clingers (*Planaria*), and shredder-swimmers (*Hyalella*). These groups ranged between about one and three times greater within the sawmill debris impacted sites. This analysis agrees with the analysis done on number of major taxa present per unit squared. Filter-burrowers, filter-clingers, and scraper-sprawlers were found in higher abundances within the control sites and the most common species within these were within the Bivalvia class. Predator-burrowers and shredder-climbers were also found in higher numbers within the control sites and these functional trait groups were dominated by chironomids. This also supports the number of major taxa present per unit squared analysis although chironomids were not significantly different. Gatherer-burrowers, shredder-sprawlers, and shredder-swimmers were more abundant within the sawmill debris impacted sites and contain several species from Oligochataeta, Isopoda, and Amphipoda.

Water Chemistry Analysis

The analysis of water chemistry data showed only temperature differed significantly between control and sawmill debris sites (p=0.025). The control site had a higher average temperature by two degrees (Table 5). There was no significant difference seen in dissolved oxygen (p=0.82) or Chlorophyll α (p=1) between the two site types.

Table 3. Minimum, maximum, and mean abundance of each functional trait group within the control and sawmill debris sites within Muskegon Lake, MI. Functional trait groups were based on the combination of functional feeding groups and habitat trait groups. Also shown are common genera found within the sampling sites for each functional trait group.

	Control			Sawmill Debris			All			
Functional Group	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Most common genera
Collector-clingers	0	0	0	2	0	43	2	0	43	*Cyrnellus fraternus, Heterlimnius, Neocylloepus*
FIlterer-burrowers	2237	43	4763	370	0	2468	837	0	4763	*Pisidium, Sphaerium*
Filterer-climbers	149	0	909	245	0	1472	221	0	1472	*Tanytarsus*
Filterer-clingers	2060	43	129554	5400	0	22343	9202	0	129554	*Dreissena polymorpha*
Gatherer-burrowers	11118	5975	29661	13289	779	70319	12746	779	70319	*Dero digitata,* immatures w/o hairs/chaetae, *Limnodrilus hoffmeisteri*
Gatherer-clingers	254	0	996	405	0	1949	367	0	1949	*Physa*
Gatherer-sprawlers	8036	259	22906	4253	130	29920	5199	130	29920	*Valvata tricarinata, Valvata piscinalis*
Gatherer-swimmers	0	0	0	2	0	43	1	0	43	*Leptophepiidae*
Herbivore-clingers	57	0	260	61	0	736	60	0	736	*Agraylea, Hydroptila*
Predator-burrowers	161	0	736	65	0	650	89	0	736	*Clinotanypus, Coelotanypus*
Predator-climbers	36	0	173	67	0	390	59	0	390	*Coenagrion*
Predator-clingers	565	87	1732	1307	43	16411	1122	43	16411	*Planaria*
Predator-sprawlers	103	0	303	118	0	823	114	0	823	*Procladius, Ablabesmyia*
Predator-swimmers	67	0	303	33	0	563	42	0	563	*Lebertia*
Scraper-clingers	19	0	173	38	0	476	33	0	476	*Stenacron*
Scraper-sprawlers	14613	303	54991	5908	0	37022	8084	0	54991	*Amnicola limosa*
Shredders-climbers	180	0	953	42	0	260	76	0	953	*Polypedium*
Shredders-sprawlers	0	0	0	182	0	1342	137	0	1342	*Asellota*
Shredders-swimmer	981	43	3940	2774	0	16974	2326	0	16974	*Hyalella*

Table 4. Water quality measurements from the control and mill debris transects within the North Muskegon Water Sports Park area, collected within Muskegon Lake during August and September 2015. Measurements taken included temperature (C°; Temp C°), dissolved oxygen (mg/L; DO mg/L), pH, specific conductivity (μS/cm; SpC μS/cm), turbidity (NTU; Turb NTU), and chlorophyll α (μg/L; Chl α μg/L). The Site ID's correspond to Water Sports Park (WP), either Control A (Ca), Control B (Cb), or the mill debris transects 1-6, along with the depths sampled (m). Difference between mill debris and control sites were calculated using Wilcoxon Rank Sum tests and the means of the control and mill debris sites were calculated for easy comparisons.

Water quality measurements	Temp C	DO mg/L	pH	SpC u S/cm	Turb NTU	Chl a ug/L
Difference between sites (WR)	p=0.025	p=0.82	p=0.947	p=0.081	p=0.156	p=1
Mean Control	23.1	8.3	8.2	401.2	3.3	11.1
Mean Mill Debris	21.1	7.8	8.2	406.9	13.2	11.0

<u>2016 Samples North Muskegon Water Sports Park Off Shore</u>

Macroinvertebrate results from the two locations showed similar numbers and distributions for control and mill debris sites (Table f; Figure 17). Tubificidae, Bivalvia, Niadidae, Gastropoda, Amphipoda, and all were not significantly different (MW; p>0.050). Total organisms were also similar (MW; p>0.050; Figure 18) along with species richness (MW; p p>0.050; Figure 19) and Shannon Weaver diversity (MW; p>0.050; Figure 20). Since the PONAR was able to collect a sediment sample in the mill debris locations, sediment depth on the submerged dock was > 12 cm. These results suggest that wood material buried with shallow sediment coverage has similar benthic macroinvertebrate populations as natural sediment.

Table 5. Summary of Benthic Macroinvertebrate Populations from Major Taxa Groups for the Control) and Mill Debris Sites collected from North Muskegon Water Sports Park Off Shore Location 2016.

Location	Control				Mill Debris			
Metric	Mean	SE	Max	Min	Mean	SE	Max	Min
Units	#/m^2	#/m^2	#/m^2	#/m^2	#/m^2	#/m^2	#/m^2	#/m^2
Tubificidae	4227	643	17827	129	3555	148	6416	129
Naididae	1059	257	6373	301	1095	60	2842	301
Chironomidae	2292	358	8009	818	2062	231	7320	818
Ceratopogonidae	0	0	0	0	3	2	86	0
Turbellaria	155	47	904	0	1	1	43	0
Glossiphoniidae	3	2	43	0	0	0	0	0
Lebertiidae	30	14	388	0	1	1	43	0
Odonata	34	13	344	0	0	0	0	0
Coleoptera	7	5	129	0	0	0	0	0
Bivalvia	2321	483	13133	129	1176	257	6803	129
Gastropoda	2119	436	12186	301	1985	643	2497	301
Amphipoda	1043	217	4823	818	788	944	1233	818
Odonata	12	2	86	0	6	2	86	0
Trichoptera	6	2	86	0	6	2	86	0
Total Organisms	13309	2480	64332	2496	10677	2291	27457	2496
Richness	23	1.04	31	12.0	20	1	26	11
Shannon Weaver Diversity	2.84	0.05	3.20	2.29	2.75	0.04	2.75	0.69

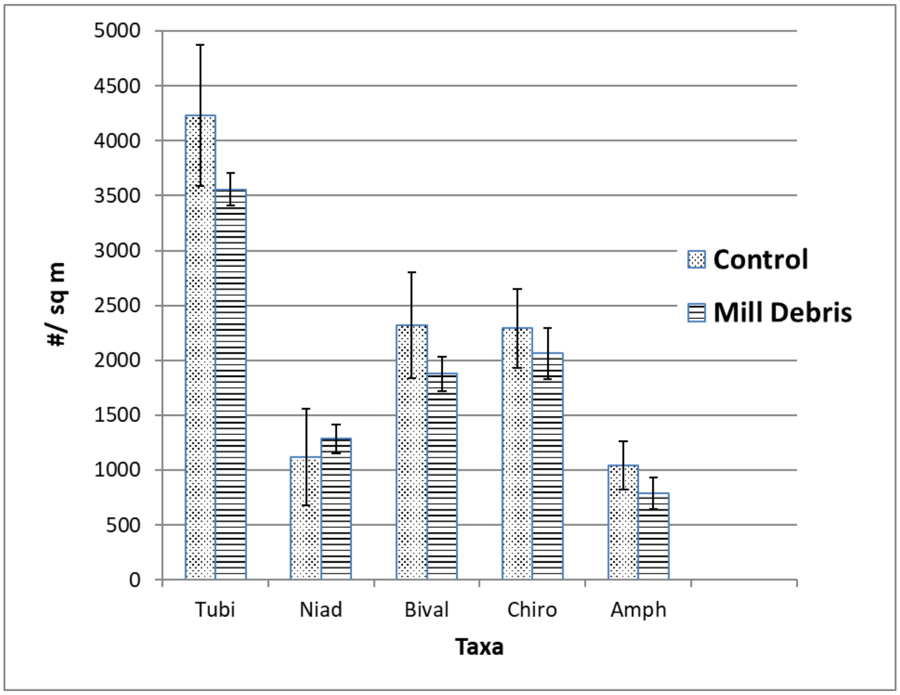

Figure 17. Summary of Benthic Macroinvertebrate Populations from Major Taxa Groups for the Control and Mill Debris Sites collected from North Muskegon Water Sports Park Off Shore Location 2016. (Tubi=Tubificidae, Nai-Naiadae, Bival=Bivalvia, Amph=Amphipoda, and Chiro=Chironomidae).

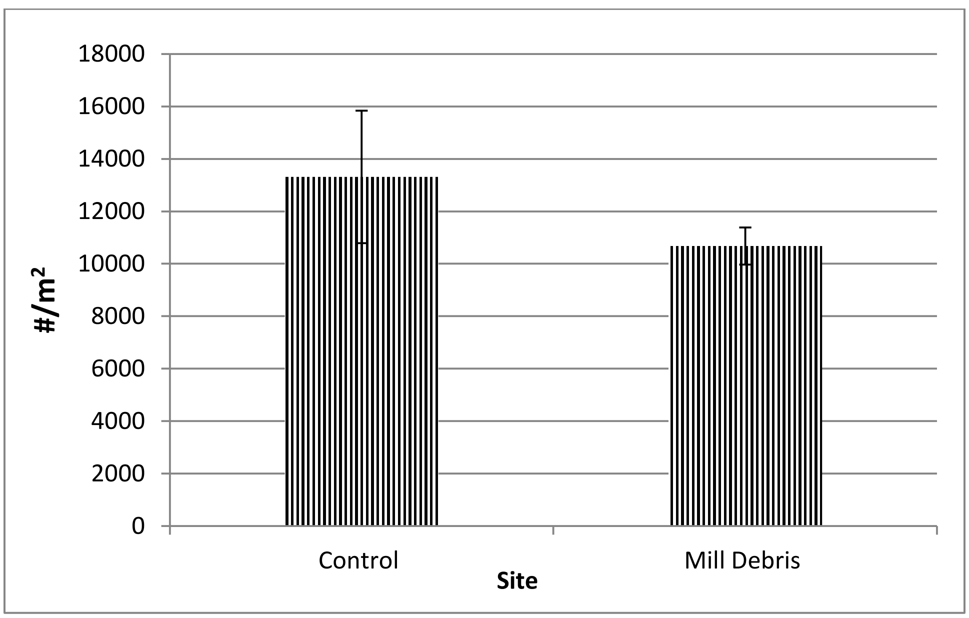

Figure 18. Macroinvertebrate Community Density for the Control and Mill Debris Sites collected from North Muskegon Water Sports Park Off Shore Location 2016.

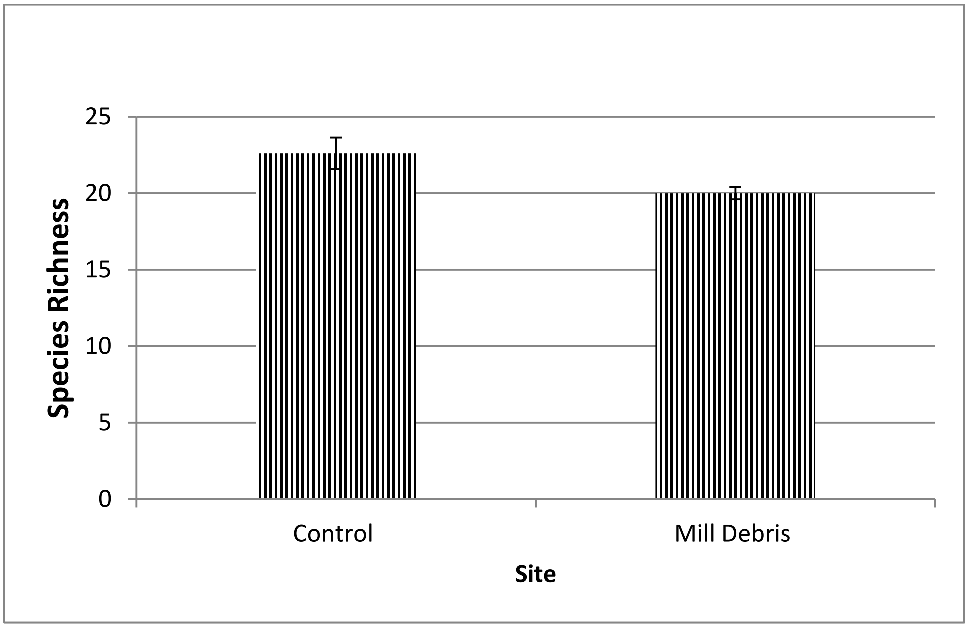

Figure 19. Macroinvertebrate Species Richness for the Control and Mill Debris Sites collected from North Muskegon Water Sports Park Off Shore Location 2016..

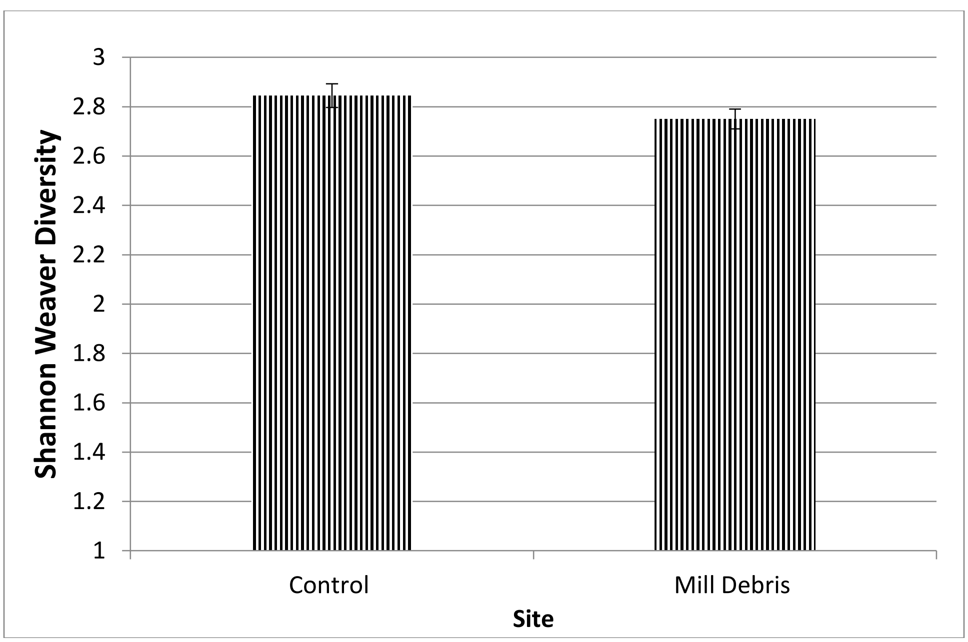

Figure 20. Shannon Weaver Diversity for the Control and Mill Debris Sites collected from North Muskegon Water Sports Park Off Shore Location 2016.

E. **Describe in detail deviations from proposed in the implementation of methods, achievements of performance metrics and/or object class expenditures. Include why the deviations were made and how they impacted the outcomes of the proposed project.**

Deviations in sampling locations were made based on data obtained after the project started. Insufficient mill debris coverage was found in the zone between the Bear Creek Channel and Snug Harbor and no mill debris were found in Bear Lake. This resulted in the shift of sampling efforts to an offshore location from the Water Sports Park and the deeper zone at the South Shore Bike Path.

F. **Describe lessons learned (e.g., new techniques, innovative partnerships, and community engagement).** The initial partnership for the restoration project was initiated by the Muskegon Lake Watershed Partnership. As the MLWP staff support organization, WMSRDC convened the private landowners, City of Muskegon, City of North Muskegon and the County of Muskegon to develop a MDEQ/NOAA AOC plan to remove mill debris from the South Shore Bike Path. WMSRDC coordinated a project team with NOAA, GVSU, MDNR Fisheries Division, NOAA GLERL, and the project's engineering consultants. Under this grant, WMSRDC advertised the RFP and two ecological restoration/engineering firms were selected. Construction bid packages advertised and a marine construction contractor was selected.

G. **Describe future plans, such as restoration and monitoring next steps, and/or plans for sharing/publishing results or description of other outreach activities and products.**

AWRI will prepare a manuscript for publication of the mill debris data. This project and the previous effort shows the complexity of mill debris assessment and habitat alteration in Muskegon Lake.

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