Lower Muskegon River Habitat Restoration Project:

Pre-Restoration Monitoring Results of Fishes Macroinvertebrates, and Water Quality

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Introduction

The overall goal of this restoration project to is to reconnect the Muskegon River with a diked wetland near the river's confluence with Muskegon Lake. The purpose of our monitoring is to provide pre- and post-restoration assessment of the fish assemblage, macroinvertebrate assemblage, and water quality in response to this habitat restoration. In this report, we summarize the results of our pre-restoration monitoring during 2018, which will provide a baseline to compare post-restoration monitoring. The baseline conditions also can be used to assess the ecological condition of the diked wetland being considered for restoration.

Methods

We refer to the diked wetland targeted for restoration as the Bosma Property, which was stratified into a West Pond and East Pond for our monitoring efforts (Figure 1). The West Pond was divided into three equal sections and the East pond was divided into two equal sections (Figure 1). At the time of site selection, each section was known to contain open-water plant zones and wet-meadow plant zones; however, the extent of each plant zone within each section was unclear. After a site visit, we determined that all wet-meadow plant zones were too shallow to fish fyke nets (i.e., water depth < 20 cm). Thus, we sampled fish and macroinvertebrates in open-water plant zones and only macroinvertebrates in wet-meadow plant zones (Figure 1, Table 1). In the West Pond, we randomly selected open-water plant zones in two of the three sections and a wet-meadow plant zone in one out of three sections (i.e., West-B open water, West-C open water, and West-C wet meadow). In the East Pond, we randomly selected an open-water plant zone in one of the two sections and a wet-meadow plant zone in one of the two sections (i.e., East-A open water and East-B wet meadow).

Fish were sampled using modified fyke nets following the protocol of Uzarski et al. (2017). Three fyke nets were set in the open-water plant zone within each of the three selected sections (i.e., West-B, West-C, East-A). Fyke nets were set individually, with the lead perpendicular to the shoreline (Figure 2A, 2B), spaced at least 25 m apart, and placed in water depths between 20 cm and 100 cm. Fyke nets were set in the West Pond on 14 August 2018 and the East Pond on 16 August 2018. Fyke nets were fished overnight with a mean soak time of

25.4 hr (range = 23.1-27.9 hr). Fish were identified, enumerated, measured for total length, and released in the field. A few individuals of certain species (i.e., ones difficult to identify in the field) were euthanized and taken to the laboratory for identification with a dissecting microscope.

Macroinvertebrates were sampled using D-frame dip nets (D-net) with 500-µm mesh following the protocol of Uzarski et al. (2017). Macroinvertebrates were sampled near the fyke net lead at open-water plant zones. In wet-meadow plant zones, we sampled macroinvertebrates in an approximately 20-m^2 area (Figure 2C), with at least 25 m between each replicate. The total number of D-net sweeps (1 m each) used to collect macroinvertebrates was recorded for each replicate. A maximum of 150 macroinvertebrates and a minimum of 50 macroinvertebrates were picked in the field for each replicate following the protocol of Uzarski et al. (2017). Briefly, once a minimum of 30 person minutes was spent picking a replicate, picking was continued until the nearest multiple of 50 individuals was reached. Thus, the number of macroinvertebrates picked for any replicate was influenced strongly by macroinvertebrate abundance and amount of debris in the sorting tray. Once picking of a replicate was completed in the field, the number of macroinvertebrates picked and the number of person minutes spent picking was recorded for each replicate. Macroinvertebrate samples were preserved in 70% ethanol and taken to the laboratory for identification to the lowest reasonable taxonomic level using a dissecting microscope. The number of D-net sweeps, number of macroinvertebrates picked, and person minutes spent picking (all done in the field) provide an index of effort and a semi-quantitative measure of macroinvertebrate abundance for each replicate. For instance, a low number of sweeps, high number of macroinvertebrates picked, and low number of person minutes spent picking would be consistent with high abundance of macroinvertebrates in a plant zone.

A suite of chemical and physical variables were recorded for each plant zone. Depth was measured at the mouth of the fyke net for open-water plant zones and the center of where macroinvertebrates were collected for wet-meadow plant zones. Submerged aquatic vegetation (SAV) and emergent aquatic vegetation (EAV) was visually estimated for the length of the fyke-net lead between the two wings for open-water plant zones and in the general area where macroinvertebrates were collected in wet-meadow plant zones. At each plant zone, a YSI 6600 V2 multi-parameter data sonde (Figure 2D) was used to measure water temperature, dissolved oxygen, specific conductivity, total dissolved solids, turbidity, pH, and chlorophyll-*a*.

Results

Chemical and physical variables varied spatially and were consistent with poor water quality in this diked wetland (Table 2). The spatial pattern was especially clear for specific conductivity and dissolved oxygen concentration. Specific conductivity was high overall but tended to be higher in the West Pond (mean = 807 µS/cm) than the East Pond (mean = 726 µS/cm). Dissolved oxygen concentration were low overall and also varied between ponds; however, the spatial pattern also was dependent on plant zone. Dissolved oxygen concentrations were highest among the open-water plant zones in the West Pond (mean = 4.13 mg/L). Dissolved oxygen concentrations were consistently low in the wet-meadow plan zones (in both ponds; mean = 0.62 mg/L) but the lowest observations were in the open-water plant zone of the East Pond (0.45 mg/L).

A total of 1577 fish were captured in nine fyke nets set in the two ponds that we sampled (Table 3). Fish species richness was low with only six species represented in the catch (Table 3; Figure 3). Fish species richness and catch per unit effort (CPUE) was higher in the West Pond than the East Pond (Table 3). In the West Pond, four species (common carp, pumpkinseed, bluegill, and fathead minnow) comprised 95% of the total catch (Figure 3), with a mean CPUE of 247 fish/fyke net. In the East Pond, only two fish species were captured, with central mudminnow compromising almost 99% of the catch (Figure 3). The CPUE in the East Pond was 31 fish/fyke net (Table 3). The size distribution of the catch was skewed toward smaller individuals, with 98.8% of fish sampled less than 10 cm TL (Figure 4).

Macroinvertebrates from 27 families, representing 30 different genera were sampled in the diked wetland (Table 4). A high amount of effort was necessary to sample macroinvertebrates in both ponds and plant zones (Table 5). In general, the number of macroinvertbrates captured in the field was low, especially given the high number of person-minutes spent picking in the field (Table 5), suggesting that macroinvertebrates were at low densities in the habitats we sampled. Coleoptera, Culicidae (Diptera), Belostomatidae (Hemiptera), and Stratiomyidae (Diptera) were more common in wet-meadow plant zones but rarely encountered at open-water plant zones (Table 6; Figure 5). Conversely, Chironomidae (Diptera), Corixidae (Hemiptera), and Caenidae (Ephemeroptera) were more common in open-water plant zones but rarely encountered in wet-meadow plant zones (Table 6). Ceratopogonidae (Diptera) was abundant in the open-water plant zone in the East Pond but uncommon elsewhere (Table 6). Physidae (Gastropoda) was found in both plant zones in the East Pond but rarely encountered in either plant zone in the West Pond.

Discussion

The monitoring of fish, macroinvertebrates, and water quality at the Bosma Property suggests this diked wetland is degraded and ripe for improvement as a result of reconnection to the Muskegon River. In terms of water quality, specific conductivity was high and dissolved oxygen concentrations were low. In fact, the mean specific conductivity for the wetland was 755 µS/cm (Table 2), which was much higher than reported for littoral habitats in other drowned river mouth lakes (Janetski & Ruetz 2015). High specific conductivity is often associated with anthropogenic disturbance in Great Lakes coastal wetlands (Uzarski et al. 2005). Additionally, low dissolved oxygen concentrations will affect which species of fish and macroinvertebrates can inhabit a wetland. For instance, we only captured six fish species in our sampling, which is much less than the number of species captured in littoral habitats of Muskegon Lake (Bhagat & Ruetz 2011) and other drowned river mouths (Janetski & Ruetz 2015) using the same type of fyke nets. Half of the fish species in the catch at the Bosma Property—such as common carp, fathead minnow, and central mudminnow (Table 3)—are rarely captured in littoral habitats of Muskegon Lake (Bhagat & Ruetz 2011) or other drowned river mouths (Janetski & Ruetz 2015). Moreover, all three of these fish species are often associated with poor water quality (Becker 1983). Similarly, the open-water plant zone was dominated by tolerant macroinvertebrate taxa such as Chironomidae, Caenidae, and Corixidae, which are indicative of poor water quality (Merritt and Cummins 1996). The low abundance of Amphipoda throughout our sampling can be explained by this group's intolerance to low dissolved oxygen concentrations (Hoback & Barnhart 1996, Irving et al. 2004). Nevertheless, their near absence is noteworthy because Amphipoda is generally well represented in wetland environments (Burton et al. 1999, Cooper & Uzarski 2016).

In terms of the fish assemblage, we also saw difference between the East and West ponds, which may be the results of differing dissolved oxygen concentrations and connectivity between the ponds as well as to the Muskegon River. The dissolved oxygen concentration at the open-water plant zone in the East Pond approached 0 mg/L and was substantially lower than the West Pond (Table 2). In terms of connectivity, we were told by local landowners there may be a route for fish to move from the Muskegon River into the West Pond via an old culvert that connects the West Pond with the ponds further to the west where breaks in the levee can create a connection to the Muskegon River during certain times of the year (i.e., during high water levels). We also were told that the East Pond is likely more isolated than the West Pond because of the lack of a viable connection for fish to move between the East and West ponds. A better connection between the Muskegon River and the West Pond could explain the higher fish species richness in the West Pond. Moreover, the East Pond was dominated by the central mudminnow, which is known for withstanding low dissolved oxygen concentrations (Becker 1983). In fact, Becker (1983) noted that the central mudminnow even has the ability to burrow into mud to persist through drought conditions, suggesting central mudminnow is a fish species expected to be in more isolated wetlands.

In conclusion, the observations reported here provide a pre-restoration assessment of the fish assemblage, macroinvertebrate assemblage, and water quality at the diked wetlands targeted for restoration. We found evidence of degraded water quality (especially high specific conductivity) with corresponding faunal assemblages. Given these baseline conditions, we predict that fish and macroinvertebrate assemblages will respond favorably to habitat restoration that improves water quality and connectivity with the Muskegon River.

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Table 1. Locations (latitude and longitude) for each 2018 fish and macroinvertebrate sampling site at the Bosma Property; coordinates are the mean of the three replicates at each site. Fish were sampled in open-water (OW) plant zones; macroinvertebrates were sampled in open-water and wet-meadow (WM) plant zones. Submerged aquatic vegetation (SAV) and emergent aquatic vegetation (EAV) was visually estimated at each sampling location. Mean ± 1 standard error (*n* = 3) of water depth, SAV, and EAV at fish and macroinvertebrate sampling sites. Site locations are depicted in Figure 1.

Site	Plant Zone	Taxa Sampled	Lat (°)	Long (°)	Depth (cm)	SAV	EAV
West-B	OW	Fish, Macroinvertebrates	43.26969	-86.23155	84±2	0±0	0±0
West-C	OW	Fish, Macroinvertebrates	43.26991	-86.22967	79±1	0±0	0±0
East-A	OW	Fish, Macroinvertebrates	43.27122	-86.22714	89±6	0±0	0±0
East-B	WM	Macroinvertebrates	43.27225	-86.22588	17±1	0±0	82±2
West-C	WM	Macroinvertebrates	43.27054	-86.22975	23±2	0±0	63±2

Table 2. Mean ± 1 standard error (*n* = 3) of water quality variables at fish and macroinvertebrate sampling sites at the Bosma Property. Measurements were made with a YSI sonde. Fish were sampled in open-water (OW) plant zones; macroinvertebrates were sampled in open-water and wet-meadow (WM) plant zones. Measurements for macroinvertebrates were concurrent with fish fyke net measurements for open-water zones.

Site	Date of Measurement	Plant Zone	Water Temperature (°C)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (%)	Specific Conductivity (uS/cm)	Total Dissolved Solids (g/L)	Turbidity (NTU)	pH	Chlorophyll *a* (ug/L)
West-B	8/15/2018	OW	26.20±0.26	3.84±0.97	47.97±12.45	802±1	0.52±0.000	8.0±0.8	7.44±0.04	106.6±11.4
West-C	8/15/2018	OW	27.72±0.73	4.42±2.22	56.60±28.78	818±6	0.53±0.004	9.3±1.0	7.27±0.21	93.6±4.6
East-A	8/17/2018	OW	24.54±0.11	0.45±0.09	5.53±1.09	753±3	0.49±0.001	11.3±0.2	7.07±0.06	74.7±4.8
East-B	8/22/2018	WM	17.51±0.52	0.64±0.13	6.80±1.40	699±30	0.45±0.020	26.7±9.3	6.42±0.07	98.3±3.2
West-C	8/22/2018	WM	20.21±0.82	0.60±0.06	6.70±0.72	806±31	0.52±0.020	15.7±0.9	6.43±0.04	74.2±11.5

Table 3. Number and mean total length (TL; range reported parenthetically) of fish captured by fyke netting (*n* = 3 nets per site) at the Bosma Property on 15 and 17 August 2018. Fish were only sampled in open-water plant zones. Site locations are depicted in Figure 1.

		West-B		West-C		East-A		
Common name	Scientific name	Catch	TL (cm)	Catch	TL (cm)	Catch	TL (cm)	Grand Total
common carp	*Cyprinus carpio*	247	6.3 (2.5-42.0)	46	4.1 (2.1-7.8)	0	--	293
pumpkinseed	*Lepomis gibbosus*	536	4.9 (3.1-14.8)	24	4.7 (3.7-8.6)	0	--	560
bluegill	*Lepomis macrochirus*	311	3.8 (2.2-8.6)	59	3.7 (2.4-5.0)	0	--	370
golden shiner	*Notemigonus crysoleucas*	50	8.0 (4.8-10.3)	8	5.8 (4.5-9.1)	1	8.9	59
fathead minnow	*Pimephales promelas*	174	6.0 (3.5-7.4)	15	5.3 (4.0-7.0)	0	--	189
central mudminnow	*Umbra limi*	9	8.2 (6.8-9.7)	5	5.7 (5.0-7.0)	92	6.1 (3.8-11.2)	106
	Total	**1327**		**157**		**93**		**1577**

Table 4. Lists of macroinvertebrates sampled at the Bosma Property. Total number of families and genera is listed at the bottom of the table. Subfamily or tribe is listed in parentheses for Chironomidae. An * indicates that these particular specimens were not identified beyond either class/sub-class/order or family.

Class/Sub-Class/Order	Family	Genus
Acari	*	*
Amphipoda	Crangonyctidae	*Crangonyx*
Amphipoda	Hyalellidae	*Hyalella*
Arhynchobdellida	Erpobdellidae	*
Coleoptera	Dytiscidae	*
Coleoptera	Haliplidae	*Haliplus*
Coleoptera	Haliplidae	*Peltodytes*
Coleoptera	Hydrophilidae	*Enochrus*
Coleoptera	Hydrophilidae	*Hydrochus*
Coleoptera	Hydrophilidae	*Tropisternus*
Coleoptera	Lampyridae	*
Coleoptera	Noteridae	*Hydrocanthus*
Coleoptera	Noteridae	*Suphisellus*
Coleoptera	Scirtidae	*Cyphon*
Coleoptera	Scirtidae	*Scirtes*
Diptera	Ceratopogonidae	*Bezzia/Palpomyia*
Diptera	Chaoboridae	*Chaoborus*
Diptera	Chironomidae (Pseudochironomini/Chironomini)	*
Diptera	Chironomidae (Tanypodinae)	*
Diptera	Chironomidae (Tanytarsini)	*
Diptera	Culicidae	*Mansonia/Coquillettidia*
Diptera	Stratiomyidae	*Odontomyia*
Diptera	Stratiomyidae	*Odontomyia/Hedriodiscus*
Diptera	Tipulidae	*
Ephemeroptera	Baetidae	*Callibaetis*
Ephemeroptera	Caenidae	*Caenis*
Gastropoda	Physidae	*Physa*
Gastropoda	Planorbidae	*Gyraulus*
Gastropoda	Succineidae	*Succinea*
Hemiptera	Belostomatidae	*Belostoma*
Hemiptera	Corixidae	*Hesperocorixa*
Hemiptera	Corixidae	*Trichocorixa*
Hemiptera	Pleidae	*Neoplea*
Isopoda	Asellidae	*Caecidotea*
Odonata	Coenagrionidae	*Ischnura*
Odonata	Corduliidae	*Epitheca*
Odonata	Libellulidae	*Erythemis*
Odonata	Libellulidae	*Pachydiplax*
Oligochaeta	*	*
Count	**27**	**30**

Table 5. Mean ± 1 standard error ($n = 3$) for variables related to field collection of macroinvertebrates at the Bosma Property. Macroinvertebrates were sampled in open-water (OW) and wet-meadow (WM) plant zones.

Site	Date of Collection	Plant Zone	Number of 1-m Net Sweeps	Person-Minutes Spent Picking (min)	Number of Macroinvertebrates Picked
West-B	8/16/2018	OW	13.0±0.0	42.8±7.1	83.3±16.7
West-C	8/14/2018	OW	15.3±1.5	98.9±31.2	50.0±0.0
East-A	8/15/2018	OW	12.0±0.0	39.6±4.5	66.7±16.7
East-B	8/22/2018	WM	23.0±1.5	54.1±1.4	83.3±16.7
West-C	8/22/2018	WM	21.0±1.0	54.6±9.1	50.0±0.0

Table 6. Assemblage composition of macroinvertebrates collected at the Bosma Property. An * indicates that these particular specimens were not identified beyond Class/Sub-Class/Order.

Class/Sub-Class/Order	Family	East-A Open Water	East-B Wet Meadow	West-B Open Water	West-C Open Water	West-C Wet Meadow	Grand Total
Acari	*	3		7	2		12
Amphipoda	Crangonyctidae					2	2
Amphipoda	Hyalellidae	3		1		2	6
Arhynchobdellida	Erpobdellidae		2			1	3
Coleoptera	Dytiscidae		13			7	20
Coleoptera	Haliplidae		2				2
Coleoptera	Hydrophilidae		34		1	9	44
Coleoptera	Lampyridae		1			1	2
Coleoptera	Noteridae		4			4	8
Coleoptera	Scirtidae		40			26	66
Diptera	Ceratopogonidae	39		3	5		47
Diptera	Chaoboridae	1					1
Diptera	Chironomidae	53	13	78	33	5	182
Diptera	Culicidae		20			29	49
Diptera	Stratiomyidae		4			7	11
Diptera	Tipulidae		2				2
Ephemeroptera	Baetidae	3		1	1		5
Ephemeroptera	Caenidae	6	1	59	23		89
Gastropoda	Physidae	22	26		1	2	51
Gastropoda	Planorbidae	2	1		1		4
Gastropoda	Succineidae		1				1
Hemiptera	Belostomatidae		11			11	22
Hemiptera	Corixidae	11		78	31		120
Hemiptera	Pleidae	33	73		2	17	125
Isopoda	Asellidae	1		1	3	7	12
Odonata	Coenagrionidae	1	7	9		1	18
Odonata	Corduliidae			1			1
Odonata	Libellulidae		2				2
Oligochaeta	*	27	13	12	48	24	124
	Total	205	270	250	151	155	

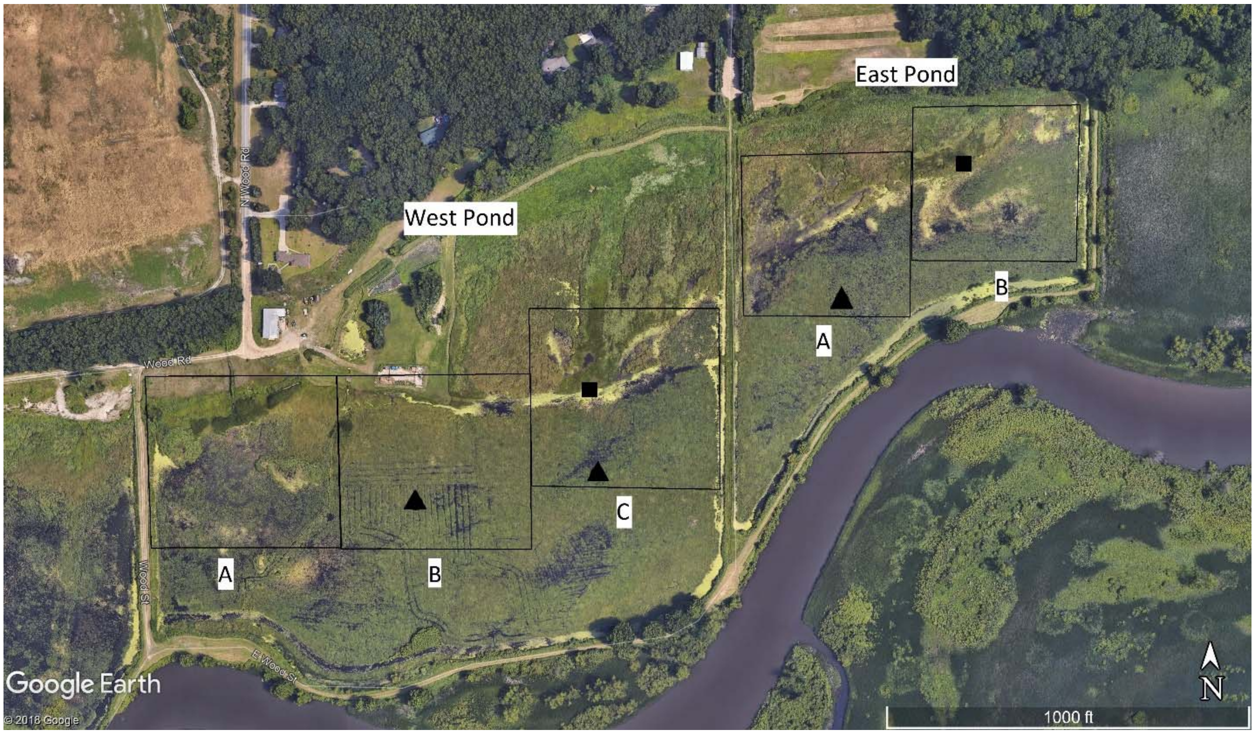

Figure 1. Map of Bosma Property (Muskegon County, Michigan). Fish and macroinvertebrate sampling was conducted in the East Pond and West Pond. Black triangles represent sampling locations of open-water plant zones, and black squares represent sampling locations of wet-meadow plant zones.

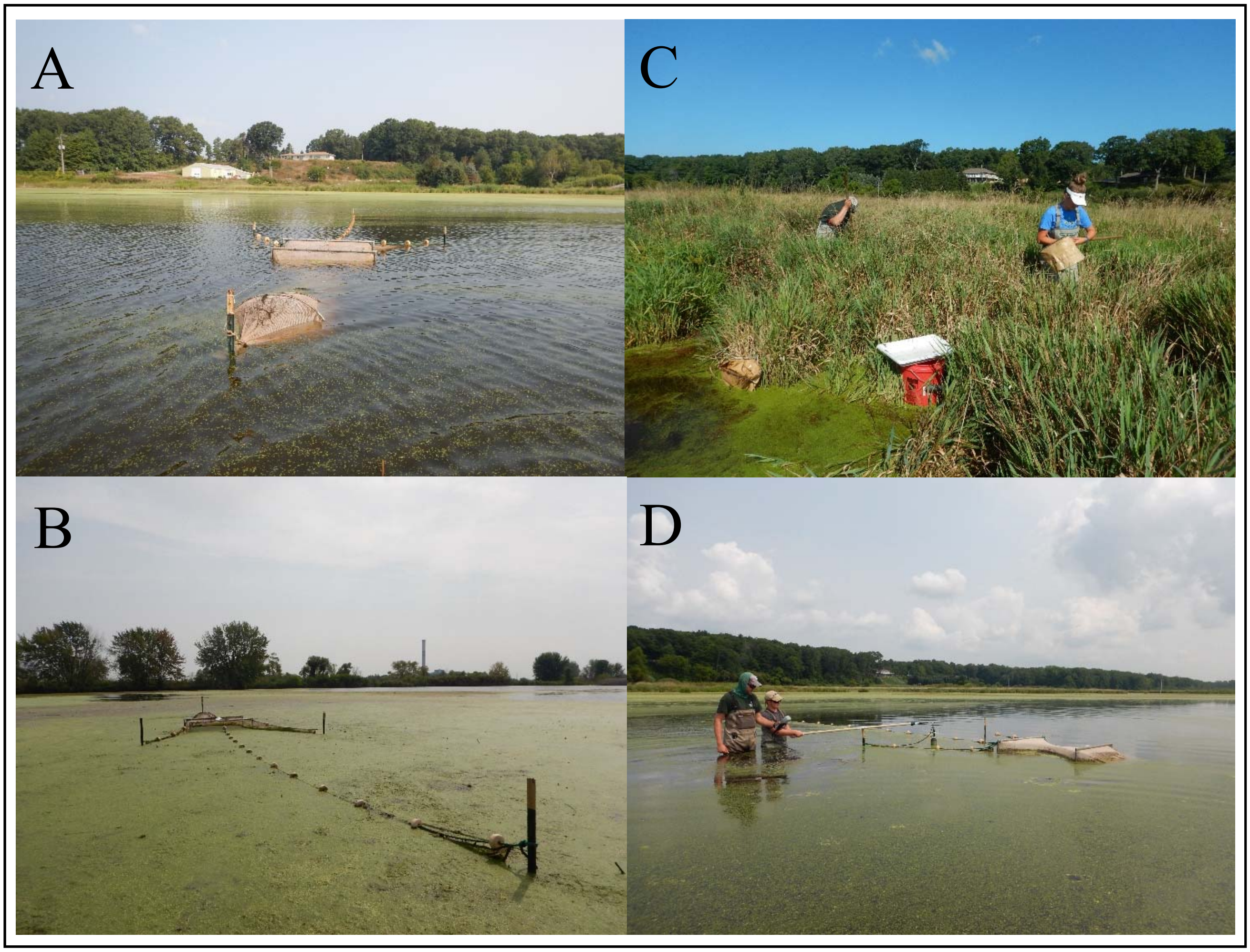

Figure 2. Photos taken while sampling the Bosma Property in August 2018. (**A**) A single fyke net set in an open-water plant zone in the West Pond. (**B**) The mouth and lead of a fyke net. (**C**) Macroinvertebrates collected using D-nets in a wet-meadow plant zone. (**D**) Water chemistry variables measured at the mouth of a fyke net mouth using a YSI sonde.

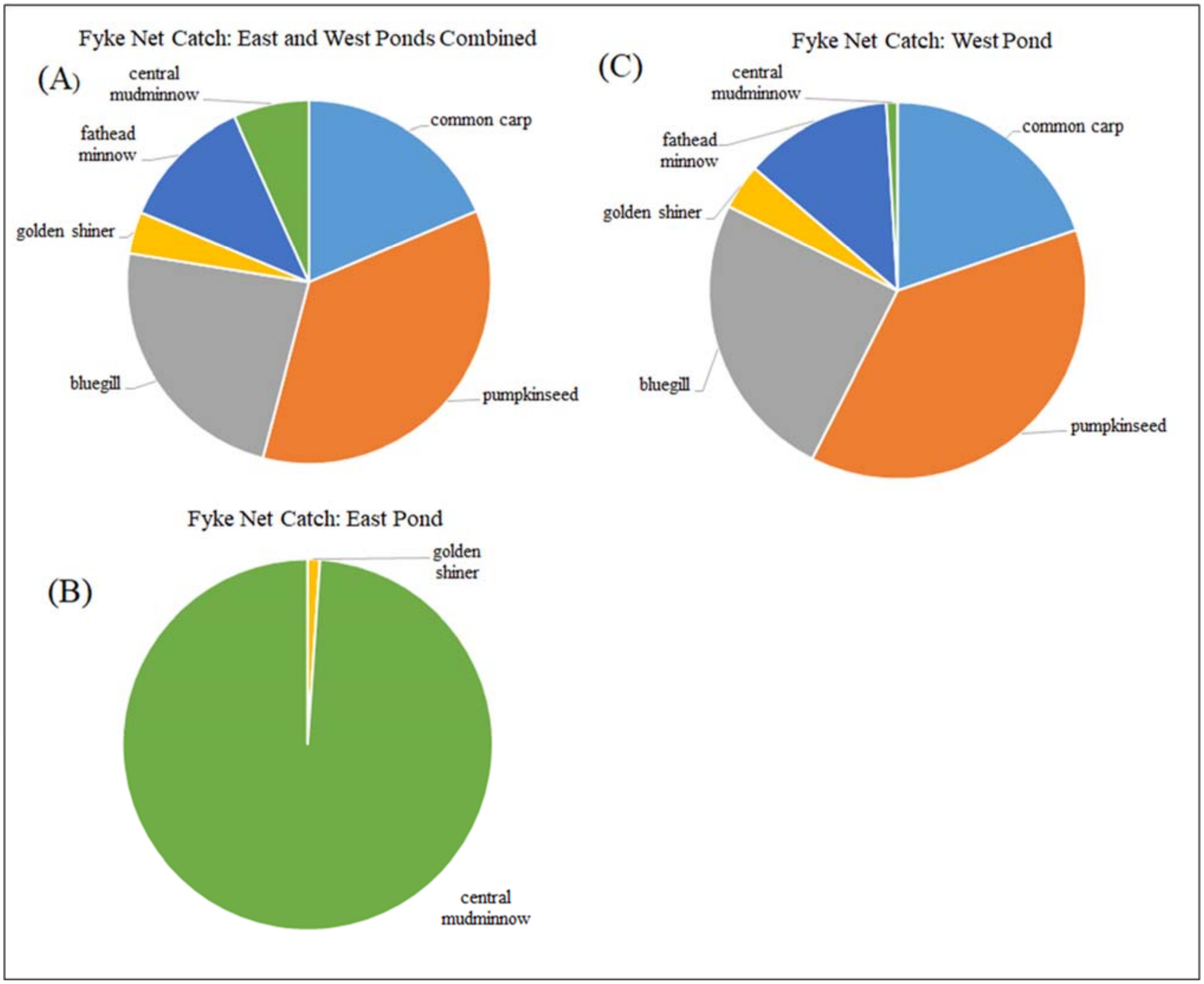

Figure 3. Fish species captured at the Bosma Property (Muskegon County, Michigan) by fyke netting (n = 6 nets for West Pond, n = 3 nets for East Pond) during August 2018. Catch data are reported in Table 3.

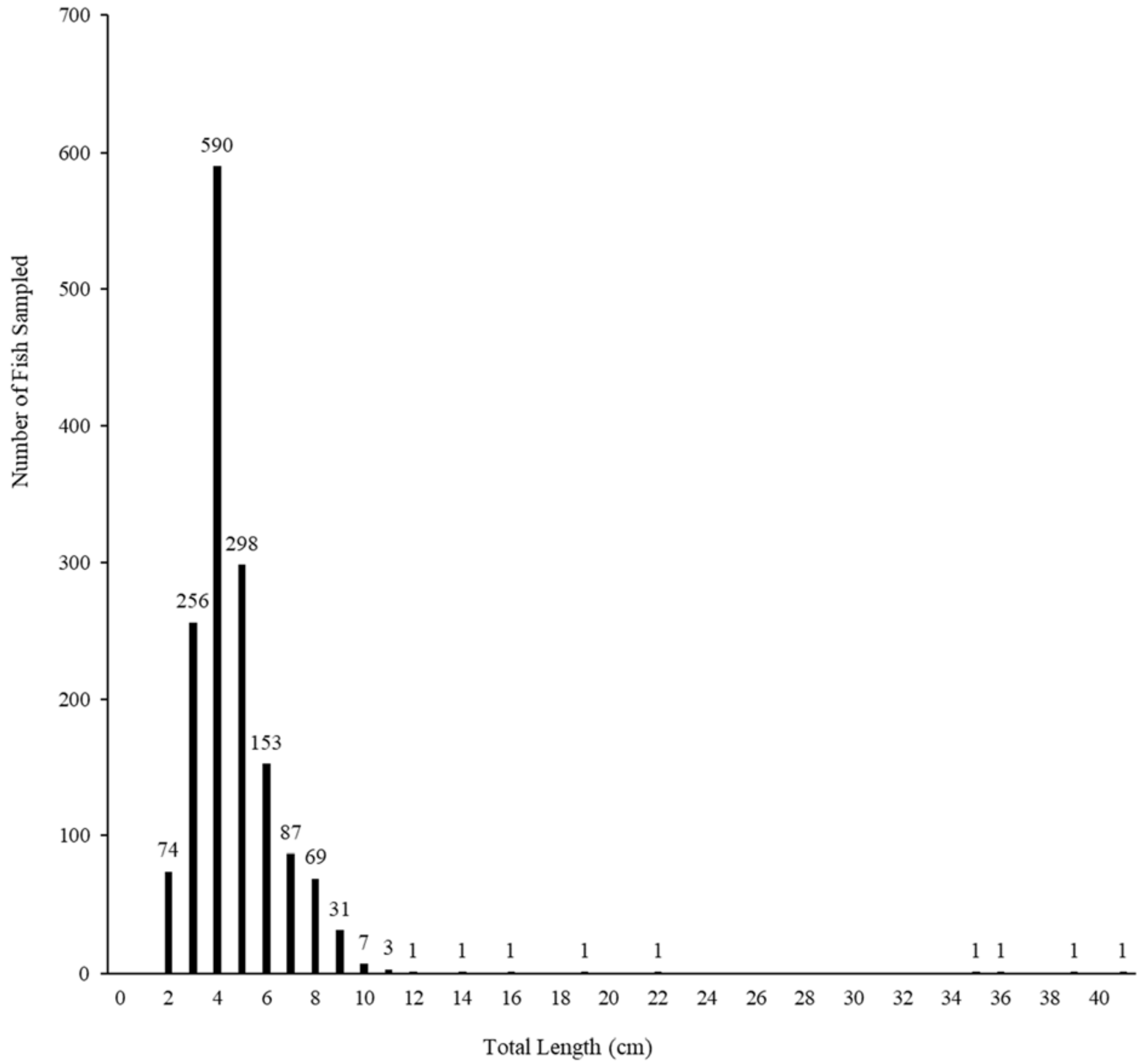

Figure 4. Size distribution for fish captured at the Bosma Property (Muskegon County, Michigan) by fyke netting (*n* = 9 nets) during August 2018. The number above bars represent the number of individuals in the size class. Values on the *x* axis represent the start of each 1-cm size class (e.g., 4 cm represents fish with a total length ranging from 4.0 cm to 4.9 cm).

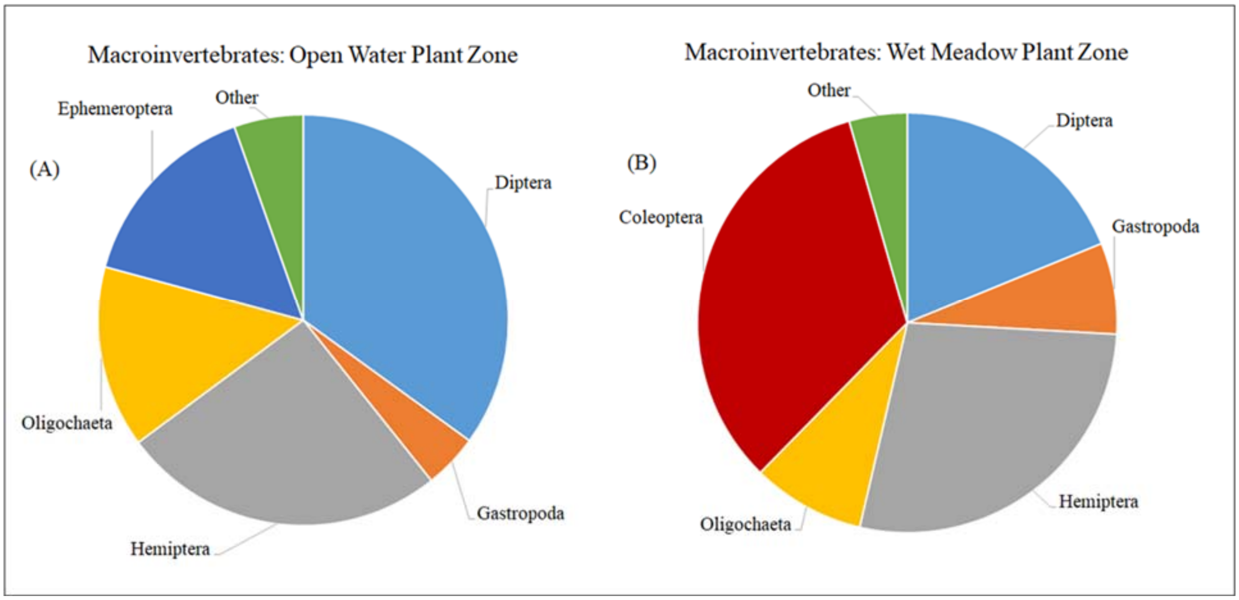

Figure 5. Macroinvertebrate orders sampled at the Bosma Property (Muskegon County, Michigan) by D-frame dip nets during August 2018 (n = 9 for open-water plant zone replicates and n = 6 for wet-meadow plant zone replicates). A more detailed community composition, including the taxa pooled in the "other" category, are reported in Table 5.