Long-Term Fish Monitoring of Lake Macatawa: Results from Year 1

Carl R. Ruetz III[1] and Andrya Whitten
Annis Water Resources Institute
Grand Valley State University
740 W. Shoreline Drive, Muskegon, Michigan 49441

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[1] Corresponding author; Office: 616-331-3946; E-mail: ruetzc@gvsu.edu

Introduction

This study was initiated to provide critical information on littoral fish populations that will be used to evaluate the performance of watershed restoration activities that are part of Project Clarity. Although we do not expect the benefits of the restoration activities in the watershed to be expressed in Lake Macatawa immediately, establishing baseline conditions in Lake Macatawa will be critical for evaluating ecological change over time. In autumn 2014, we initiated a long-term monitoring effort of the littoral fish assemblage of Lake Macatawa. Our fish sampling plan for Lake Macatawa is similar to our ongoing, long-term (since 2003) monitoring effort in Muskegon Lake (Bhagat and Ruetz 2011). By using the same monitoring protocols in each water body, Muskegon Lake can serve as a "control" to evaluate temporal changes in Lake Macatawa in an effort to assess how the lake is responding to watershed restoration activities. Our primary objective for this first year of sampling was to characterize the pre-restoration (baseline) littoral fish assemblage. We made preliminary comparisons with our ongoing work in Muskegon Lake (see Ruetz et al. 2007; Bhagat and Ruetz 2011) as well as with six Lake Michigan drowned river mouths for which we have data (see Janetski and Ruetz 2014). However, the true value of this fish monitoring effort will come in future years as we examine how the littoral fish assemblage responds to restoration activities in the watershed.

Methods

Study sites.— Lake Macatawa is a drowned river mouth lake in Holland, Michigan that is located on the eastern shore of Lake Michigan in Ottawa County. Lake Macatawa has an area of 7.20 km^2, mean depth of 3.66 m, and maximum depth of 12.19 m (MDNR 2011). The shoreline has high residential and commercial development, and the watershed consists mainly of agricultural land (MDNR 2011). Fish sampling was conducted at four littoral sites in Lake Macatawa that represented a gradient from the mouth of the Macatawa River to the connecting channel with Lake Michigan (Figure 1; Table 1).

Fish sampling.—At each study site, we sampled fish via fyke netting and boat electrofishing. Fyke nets were set on 8 September 2014 during daylight hours (i.e., between 1030 and 1330) and fished for about 24.6 h (range = 24.2-24.9 h). Three fyke nets (4-mm mesh) were fished at each site; two fyke nets were set facing each other and parallel to the shoreline, whereas the other fyke net was set perpendicular to the shoreline following the protocol used by Bhagat and Ruetz (2011). A description of the design of the fyke nets is reported in Breen and Ruetz (2006). We conducted nighttime boat electrofishing at each site on 11 September 2014. A 10-min (pedal time) electrofishing transect was conducted parallel to the shoreline at each site with two people at the front of the boat to net fish. The electrofishing boat was equipped with a Smith-Root 5.0 generator-powered pulsator control box (pulsed DC, 220 volts, ~7 amp). For both sampling methods, all fish captured were identified to species, measured (total length), and released in the field; however, some specimens were preserved to confirm identifications in the laboratory. We also measured water quality variables (i.e., temperature, dissolved oxygen, specific conductivity, total dissolved solids, turbidity, pH, oxidation-reduction potential, and chlorophyll *a*) in the middle of the water column using a YSI 6600 multi-parameter data sonde. We made one measurement at each fyke net and one measurement at the beginning of each electrofishing transect. We measured the water depth at the mouth of each fyke net and visually estimated the percent macrophyte cover for the length of the lead between the wings of each fyke net (see Bhagat and Ruetz 2011). We also estimated the percent macrophyte cover for the length of each electrofishing transect during fish sampling.

Results and Discussion

We characterized water quality variables at each site during fish sampling (Tables 2 & 3). The mean water depth where we set fyke nets was 86 cm (Table 2). Water temperature was slightly (~2.9 °C) warmer when we conducted fyke netting compared with boat electrofishing (Tables 2 & 3). We observed few aquatic macrophytes during fish sampling. During fyke netting, % cover of macrophytes was zero at every site except site #2, which was estimated to be 1% cover. Similarly, during electrofishing transects, we visually estimated % macrophyte cover to be near zero, with estimates of 5% cover at sites #2 and #4 (and zero at the other two sites). The lack of macrophytes is presumably because of insufficient light penetrating the water column to allow the submersed plants to grow; both turbidity from inflowing sediment and abundant phytoplankton growth in the lake water column can reduce light penetration. Given the importance of aquatic macrophytes as habitat for fish (e.g., Radomski and Goeman 2001), their return is an important goal for the restoration of natural fish communities in Lake Macatawa.

Compared to six Lake Michigan drowned river mouths, water quality in Lake Macatawa was most similar to Kalamazoo Lake, especially with respect to high turbidity and specific conductivity (Janetski and Ruetz 2014). Turbidity and specific conductivity were higher in Lake Macatawa than Muskegon Lake, the drowned river mouth lake that we have the longest time series of water quality observations (Bhagat and Ruetz 2011). High levels of turbidity and specific conductivity often are associated with relatively high anthropogenic disturbance in Great Lakes coastal wetlands (Uzarski et al. 2005). Thus, the water quality we measured in Lake Macatawa appears on the degraded side of the spectrum among Lake Michigan drowned river mouths (see Uzarski et al. 2005, Janetski and Ruetz 2014).

We captured 1,127 fish comprising 28 species[2] in Lake Macatawa (Table 4). The most abundant fishes in the combined catch of both gears (fyke netting and boat electrofishing) were gizzard shad (39%), white perch (15%), yellow perch (9%), and spottail shiner (8%), which composed 71% of the total catch (Figure 2A). Gizzard shad—the most abundant species in our catch—is an important forage fish (especially smaller individuals), and high turbidity is one of the conditions associated with optimal habitat of this species (Becker 1983). Three of the 28 species we captured were non-native to the Great Lakes basin (Bailey et al. 2004)—alewife (2%), round goby (5%), and white perch (15%)—which composed 22% of the total catch (Table 4). More than twice as many individuals were captured in fyke netting than boat electrofishing (Table 4). Similarly, more fish species were captured in fyke netting (23 species) than boat electrofishing (19 species). Nine fish species were collected only by fyke netting, and five species were collected only by boat electrofishing. Thus, using both sampling gears provided a better characterization of the littoral fish assemblage of Lake Macatawa than either gear by itself. This finding was consistent with research in Muskegon Lake that found a similar pattern where small-bodied fishes were better represented in fyke netting and large-bodied fishes were better represented in nighttime boat electrofishing (Ruetz et al. 2007).

In fyke netting, gizzard shad (56%), white perch (10%), round goby (6%), and spottail shiner (6%) were the most abundant fishes captured, which composed nearly 78% of the total fish captured (Figure 2B). Janetski and Ruetz (2014) found that gizzard shad was associated with high turbidity among six drowned river mouths and was most abundant in Kalamazoo Lake, which is the drowned river mouth that had the most similar water quality to Lake Macatawa. In Muskegon Lake, both gizzard shad and white perch were associated with autumn sampling (as

[2] We did not include the unknown species of sunfish captured during boat electrofishing in any of our reports of species richness (see Table 4).

opposed to spring or summer; Bhagat and Ruetz 2011), which corresponded to the time of our sampling in Lake Macatawa. Although gizzard shad was most abundant at each site, the next most abundant species varied among sites, with white perch being the next most abundant at site #1, bluegill at site #2, alewife at site #3, and round goby at site #4 (Table 5). There was variation in total catch among the sites, with site #4 having the highest catch and site #2 having the lowest catch (Table 5). As we continue our monitoring of Lake Macatawa, we will be able to assess whether these spatial patterns among sites are stable or dynamic over time.

In boat electrofishing, the most abundant fishes captured were white perch (27%), yellow perch (21%), pumpkinseed (12%), and spottail shiner (12%), which composed 71% of the total catch (Figure 2C). The fish assemblage was not dominated by a single fish species at every site in contrast to what was observed in the fyke netting. White perch was the most abundant species in the catch at sites #1 and #2, whereas spottail shiner was most abundant at site #3 and spottail shiner and yellow perch were most abundant at site #4 (Table 6). Total catch varied among sites, with the most fish captured at site #2 and the least at site #3 (Table 6). Finally, there was not a positive association in total catch across sites between the two gears (Tables 5 & 6).

In conclusion, the observations reported here provide the first year of a 5 year effort to characterize the littoral fish assemblage of Lake Macatawa. This monitoring effort will provide a baseline to assess how the fish assemblage responds to restoration activities in the Lake Macatawa watershed. Once we accumulate multiple years of observations, we will be able to make more robust inferences about the littoral fish assemblage of Lake Macatawa (both in terms of assessing the baseline and change over time) as well as how the assemblage compares with other drowned river mouth lakes in the region.

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Table 1. Locations (latitude and longitude) for each fish sampling site; coordinates are the mean of the three fyke nets and the start and end of each boat electrofishing transect.

			Boat Electrofishing			
	Fyke netting		Start		End	
Site	Lat (°)	Long (°)	Lat (°)	Long (°)	Lat (°)	Long (°)
1	42.79566	86.12238	42.79533	86.12370	42.79612	86.11992
2	42.78934	86.14403	42.78811	86.14484	42.79020	86.14384
3	42.78639	86.17498	42.78535	86.17406	42.78721	86.17584
4	42.77973	86.19631	42.77896	86.19792	42.78045	86.19536

Table 2. Mean ± 1 standard error (*n* =3) of water quality variables at fish sampling sites in Lake Macatawa. Measurements were made during fyke netting on 8 September 2014. Site locations are depicted in Figure 1.

Site	Depth (cm)	Water Temperature (°C)	Dissolved Oxygen (mg/L)	% Dissolved Oxygen	Specific Conductivity (uS/cm)	Total Dissolved Solids (g/L)	Turbidity (NTU)	pH	Oxidation Reduction Potential	Chlorophyll *a* (ug/L)
1	89±1	24.15±0.02	10.69±0.07	127.5±0.9	591±1	0.385±0.000	23.9±1.8	8.19±0.01	323±4	36.3±3.3
2	97±1	24.51±0.06	15.09±0.33	181.1±3.9	503±0	0.327±0.000	25.3±3.1	9.06±0.01	286±5	35.4±7.3
3	79±1	23.26±0.03	13.76±0.18	161.4±2.1	432±0	0.281±0.000	24.6±0.8	9.18±0.01	303±1	17.4±0.6
4	79±2	23.87±0.02	12.61±0.17	149.5±2.0	416±0	0.270±0.000	19.0±0.1	9.11±0.01	242±6	11.4±0.6

Table 3. Water quality variables at fish sampling sites in Lake Macatawa. Measurements were made during nighttime boat electrofishing on 11 September 2014. Site locations are depicted in Figure 1.

Site	Water Temperature (°C)	Dissolved Oxygen (mg/L)	% Dissolved Oxygen	Specific Conductivity (uS/cm)	Total Dissolved Solids (g/L)	Turbidity (NTU)	pH	Oxidation Reduction Potential (mV)	Chlorophyll *a* (ug/L)
1	21.85	8.97	102.5	628	0.408	24.2	7.80	333	18.7
2	20.70	8.69	97.0	504	0.328	26.3	8.49	338	18.4
3	20.82	11.39	127.5	433	0.281	22.6	8.93	286	17.9
4	20.97	8.12	91.1	406	0.264	17.9	8.54	338	13.8

Table 4. Number and mean total length (TL; ranges reported parenthetically) of fish captured by fyke netting (*n* = 12 nets) on 9 September 2014 and boat electrofishing (*n* = 4 transects) on 11 September 2014 at four sites in Lake Macatawa.

		Total	Fyke netting		Electrofishing	
Common name	Scientific name	Catch	Catch	TL (cm)	Catch	TL (cm)
alewife	*Alosa pseudoharengus*	22	22	5.9 (3.3-10.0)	0	--
black bullhead	*Ameiurus melas*	1	1	2.6	0	--
yellow bullhead	*Ameiurus natalis*	1	1	25.0	0	--
bowfin	*Amia calva*	1	0	--	1	46.5
freshwater drum	*Aplodinotus grunniens*	2	0	--	2	15.3 (9.3-21.3)
quillback	*Carpiodes cyprinus*	2	1	12.9	1	29.5
white sucker	*Catostomus commersonii*	10	3	34.2 (21.1-40.9)	7	31.6 (18.5-46.5)
common carp	*Cyprinus carpio*	4	0	--	4	66.7 (61.2-74.0)
gizzard shad	*Dorosoma cepedianum*	445	433	8.6 (5.1-19.3)	12	11.2 (7.0-17.3)
northern pike	*Esox lucius*	1	1	84.0	0	--
banded killifish	*Fundulus diaphanus*	1	0	--	1	9.0
channel catfish	*Ictalurus punctatus*	4	4	52.6 (49.5-58.9)	0	--
brook silverside	*Labidesthes sicculus*	17	17	6.7 (5.4-7.8.8)	0	--
pumpkinseed	*Lepomis gibbosus*	57	15	15.6 (12.0-17.5)	42	13.8 (6.6-18.0)
bluegill	*Lepomis macrochirus*	42	34	4.4 (2.6-14.8)	8	13.4 (6.5-20.2)
unknown sunfish[1]	*Lepomis* spp.	1	0	--	1	17.1
longnose gar	*Lepisosteus osseus*	2	2	43.8 (40.5-47.0)	0	--
largemouth bass	*Micropterus salmoides*	30	10	15.7 (6.5-33.1)	20	18.3 (6.5-44.5)
white perch	*Morone americana*	174	78	11.5 (5.5-28.0)	96	10.6 (7.6-19.6)
golden redhorse	*Moxostoma erythrurum*	1	0	--	1	43.1
shorhead redhorse	*Moxostoma macrolepidotum*	1	1	42.4	0	--
round goby	*Neogobius melanostomus*	52	49	4.3 (2.5-8.0)	3	7.2 (6.9-7.5)
emerald shiner	*Notropis atherinoides*	23	9	8.6 (4.9-10.9)	14	9.5 (7.0-11.2)
golden shiner	*Notemigonus crysoleucas*	10	3	8.4 (4.1-11.3)	7	13.0 (8.8-21.5)
spottail shiner	*Notropis hudsonius*	86	44	7.8 (4.0-11.4)	42	10.0 (7.5-12.1)
yellow perch	*Perca flavescens*	97	23	11.7 (8.0-23.9)	74	10.4 (8.3-22.4)
bluntnose minnow	*Pimephales notatus*	19	15	6.9 (4.2-9.2.2)	4	8.1 (6.6-9.5)
black crappie	*Pomoxis nigromaculatus*	4	4	15.6 (5.3-24.5)	0	--
walleye	*Sander vitreus*	17	1	17.3	16	18.9 (16.0-22.5)
	Total	**1127**	**771**		**356**	

[1]Unknow sunfish was likely a hybrid between longear sunfish (*Lepomis megalotis*) and green sunfish (*L. cyanellus*).

Table 5. Number and mean total length (TL; range reported parenthetically) of fish captured by fyke netting (*n* = 3 nets per site) at four sites in Lake Macatawa on 9 September 2014. Site locations are depicted in Figure 1.

		Site #1		Site #2		Site #3		Site #4	
Common name	Scientific name	Catch	TL (cm)	Catch	TL (cm)	Catch	TL (cm)	Catch	TL (cm)
alewife	*Alosa pseudoharengus*	1	4.6	1	4.5	17	5.8 (3.3-10.0)	3	7.1 (4.9-9.5)
yellow bullhead	*Ameiurus natalis*	0	--	0	--	1	25.0	0	--
black bullhead	*Ameiurus melas*	0	--	1	2.6	0	--	0	--
quillback	*Carpiodes cyprinus*	0	--	1	12.9	0	--	0	--
white sucker	*Catostomus commersonii*	2	40.7 (40.5-40.9)	0	--	0	--	1	21.1
gizzard shad	*Dorosoma cepedianum*	139	8.6 (6.8-16.3)	28	9.7 (6.8-16.8)	106	9.2 (5.7-19.3)	160	8.0 (5.1-11.8)
northern pike	*Esox lucius*	0	--	0	--	0	--	1	84
channel catfish	*Ictalurus punctatus*	0	--	2	54.2 (49.5-58.9)	2	50.9 (50.3-51.5)	0	--
brook silverside	*Labidesthes sicculus*	1	7.8	0	--	7	6.5 (5.5-7.5)	9	6.7 (5.4-7.7)
pumpkinseed	*Lepomis gibbosus*	3	16.5 (15.5-17.5)	5	14.4 (12.0-16.8)	3	16.7 (16.5-17.1)	4	15.6 (13.5-17.2)
bluegill	*Lepomis macrochirus*	7	6.3 (2.9-14.8)	27	4.0 (2.6-11.4)	0	--	0	--
longnose gar	*Lepisosteus osseus*	2	43.8 (40.5-47.0)	0	--	0	--	0	--
largemouth bass	*Micropterus salmoides*	6	20.0 (7.8-33.1)	0	--	2	10.5 (7.9-13.0)	2	8.0 (6.5-9.5)
white perch	*Morone americana*	40	10.5 (7.5-19.3)	20	13.5 (5.5-28.0)	12	11.6 (5.5-21.9)	6	9.4 (7.4-13.6)
shorhead redhorse	*Moxostoma macrolepidotum*	0	--	1	42.4	0	--	0	--
round goby	*Neogobius melanostomus*	5	4.1 (2.5-8.0)	0	--	10	5.1 (4.0-7.1)	30	4.1 (2.9-6.0)
emerald shiner	*Notropis atherinoides*	2	5.2 (4.9-5.4)	1	9.6	4	9.7 (8.5-10.9)	2	9.3 (9.0-9.5)
golden shiner	*Notemigonus crysoleucas*	3	8.4 (4.1-11.3)	4	4.35 (3.4-6.0)	0	--	0	--
spottail shiner	*Notropis hudsonius*	1	11.4	8	8.1 (4.1-11.0)	9	9.2 (7.0-11.2)	26	7.1 (4.0-10.6)
yellow perch	*Perca flavescens*	8	14.0 (9.6-23.9)	0		3	16.6 (10.5-22.3)	12	8.9 (8.0-9.8)
bluntnose minnow	*Pimephales notatus*	2	7.7 (7.0-8.4)	7	6.6 (4.2-7.3)	1	6.0	5	7.0 (5.5-9.2)
black crappie	*Pomoxis nigromaculatus*	4	15.6 (5.3-24.5)	0	--	0	--	0	--
walleye	*Sander vitreus*	0	--	0	--	0	--	1	17.3
	Total	**226**		**106**		**177**		**262**	

Table 6. Number and mean total length (TL; range reported parenthetically) of fish captured by nighttime boat electrofishing (*n* = 1 transect per site) at four sites in Lake Macatawa on 11 September 2014. Site locations are depicted in Figure 1.

		Site #1		Site #2		Site #3		Site #4	
Common name	Scientific name	Catch	TL (cm)	Catch	TL (cm)	Catch	TL (cm)	Catch	TL (cm)
bowfin	*Amia calva*	0	--	0	--	0	--	1	46.5
freshwater drum	*Aplodinotus grunniens*	0	--	2	15.3 (9.3-21.3)	0	--	0	--
quillback	*Carpiodes cyprinus*	0	--	1	29.5	0	--	0	--
white sucker	*Catostomus commersonii*	0	--	1	27.0	2	44.7 (42.8-46.5)	4	26.3 (18.5-45.7)
common carp	*Cyprinus carpio*	0	--	2	64.1 (61.2-67.0)	0	--	1	74.0
gizzard shad	*Dorosoma cepedianum*	1	64.5	4	12 (11.0-13.2)	3	10.8 (7.0-16.3)	1	17.3
banded killifish	*Fundulus diaphanus*	4	9.2 (9.0-9.6)	0	--	1	9.0	0	--
pumpkinseed	*Lepomis gibbosus*	10	14.4 (10.8-17.5)	25	12.7 (6.6-15.9)	1	13.4	6	17.1 (16.2-18.0)
bluegill	*Lepomis macrochirus*	1	14.0	6	14.4 (12.7-20.2)	0	--	1	6.5
unknown sunfish[1]	*Lepomis* spp.	0	--	1	17.1	0	--	0	--
largemouth bass	*Micropterus salmoides*	2	17.7 (10.6-24.8)	7	20.4 (9.4-27.3)	4	21.8 (6.5-34.8)	7	14.3 (6.5-44.5)
white perch	*Morone americana*	43	10.2 (8.3-19.6)	41	11.4 (8.2-18.5)	6	8.3 (7.6-9.3)	6	11.4 (8.2-14.5)
golden redhorse	*Moxostoma erythrurum*	1	43.1	0	--	0	--	0	--
round goby	*Neogobius melanostomus*	0	--	0	--	0	--	3	7.2 (6.9-7.5)
emerald shiner	*Notropis atherinoides*	2	10.2 (10.0-10.3)	3	13.2 (10.2-19.0)	5	10.0 (9.0-11.2)	7	9.0 (7.0-10.2)
golden shiner	*Notemigonus crysoleucas*	1	11.1	0	--	1	21.5	2	9.4 (8.8-10.0)
spottail shiner	*Notropis hudsonius*	2	12.1	8	9.7 (8.2-12.1)	19	10.1 (7.5-22.4)	13	9.9 (8.0-11.9)
yellow perch	*Perca flavescens*	16	11.2 (9.3-18.1)	33	9.6 (8.3-11.2)	12	11.0 (9.1-22.4)	13	10.7 (8.5-18.0)
bluntnose minnow	*Pimephales notatus*	1	6.6	1	7	0	--	2	9.5 (9.4-9.5)
walleye	*Sander vitreus*	3	20.6 (17.2-22.5)	3	19.0 (18.7-19.2)	5	18.0 (16.8-20.5)	5	18.6 (16.0-21.0)
	Total	**87**		**138**		**59**		**72**	

[1]Unknow sunfish was likely a hybrid between longear sunfish (*Lepomis megalotis*) and green sunfish (*L. cyanellus*).

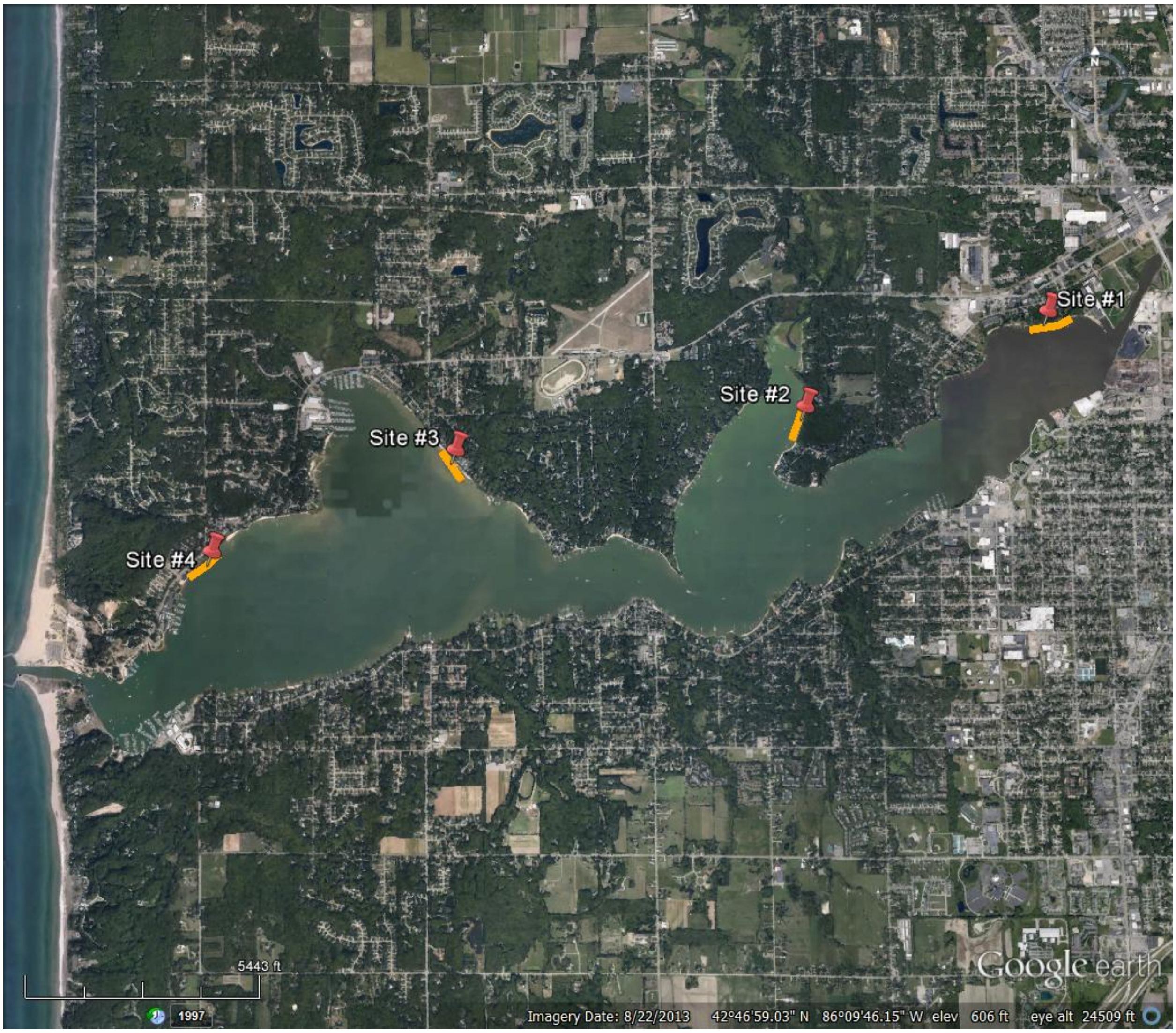

Figure 1. Map of Lake Macatawa (Ottawa County, Michigan) showing fish sampling sites. The orange transects depict where boat electrofishing was conducted at each site. Site #1 is closest to the Macatawa River and site #4 is closest to Lake Michigan.

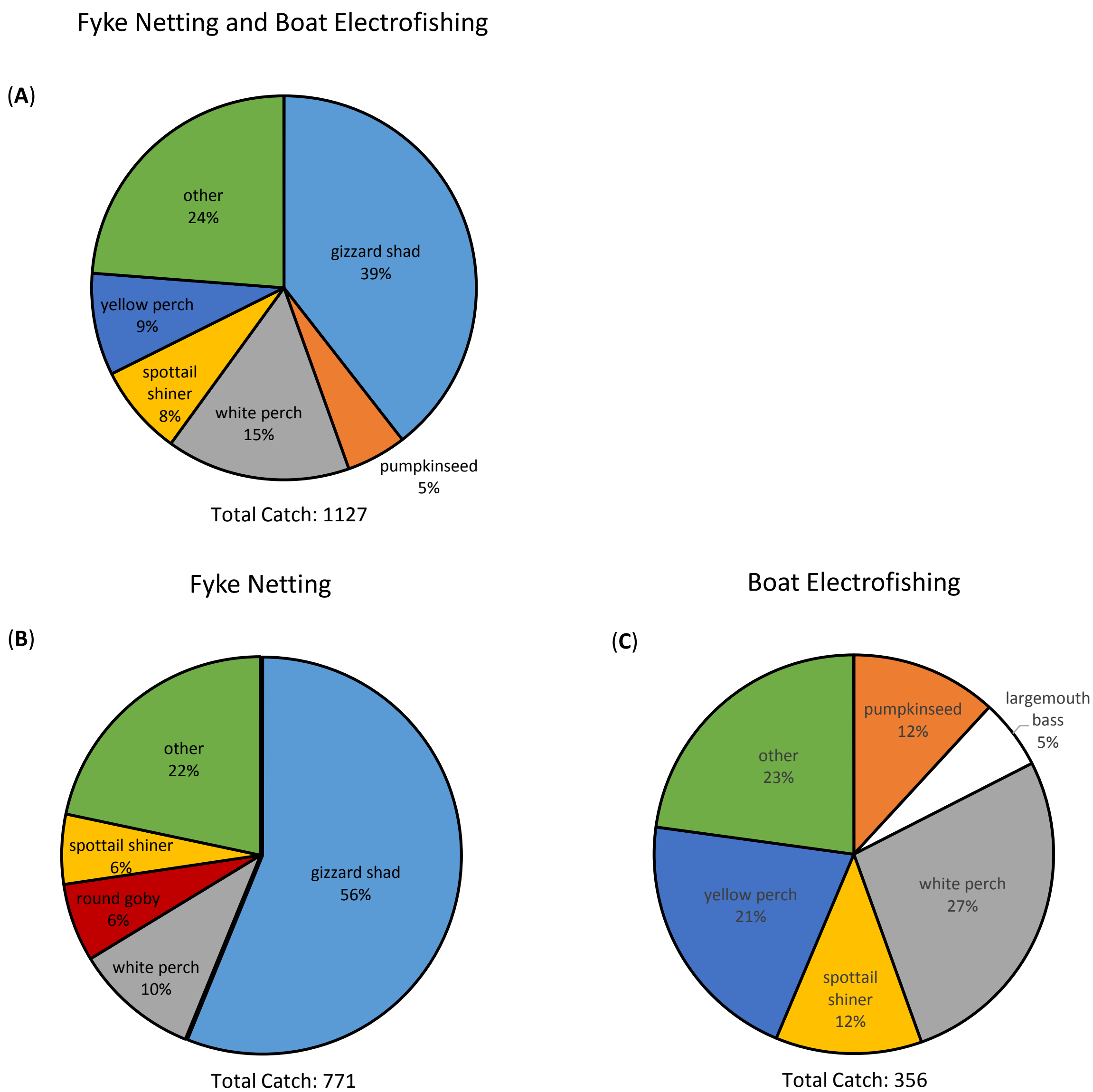

Figure 2. Fish species captured in littoral habitats of Lake Macatawa by (A) fyke netting and boat electrofishing (i.e., combined catch), (B) fyke netting (*n* = 12 nets), and (C) boat electrofishing (*n* = 4 transects) during September 2014. Catch data, including the species pooled in the "other" category, are reported in Table 4.