Long-Term Fish Monitoring of Lake Macatawa: Results from Year 4

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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 in the fourth year of sampling was to continue 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 2015). 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). In 2016, much of the riparian vegetation was removed at site #2 for a construction project. The clearing of most trees and woody vegetation that were flooded by high Great Lakes water levels at site #2 (most were cut off at the water level) provided habitat structure for fish that could be more easily accessed by sampling gear (especially with respect to boat electrofishing) than prior to removal.

Fish sampling.—At each study site, we sampled fish via fyke netting and boat electrofishing. Using both sampling gears should better characterize the littoral fish assemblage than either gear by itself because small-bodied fishes are better represented in fyke netting and large-bodied fishes are better represented in nighttime boat electrofishing (Ruetz et al. 2007). Fyke nets were set on 5 September 2017 during daylight hours (i.e., between 1000 and 1500) and fished for about 23.5 h (range = 23.0-23.9 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 a third 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 14 September 2017. 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. Note that during fyke netting at site #4 (in 2017) we caught an unusually large number of brook silverside, and only a random sample of fish were measured for total length.

We 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 (n = 12) and one measurement at the beginning of each electrofishing transect (n = 4). 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 visually 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 and 3). The mean water depth at fyke nets was 95 cm (Table 2). Water temperature was similar (at about 20.7 °C) when we conducted fyke netting and boat electrofishing (Tables 2 and 3). At fyke nets, mean % cover of macrophytes was zero at sites #1 and #3, whereas mean % cover of macrophytes was 30% and 63% at sites #2 and #4, respectively. We visually estimated macrophyte cover at electrofishing transects to be 5% at site #1, 30% at site #2, 25% at site #3, and 60% at site #4, which was similar to our estimates at fyke nets in most cases. The visual estimates of % macrophyte cover for electrofishing are over a greater area at each site than estimates for fyke netting, which likely accounted for the difference at site #3. The % macrophyte cover continued to show an increasing trend over time, although 2017 was less than 2016 when macrophyte cover was assessed during boat electrofishing transects (Figure 2). We hypothesized that low densities of macrophytes in Lake Macatawa during 2014 and 2015 were caused by insufficient light penetrating the water column to allow submersed plants to grow;

both turbidity from inflowing sediment and abundant phytoplankton growth in the lake water column can reduce light penetration.

As stated in past reports, aquatic macrophytes are important habitat for fish (e.g., Radomski and Goeman 2001), and their return is an important goal for the restoration of the fish community in Lake Macatawa. The presence of macrophyte beds in the vicinity of our fish sampling sites were likely related to the lower turbidity that we observed in the lake in 2017 compared with 2014 and 2015 (Figure 3B). A detailed macrophyte survey, conducted on a 3-5 year interval, would provide useful information for Lake Macatawa's ecological status (see Ogdahl and Steinman 2014).

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 2015). Turbidity and specific conductivity were higher in Lake Macatawa than Muskegon Lake, the drowned river mouth lake for which 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 2015). Nevertheless, turbidity and specific conductivity were lower in 2017 than in 2014 and 2015, although slightly greater than 2016 (Figure 3). Within the lake itself, there was a gradient in turbidity and total dissolved solids, with higher levels closer at the east end and lower levels closer to Lake Michigan (Tables 2 and 3). This is to be expected given that most of the sediment entering the lake comes from the Macatawa River, which runs off largely agricultural land and through urbanized Holland.

We captured 6,468 fish comprising 29 species in Lake Macatawa during the 2017 sampling surveys (Table 4). Although the number of fish species captured in 2017 was similar to previous years (2014: 28 species; 2015: 30 species; 2016: 24 species), we captured 4-12× more individuals in 2017 (2014: 1,127 fish; 2015: 537 fish; 2016: 1,648), which was due to a large number of brook silverside that were captured during fyke netting (Figure 4). In fact, brook silverside composed 87% of the combined catch (Figure 4A). However, if we exclude the 5,288 brook silverside captured from a single fyke net at site #4 (discussed below) from the species composition, then the most abundant fishes in the combined catch were brook silverside (27%), gizzard shad (19%), bluegill (14%), yellow perch (12%), largemouth bass (7%), and pumpkinseed (5%), which composed 84% of the total catch (Figure 5A). Six of the 29 species captured during 2017 were non-native to the Great Lakes basin (Bailey et al. 2004)—alewife, goldfish, common carp, white perch, round goby, and brown trout—which composed 7% of the total catch when excluding brook silverside from the single high-catch fyke net at site #4 (Table 4).

In fyke netting, 93% of all fish captured were brook silverside (Figure 4B). However, almost all of the brook silverside were captured at site #4 (5,538 individuals; Table 5) in a single fyke net (5,288 individuals). Thus, we considered the high catch of brook silverside in a single fyke net to be rare event that resulted from a large school of fish swimming into a net, and not representative of typical fish conditions in Lake Macatawa. Thus, the following patterns in the catch exclude the 5,288 brook silverside captured in a single fyke net at site #4; otherwise, this large catch of brook silverside overwhelms all other patterns in fyke netting (see Figure 4B vs. Figure 5B).

The following summary of fyke netting catch is based on excluding the 5,288 brook silverside captured in a single fyke net at site #4. The most common species in the catch were brook silverside (43%), gizzard shad (17%), bluegill (15%), and yellow perch (7%), which composed 82% of the total fish captured (Figure 5B). Although brook silverside was the most abundant species in the catch at sites #3 and #4, gizzard shad was most common at site #1 and bluegill was most common at site #2 (Table 5). The next most abundant species in the catch at each site were bluegill at site #1, yellow perch at sites #2 and #4, and alewife at site #3 (Table 5). There also was variation in total catch among the sites in 2017, with more fish captured at sites #4 followed by sites #1, #3 and #2 (Table 5; Figure 6A). Compared with the previous fyke netting surveys, the most abundant species in the catch varied among years (Figure 7) as did the patterns in total catch among sites (Figure 6A). The main differences in the relative abundance (i.e., percentage of a fish species in the total catch for a given year) were that we captured more brook silverside in 2017 than previous years—even when we excluded the 5,288 brook silverside captured in a single fyke net at site #4 (Figure 7). The relative abundance of gizzard shad in 2017 was lower than two of the previous three years, bluegill was similar to 2016, and white perch was the lowest reported in four years of monitoring (Figure 7). As we continue monitoring Lake Macatawa, we will be better able to assess how dynamic these spatial patterns among sites are over time and whether the observed patterns are associated with other environmental variables.

In boat electrofishing, the most abundant fishes captured were yellow perch (21%), gizzard shad (21%), largemouth bass (17%), bluegill (12%), and white perch (7%), which composed 78% of the total catch (Figure 5C). Yellow perch was most abundant in the catch at sites #2 and #4, and gizzard shad was most abundant in the catch at sites #1 and #3 (Table 6). The next most abundant species in the catch was largemouth bass at sites #2 and #1, yellow perch at site #3, and spottail shiner at site #4 (Table 6). Total catch also varied among sites in 2017, with the highest catch at sites #2 and the lowest catch at site #3 (Figure 6B). Thus, there was not a positive association in total catch across sites between the two sampling gears in 2017 (Figure 6). Compared with previous boat electrofishing surveys, the most abundant species in the catch varied among years (Figure 8), although the pattern was weaker than what was observed for fyke netting (Figure 7). The main difference in the littoral fish assemblage among annual electrofishing surveys was that gizzard shad and largemouth bass were more common and spottail shiner and pumpkinseed were less common in 2016 and 2017 compared with the first two years of the study (Figure 8).

As in past years, we captured more fish in fyke netting than boat electrofishing surveys even when we excluded the high catch of brook silverside from a single fyke net at site #4 (Table 4). However, the number of fish species captured in fyke netting (22 species) was similar to boat electrofishing (24 species). Five fish species were captured only by fyke netting (i.e., alewife, spotfin shiner, mimic shiner, bluntnose minnow, and brown trout), whereas six species were captured only by boat electrofishing (i.e., black bullhead, freshwater drum, common carp, banded killifish, white bass, and walleye; Table 4). Thus, using both sampling gears likely better characterized the littoral fish assemblage of Lake Macatawa, which is consistent with findings in Muskegon Lake (Ruetz et al. 2007).

In conclusion, the observations reported here are the fourth year of an 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. Although we have completed only four years of fish monitoring, we observed differences in total catch (Figure 6) and fish species composition of the catch among years (Figures 7 and 8). As we continue to build our time series of observations, we will be able to make more robust inferences about the littoral fish assemblage of Lake Macatawa (in terms of assessing the baseline, evaluating change over time, and comparing abiotic and biotic variables with other drowned river mouth lakes in the region) and better identify likely underlying mechanisms driving spatiotemporal patterns.

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Table 1. Locations (latitude and longitude) for each 2017 fish sampling site; coordinates are the mean of the three fyke nets and the start and end of each boat electrofishing transect. Site locations are depicted in Figure 1.

	Fyke netting		Electrofishing			
			Start		End	
Site	Lat (°)	Long (°)	Lat (°)	Long (°)	Lat (°)	Long (°)
1	42.79586	-86.12178	42.79555	-86.12070	42.79571	-86.12338
2	42.78900	-86.14399	42.78814	-86.14472	42.78986	-86.14393
3	42.78641	-86.17481	42.78367	-86.17196	42.78588	-86.17425
4	42.77974	-86.19680	42.77934	-86.19739	42.78075	-86.19569

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 5 September 2017 with a YSI sonde.

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	92±3	20.84±0.06	8.93±0.19	99.9±2.4	576±1	0.37±0.000	19.3±3.2	7.85±0.08	213±10	67.0±2.6
2	94±7	20.92±0.03	10.39±0.11	116.7±1.4	537±0	0.35±0.000	12.3±0.7	8.34±0.04	232±15	68.3±1.4
3	99±1	20.42±0.01	12.06±0.03	133.9±0.3	428±0	0.28±0.000	11.1±0.9	8.78±0.04	239±26	52.4±2.9
4	95±3	20.64±0.10	11.87±0.07	132.4±1.0	426±1	0.28±0.000	14.5±2.1	8.63±0.02	184±2	45.0±1.4

Table 3. Water quality variables at fish sampling sites in Lake Macatawa. Measurements were made during nighttime boat electrofishing on 14 September 2017 with a YSI sonde.

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	21.24	14.81	167.20	545	0.355	8.4	8.57	232.8	72.7
2	21.05	13.98	157.20	501	0.326	7.5	8.71	213.1	60.4
3	21.19	13.95	157.20	440	0.286	10.2	8.71	241.4	58.7
4	19.30	9.70	105.30	434	0.282	7.8	8.38	236.8	85.4

Table 4. Number and mean total length (TL; ranges reported parenthetically) of fish captured by fyke netting (*n* = 12 nets) on 6 September 2017 and boat electrofishing (*n* = 4 transects) on 14 September 2017 at four sites in Lake Macatawa. Total catch combined both gears.

		Total	Fyke netting		Electrofishing	
Common name	Scientific name	Catch	Catch[a]	TL (cm)	Catch	TL (cm)
alewife	*Alosa pseudoharengus*	16	16	6.5 (4.8-9.5)	0	--
black bullhead	*Ameiurus melas*	2	0	--	2	31.7 (29.9-33.5)
bowfin	*Amia calva*	5	4	45.3 (34.6-58.7)	1	45.5
freshwater drum	*Aplodinotus grunniens*	2	0	--	2	18.1 (17.1-19.0)
goldfish	*Carassius auratus*	3	1	33.6	2	32.0 (26.5-37.5)
white sucker	*Catostomus commersonii*	12	5	41.1 (32.8-51.5)	7	42.9 (36.1-48.9)
common carp	*Cyprinus carpio*	9	0	--	9	67.9 (53.7-85.0)
spotfin shiner	*Cyprinella spiloptera*	3	3	7.8 (7.2-8.8)	0	--
gizzard shad	*Dorosoma cepedianum*	218	122	10.4 (8.0-17.0)	96	11.6 (6.7-29.6)
northern pike	*Esox lucius*	2	1	75.4	1	53.0
banded killifish	*Fundulus diaphanus*	2	0	--	2	7.7 (5.1-10.2)
channel catfish	*Ictalurus punctatus*	3	2	46.5 (39.2-53.8)	1	46.9
brook silverside	*Labidesthes sicculus*	5610	5603	6.2 (3.8-10.1)	7	8.3 (7.1-10.2)
pumpkinseed	*Lepomis gibbosus*	53	31	12.1 (4.2-18.5)	22	13.1 (4.5-17.6)
bluegill	*Lepomis macrochirus*	165	113	4.9 (2.1-17.5)	52	13.4 (9.0-17.5)
largemouth bass	*Micropterus salmoides*	88	13	23.3 (6.1-41.7)	75	22.7 (6.5-40.9)
white perch	*Morone americana*	38	5	12.2 (6.4-18.4)	33	14.5 (7.6-18.5)
white bass	*Morone chrysops*	1	0	--	1	16.0
silver redhorse	*Moxostoma anisurum*	2	1	63.3	1	60.9
round goby	*Neogobius melanostomus*	13	12	3.9 (2.0-5.3)	1	11.5
emerald shiner	*Notropis atherinoides*	16	11	8.8 (6.5-10.4)	5	9.0 (7.9-10.1)
golden shiner	*Notemigonus crysoleucas*	4	1	8.3	3	12.2 (9.5-17.1)
spottail shiner	*Notropis hudsonius*	41	14	10.4 (8.5-11.2)	27	10.6 (8.0-13.0)
mimic shiner	*Notropis volucellus*	1	1	4.5	0	--
yellow perch	*Perca falvescens*	145	49	17.0 (8.3-24.0)	96	14.9 (9.1-22.3)
bluntnose minnow	*Pimephales notatus*	2	2	5.6 (5.5-5.6)	0	--
black crappie	*Pomoxis nigromaculatus*	8	7	16.8 (6.5-20.2)	1	8.3
brown trout	*Salmo trutta*	1	1	52.7	0	--
walleye	*Sander vitreus*	3	0	--	3	45.4 (22.7-57.2)
		6468	**6018**		**450**	

[a]Note that 5,288 brook silverside were captured in a single fyke net at site #4.

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 6 September 2017. 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[a]	TL (cm)
alewife	*Alosa pseudoharengus*	0	--	0	--	15	6.5 (4.8-9.5)	1	6.5
bowfin	*Amia calva*	1	35.1	1	34.6	1	52.9	1	58.7
goldfish	*Carassius auratus*	1	33.6	0	--	0	--	0	--
white sucker	*Catostomus commersonii*	0	--	2	41.0 (39.1-42.9)	1	39.4	2	42.2 (32.8-51.5)
spotfin shiner	*Cyprinella spiloptera*	2	8.0 (7.2-8.8)	0	--	0	--	1	7.5
gizzard shad	*Dorosoma cepedianum*	105	10.1 (8.0-12.5)	2	10.6 (10.1-11.0)	11	12.1 (9.5-17.0)	4	12.4 (11.7-13.8)
northern pike	*Esox lucius*	0	--	1	75.4	0	--	0	--
channel catfish	*Ictalurus punctatus*	0	--	2	46.5 (39.2-53.8)	0	--	0	--
brook silverside	*Labidesthes sicculus*	1	6.7	10	7.4 (6.7-8.7)	54	6.8 (4.9-8.3)	5,538	6.1 (3.8-10.1)
pumpkinseed	*Lepomis gibbosus*	4	15.0 (13.1-18.5)	11	15.0 (12.9-18.1)	3	9.2 (5.1-16.3)	13	9.4 (4.2-16.8)
bluegill	*Lepomis macrochirus*	64	4.4 (2.3-17.5)	35	5.0 (2.1-16.4)	1	3.8	13	7.0 (3.2-16.5)
largemouth bass	*Micropterus salmoides*	3	27.5 (6.1-41.7)	4	35.1 (31.4-40.6)	0	--	6	13.3 (6.6-38.8)
white perch	*Morone americana*	0	--	1	10.3	4	12.7 (6.4-18.4)	0	--
silver redhorse	*Moxostoma anisurum*	0	--	0	--	0	--	1	63.3
round goby	*Neogobius melanostomus*	1	2.0	1	4.9	5	3.7 (3.2-4.2)	5	4.2 (3.0-5.3)
emerald shiner	*Notropis atherinoides*	0	--	0	--	8	9.2 (7.0-10.4)	3	7.8 (6.5-10.3)
golden shiner	*Notemigonus crysoleucas*	1	8.3	0	--	0	--	0	--
spottail shiner	*Notropis hudsonius*	1	10.7	2	9.4 (8.5-10.2)	5	10.5 (10.1-11.2)	6	10.7 (10.2-11.1)
mimic shiner	*Notropis volucellus*	0	--	0	--	0	--	1	4.5
yellow perch	*Perca falvescens*	6	15.2 (14.1-16.4)	18	18.5 (13.5-23.3)	4	16.3 (15.0-18.4)	21	16.3 (8.3-24.0)
bluntnose minnow	*Pimephales notatus*	0	--	2	5.6 (5.5-5.6)	0	--	0	--
black crappie	*Pomoxis nigromaculatus*	1	18.6	0	--	0	--	6	16.5 (6.5-20.2)
brown trout	*Salmo trutta*	0	--	0	--	1	52.7	0	--
	Total	**191**		**92**		**113**		**5,622**	

[a]Note that 5,288 brook silverside were captured in a single fyke net.

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 14 September 2017. 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)
black bullhead	*Ameiurus melas*	0	--	0	--	0	--	2	31.7 (29.9-33.5)
bowfin	*Amia calva*	0	--	0	--	0	--	1	45.5
freshwater drum	*Aplodinotus grunniens*	0	--	0	--	0	--	2	18.1 (17.1-19.0)
goldfish	*Carassius auratus*	0	--	0	--	0	--	2	32.0 (26.5-37.5)
white sucker	*Catostomus commersonii*	2	39.0 (36.9-41.0)	0	--	1	36.1	4	46.5 (44.2-48.9)
common carp	*Cyprinus carpio*	2	64.2 (54.7-73.6)	2	65.3 (58.0-72.5)	3	69.6 (53.7-85.0)	2	71.8 (67.0-76.6)
gizzard shad	*Dorosoma cepedianum*	46	10.0 (6.7-16.7)	4	12.1 (9.1-16.0)	34	13.4 (8.6-29.6)	12	12.6 (11.0-14.1)
northern pike	*Esox lucius*	1	53.0	0	--	0	--	0	--
banded killifish	*Fundulus diaphanus*	0	--	0	--	0	--	2	7.7 (5.1-10.2)
channel catfish	*Ictalurus punctatus*	1	46.9	0	--	0	--	0	--
brook silverside	*Labidesthes sicculus*	0	--	4	8.2 (7.6-9.1)	2	7.7 (7.1-8.2)	1	10.2
pumpkinseed	*Lepomis gibbosus*	7	12.5 (11.0-13.5)	11	13.1 (4.5-17.6)	2	12.9 (11.9-13.9)	2	14.8 (14.1-15.5)
bluegill	*Lepomis macrochirus*	10	12.2 (9.0-14.9)	36	13.5 (10.0-17.5)	0	--	6	14.3 (11.9-16.0)
largemouth bass	*Micropterus salmoides*	13	20.6 (10.0-39.0)	47	25.6 (16.3-40.9)	0	--	15	15.3 (6.5-34.8)
white perch	*Morone americana*	3	15.1 (10.6-18.5)	15	12.6 (7.6-17.6)	2	16.2 (15.5-16.8)	13	16.4 (15.2-18.2)
white bass	*Morone chrysops*	0	--	1	16.0	0	--	0	--
silver redhorse	*Moxostoma anisurum*	0	--	0	--	0	--	1	60.9
round goby	*Neogobius melanostomus*	0	--	1	11.5	0	--	0	--
emerald shiner	*Notropis atherinoides*	0	--	5	9.0 (7.9-10.1)	0	--	0	--
golden shiner	*Notemigonus crysoleucas*	3	12.2 (9.5-17.1)	0	--	0	--	0	--
spottail shiner	*Notropis hudsonius*	1	10.6	6	10.0 (8.0-11.1)	2	11.8 (10.5-13.0)	18	10.7 (10.0-11.5)
yellow perch	*Perca falvescens*	12	14.8 (10.1-16.5)	48	14.6 (10.3-22.3)	7	15.8 (14.2-19.6)	29	15.2 (9.1-21.9)
black crappie	*Pomoxis nigromaculatus*	0	--	0	--	0	--	1	8.3
walleye	*Sander vitreus*	1	22.7	0	--	2	56.8 (56.3-57.2)	0	--
	Total	**102**		**180**		**55**		**113**	

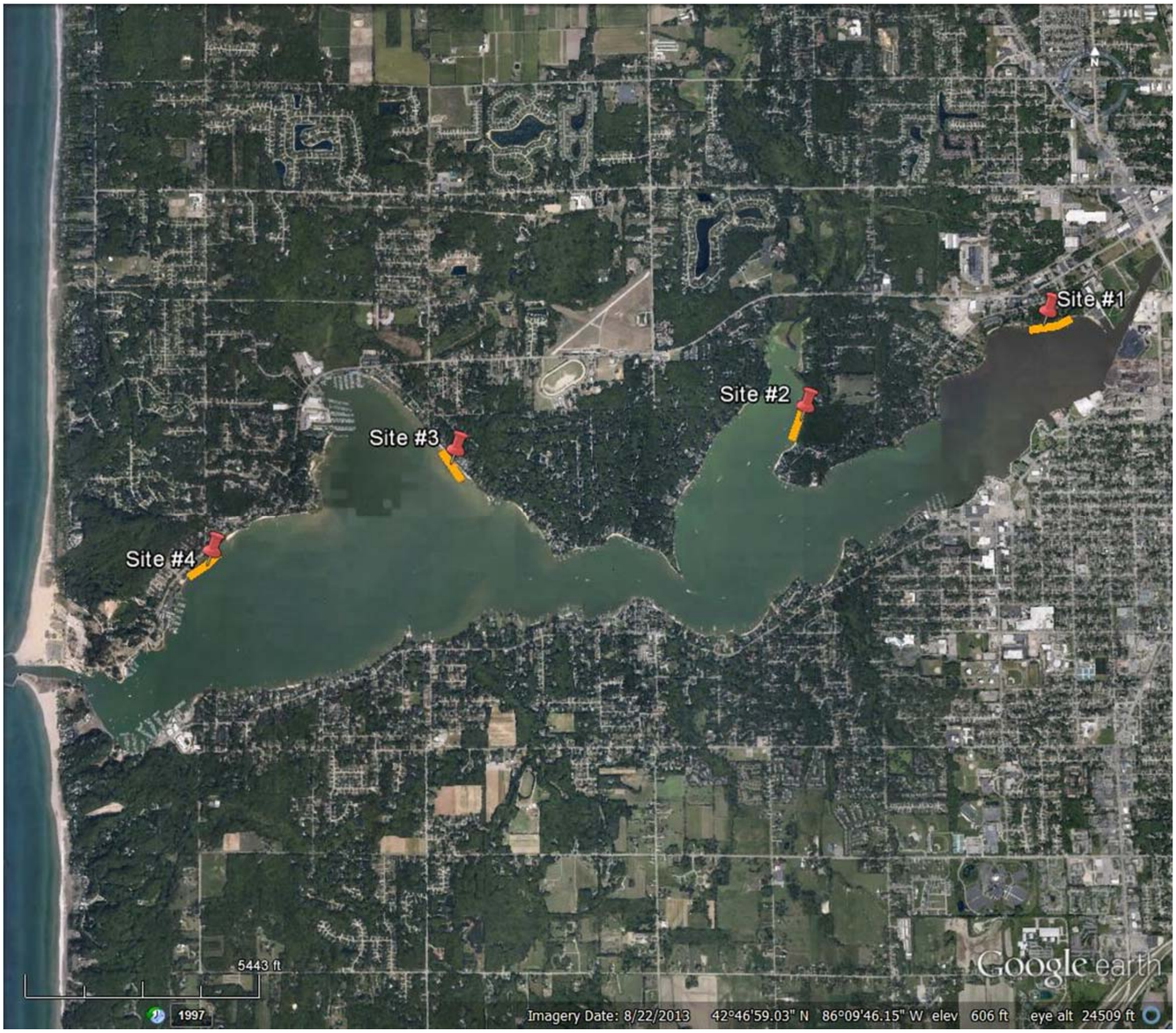

Figure 1. Map of Lake Macatawa (Ottawa County, Michigan) showing fish sampling sites. The orange transects depict approximately where boat electrofishing was conducted at each site. Site #1 is closest to the Macatawa River and site #4 is closest to Lake Michigan.

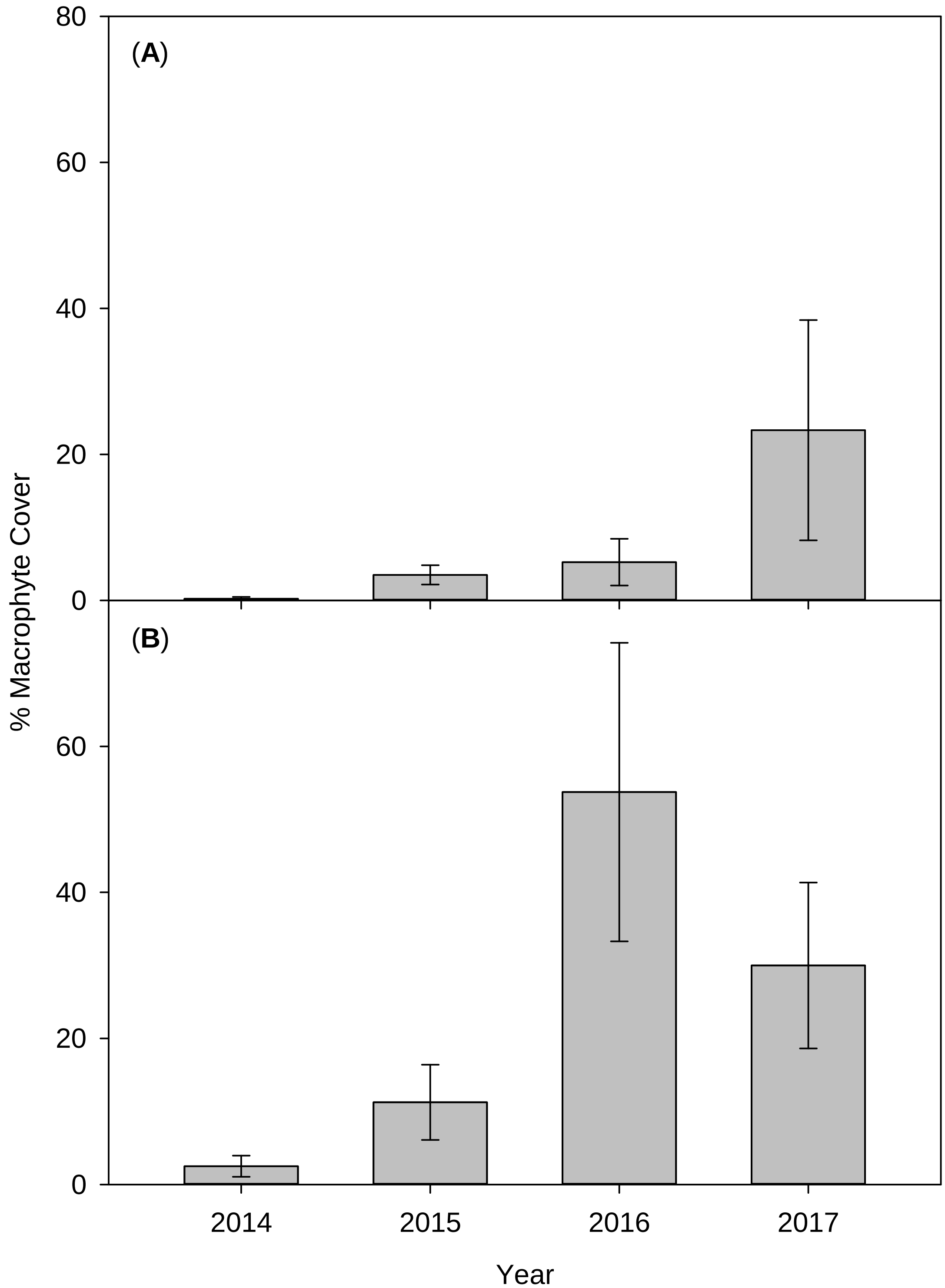

Figure 2. Mean (±1 standard error) % macrophyte cover visually estimated at (A) fyke net locations and (B) boat electrofishing transects in Lake Macatawa (n = 4 sites per year). Note that the area where macrophyte cover is assessed during fyke netting is much less compared with a boat electrofishing transect.

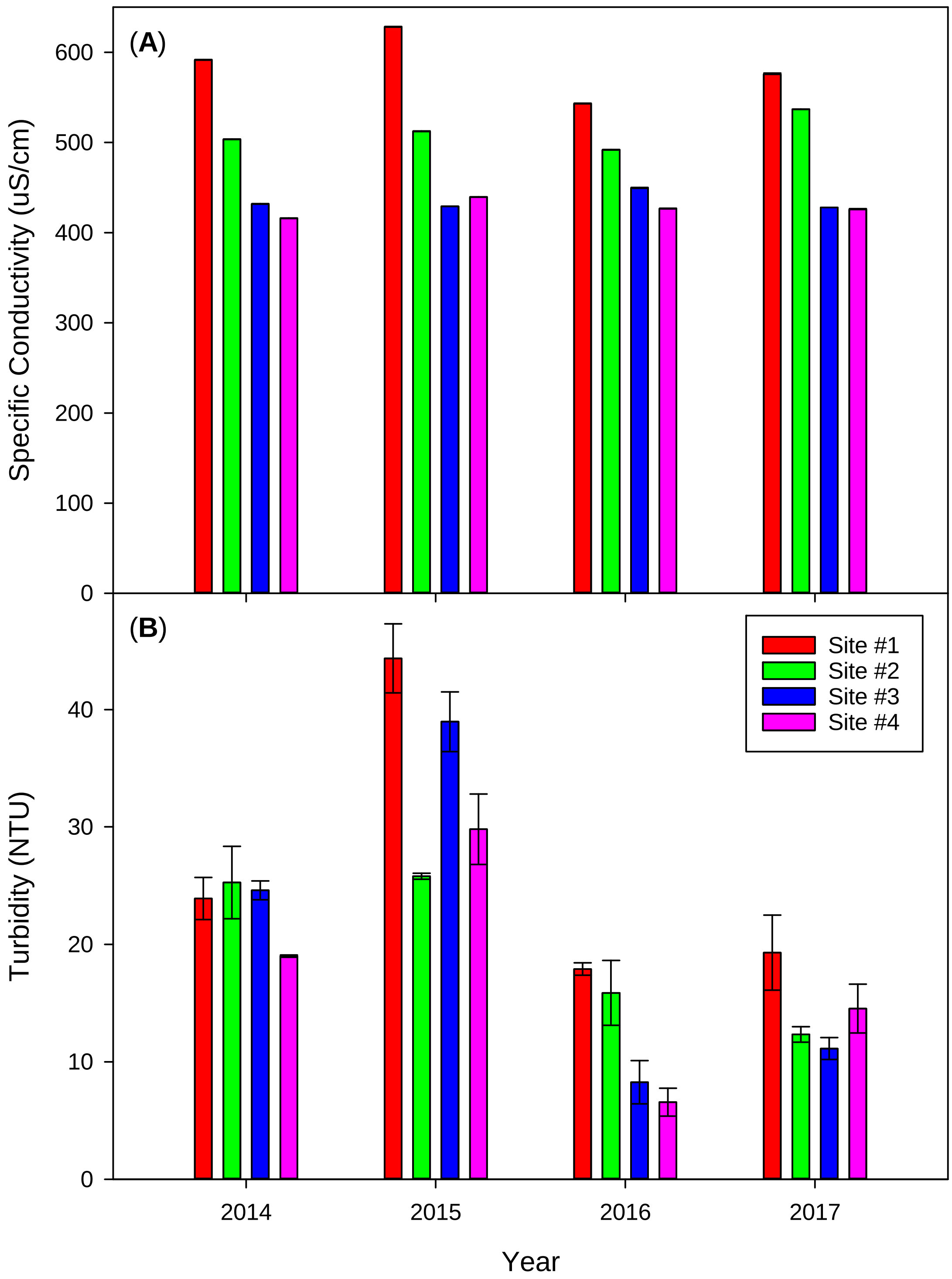

Figure 3. Mean (A) specific conductivity and (B) turbidity measured during fyke netting in Lake Macatawa. Error bars represent ±1 standard error (n = 3 nets per site), although they may be too small to be visible for some means.

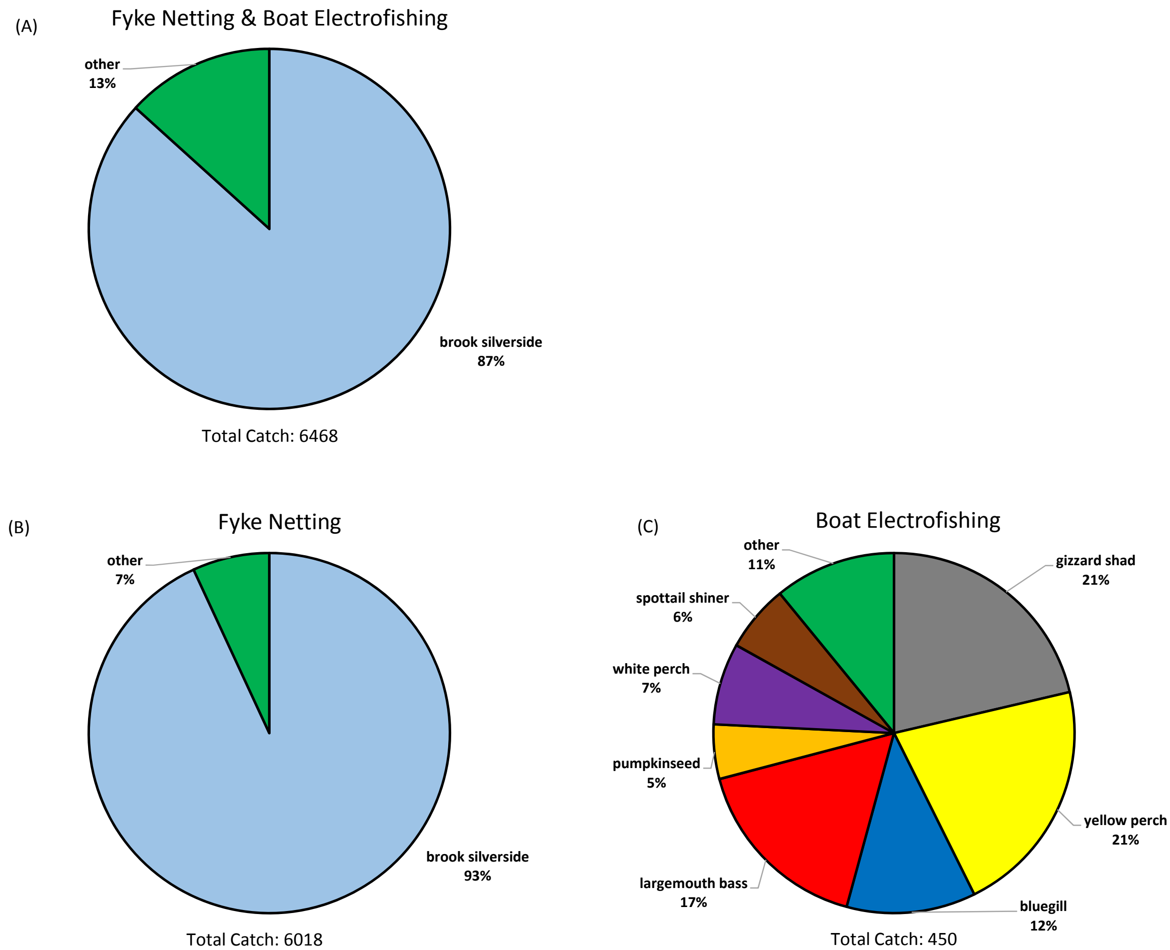

Figure 4. Fish species captured in littoral habitats of Lake Macatawa by (A) fyke netting and boat electrofishing (i.e., combined catch), (B) fyke netting (*n* = 12 nets), and (C) boat electrofishing (*n* = 4 transects) during September 2017. Catch data, including the species pooled in the "other" category, are reported in Table 4.

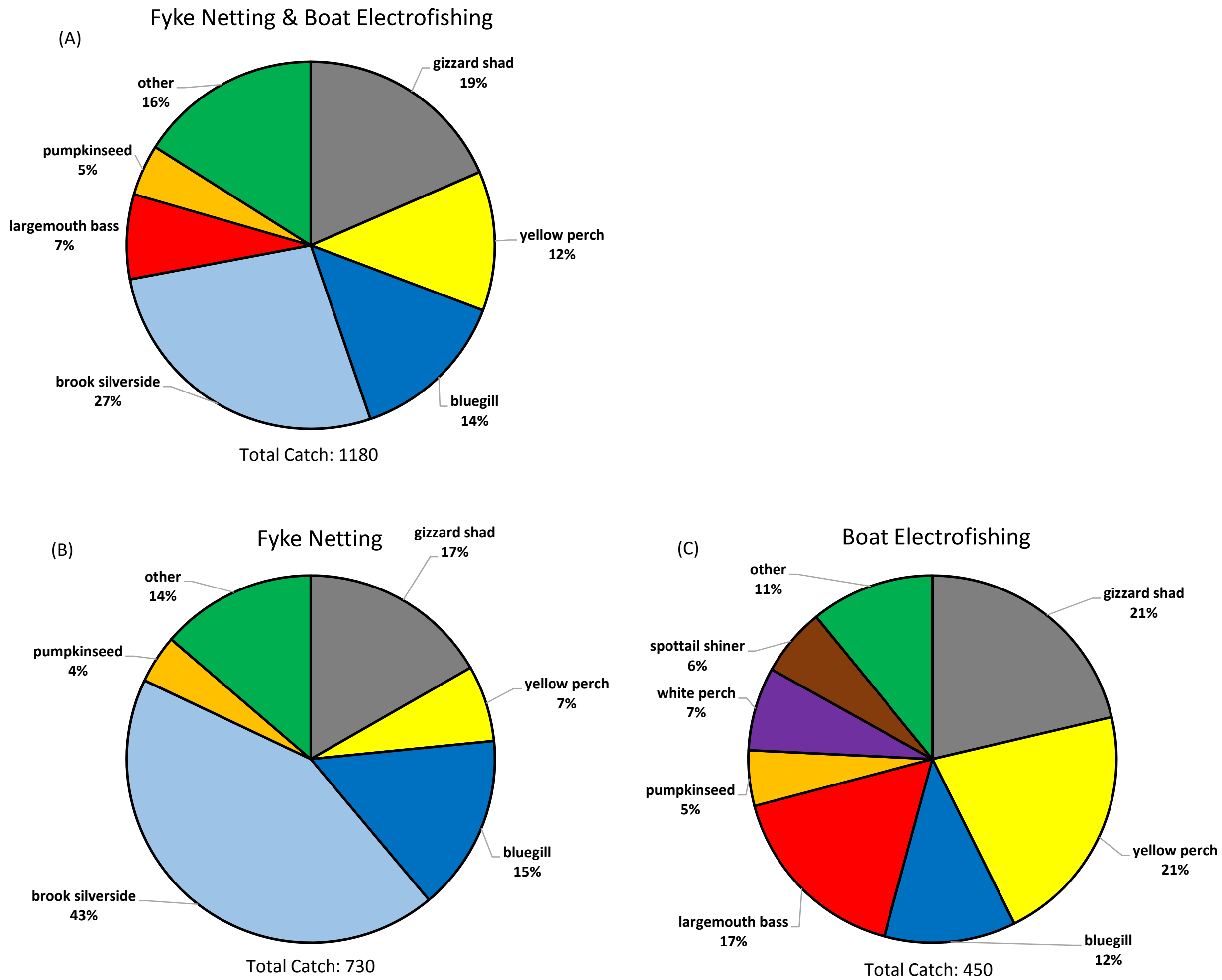

Figure 5. Fish species captured—excluding 5,288 brook silverside captured in a single fyke net at site #4—in littoral habitats of Lake Macatawa by (A) fyke netting and boat electrofishing (i.e., combined catch), (B) fyke netting (n = 12 nets), and (C) boat electrofishing (n = 4 transects) during September 2017. Catch data, including the species pooled in the “other” category, are reported in Table 4.

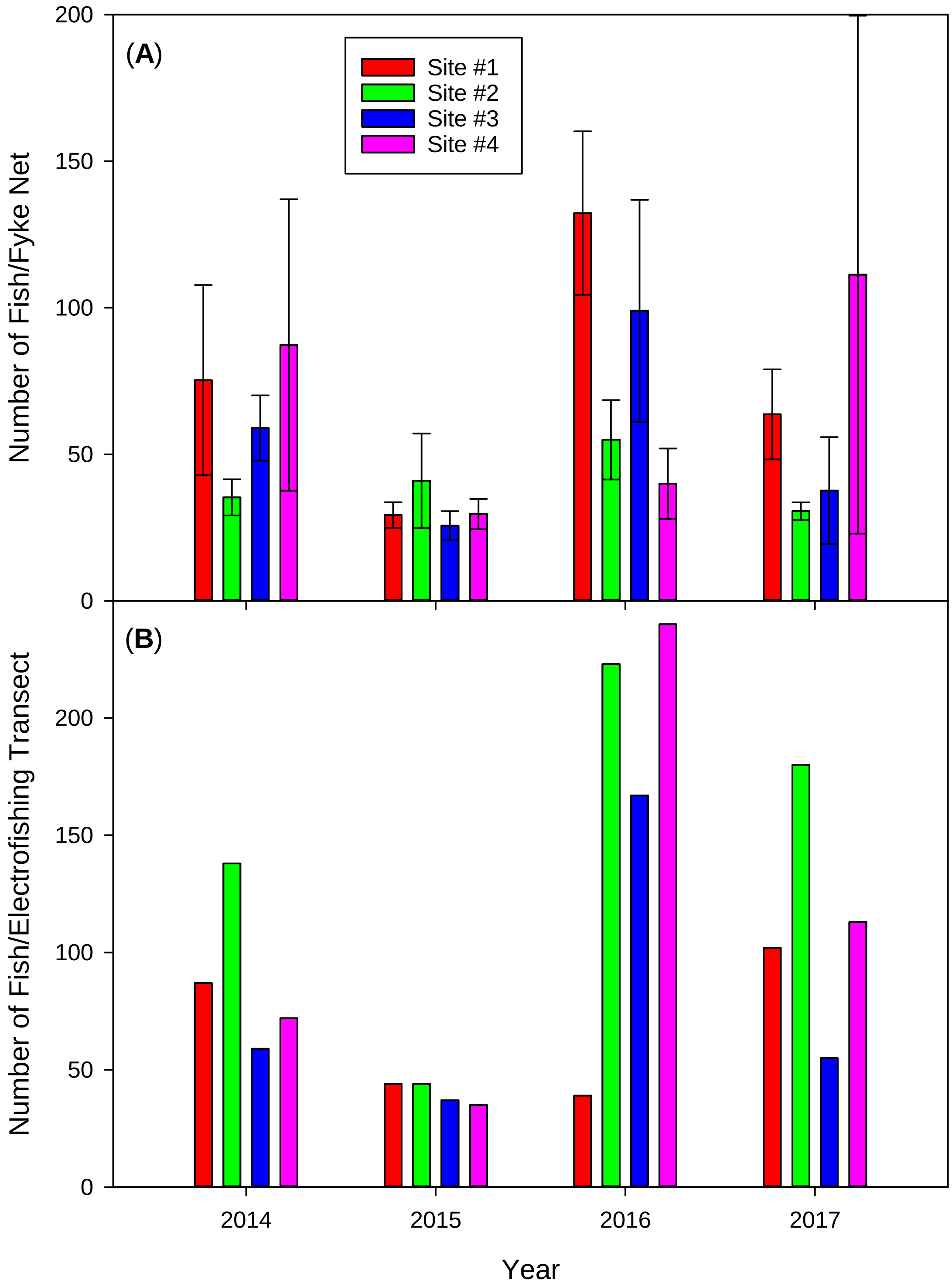

Figure 6. (A) Mean number (±1 standard error) of fish captured in fyke nets (*n* = 3 nets per site) and (B) number of fish captured during a boat electrofishing transect (*n* = 1 transect per site) in Lake Macatawa. *Note*: we did not include 5,288 brook silverside captured a single fyke net at site #4 in 2017 when calculating means.

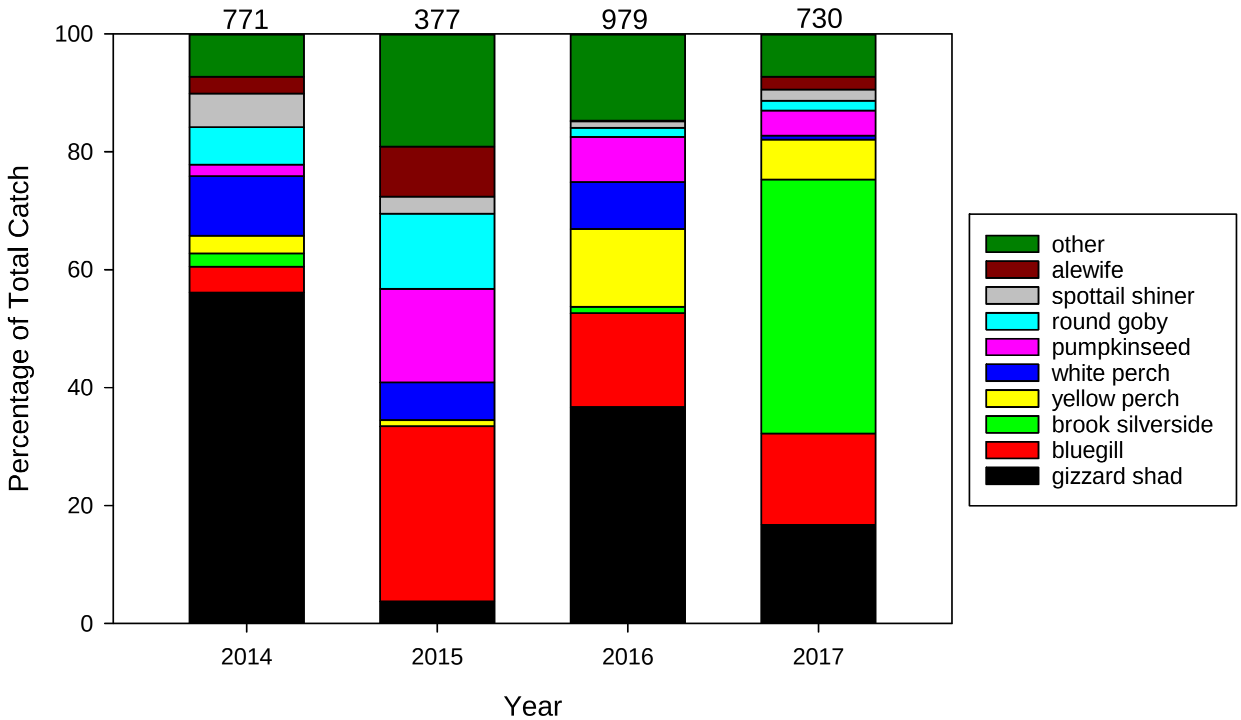

Figure 7. Fish species composition (pooled across sites) in fyke netting surveys for each sampling year. The number of fish captured differed among years, which is reported at the top of each bar. Additionally, 5,288 brook silverside that were captured in a single fyke net at site #4 during 2017 were not included in the percentage of total catch.

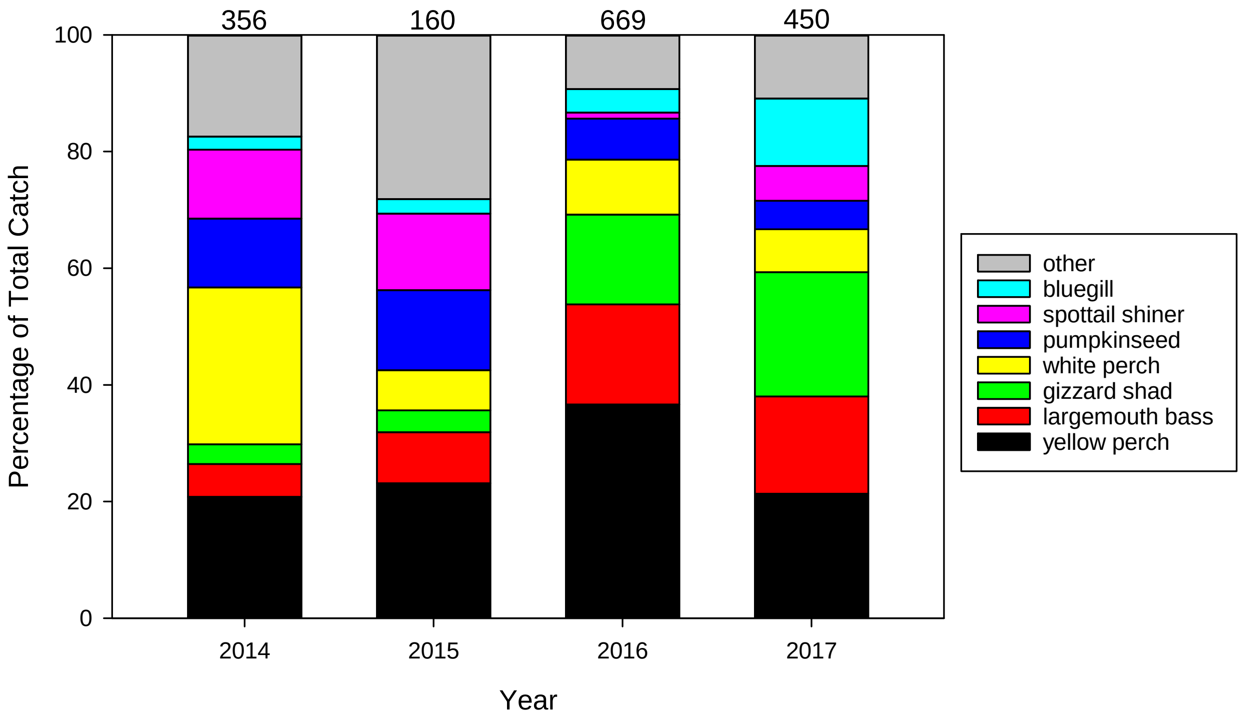

Figure 8. Fish species composition (pooled across sites) in boat electrofishing surveys for each sampling year. Note that the number of fish captured differed among years, which is reported at the top of each bar.