Long-Term Fish Monitoring of Lake Macatawa: Results from Year 3

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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 third 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 (Figure 2).

Fish sampling.—At each study site, we sampled fish via fyke netting and boat electrofishing. Fyke nets were set on 6 September 2016 during daylight hours (i.e., between 0900 and 1300) and fished for about 25.7 h (range = 22.9-29.2 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 8 September 2016. 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 (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 85 cm (Table 2). Water temperature was similar (at about 24 °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 13% and 8% at sites #2 and #4, respectively. Conversely, we visually estimated macrophyte cover at electrofishing transects to be 5% at site #1, 35% at site #2, 85% at site #3, and 90% at site #4, which was greater than our estimates at fyke nets. The visual estimates of % macrophyte cover for electrofishing is over a greater area at each site than estimates for fyke netting, which accounts for the differences. For instance, we observed extensive macrophyte beds at site #3 that were in deeper water than we were able to fish fyke nets but were part of the electrofishing transect. The % macrophyte cover in 2016 was higher than the two previous years, especially when macrophyte cover was assessed during boat electrofishing transects (Figure 3). 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. Moreover, 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 natural fish communities in Lake Macatawa. The presence of macrophyte beds in the vicinity of our fish sampling sites were likely related to the lower turbidity we observed in the lake in 2016 compared with previous years (Figure 4B); however, the low turbidity in 2016 was likely the result of natural inter-annual variation in the system.

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 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 2015). Nevertheless, turbidity and, to a lesser degree, specific conductivity were lower in 2016 than in the previous two years (Figure 4). In fact, turbidity was lowest at every site in 2016 (when compared to the previous two years; Figure 4B), whereas specific conductivity showed a clear decrease at only site #1 (Figure 4A), which is closest to the mouth of the Macatawa River (Figure 1). As expected, we found a negative correlation between % macrophyte cover and turbidity (Figure 5), although we caution that this relationship is based on observations at only four sites during a single year in autumn.

We captured 1,648 fish comprising 24 species in Lake Macatawa during the 2016 sampling surveys (Table 4). Although we captured fewer fish species in 2016 than in previous years (2014: 28 species; 2015: 30 species), we captured more individuals in 2016 (2014: 1,127 fish; 2015: 537 fish). The most abundant fishes in the combined catch of both gears (fyke netting and boat electrofishing during 2016) were gizzard shad (28%), yellow perch (23%), bluegill (11%), white perch (9%), largemouth bass (8%), and pumpkinseed (7%), which composed 86% of the total catch (Figure 6A). Three of the 24 species captured during 2016 were non-native to the Great Lakes basin (Bailey et al. 2004)—alewife (<1%), white perch (9%), and round goby (1%)—which composed 10% of the total catch (Table 4). For the first time during this study, we captured a native logperch (Bailey et al. 2004), which is a small benthic species that is often displaced by the invasive round goby (e.g., Balshine et al. 2005, Bergstrom and Mensinger 2009).

We captured about 1.5 times as many fish in fyke netting as boat electrofishing (Table 4), but the number of fish species captured in fyke netting (22 species) was similar to boat electrofishing (21 species). Three fish species were captured only by fyke netting (i.e., alewife, green sunfish, and bluntnose minnow), whereas two species were captured only by boat electrofishing (i.e., logperch and walleye). However, the difference in catch between the two gears was less pronounced in 2016 compared with the previous two years. Nevertheless, using both sampling gears likely provide a better characterization of the littoral fish assemblage of Lake Macatawa than either gear by itself, which is consistent with findings in Muskegon Lake 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 (37%), bluegill (16%), yellow perch (13%), white perch (8%), and pumpkinseed (8%) were the most abundant fishes captured, which composed 81% of the total fish captured (Figure 6B). Although gizzard shad was the most abundant species in the catch at sites #1 and #3, bluegill was most common at site #2 and pumpkinseed was most common at site #4 (Table 5). The next most abundant species in the catch at each site were white perch and bluegill at sites #3, yellow perch and spotfin shiner at site #2, bluegill and yellow perch at site #1, and yellow perch at site #4 (Table 5). There also was variation in total catch among the sites, with more fish captured at sites #1 and #3 than sites #2 and #4 (Table 5; Figure 7A). Compared with the previous two fyke netting surveys, the most abundant species in the catch varied among years (Figure 8) as did the patterns in total catch among sites (Figure 7A). 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 fewer round goby and more yellow perch in 2016 than the previous two years (Figure 8). The relative abundance of gizzard shad in 2016 was intermediate compared with the other two years (Figure 8). However, as we continue our monitoring of 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 (37%), largemouth bass (17%), gizzard shad (15%), white perch (10%), pumpkinseed (7%), bluegill (4%), and brook silverside (2%), which composed 92% of the total catch (Figure 6C). Yellow perch was most abundant in the catch at sites #4 and #3, and largemouth bass was most abundant in the catch at sites #2 and #1 (Table 6). The next most abundant species in the catch was gizzard shad at sites #3, #4, and #1, whereas yellow perch and white perch were nearly equally abundant in the catch at site #2 (Table 6). Total catch also varied among sites. In 2016, total catch at sites #2, #3, and #4 were among the highest during this study, whereas catch at site #1 was among the lowest (Figure 7B). Thus, there was not a positive association in total catch across sites between the two sampling gears in 2016 (Figure 7). Compared with the two previous boat electrofishing surveys, the most abundant species in the catch varied among years (Figure 9), although the pattern was weaker than what was observed for fyke netting (Figure 8). 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 was less common in 2016 compared with the two previous years (Figure 9).

In conclusion, the observations reported here are the third 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 three years of fish monitoring, we observed differences in total catch (Figure 7) and fish species composition of the catch among years (Figures 8 and 9). Water clarity was higher (i.e., lower turbidity; Figure 4B) and macrophytes were more common at our sampling sites in 2016 than in previous years (Figure 3). These environmental conditions were likely, in part, responsible for the higher total catch of fish in 2016. Nevertheless, not too much weight should be attributed to differences among only three sampling years. Once we accumulate several years 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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References

Bailey, R.M., W.C. Latta, and G.R. Smith. 2004. An atlas of Michigan fishes with keys and illustrations for their identification. Miscellaneous Publications, Museum of Zoology, University of Michigan, No. 192.

Balshine, S., A. Verma, V. Chant, and T. Theysmeyer. 2005. Competitive interactions between round gobies and logperch. Journal of Great Lakes Research 31:68-77.

Bergstrom, M.A., and A.F. Mensinger. 2009. Interspecific resource competition between the invasive round goby and three native species: logperch, slimy sculpin, and spoonhead sculpin. Transactions of the American Fisheries Society 138:1009-1017.

Bhagat, Y., and C.R. Ruetz III. 2011. Temporal and fine-scale spatial variation in fish assemblage structure in a drowned river mouth system of Lake Michigan. Transactions of the American Fisheries Society 140:1429-1440.

Breen, M.J., and C.R. Ruetz III. 2006. Gear bias in fyke netting: evaluating soak time, fish density, and predators. North American Journal of Fisheries Management 26:32-41.

Janetski, D.J., and C.R. Ruetz III. 2015. Spatiotemporal patterns of fish community composition in Great Lakes drowned river mouths. Ecology of Freshwater Fish 24:493-504.

Michigan Department of Natural Resources (MDNR). 2011. Lake Macatawa Ottawa County. Fish Collection System (printed 6/11/2011). Accessed at http://www.the-macc.org/wp-content/uploads/History-of-Lake-Mactawa-and-Fish.pdf (on 12/1/2014).

Radomski, P., and T.J. Goeman. 2001. Consequences of human lakeshore development on emergent and floating-leaf vegetation abundance. North American Journal of Fisheries Management 21:46-61.

Ruetz, C.R., III, D.G. Uzarski, D.M. Krueger, and E.S. Rutherford. 2007. Sampling a littoral fish assemblage: comparing small-mesh fyke netting and boat electrofishing. North American Journal of Fisheries Management 27:825-831.

Uzarski, D.G., T.M. Burton, M.J. Cooper, J.W. Ingram, and S.T.A. Timmermans. 2005. Fish habitat use within and across wetland classes in coastal wetlands of the five Great Lakes: development of a fish-based index of biotic integrity. Journal of Great Lakes Research 31(Suppl. 1):171-187.

Table 1. Locations (latitude and longitude) for each 2016 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. The coordinates at the end of transect at site #3 were not recorded.

			Electrofishing			
	Fyke netting		Start		End	
Site	Lat (°)	Long (°)	Lat (°)	Long (°)	Lat (°)	Long (°)
1	42.79586	86.12163	42.79548	86.12354	42.79600	86.12086
2	42.78896	86.14401	42.78809	86.14471	42.78959	86.14384
3	42.78642	86.17484	42.78544	86.17400	.	.
4	42.77993	86.19643	42.77910	86.19769	42.77985	86.19606

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 6 September 2016 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	91±2	23.96±0.02	9.01±0.04	107.1±0.5	543±1	0.353±0.000	17.9±0.5	7.93±0.01	398±1	56.1±3.7
2	89±6	24.26±0.02	8.92±0.16	106.6±1.9	492±0	0.320±0.000	15.9±2.8	8.24±0.03	381±1	46.3±2.8
3	82±4	24.41±0.01	9.98±0.10	119.6±1.2	449±1	0.292±0.000	8.3±1.8	8.70±0.01	366±3	34.8±2.0
4	79±7	24.00±0.11	10.58±0.08	125.8±0.8	426±1	0.277±0.000	6.6±1.2	8.75±0.01	378±3	24.0±0.8

Table 3. Water quality variables at fish sampling sites in Lake Macatawa. Measurements were made during nighttime boat electrofishing on 8 September 2016 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	24.40	8.16	97.80	542	0.352	16.4	7.89	413	41.4
2	24.52	9.16	110.00	489	0.318	11.2	8.24	374	69.8
3	24.23	9.82	117.30	424	0.276	8.9	8.93	352	21.3
4	22.77	8.36	97.20	429	0.279	5.9	8.41	381	25.5

Table 4. Number and mean total length (TL; ranges reported parenthetically) of fish captured by fyke netting (*n* = 12 nets) on 7 September 2016 and boat electrofishing (*n* = 4 transects) on 8 September 2016 at four sites in Lake Macatawa. Total catch combined both gears.

		Total	Fyke netting		Electrofishing	
Common name	Scientific name	Catch	Catch	TL (cm)	Catch	TL (cm)
alewife	*Alosa pseudoharengus*	1	1	7.9	0	--
bowfin	*Amia calva*	6	3	48.9 (43.6-54.8)	3	46.7 (43.2-50.0)
freshwater drum	*Aplodinotus grunniens*	15	7	10.5 (9.5-12.3)	8	17.9 (10.7-39.5)
white sucker	*Catostomus commersoni*	16	5	39.9 (33.9-45.1)	11	35.6 (24.2-43.6)
common carp	*Cyprinus carpio*	10	3	66.1 (64.2-69.6)	7	57.3 (37.4-68.2)
spotfin shiner	*Cyprinella spiloptera*	67	61	8.0 (5.5-10.1)	6	7.9 (7.0-8.6)
gizzard shad	*Dorosoma cepedianum*	462	359	9.6 (5.1-17.2)	103	12.3 (8.0-17.6)
banded killifish	*Fundulus diaphanus*	4	3	8.4 (7.0-10.7)	1	6.5
channel catfish	*Ictalurus punctatus*	7	6	34.2 (7.2-57.8)	1	51.0
brook silverside	*Labidesthes sicculus*	26	11	7.2 (6.4-7.8)	15	7.1 (4.6-8.0)
green sunfish	*Lepomis cyanellus*	1	1	6.0	0	--
pumpkinseed	*Lepomis gibbosus*	122	75	9.5 (5.4-17.8)	47	9.2 (5.6-17.7)
bluegill	*Lepomis macrochirus*	183	156	6.8 (2.5-20.8)	27	9.0 (4.3-18.7)
hybrid sunfish	*Lepomis* sp.[1]	8	8	16.4 (14.5-18.8)	0	
largemouth bass	*Micropterus salmoides*	137	22	11.0 (6.1-25.4)	115	16.5 (5.3-41.1)
white perch	*Morone americana*	141	78	9.3 (7.3-10.8)	63	9.9 (6.7-22.5)
round goby	*Neogobius melanostomus*	18	15	6.5 (3.8-9.7)	3	9.8 (8.7-11.2)
emerald shiner	*Notropis atherinoides*	4	3	8.9 (8.3-9.6)	1	8.9
golden shiner	*Notemigonus crysoleucas*	12	11	9.3 (7.7-10.8)	1	7.2
spottail shiner	*Notropis hudsonius*	18	11	8.5 (6.8-10.7)	7	9.6 (8.0-12.4)
yellow perch	*Perca falvescens*	374	129	12.5 (5.6-24.0)	245	10.1 (7.7-25.9)
logperch	*Percina caprodes*	1	0	--	1	12.2
bluntnose minnow	*Pimephales notatus*	2	2	8.0 (7.0-8.9)	0	--
black crappie	*Pomoxis nigromaculatus*	12	9	9.8 (7.1-20.2)	3	7.6 (6.2-9.6)
walleye	*Sander vitreus*	1	0	--	1	35.5
	Total	**1648**	**979**		**669**	

[1]The hybrid sunfish was likey a cross between a pumpkinseed and green sunfish. We did not include this taxon in our counts when we report species richness.

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 7 September 2016. 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	7.9	0	--	0	--	0	--
bowfin	*Amia calva*	1	43.6	0	--	2	51.5 (48.2-54.8)	0	--
freshwater drum	*Aplodinotus grunniens*	2	10.4 (10.3-10.6)	1	12.3	3	10.0 (9.5-10.9)	1	10.3
white sucker	*Catostomus commersoni*	1	33.9	2	40.4 (38.0-42.7)	1	40.0	1	45.1
common carp	*Cyprinus carpio*	0	--	0	--	2	66.9 (64.2-69.6)	1	64.5
spotfin shiner	*Cyprinella spiloptera*	19	7.4 (5.5-9.8)	32	8.1 (6.6-10.1)	6	8.8 (6.1-10.1)	4	9.2 (8.5-9.8)
gizzard shad	*Dorosoma cepedianum*	279	9.2 (5.1-14.3)	6	12.4 (10.9-15.2)	68	10.8 (7.8-14.5)	6	13.9 (11.0-17.2)
banded killifish	*Fundulus diaphanus*	0	--	0	--	3	8.4 (7.0-10.7)	0	--
channel catfish	*Ictalurus punctatus*	2	23.6 (7.2-40.1)	0	--	2	26.0 (18.6-33.4)	2	53.0 (48.1-57.8)
brook silverside	*Labidesthes sicculus*	1	7.5	7	7.5 (6.9-7.8)	2	6.5 (6.4-6.5)	1	6.4
green sunfish	*Lepomis cyanellus*	0	--	0	--	0	--	1	6.0
pumpkinseed	*Lepomis gibbosus*	11	9.0 (6.2-15.9)	13	14.4 (7.6-17.7)	23	7.4 (5.5-13.2)	28	9.1 (5.4-17.8)
hybrid sunfish	*Lepomis* sp.[1]	0	--	0	--	0	--	8	16.4 (14.5-18.8)
bluegill	*Lepomis macrochirus*	37	6.2 (2.6-16.4)	49	6.9 (3.5-18.8)	53	6.4 (4.2-14.7)	17	8.5 (2.5-20.8)
largemouth bass	*Micropterus salmoides*	4	14.4 (6.6-25.4)	8	10.1 (8.2-12.7)	3	11.8 (11.1-13.0)	7	9.7 (6.1-15.7)
white perch	*Morone americana*	3	8.9 (7.8-10.0)	3	10.0 (9.2-10.6)	60	9.4 (7.4-10.8)	12	8.9 (7.3-10.1)
round goby	*Neogobius melanostomus*	1	5.7	1	3.8	8	6.4 (5.5-8.4)	5	7.3 (6.4-9.1)
emerald shiner	*Notropis atherinoides*	0	--	2	9.2 (8.9-9.6)	1	8.3	0	--
golden shiner	*Notemigonus crysoleucas*	5	8.9 (7.7-10.8)	5	9.6 (8.1-10.7)	1	10.0	0	--
spottail shiner	*Notropis hudsonius*	0	--	0	--	11	8.5 (6.8-10.7)	0	--
yellow perch	*Perca falvescens*	26	12.6 (9.2-22.9)	35	17.2 (9.7-21.1)	46	9.8 (6.4-20.1)	22	10.8 (5.6-24.0)
bluntnose minnow	*Pimephales notatus*	1	7.0	0	--	1	8.9	0	--
black crappie	*Pomoxis nigromaculatus*	3	4.3 (7.1-20.2)	1	11.9	1	8.5	4	8.2 (7.4-8.7)
	Total	**397**		**165**		**297**		**120**	

[1]The hybrid sunfish was likey a cross between a pumpkinseed and green sunfish.

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 8 September 2016. 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	--	1	43.2	2	48.8 (47.7-50.0)
freshwater drum	*Aplodinotus grunniens*	3	26.3 (19.4-39.5)	3	13.5 (10.7-18.8)	2	11.9 (11.1-12.7)	0	--
white sucker	*Catostomus commersoni*	3	38.3 (34.9-42.6)	2	26.7 (24.2-29.2)	3	37.0 (30.5 -43.6)	3	37.6 (28.5-42.2)
common carp	*Cyprinus carpio*	2	59.1 (50.5-67.6)	1	37.4	4	61.4 (52.6-68.2)	0	--
spotfin shiner	*Cyprinella spiloptera*	0	--	6	7.9 (7.0-8.6)	0	--	0	--
gizzard shad	*Dorosoma cepedianum*	8	10.5 (8.0-14.7)	13	11.7 (9.7-15.0)	45	12.1 (8.2-15.8)	37	13.1 (10.6-17.6)
banded killifish	*Fundulus diaphanus*	0	--	1	6.8	0	--	0	--
channel catfish	*Ictalurus punctatus*	0	--	1	51.0	0	--	0	--
brook silverside	*Labidesthes sicculus*	0	--	8	7.2 (4.6-8.0)	1	6.5	6	7.1 (6.7-7.5)
pumpkinseed	*Lepomis gibbosus*	4	12.4 (7.7-17.0)	15	10.7 (7.5-17.0)	3	9.8 (7.7-13.5)	25	7.8 (5.6-17.7)
bluegill	*Lepomis macrochirus*	0	--	23	9.4 (4.3-18.7)	0	--	4	6.4 (5.5-7.1)
largemouth bass	*Micropterus salmoides*	10	18.6 (12.7-25.6)	53	20.0 (9.7-41.1)	31	13.6 (9.4-25.1)	21	11.1 (5.3-15.5)
white perch	*Morone americana*	3	17.0 (9.2-22.5)	45	9.7 (7.9-11.9)	8	9.6 (7.7-10.5)	7	8.1 (6.7-9.9)
round goby	*Neogobius melanostomus*	0	--	1	11.2	1	8.7	1	9.6
emerald shiner	*Notropis atherinoides*	1	8.9	0	--	0	--	0	--
golden shiner	*Notemigonus crysoleucas*	0	--	1	7.2	0	--	0	--
spottail shiner	*Notropis hudsonius*	0	--	1	11.5	2	8.4 (8.2-8.5)	4	9.7 (8.0-12.4)
yellow perch	*Perca falvescens*	5	9.8 (8.7-10.5)	47	11.4 (8.0-25.9)	65	9.6 (8.1-20.0)	128	9.8 (7.7-22.6)
logperch	*Percina caprodes*	0	--	0	--	1	12.2	0	--
black crappie	*Pomoxis nigromaculatus*	0	--	1	9.6	0	--	2	6.6 (6.2-7.1)
walleye	*Sander vitreus*	0	--	1	35.5	0	--	0	--
	Total	**39**		**223**		**167**		**240**	

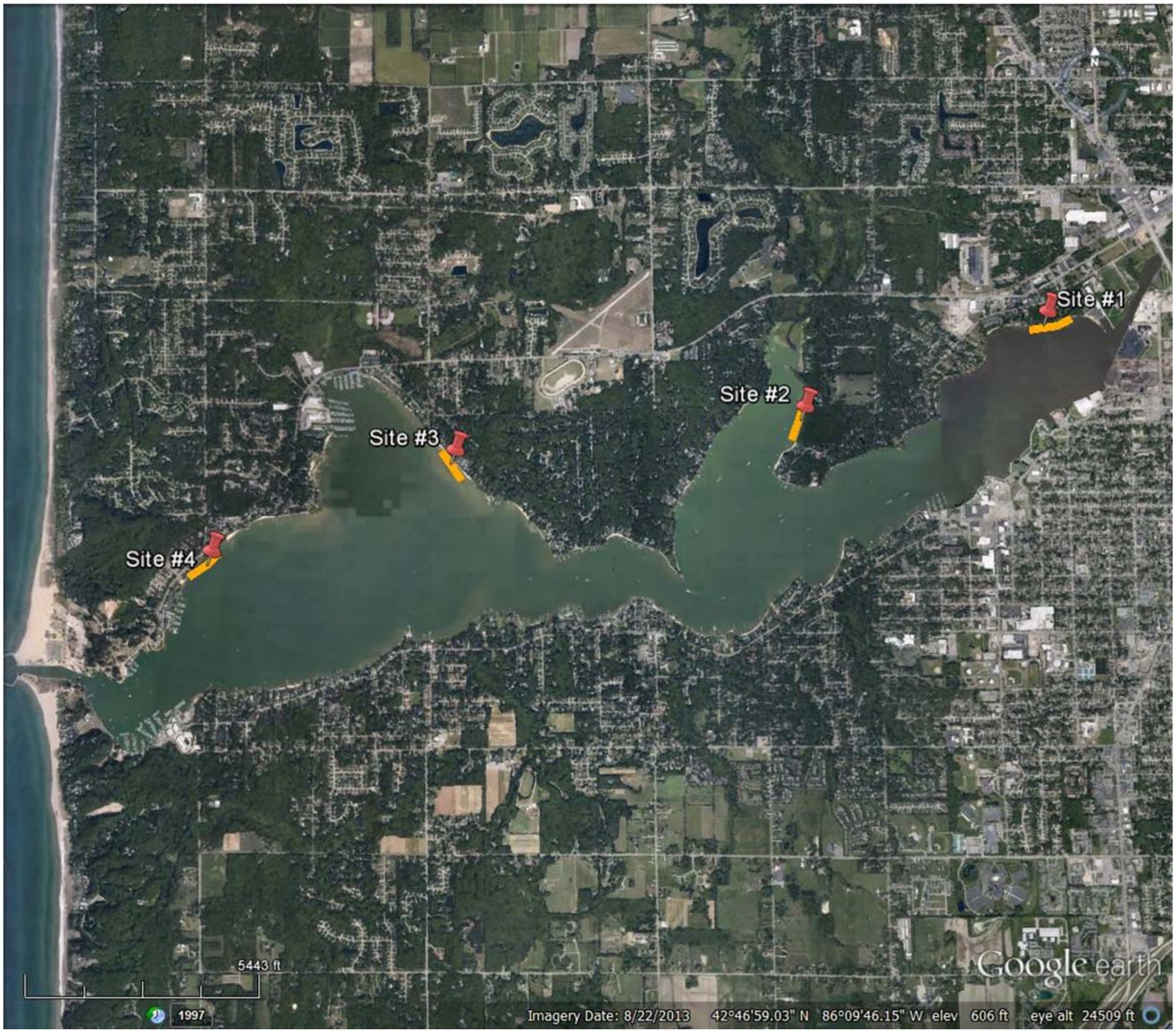

Figure 1. Map of Lake Macatawa (Ottawa County, Michigan) showing fish sampling sites. The orange transects depict approximately where boat electrofishing was conducted at each site. Site #1 is closest to the Macatawa River and site #4 is closest to Lake Michigan.

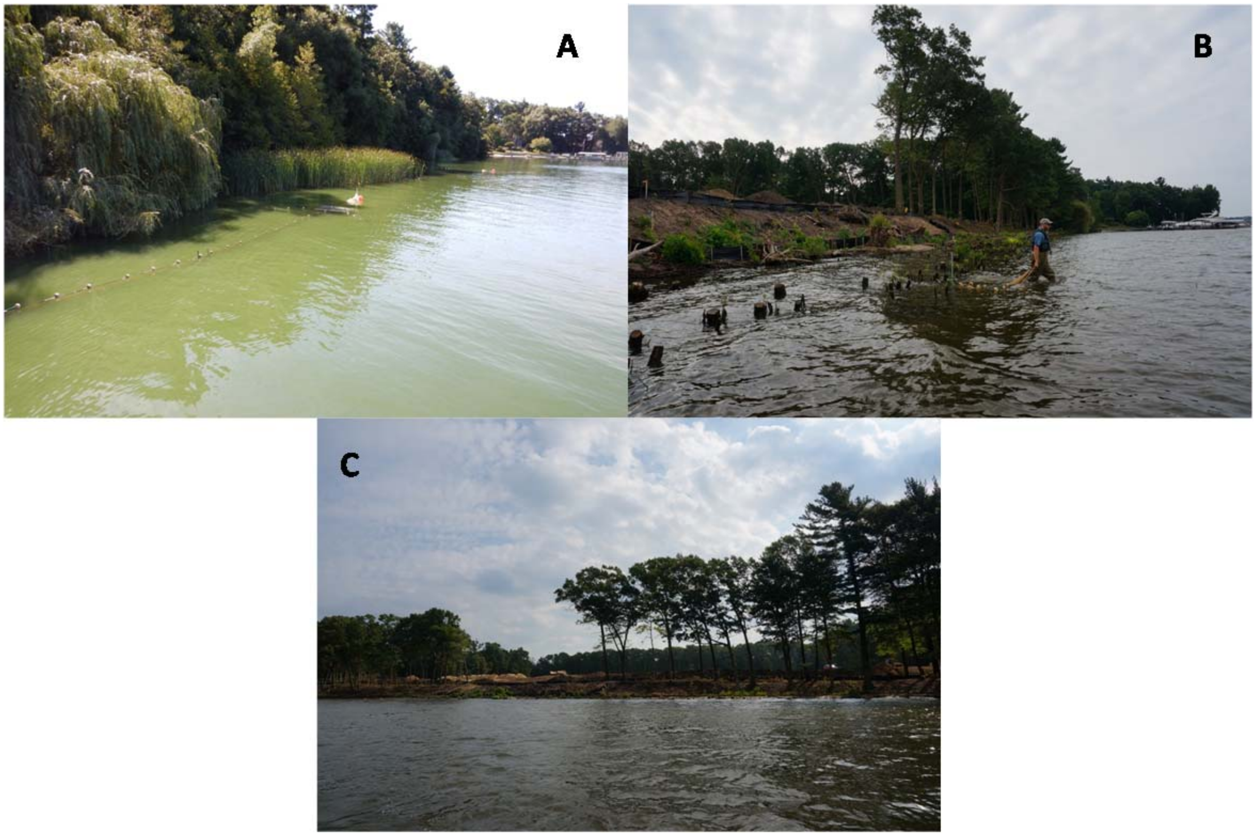

Figure 2. Photographs of riparian area at site #2 in (A) 2014 and (B and C) 2016 showing change in raparian area. Note that pictures A and B were taken with the photographer looking in a southernly direction. The riparian area looked similar in 2014 and 2015 (not shown).

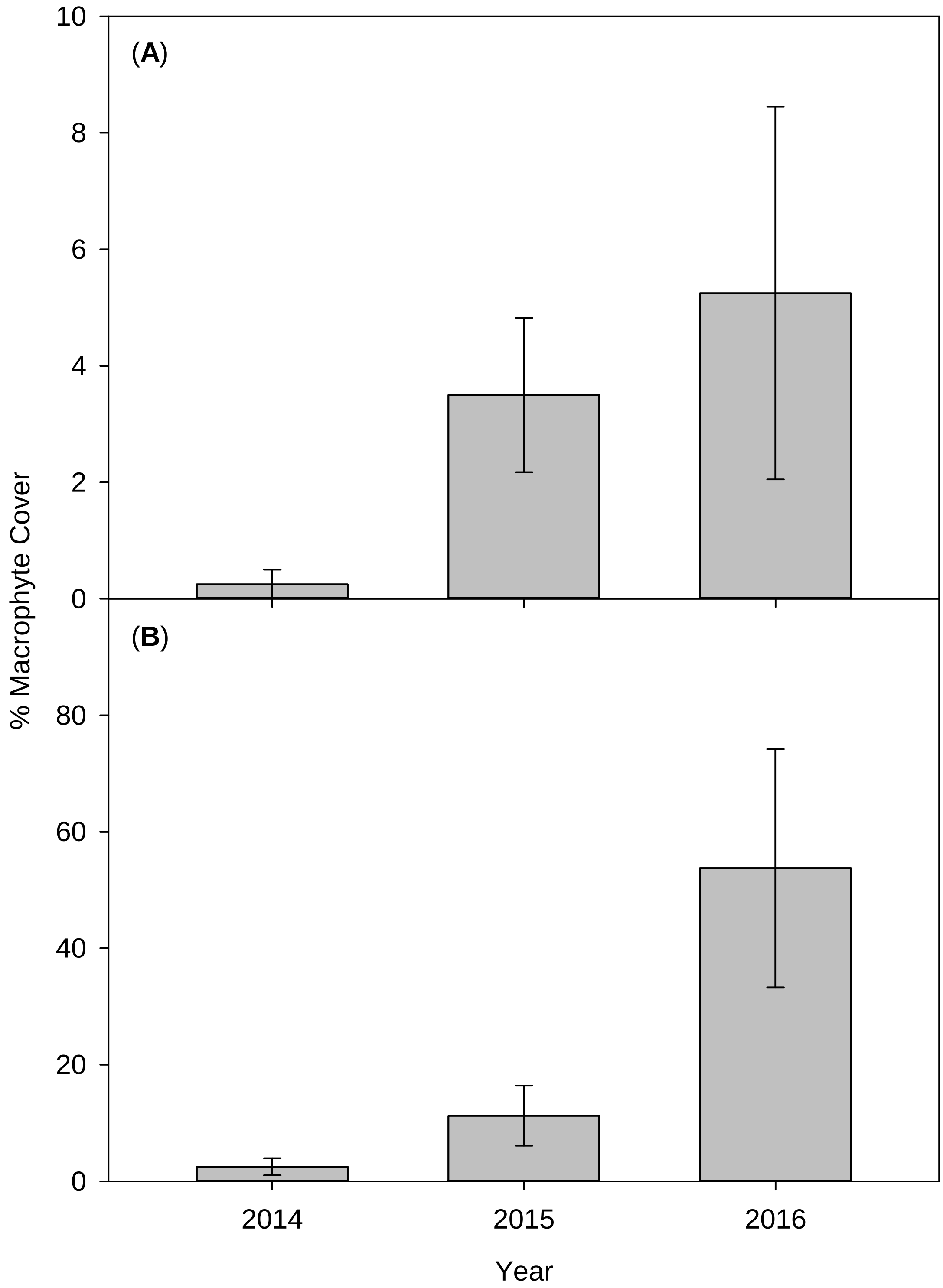

Figure 3. Mean (±1 standard error) % macrophyte cover visually estimated at (A) fyke net locations and (B) boat electrofishing transects in Lake Macatawa (*n* = 4 sites per year). Note that the *y*-axis varies by an order of magnitude between the two panels. The area where macrophyte cover is assessed during fyke netting is much less compared with a boat electrofishing transect.

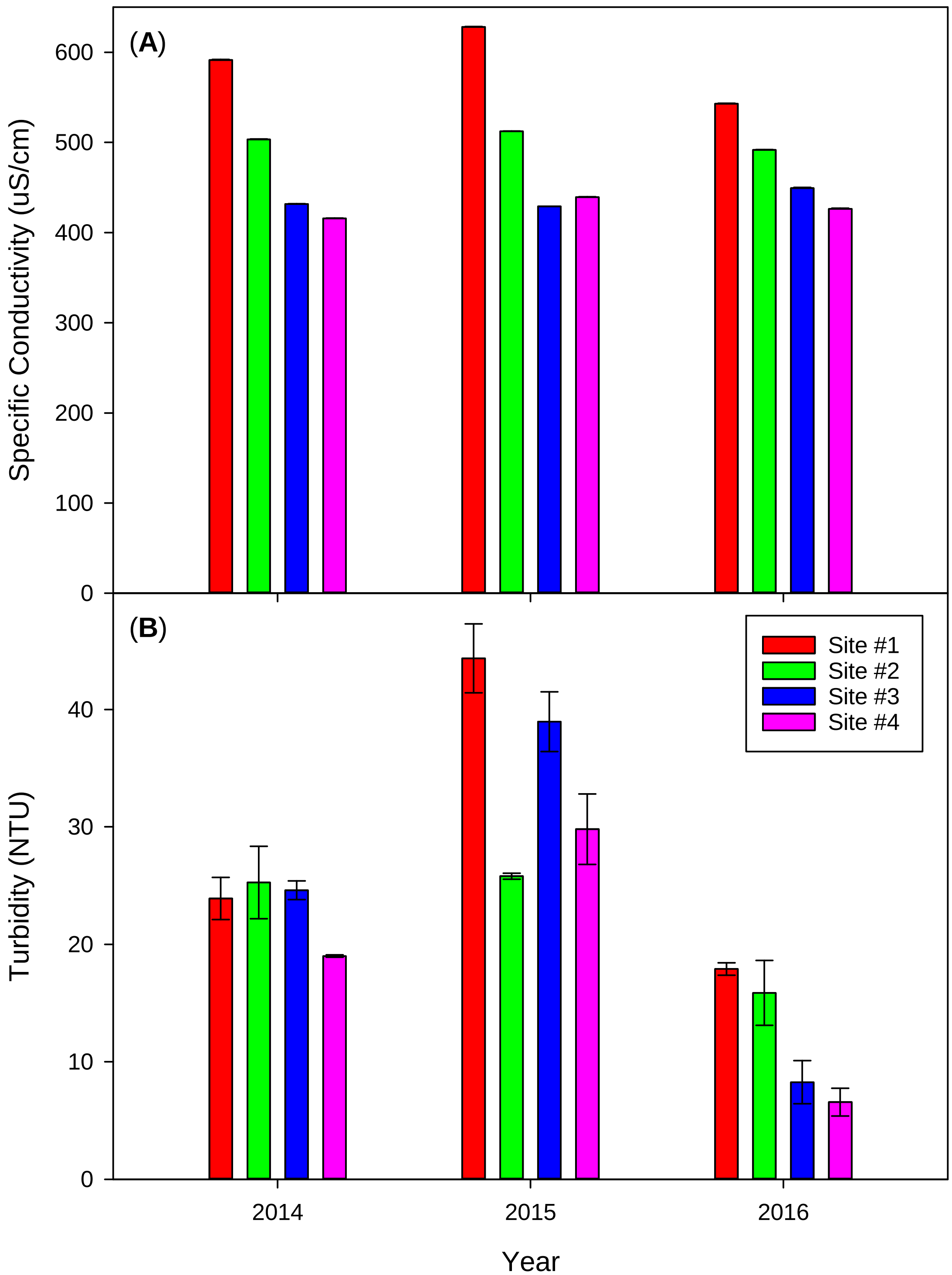

Figure 4. Mean (A) specific conductivity and (B) turbidity measured during fyke netting in Lake Macatawa. Error bars represent ±1 standard error (n = 3 nets per site), although they may be too small to be visible for some means.

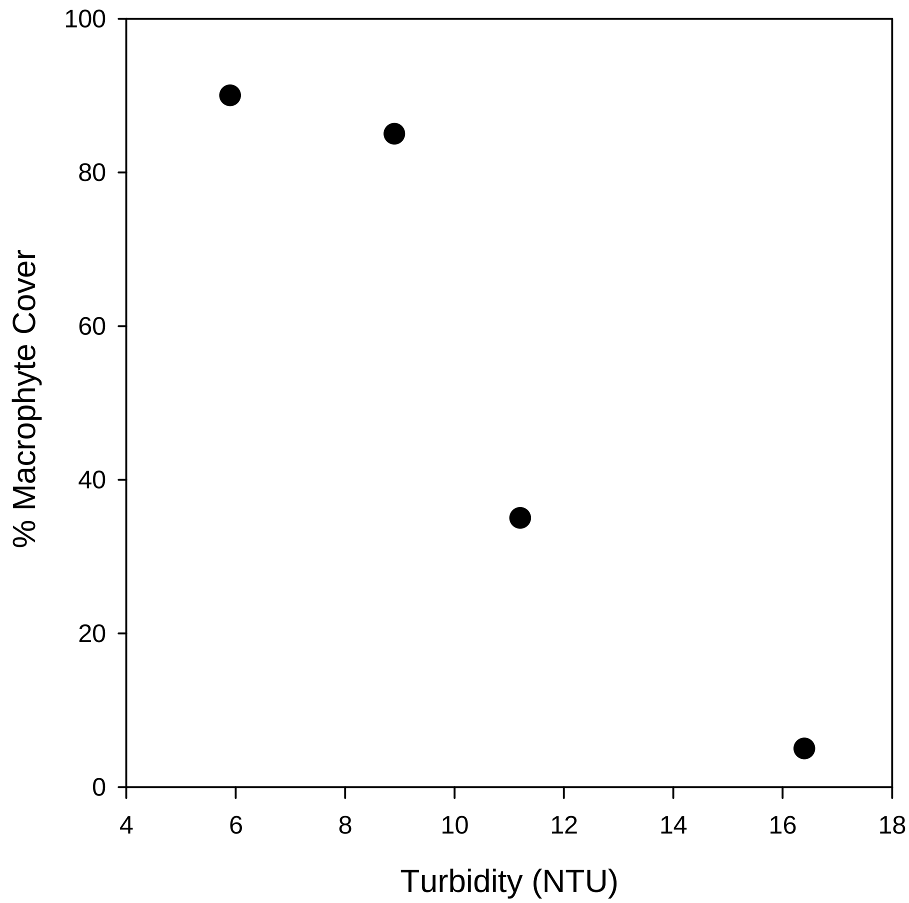

Figure 5. A significant negative correlation was detected between % macrophyte cover and turbidity (r = -0.95, P = 0.049). Variables were measured during nighttime boat electrofishing surveys in Lake Macatawa during 2016 (Table 3). Each point represents a single fish sampling site.

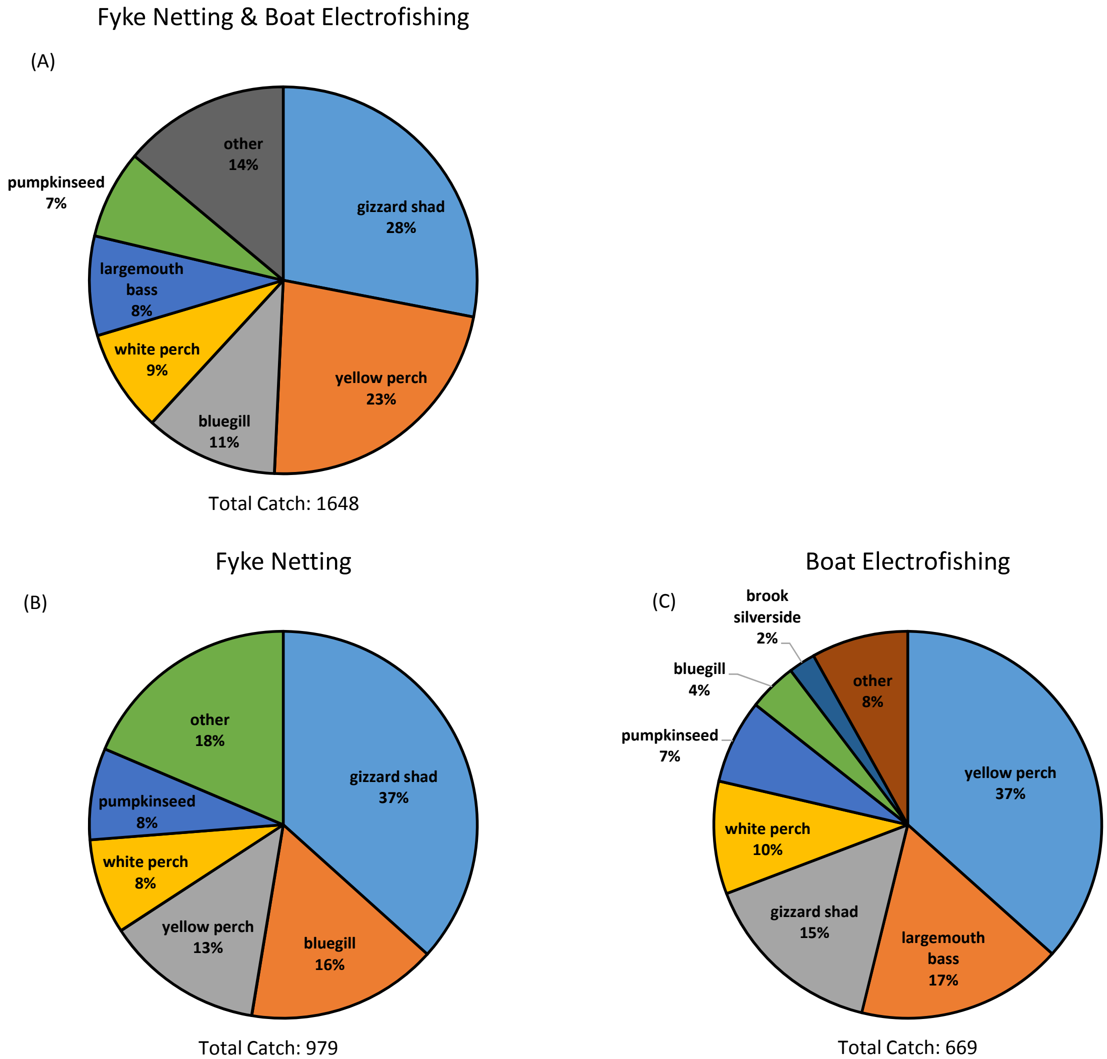

Figure 6. Fish species captured in littoral habitats of Lake Macatawa by (A) fyke netting and boat electrofishing (i.e., combined catch), (B) fyke netting (*n* = 12 nets), and (C) boat electrofishing (*n* = 4 transects) during September 2016. Catch data, including the species pooled in the “other” category, are reported in Table 4.

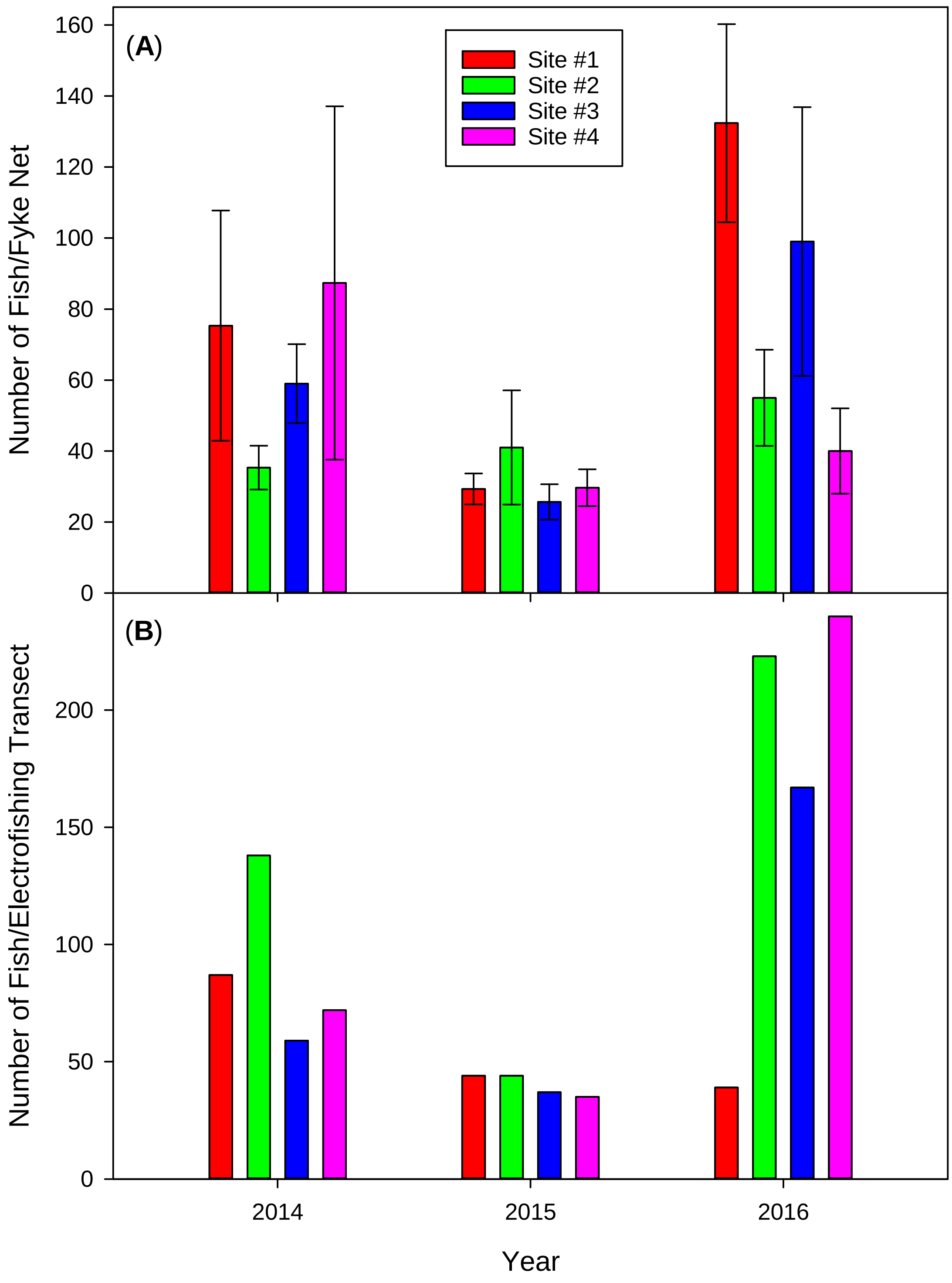

Figure 7. (A) Mean number (±1 standard error) of fish captured in fyke nets (*n* = 3 nets per site) and (B) number of fish captured during a boat electrofishing transect (*n* = 1 transect per site) in Lake Macatawa.

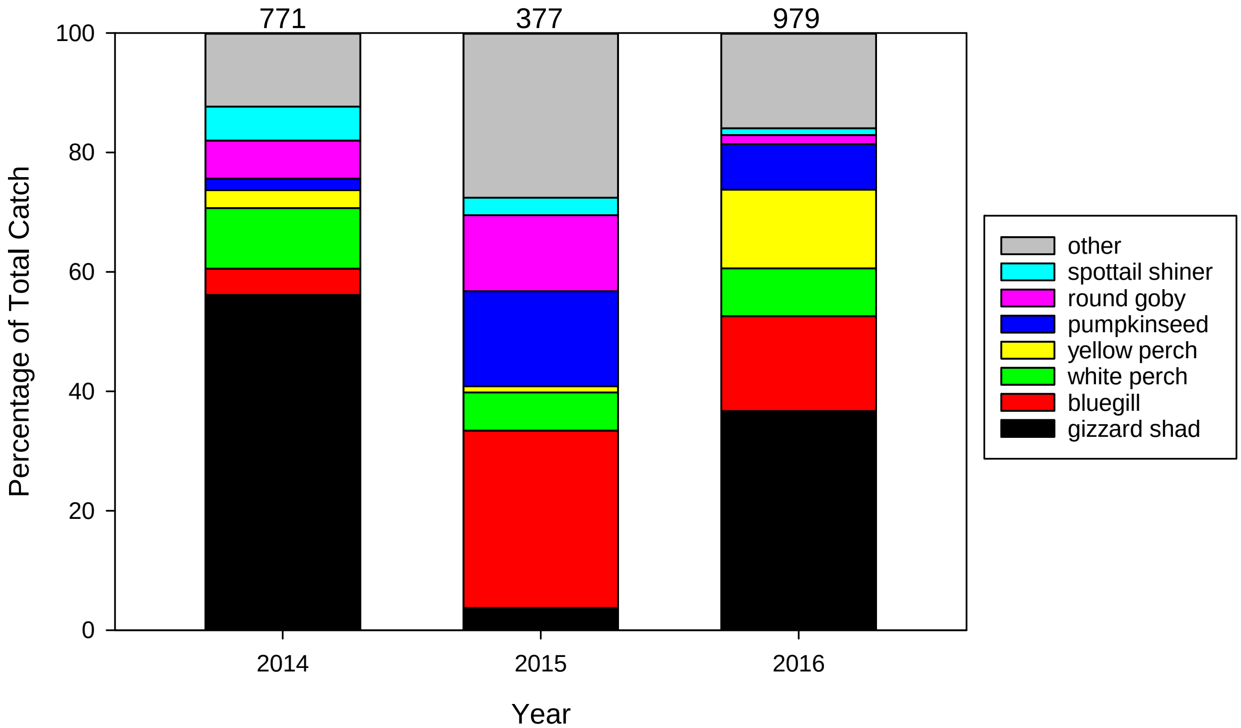

Figure 8. Fish species composition (pooled across sites) in fyke netting surveys for each sampling year. Note that the number of fish captured differed among years, which is reported at the top of each bar.

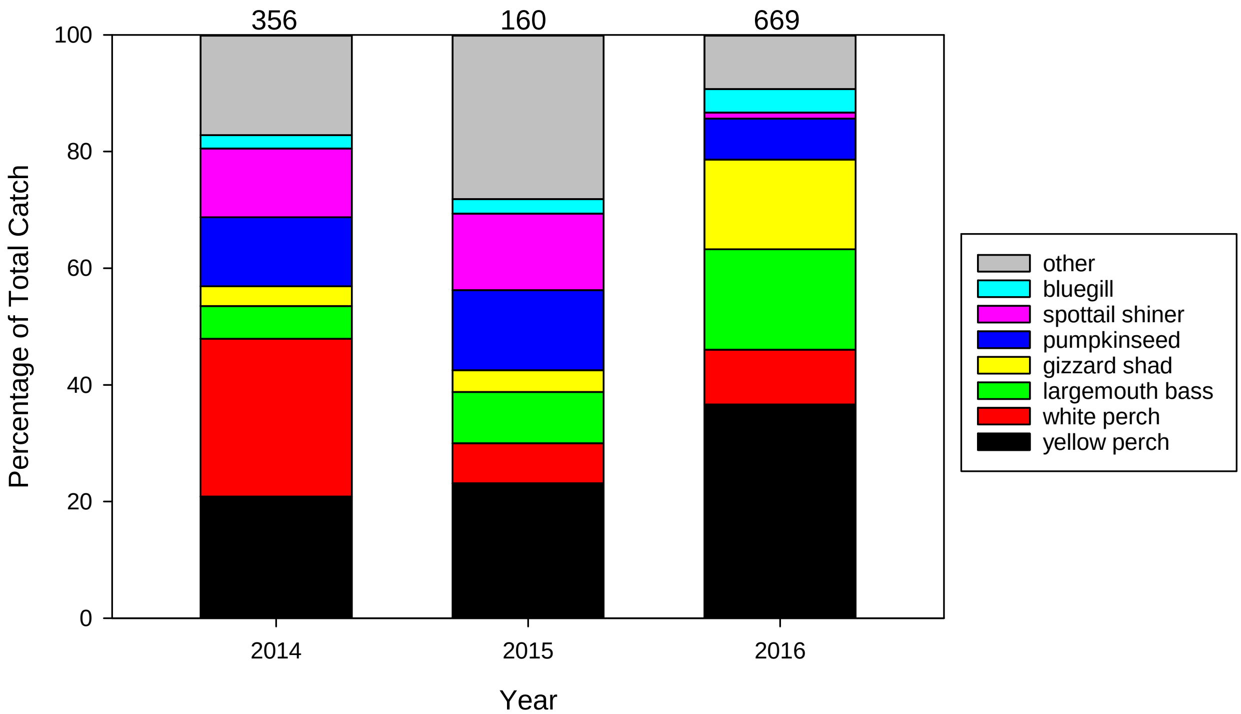

Figure 9. Fish species composition (pooled across sites) in boat electrofishing surveys for each sampling year. Note that the number of fish captured differed among years, which is reported at the top of each bar.