Long-Term Fish Monitoring of Lake Macatawa: Results from Year 2

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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 second 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).

Fish sampling.—At each study site, we sampled fish via fyke netting and boat electrofishing. Fyke nets were set on 8 September 2015 during daylight hours (i.e., between 1030 and 1430) and fished for about 24.8 h (range = 24.5-24.9 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 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 10 September 2015. 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 & 3). The mean water depth at fyke nets was 96 cm (Table 2). Water temperature was slightly (~1.5 °C) warmer when we conducted fyke netting compared with boat electrofishing (Tables 2 & 3). We visually observed few aquatic macrophytes during fish sampling. During fyke netting, mean % cover of macrophytes was zero at site #1 and <10% at the remaining sites (site #2: 5%; site #3: 6%; site #4: 3%). During electrofishing transects, we visually estimated macrophyte cover to be ≤25% at all sites (site #1: 0%; site #2: 10%; site #3: 10%; site #4: 25%), which was greater than our estimates during fyke netting (note that visual estimates of % macrophyte cover for electrofishing is over a greater area at each site than fyke netting). The low densities of macrophytes in Lake Macatawa 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 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).

We captured 537 fish comprising 30 species in Lake Macatawa (Table 4). The most abundant fishes in the combined catch of both gears (fyke netting and boat electrofishing) were bluegill (22%), pumpkinseed (15%), round goby (9%), yellow perch (8%), white perch (7%), alewife (6%), spottail shiner (6%), and largemouth bass (5%), which composed 77% of the total catch (Figure 2A). Three of the 30 species captured were non-native to the Great Lakes basin (Bailey et al. 2004)—alewife (6%), white perch (7%), and round goby (9%)—which composed 22% of the total catch (Table 4). Although not an abundant species in our catch, we captured muskellunge—a native predator (Becker 1983)—for the first time (during this study) in Lake Macatawa (Table 4). The Michigan Department of Natural Resources has stocked muskellunge in Lake Macatawa annually since 2012 (MDNR 2016).

We captured more than twice as many fish in fyke netting than boat electrofishing (Table 4). Similarly, more fish species were captured in fyke netting (27 species) than boat electrofishing (20 species). Ten fish species were collected only by fyke netting, and three 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, bluegill (30%), pumpkinseed (16%), round goby (13%), alewife (8%), and white perch (6%) were the most abundant fishes captured, which composed 73% of the total fish captured (Figure 2B). Although bluegill was the most abundant species in the catch at sites #1 and #2, alewife was most common at site #3 and pumpkinseed was most common at site #4 (Table 5). The next most abundant species in the catch at sites #1 and #4 was the round goby (Table 5), whereas there was not one species that was clearly next most abundant in the catch at sites #2 and #3. Largemouth bass and gizzard shad were nearly equally represented in the catch as the next most abundant species at site #2, and pumpkinseed, bluegill, white perch, and spottail shiner were equally represented in the catch as the next most abundant species at site #3 (Table 5). There also was variation in total catch among the sites, with site #2 having the highest catch and site #3 having the lowest catch, although the variation in total catch among sites #1, #3, and #4 was small (Table 5; Figure 3A). Compared with 2014 fyke netting surveys, the most abundant species in the catch varied between years (Figure 4) as did the patterns in total catch among sites (Figure 3A). However, as we continue our monitoring of Lake Macatawa, we will be better able to assess whether these spatial patterns among sites are stable or dynamic over time.

In boat electrofishing, the most abundant fishes captured were yellow perch (23%), pumpkinseed (14%), spottail shiner (13%), largemouth bass (9%), white sucker (7%), white perch (7%), and walleye (6%), which composed 79% of the total catch (Figure 2C). The fish assemblage was not dominated by a single fish species at every site in the electrofishing catch, which contrasted with what was observed in fyke netting. Yellow perch was among the most abundant species in the catch at sites #1, #2, and #4, whereas spottail shiner was most abundant at site #3 (Table 6). Unlike fyke netting, total catch was similar among sites in 2015 (Figure 3B). Thus, there was not a strong, positive association in total catch across sites between the two sampling gears (Tables 5 & 6). Compared with 2014 boat electrofishing surveys, the most abundant species in the catch varied between years (Figure 5), although the pattern was weaker than what was observed for fyke netting (Figure 4), and total catch was lower in 2015 (Figure 3B).

In conclusion, the observations reported here provide the second 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. Although we only have completed two years of fish monitoring, we observed differences in total catch (Figure 3) and fish species composition of the catch between 2014 and 2015 (Figures 4 & 5) even though we observed similar water quality (i.e., high specific conductivity and turbidity; Figure 6) and habitat (i.e., low densities of submersed macrophytes) during both years. With respect to the catch, we captured fewer fish in both sampling gears at almost every site in 2015 compared with 2014 (Figure 3). Although gizzard shad and white bass dominated fyke netting catch in 2014, bluegill and pumpkinseed were dominant in 2015 (Figure 4). There was less variability in the fish species composition of boat electrofishing surveys compared with fyke netting surveys (Figures 4 & 5). Nevertheless, not too much weight should be attributed to differences between only two 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 (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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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.

Becker, G.C. 1983. Fishes of Wisconsin. University of Wisconsin Press, Madison.

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).

Michigan Department of Natural Resources (MDNR). 2016. Fish Stocking Database (http://www.michigandnr.com/fishstock/). Accessed on 8 January 2016.

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 2015 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.

			Electrofishing			
	Fyke netting		Start		End	
Site	Lat (°)	Long (°)	Lat (°)	Long (°)	Lat (°)	Long (°)
1	42.79593	86.12144	42.79585	86.12052	42.79564	86.12253
2	42.78838	86.14430	42.78813	86.14484	42.78947	86.14399
3	42.78646	86.17502	42.78663	86.17550	42.78542	86.17347
4	42.78002	86.19627	42.77891	86.19763	42.78101	86.19528

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 2015 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	110±9	25.98±0.03	10.63±0.11	131.2±1.5	628±1	0.408±0.000	44.4±2.9	8.23±0.01	432±10	53.5±0.7
2	96±1	25.45±0.05	13.00±0.33	158.7±4.2	512±0	0.333±0.000	25.8±0.3	9.01±0.03	379±2	36.7±1.9
3	95±2	24.25±0.01	11.20±0.01	134.3±0.1	429±0	0.279±0.000	39.0±2.6	9.01±0.01	385±2	18.5±0.4
4	86±5	23.44±0.01	9.43±0.11	110.9±1.3	439±0	0.285±0.000	29.8±3.0	8.67±0.03	366±2	17.4±0.7

Table 3. Water quality variables at fish sampling sites in Lake Macatawa. Measurements were made during nighttime boat electrofishing on 10 September 2015 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	24.25	5.56	66.5	655	0.426	21.1	7.68	307	17.1
2	23.55	12.99	153.2	539	0.350	27.0	8.93	271	40.7
3	22.66	12.72	147.5	452	0.294	20.5	9.12	258	15.3
4	22.81	9.48	110.3	430	0.280	14.8	8.69	258	12.6

Table 4. Number and mean total length (TL; ranges reported parenthetically) of fish captured by fyke netting (*n* = 12 nets) on 9 September 2015 and boat electrofishing (*n* = 4 transects) on 10 September 2015 at four sites in Lake Macatawa.

		Total	Fyke netting		Electrofishing	
Common name	Scientific name	Catch	Catch	TL (cm)	Catch	TL (cm)
alewife	*Alosa pseudoharengus*	32	32	7.5 (4.8-9.0)	0	--
black bullhead	*Ameiurus melas*	2	2	18.4 (14.2-22.5)	0	--
yellow bullhead	*Ameiurus natalis*	2	1	24.1	1	36.2
bowfin	*Amia calva*	2	2	38.7 (37.4-40.0)	0	--
freshwater drum	*Aplodinotus grunniens*	6	3	10.5 (5.7-18.5)	3	15.6 (7.8-21.5)
white sucker	*Catostomus commersoni*	20	9	38.0 (30.0-48.2)	11	29.9 (21.3-35.9)
common carp	*Cyprinus carpio*	5	2	52.7 (31.0-74.4)	3	45.7 (34.4-58.3)
spotfin shiner	*Cyprinella spiloptera*	1	1	9.4	0	--
gizzard shad	*Dorosoma cepedianum*	20	14	9.9 (6.0-21.9)	6	12.1 (9.6-13.4)
muskellunge	*Esox masquinongy*	2	1	45.6	1	51.1
banded killifish	*Fundulus diaphanus*	3	3	7.0 (5.8-8.2)	0	--
channel catfish	*Ictalurus punctatus*	13	12	36.4 (5.2-62.2)	1	57.5
brook silverside	*Labidesthes sicculus*	1	0	--	1	6.5
green sunfish	*Lepomis cyanellus*	2	2	8.4 (7.6-9.1)	0	--
pumpkinseed	*Lepomis gibbosus*	82	60	8.8 (3.8-17.9	22	13.5 (6.2-17.4)
bluegill	*Lepomis macrochirus*	116	112	5.6 (2.1-18.5)	4	13.7 (9.2-18.2)
largemouth bass	*Micropterus salmoides*	27	13	11.5 (5.3-39.8)	14	15.6 (6.5-38.3)
white perch	*Morone americana*	35	24	12.6 (5.8-27.8)	11	11.1 (7.2-27.1)
white bass	*Morone chrysops*	4	1	24.8	3	24.6 (23.3-25.5)
silver redhorse	*Moxostoma anisurum*	1	1	61.3	0	--
shorthead redhorse	*Moxostoma macrolepidotum*	2	2	40.5 (37.0-43.9)	0	--
round goby	*Neogobius melanostomus*	51	48	4.4 (2.6-10.2)	3	10.5 (9.5-11.4)
emerald shiner	*Notropis atherinoides*	4	3	8.9 (6.1-11.3)	1	10.5
golden shiner	*Notemigonus crysoleucas*	10	4	15.7 (13.1-17.0)	6	14.5 (8.5-18.6)
spottail shiner	*Notropis hudsonius*	32	11	11.1 (9.2-12.2)	21	10.9 (10.0-12.0)
yellow perch	*Perca falvescens*	41	4	14.9 (14.6-15.3)	37	15.6 (9.0-23.4)
bluntnose minnow	*Pimephales notatus*	6	6	5.6 (3.8-7.3)	0	--
flathead catfish	*Pylodictis olivaris*	1	0	--	1	35.0
black crappie	*Pomxsis nigromaculatus*	4	4	18.3 (6.5-25.9)	0	--
walleye	*Sander vitreus*	10	0	--	10	25.3 (17.0-37.6)
	Total	**537**	**377**		**160**	

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 2015. 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	6.6	5	7.02 (6.4-7.8)	25	7.648 (4.8-9.0)	1	8.5
black bullhead	*Ameiurus melas*	0	--	1	14.2	0	--	1	22.5
yellow bullhead	*Ameiurus natalis*	0	--	1	24.1	0	--	0	--
bowfin	*Amia calva*	0	--	0	--	0	--	2	38.7 (37.4-40.0)
freshwater drum	*Aplodinotus grunniens*	1	18.5	1	7.2	1	5.7	0	--
white sucker	*Catostomus commersoni*	2	32.6 (32.2-33)	3	38.6 (30.2-43.0)	1	30.0	3	43.7 (38.8-48.2)
common carp	*Cyprinus carpio*	1	31	0	--	0	--	1	74.4
spotfin shiner	*Cyprinella spiloptera*	0	--	1	9.4	0	--	0	--
gizzard shad	*Dorosoma cepedianum*	3	12.9 (12.1-13.3)	11	9.1 (6.0-21.9)	0	--	0	--
muskellunge	*Esox masquinongy*	0	--	1	45.6	0	--	0	--
banded killifish	*Fundulus diaphanus*	0	--	0	--	1	8.2	2	6.4 (5.8-6.9)
channel catfish	*Ictalurus punctatus*	6	37.4 (5.6-57.4)	6	35.4 (5.2-62.2)	0	--	0	--
green sunfish	*Lepomis cyanellus*	0	--	0	--	0	--	2	8.4 (7.6-9.1)
pumpkinseed	*Lepomis gibbosus*	6	13.2 (10.6-14.7)	5	15.8 (14.8-17.1)	9	6.6 (3.8-17.4)	40	7.75 (4.0-17.9)
bluegill	*Lepomis macrochirus*	36	4.7 (2.2-18.0)	62	5.6 (2.1-18.1)	9	6.3 (2.7-18.5)	5	11.4 (5.3-16.1)
largemouth bass	*Micropterus salmoides*	1	39.8	3	10.1 (9.0-10.9)	2	5.4 (5.3-5.4)	7	9.8 (5.6-16.0)
white perch	*Morone americana*	3	8.1 (7.1-9.6)	12	17.8 (6.2-27.8)	9	7.1 (5.8-9.0)	0	--
white bass	*Morone chrysops*	0	--	0	--	1	24.8	0	--
silver redhorse	*Moxostoma anisurum*	0	--	0	--	0	--	1	61.3
shorthead redhorse	*Moxostoma macrolepidotun*	1	37	0	--	0	--	1	43.9
round goby	*Neogobius melanostomus*	21	4.9 (2.6-10.2)	4	3.5 (3.0-3.9)	7	3.7 (3.5-3.9)	16	4.2 (3.0-5.5)
emerald shiner	*Notropis atherinoides*	1	6.1	0	--	1	9.2	1	11.3
golden shiner	*Notemigonus crysoleucas*	4	15.7 (31.1-17.0)	0	--	0	--	0	--
spottail shiner	*Notropis hudsonius*	0	--	2	10.2 (9.2-11.1)	9	1.4 (10.2-12.2	0	--
yellow perch	*Perca falvescens*	0	--	0	--	0	--	4	14.9 (14.6-15.3)
bluntnose minnow	*Pimephales notatus*	1	6.2	2	5.5 (4.4-6.6)	1	5.5	2	5.6 (3.8-7.3)
black crappie	*Pomxsis nigromaculatus*	0	--	3	22.2 (15.9-25.9)	1	6.5	0	--
	Total	**88**		**123**		**77**		**89**	

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 10 September 2015. 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)
yellow bullhead	*Ameiurus natalis*	0	--	0	--	0	--	1	36.2
freshwater drum	*Aplodinotus grunniens*	1	21.5	1	7.8	1	17.6	0	--
white sucker	*Catostomus commersoni*	6	29.2 (22.1-33.6)	1	33.1	2	33.7 (31.5 -35.9)	2	26.4 (21.3-31.5)
common carp	*Cyprinus carpio*	2	46.4 (34.4-58.3)	1	44.5	0	--	0	--
gizzard shad	*Dorosoma cepedianum*	0	--	0	--	4	11.8 (9.6-13.4)	2	12.6 (12.3-12.9)
muskellunge	*Esox masquinongy*	0	--	1	51.1	0	--	0	--
channel catfish	*Ictalurus punctatus*	0	--	0	--	1	57.5	0	--
brook silverside	*labidesthes sicculus*	0	--	1	6.5	0	--	0	--
pumpkinseed	*Lepomis gibbosus*	6	14.5 (12.1-16.0)	12	12.6 (6.2-15.8)	0	--	4	14.4 (6.4-17.4)
bluegill	*Lepomis macrochirus*	0	--	3	15.2 (13.5-18.2)	0	--	1	9.2
largemouth bass	*Micropterus salmoides*	3	26.8 (19.5-38.3)	3	20.0 (18.4-22.4)	2	11.0 (10.4-11.5)	6	9.3 (6.5-11.2)
white perch	*Morone americana*	3	7.7 (7.2-8.1)	2	17.6 (8.1-27.1)	4	11.6 (8.4-19.5)	2	8.6 (8.5-9.2)
white bass	*Morone chrysops*	3	24.6 (23.3-25.5)	0	--	0	--	0	--
round goby	*Neogobius melanostomus*	0	--	1	11.4	0	--	2	10.1 (9.5-10.6)
emerald shiner	*Notropis atherinoides*	0	--	1	10.5	0	--	0	--
golden shiner	*Notemigonus crysoleucas*	3	14.8 (13.6-15.7)	1	18.6	0	--	2	12.0 (8.5-15.5)
spottail shiner	*Notropis hudsonius*	3	11.5 (11.0-11.9)	2	10.9 (10.6-11.2)	12	10.8 (10.0-12.0)	4	10.9 (10.5-11.2)
yellow perch	*Perca falvescens*	8	15.2 (10.4-16.5)	14	14.3 (9.0-16.5)	6	16.6 (9.4-23.4)	9	17.4 (15.2-22.5)
flathead catfish	*Pylodictis olivaris*	1	35.0	0	--	0	--	0	--
walleye	*Sander vitreus*	5	29.0 (19.6-37.6)	0	--	5	21.5 (17.0-36.0)	0	--
	Total	**44**		**44**		**37**		**35**	

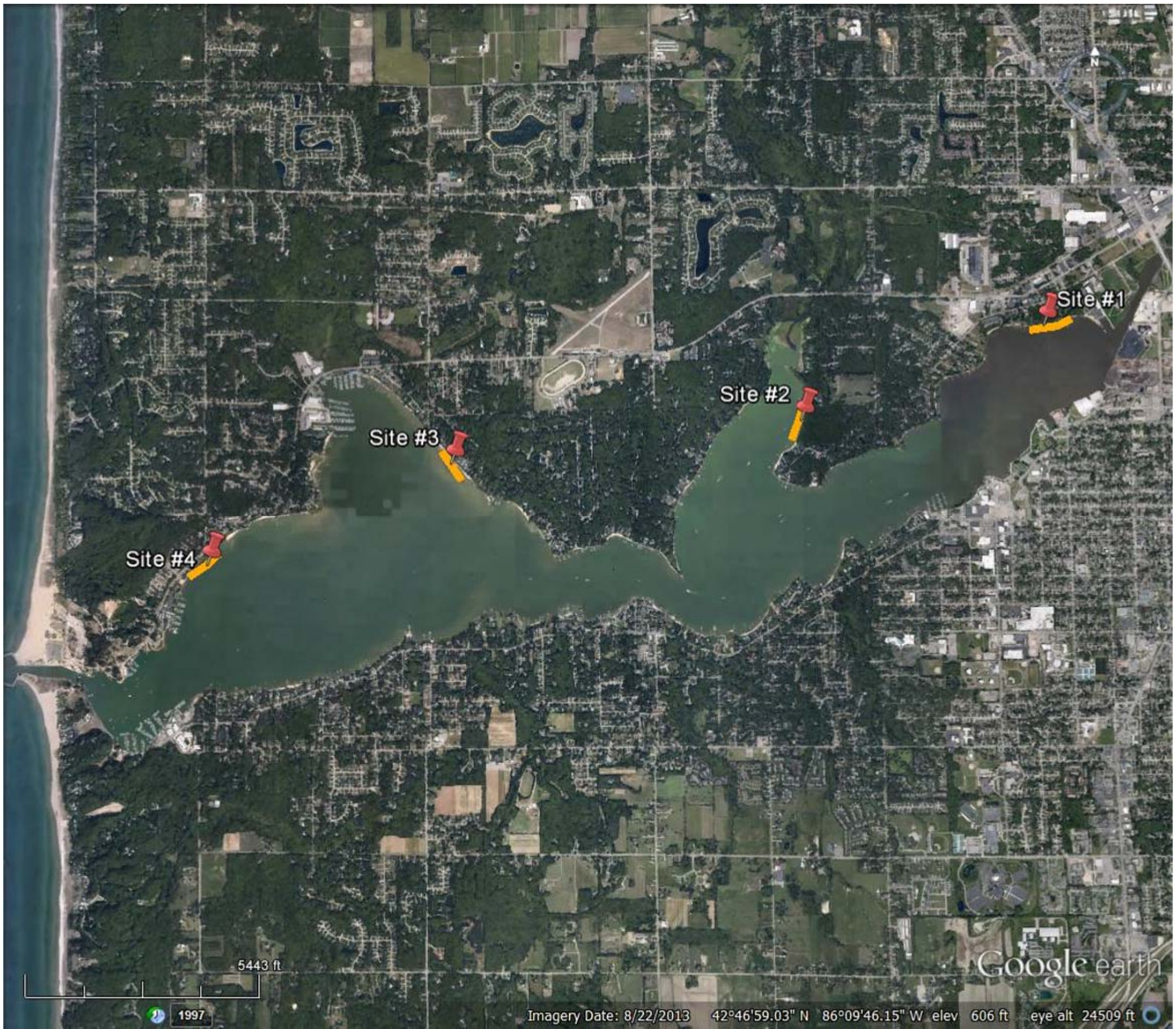

Figure 1. Map of Lake Macatawa (Ottawa County, Michigan) showing fish sampling sites. The orange transects depict where boat electrofishing was conducted at each site. Site #1 is closest to the Macatawa River and site #4 is closest to Lake Michigan.

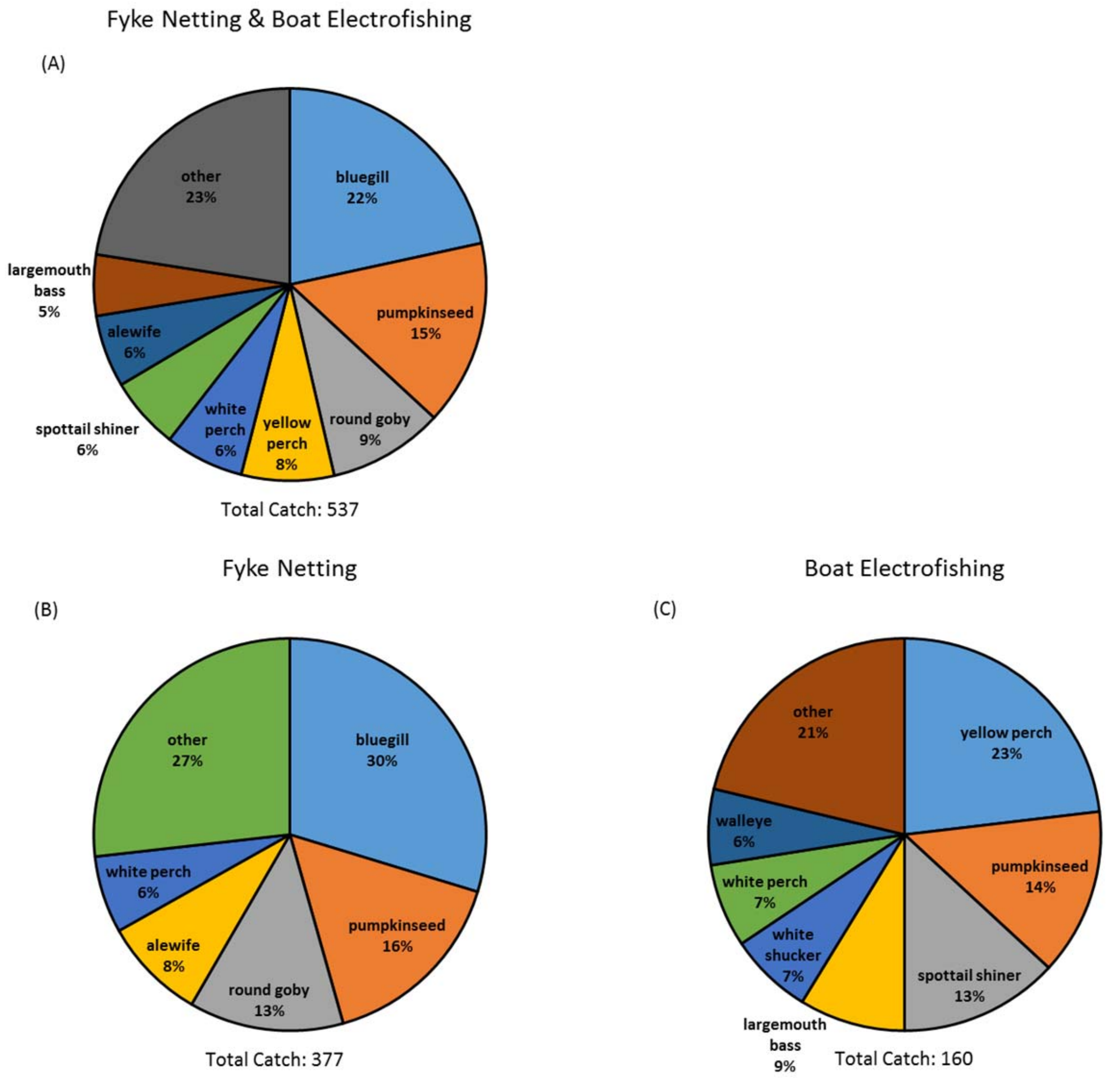

Figure 2. Fish species captured in littoral habitats of Lake Macatawa by (A) fyke netting and boat electrofishing (i.e., combined catch), (B) fyke netting (n = 12 nets), and (C) boat electrofishing (n = 4 transects) during September 2015. Catch data, including the species pooled in the “other” category, are reported in Table 4.

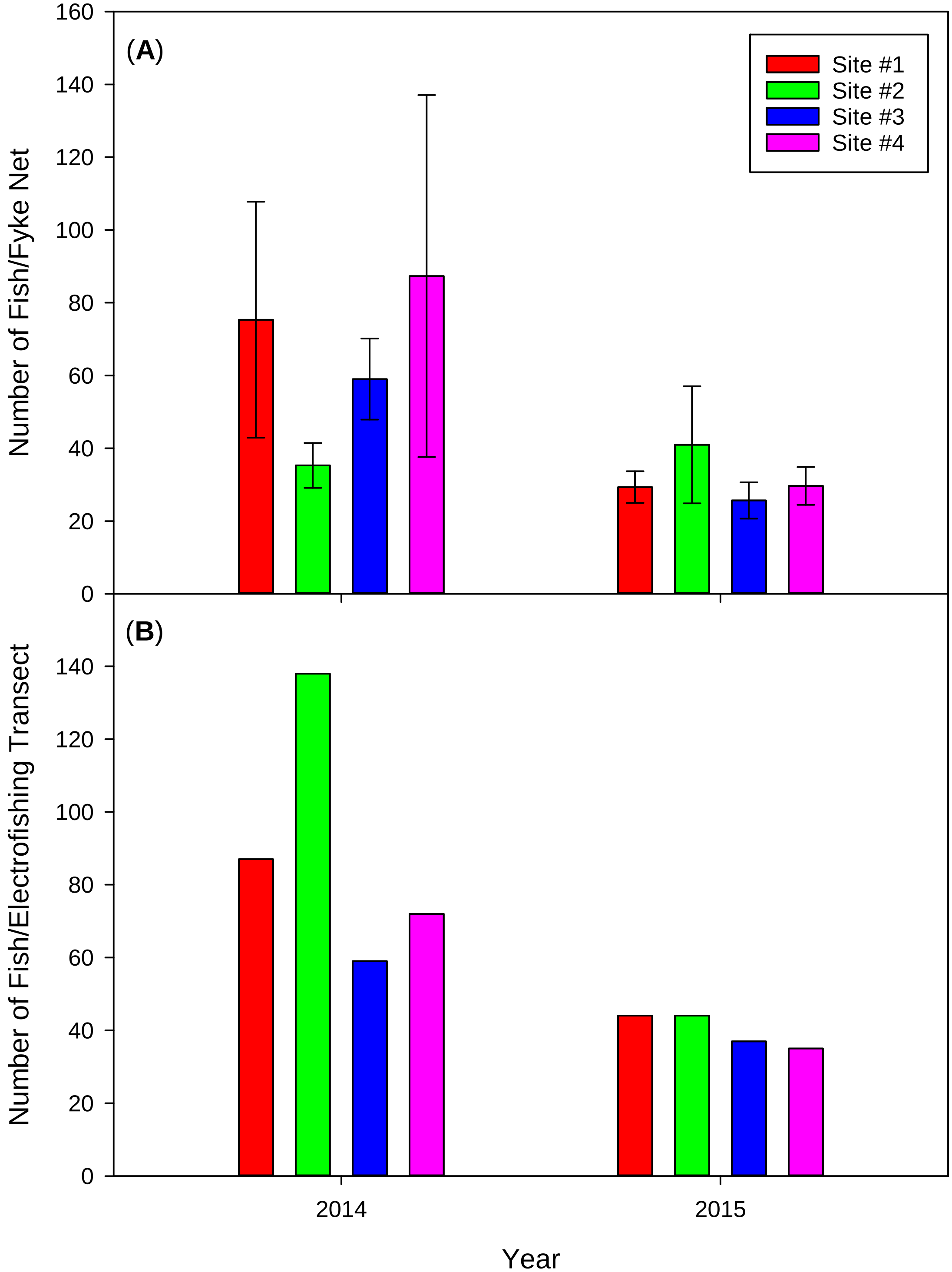

Figure 3. (A) Mean number (±1 standard error) of fish captured in fyke nets (*n* = 3 nets per site) and (B) number of fish captured during a boat electrofishing transect (*n* = 1 transect per site) in Lake Macatawa.

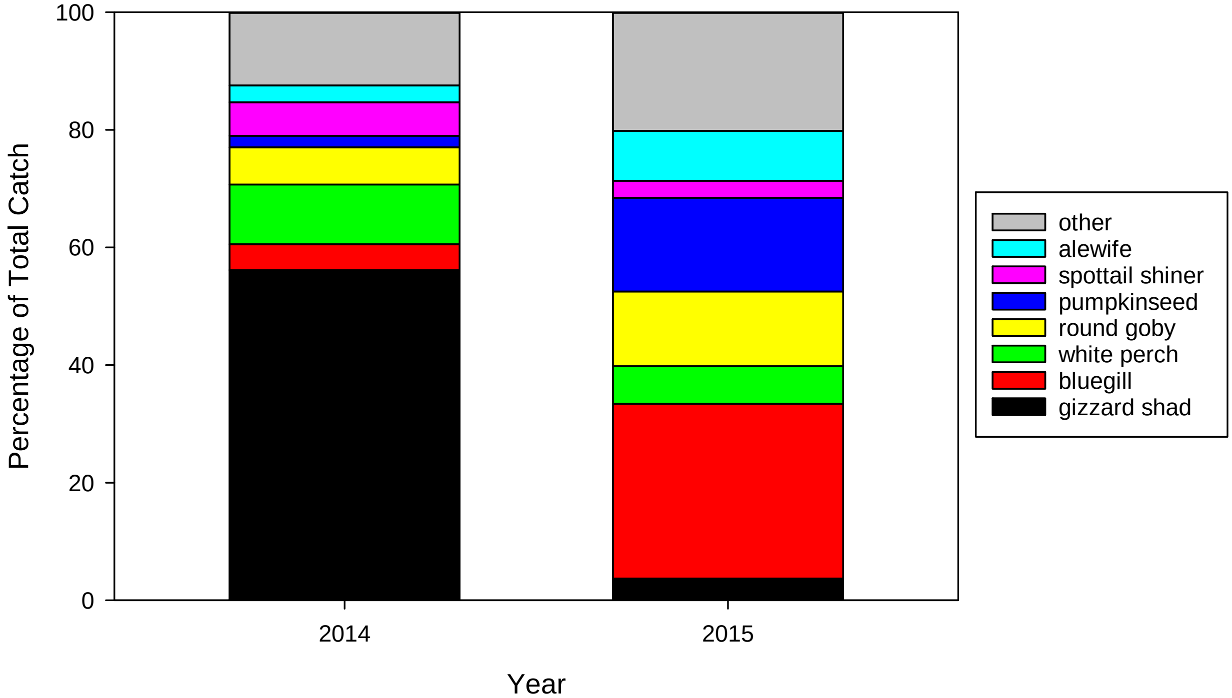

Figure 4. Fish species composition (pooled across sites) in fyke netting surveys for each sampling year. Note that the number of fish captured differed between years (Figure 3A).

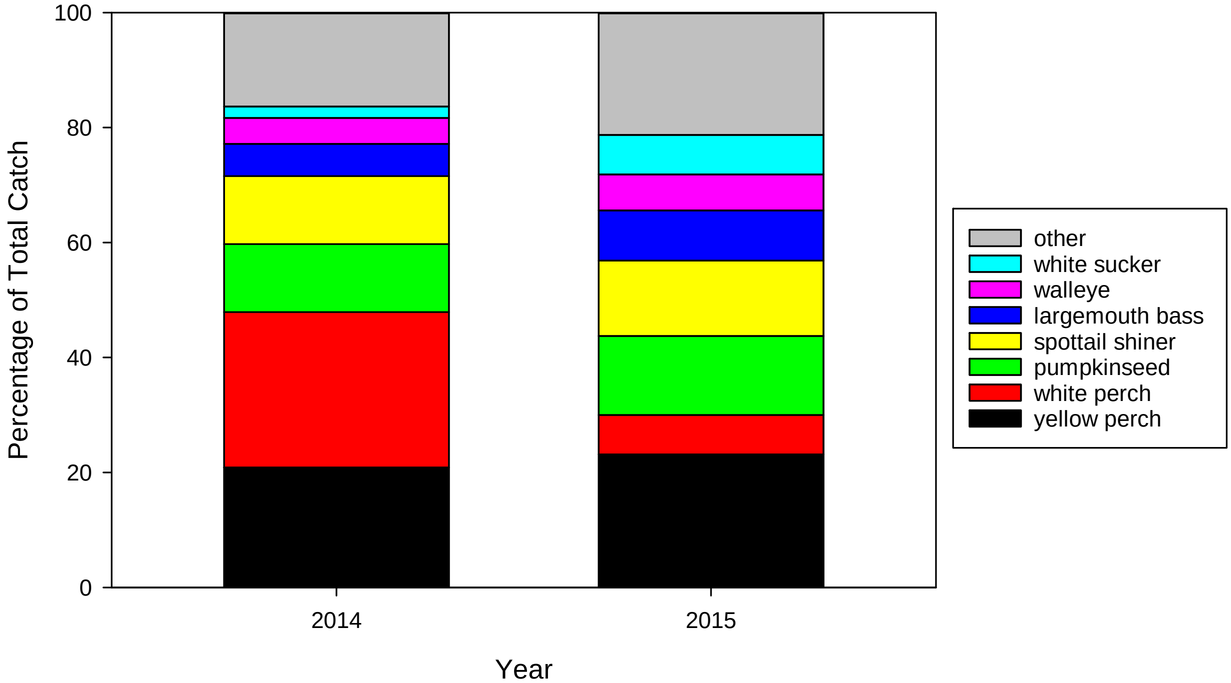

Figure 5. Fish species composition (pooled across sites) in boat electrofishing surveys for each sampling year. Note that the number of fish captured differed between years (Figure 3B).

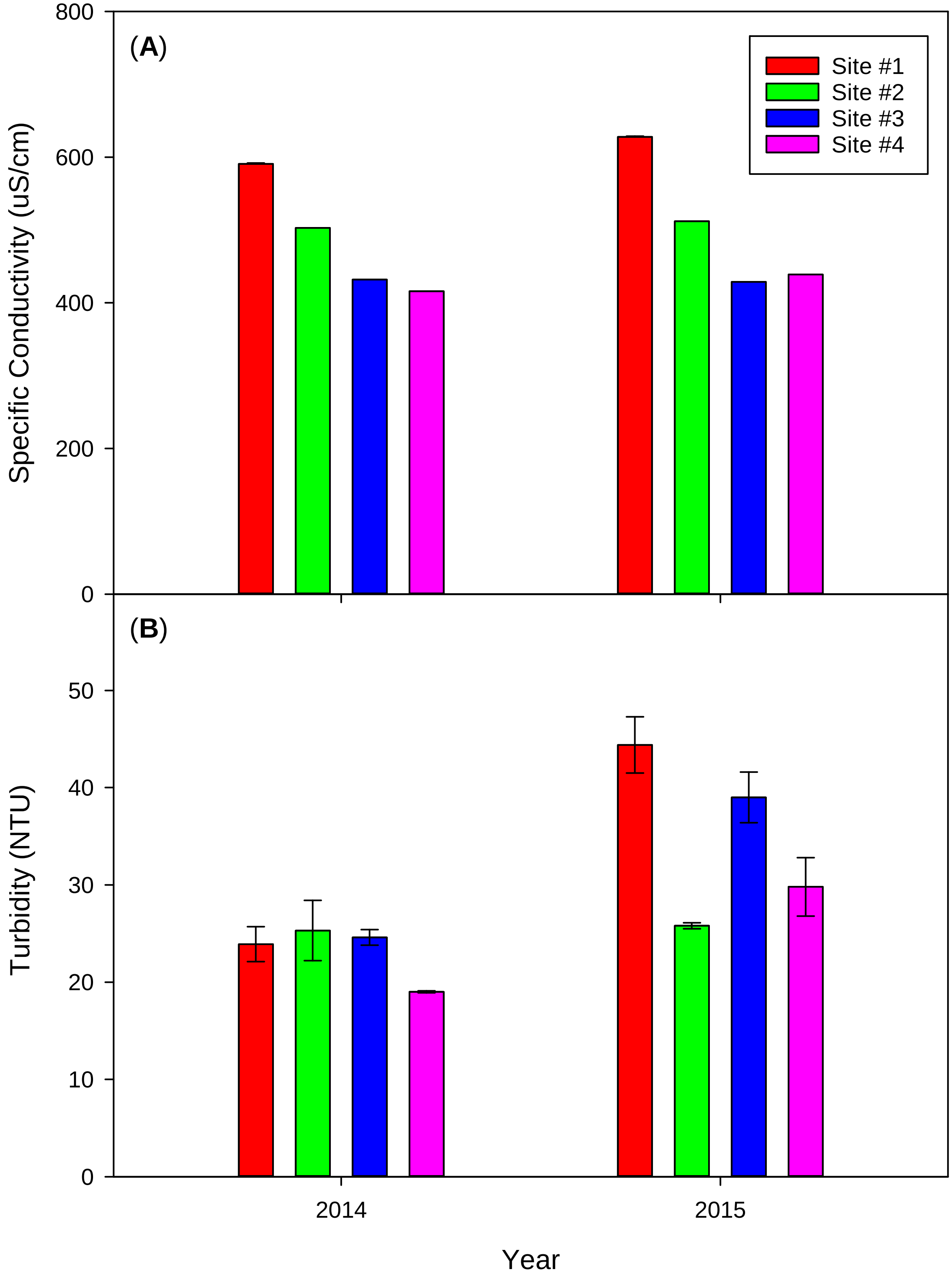

Figure 6. Mean (A) specific conductivity and (B) turbidity measured during fyke netting in Lake Macatawa. Error bars represent ±1 standard error (*n* = 3 nets per site), although they may to small to be visible for some means.