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MANAGEMENT BRIEF

Fish Community Responses to Submerged Aquatic Vegetation in Maumee Bay, Western Lake Erie

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Abstract

Submerged aquatic vegetation (SAV) in clearwater systems simultaneously provides habitat for invertebrate prey and acts as refugia for small fishes. Many fishes in Lake Erie rely on shallow, heavily vegetated bays as spawning grounds and the loss or absence of which is known to reduce recruitment in other systems. The Maumee River and Maumee Bay, which once had abundant macrophyte beds, have experienced a decline of SAV and an increase in suspended solids (turbidity) over the last century due to numerous causes. To compare fish communities in open-water (turbid) and in SAV (clearer water) habitats in this region, which is designated by the U.S. Environmental Protection Agency as an Area of Concern, and to indicate community changes that could occur with expansion of SAV habitat, we sampled a 300-ha sector of northern Maumee Bay that contained both habitats. Using towed neuston nets through patches of each habitat, we determined that areas of SAV contained more species and a different species complex (based on the Jaccard index and the wetland fish index), than did the open-water habitat (averaging 8.6 versus 5 species per net trawl). The SAV habitat was dominated by centrarchids, namely Largemouth Bass *Micropterus salmoides*, Bluegill *Lepomis macrochirus*, and Black Crappie *Pomoxis nigromaculatus*. Open-water habitat was dominated by Spottail Shiner *Notropis hudsonius*, Gizzard Shad *Dorosoma cepedianum*, and White Perch *Morone americana*, an invasive species. These results indicate that restoration efforts aimed at decreasing turbidity and increasing the distribution of SAV could cause substantive shifts in the fish community and address important metrics for assessing the beneficial use impairments in this Area of Concern.

Submerged aquatic vegetation (SAV) in shallow bays and estuaries near river mouths serves as important aquatic habitat and plays an important role in improving water quality (Bakker et al. 2013; Trebitz and Hoffman 2015). Submerged aquatic vegetation provides food and nesting material for waterfowl, reduces bank erosion by buffering wave energy, and reduces flow, which allows suspended sediments to settle out of the water column, thereby increasing water clarity (Carpenter and Lodge 1986; Perrow et al. 1999; Hering et al. 2006; Hestir et al. 2016). Submerged aquatic vegetation also serves as nursery habitat for juvenile fish by providing prey resources and protection (Boesch and Turner 1984; Werner and Gilliam

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1984; Kahn and Kemp 1985; Peterson 2003). Thus, wetlands and estuaries are important focal points for ecosystem restoration, particularly as these habitats are among the most degraded aquatic environments due to sedimentation from agriculture and changes in depth due to dredging for shipping channels (Edgar et al. 2000; Richards et al. 2008; Thrush et al. 2008). In addition, other activities such as bank stabilization with riprap and corrugated shipping bulkheads can further reduce habitat heterogeneity and support rapid riverine discharge of highly turbid water into estuarine and wetland habitats. Restoration of habitat can affect the entire aquatic community and thus enhance community diversity and ecosystem services in systems that have become degraded over time (Lotze et al. 2006; Trebitz and Hoffman 2015).

As a consequence of habitat degradation in many ports, harbors, and wetlands of the Laurentian Great Lakes, the USA–Canada Great Lakes Water Quality Agreement identified special Areas of Concern (AOC) including four along the Lake Erie shores of Ohio (OEPA 2016). For an AOC to be delisted by the U.S. Environmental Protection Agency, a series of 14 beneficial use impairments (BUIs) that need to be addressed are identified. Included are improvements in degraded fish and wildlife populations, benthos, and fish and wildlife habitat. There is good evidence that increases of water clarity and proliferation of SAV can enhance fish communities and habitat and improve this particular BUI (Cvetkovic et al. 2012; Grabas et al. 2012; Janetski and Ruetz 2015).

The main purpose of our study was to assess the fish community in areas with and without SAV in the Maumee River–Bay AOC (the lacustrine–freshwater estuary), and examine possible effects that restoration efforts may have on the area and BUIs. Due to the paucity of SAV in the open-water lacustrine areas of this AOC, we identified study sites in northern Maumee Bay with sufficient SAV. We quantified fish community differences in SAV habitat versus adjacent unvegetated habitat in relatively the same water depth. Environmental factors and benthic macroinvertebrate prey abundance were also measured and compared between the two habitats. We suggest that the fish community in SAV represents an assemblage that, if expanded through restoration, could lead to changes in metrics such as the lacustuary index of biotic integrity (L-IBI; Karr 1981; Thoma 2006; Ohio EPA 2014, 2016) and potentially affect this AOC delisting opportunity.

METHODS

The Maumee River watershed (17,114 km^2) is more than 90% row-crop agricultural or urbanized and contributes large amounts of sediment to Lake Erie (Shindel et al. 2002). Sedimentation contributes to the shallow depth of the bay (mean depth = 1.7 m: Herdendorf and Krieger 1989). These sediments are commonly resuspended during storm events and, despite the bay's shallow depth, the high sediment loading has contributed to the decline of native SAV abundance since the late 1880s (Herdendorf 1987). Thus, we conducted the study in a 300-ha (3 km^2) sector of northern Maumee Bay near Indian Island (41.7491, −83.4535; Figure 1) where sufficient SAV was present.

Fish abundance.— During late June and early July 2014, fish were collected from either turbid, open-water or SAV habitats. We used a surface-sampling, metal-framed neuston net (1 m deep × 2 m wide, 61 m head rope, 9.5-mm bar mesh body and 1-mm mesh cod end; Sea-Gear Corporation, Melbourne, Florida). The neuston net was used for fish collection in this area of the bay due to its average depth of 1–2 m and the difficulty that other capture methods would face in areas of dense SAV. Sixteen transects in each habitat type—open water and SAV—were sampled for a total of 32 collection transects. The locations for these transects within northern Maumee Bay were chosen by initially conducting a side-scan sonar traverse with a Humminbird 798ci side-imaging depth finder (Humminbird, Eufala, Alabama) and sampling with a vegetation

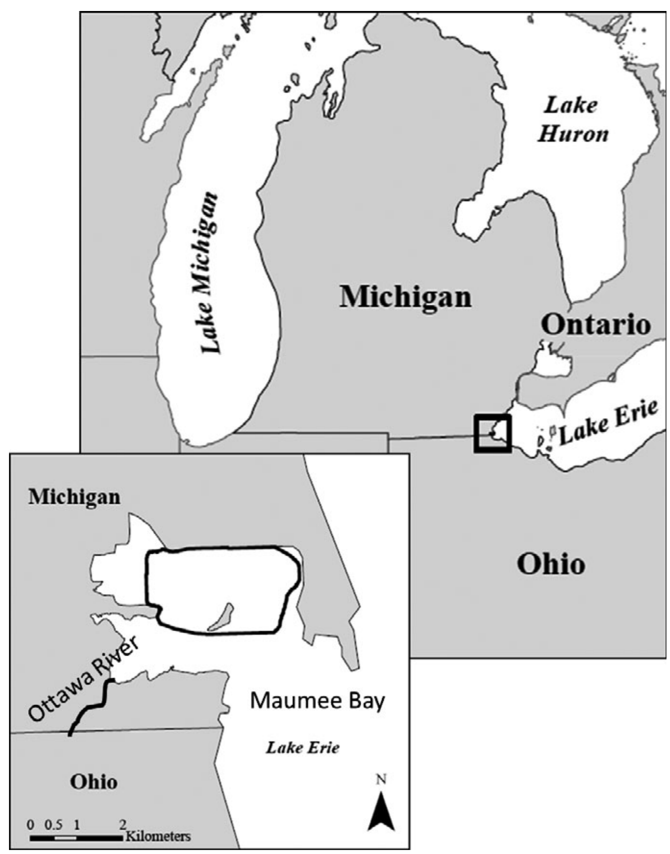

FIGURE 1. Maumee Bay in western Lake Erie. The 300-ha quadrant sampled in northern Maumee Bay is circled. The Maumee River enters the bay about 3 km south of the area depicted in the inset.

rake to confirm habitat type. Transects were conducted in a straight line for up to 300 m at a maintained speed of 2.2 m/s in order to reduce gear avoidance by the fishes (Meerbeek et al. 2002; Figure 2). However, transect samples were often less than 300 m because habitats were patchily distributed, and we needed to terminate a sample in order to not sample both habitat types in a single transect. Additionally, occasionally in SAV, a shortened sample was taken when tow velocity of 2.2 m/s could not be maintained. Captured fish were euthanized using a solution of tricaine methanesulfonate (MS-222), immediately frozen, and subsequently identified to species.

Catch per unit effort was calculated as the number of fish per 100 m. The CPUE, Shannon–Wiener diversity index, and species richness were compared between habitats using *t*-tests ($\alpha = 0.05$). Jaccard's community difference index was used to determine the similarity of the fish communities in the two habitats (Birks 1987; Real and Vargas 1996). The wetland fish index (WFI_{PA}), developed to assess wetland quality in the Great Lakes, was also calculated from presence–absence data (Seilheimer and Chow-Fraser 2006, 2007). To compute the WFI_{PA} between habitats, we used published parameters for Maumee Bay fishes listed in Table 3 of Seilheimer and Chow-Fraser (2007); for collected fishes not listed in the table, we substituted parameters for similar species as follows: parameters for Silver Redhorse *Moxostoma anisurum* were used for Quillback *Carpiodes cyprinus*, Bluegill parameters for Orangespotted Sunfish *Lepomis humilis*, Golden Shiner *Notemigonus crysoleucas* parameters for Redfin Shiner *Lythrurus umbratilis* and Rosefin Shiner *L. ardens*, Black Bullhead *Ameiurus melas* parameters for Yellow Bullhead *A. natalis*, and Tadpole Madtom *Noturus gyrinus* parameters for Stonecat *N. flavus*.

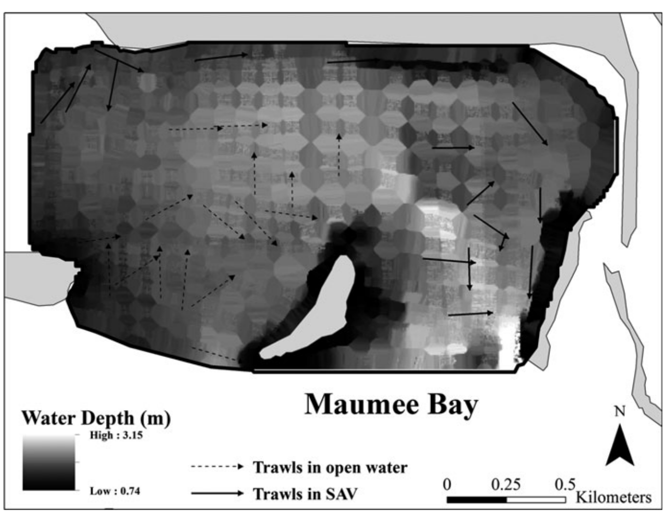

FIGURE 2. Locations of fish sampling transects in submerged aquatic vegetation (16 solid lines) and open-water habitat (16 dashed lines) using a 1 × 2-m neuston net in northern Maumee Bay. The length of each arrow indicates the approximate length and the arrowhead indicates the direction of the sampling transects. Water depth profile was determined from depth measurements with a Humminbird depth finder and interpolation with ArcGIS version 10.2.

Habitat characteristics: macrophyte and macroinvertebrate abundance.— In early July 2014, macrophyte and benthic macroinvertebrate samples were collected in this same sector of northern Maumee Bay. Submerged aquatic vegetation samples were collected at 20 random locations by scuba diving with a 0.36-m^2 square quadrat sampler; three haphazard subsamples (pooled) were taken at each location. Vegetation was identified to species, separated by taxon, dried for 72 h at 60°C to achieve a constant dry weight (Hengst et al. 2010), and then weighed to the nearest 0.01 g. The vegetation quadrat sampling allowed us to identify locations for the macroinvertebrate sampling in the different types of habitats. The three dominant habitat types were wild celery *Vallisneria americana*, variable pondweed *Potamogeton gramineus*, and areas devoid of SAV (Miller 2015). At five of these locations (randomly determined) per habitat type, macroinvertebrate samples were collected. Sediment grabs for macroinvertebrates were collected with a Petite Ponar 6-in (15 cm) sampler (Wildco, Saginaw, Michigan) and immediately preserved in 85% ethanol with Rose Bengal disodium salt (Fisher Scientific, Fair Lawn, New Jersey) to stain the specimens. Samples were rinsed in a 500-μm-mesh sieve (U.S. Standard Sieve Series, Chicago) before specimens were counted and identified to the family level. Densities of macroinvertebrates were converted to number of organisms per square meter, log transformed ($\log x + 1$), and compared among the three habitats using a one-way ANOVA and Tukey's honestly significantly different (HSD) post hoc tests ($\alpha = 0.05$).

To identify potential differences in the physical attributes of the unvegetated (open water) and SAV habitats, dissolved oxygen (DO), temperature, turbidity, and water depth were measured at each of the fish transects. Dissolved oxygen and water temperature were measured with a YSI Pro 20 sensor (Yellow Springs, Ohio). Turbidity was assessed by measuring Secchi disk depths, and water depth was determined from the Humminbird depth finder. Depth data were imported into ArcGIS, and a bathymetry layer was generated for the entire sector (ArcGIS version 10.2, Esri, Redlands, California). To assess whether these variables differed between the two habitats at the sites of the fish transects, *t*-tests were conducted ($\alpha = 0.05$).

RESULTS

Fish Abundance

Catch per unit effort of fishes in SAV habitat was 60% higher than in the open-water habitat, but the difference was only marginally significant ($t = -1.94$, df = 30, $P = 0.06$; Table 1). However, species richness was significantly greater in SAV, for which there was an average of

TABLE 1. Percent composition of fish (grouped by family) caught with a neuston net in submersed aquatic vegetation (SAV) and turbid open-water habitats in Maumee Bay of western Lake Erie (n = 16 trawls per habitat, NC = none collected).

Species	% composition of samples ± SE	
	Turbid (open water)	SAV
Atherinidae		
Brook Silverside *Labidesthes sicculus*	4.0 ± 3.9	NC
Catastomidae		
Quillback *Carpiodes cyprinus*	0.04 ± 0.01	NC
White Sucker *Catastomus commersonii*	0.1 ± 0.01	0.4 ± 0.2
Centrarchidae		
Rock Bass *Ambloplites rupestris*	NC	0.01 ± 0.01
Orangespotted Sunfish *Lepomis humilis*	0.01 ± 0.01	0.2 ± 0.1
Bluegill *Lepomis macrochirus*	4.9 ± 2.1	68.5 ± 4.5
Largemouth Bass *Micropterus salmoides*	0.2 ± 0.01	3.1 ± 1.0
Black Crappie *Pomoxis nigromaculatus*	NC	0.5 ± 0.2
Clupeidae		
Gizzard Shad *Dorosoma cepedianum*	14.8 ± 3.9	1.2 ± 0.8
Cyprinidae		
Goldfish *Carassius auratus*	1.1 ± 0.9	5.0 ± 2.4
Redfin Shiner *Lythrurus umbratillis*	0.01 ± 0.01	NC
Golden Shiner *Notemigonus crysoleucas*	0.01 ± 0.01	0.01 ± 0.01
Emerald Shiner *Notropis atherinoides*	1.5 ± 1.0	1.2 ± 1.1
Spottail Shiner *Notropis hudsonius*	57.5 ± 6.9	13.2 ± 3.9
Rosyface Shiner *Notropis rubellus*	1.2 ± 1.0	NC
Bluntnose Minnow *Pimephales notatus*	NC	1.1 ± 0.5
Fathead Minnow *Pimephales promelas*	NC	0.01 ± 0.01
Fundulidae		
Banded Killifish *Fundulus diaphanus*	NC	1.5 ± 0.7
Gobidae		
Round Goby *Neogobius melanostomus*	NC	0.01 ± 0.01
Ictaluridae		
Yellow Bullhead *Ameiurus natalis*	NC	0.01 ± 0.01
Channel Catfish *Ictalurus punctatus*	0.1 ± 0.01	0.01 ± 0.01
Stonecat *Noturus flavus*	NC	0.01 ± 0.01
Tadpole Madtom *Noturus gyrinus*	NC	0.01 ± 0.01
Lepisosteidae		
Longnose Gar *Lepisosteus osseus*	NC	0.01 ± 0.01
Moronidae		
White Perch *Morone americana*	14.5 ± 4.7	1.7 ± 1.0
Percidae		
Yellow Perch *Perca flavescens*	0.01 ± 0.01	0.2 ± 0.01
Logperch *Percina caprodes*	0.01 ± 0.01	2.1 ± 0.6
Scaenidae		
Freshwater Drum *Aplodinotus grunniens*	0.01 ± 0.01	NC
Total number of fish	2,871	4,435
Distance sampled with neuston net (m)	3,465	3,165
Average CPUE (number of fish/100 m) ± SE	82.8 ± 15.4	140.1 ± 29.6
Average species richness ± SE	5 ± 0.5	8.6 ± 0.6

8.6 species compared with five species in open water ($t = -4.23$, df = 30, $P < 0.0001$; Table 1). The open-water habitat was dominated by the midwater species: Spottail Shiner (65.4%), Gizzard Shad (21.6%), the invasive White Perch (7.4%), as well as Emerald Shiner (0.83%), and Rosyface shiner (0.21%). Submerged aquatic vegetation habitat supported three littoral species, namely Bluegill (71.4%), Largemouth Bass (3.1%), and Black Crappie (0.65%), as well as the surface-feeding invertivore Banded Killifish (1.9%), and the epibenthic Logperch (1.5%). Thus, the two habitats were dominated by different taxa such that the Shannon–Wiener diversity index was not different between the habitats ($t = 0.87$, df = 31, $P = 0.19$). However, the composition of fishes in the two habitats differed significantly based on the Jaccard index ($J = 0.34$, $P = 0.016$). Likewise, the WFI_{PA} in open-water habitat was 2.52 and 2.95 in SAV.

Habitat Characteristics: Macrophytes and Macroinvertebrates

Quadrat sampling at the 20 random scuba locations yielded five species of SAV: wild celery, variable pondweed, leafy pondweed *Potamogeton foliosus*, muskgrass *Chara vulgaris*, and sago pondweed *Potamogeton pectinatus*. Of the 14 sampling locations with SAV, wild celery was the most abundant species, making up 73.4% of the total biomass, followed by variable pondweed (21.8%). When SAV was present total biomass averaged 55.9 g dry weight/m^2 (SE = 9.9, $n = 14$).

In these three habitat types, the dominant macroinvertebrate taxa were chironomids and oligochaetes, comprising, on average, 60.4% and 26.3% of the total macroinvertebrate community, respectively (Figure 3). No significant difference in density was detected among habitats for each taxon (chironomids: $F = 1.00$; df = 2, 14; $P = 0.39$; oligochaetes: $F = 2.92$; df = 2, 14; $P = 0.09$) despite a tendency to harbor more benthic organisms in turbid waters. Despite there being differences in SAV density, species biomass, depth, and location of the different habitats, there was no apparent difference in available benthic food resources for the fish species across habitats.

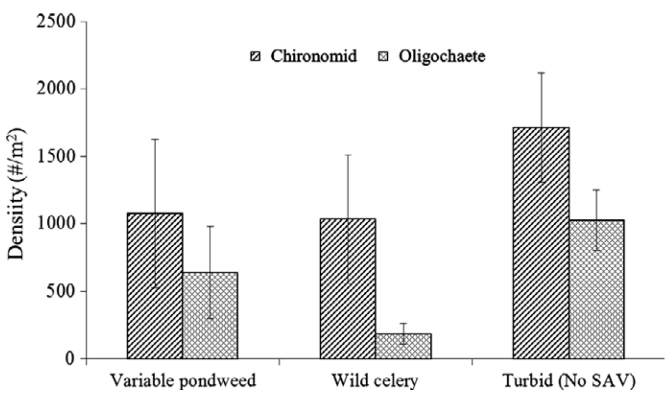

FIGURE 3. Density (mean number of organisms/m^2 ± SE) of chironomids and oligochaetes, the dominant macroinvertebrate taxa, in three dominant habitat types in northern Maumee Bay determined from Ponar samples, $n = 5$ per habitat.

Water clarity (determined at the time of fish collections) in the vegetated and open-water habitats differed significantly. Secchi disk depths were greater inside the SAV habitat (mean = 103 cm, SE = 7.4, $n = 16$) than in the open-water locations (mean = 50.3 cm, SE = 3.2, $n = 16$; $t = -6.55$, df = 30, $P < 0.0001$). Thus, differences observed in fish communities between SAV and open-water habitats could also be attributed to these differences in water turbidity. Average water depth in the fish transects from the SAV habitat was 1.44 m, while in the open-water habitat it was 1.46 m; there was no significant depth difference between transects in these two habitats ($t = 0.91$, df = 30, $P = 0.80$; see Figure 2 for GIS map of depth and transects). Neither water temperature nor DO levels were significantly different between the two habitats (temperature: $t = 0.35$, df = 30, $P = 0.64$; DO: $t = 0.93$, df = 30, $P = 0.82$).

DISCUSSION

Fish species richness was substantially higher in northern Maumee Bay SAV ($\bar{x} = 8.6$ species per trawl) than in nearby unvegetated and more turbid open-water habitat ($\bar{x} = 5$ species per trawl). The community composition of fishes in the two habitats was consistent with expected habitat use by these species. For example, centrarchids are often associated with SAV (Werner et al. 1983). In Maumee Bay SAV, the fish community was dominated (75.3%) by centrarchids, which were rare (3.5%) in turbid, open water (Table 1). In contrast, the open-water habitat harbored predominantly Gizzard Shad, Spottail Shiner, and White Perch, which, as in other systems, were rare in SAV (Creque and Czesny 2012; Kerr and Secor 2012). Indeed, these three species represented only 9.5% of the fish collected in SAV samples. In addition, the average Secchi disk depths was 1 m in SAV beds and 0.5 m in open water. Reduced visibility can act as a predation risk refuge for some species, so we could not explicitly differentiate the relative mechanistic effects of SAV and turbidity changes on the fish community; this would be best determined in a manipulated field experiment. Although the locations of the sampling transects (Figure 2) could lead one to interpret that there may be three sampling clusters—two areas with SAV and the locations without SAV—habitat characteristics between the two perceived SAV regions were similar (depth and vegetation type); additionally, the fish communities between the two habitat types (with SAV and without SAV) were clearly different.

The computed WFI_{PA} scores—2.92 in SAV and 2.52 in open water—also indicate that SAV is a higher quality habitat for fishes than are turbid open waters. These scores match well with the water quality index (WQI) of Seilheimer and Chow-Fraser (2006). Although the absolute results cannot be directly compared, the change in WFI_{PA} is substantive, suggesting that even proliferation of

SAV can have marked changes in the fish community. Seilheimer and Chow-Fraser (2006) demonstrated a nonlinear (asymptotic) relationship between the richness of SAV species and WFI_{PA}, in which the greatest increase in WFI_{PA} occurred when SAV species richness increased from zero to five species (Figure 4 in Seilheimer and Chow-Fraser 2006). In northern Maumee Bay, two species dominate (wild celery and variable pondweed), but five species were collected in quadrat sampling. The observed results suggest that restoration efforts to promote SAV in Maumee Bay could lead to better fish community metrics (e.g., L-IBI) and water quality (reduced turbidity) for addressing some BUIs in this AOC.

A cautionary note for any future Lake Erie wetland restoration initiative is that successful reproduction of herbivorous Grass Carp *Ctenopharyngodon idella* (Chapman et al. 2013; Embke et al. 2016) has been detected and potentially threatens to negatively affect SAV restoration efforts (Madsen 2000). Mitzner (1978) reported that the first introduction of Grass Carp in an Iowa reservoir caused a reduction of SAV by 91%. Similarly, removal of 3,600 ha of SAV from a Texas reservoir in 1981 by Grass Carp in 1 year also resulted in a substantial decline in the biomass of several sport fish species, including Bluegill and Black Crappie, along with the decline of age-1 and older Largemouth Bass (Bettoli et al. 1993).

Clearly, Maumee Bay is a degraded system with a persistent influx of nutrient-rich and sediment-laden water from the Maumee River (Richards et al. 2008) (Figure 1). Additional influence of suspended sediments from the Ottawa River, wind-driven resuspension, and anthropogenic activities support the maintenance of the degraded condition. However, where abiotic and biotic conditions are capable of supporting even disturbance-tolerant SAV, fish communities using this habitat are markedly different from those in close-proximity habitat without SAV, and they consist of taxa indicative of an improved wetland community (Casselman and Lewis 1996). These community differences suggest that mitigation strategies to reduce suspended sediment (Canfield et al. 1985; Bakker et al. 2013) could lead to increased distribution of SAV in the Maumee AOC with accompanying shifts in the fish community, potentially affecting the BUI metrics used to assess water quality characteristics of this system.

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