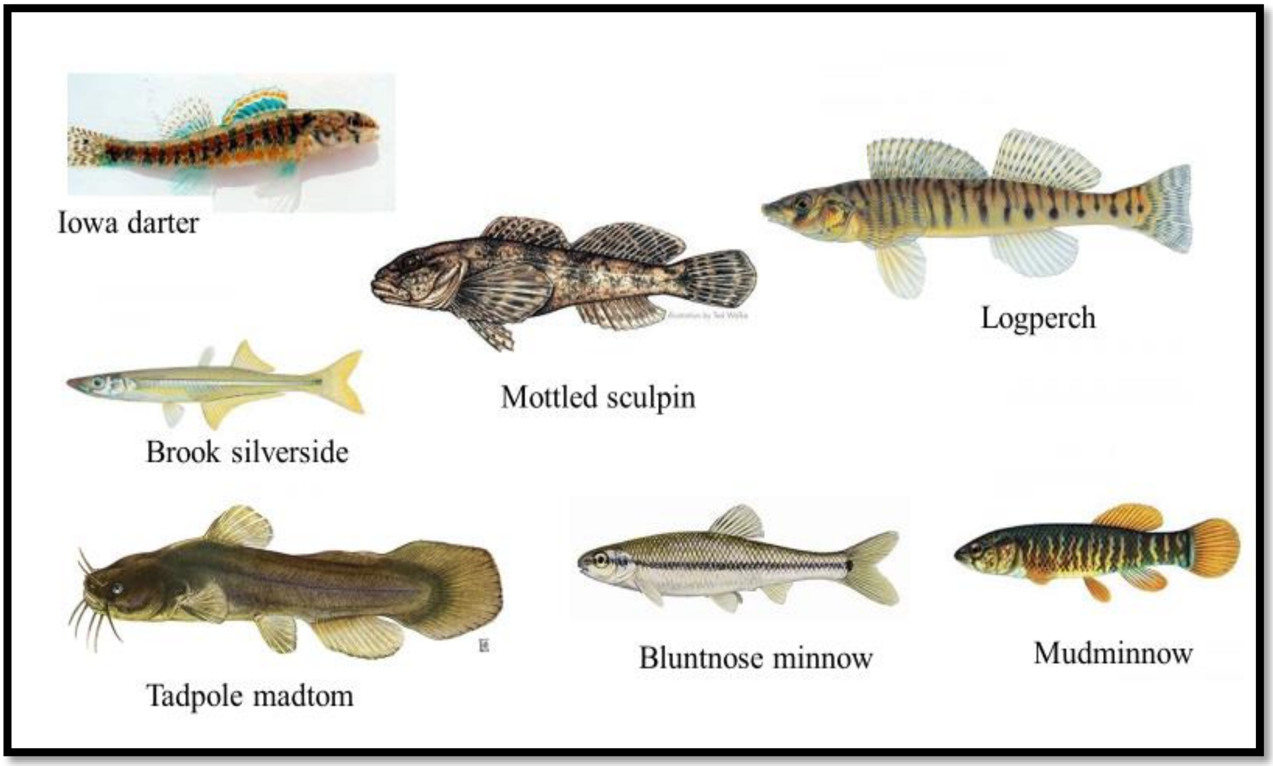
Littoral Zone Fishes of the Yahara Chain of Lakes



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Abstract

Fish populations in Lake Mendota, Lake Monona, Lake Waubesa and Lake Kegonsa were sampled to identify species within various nearshore habitats and to assess potential factors that may affect species distributions. Lake Mendota and Lake Monona were sampled at 20 sites each in 2017 using wadable DC electroshocking gear and targeting smaller-bodied fish. Lake Kegonsa was sampled at 18 sites in 2019 and Lake Waubesa at 18 sites in 2020 using the same electroshocking gear. The surveys were also useful for reviewing the status of environmentally sensitive and uncommon species that were previously found in the lakes. With the exception of the tadpole madtom (*Noturus gyrinus*), the status of seven other small littoral zone species that had disappeared from the Yahara Chain of Lakes remain unchanged. None were found. The tadpole madtom was recently discovered at one site in Cherokee Marsh and at two sites in Lake Kegonsa. Other small nongame fish species, including the Iowa darter (*Etheostoma exile*), displayed a clear preference for cobble-gravel shoals. However, this habitat type is now uncommon in the lakes as most shorelines are armored with riprap and to a lesser extent seawall. Our data suggests that in addition to widely accepted environmental factors such as eutrophication, invasive Eurasian watermilfoil, and numerous piers, these small nongame fish species are also susceptible to sustained high water levels combined with shoreline armoring. The pattern is similar for all four lakes. Most littoral zones that are lined with boulder riprap and are primarily inhabited by green sunfish (*Lepomis cyanellus*), yellow bullhead (*Ameiurus natalis*), juvenile smallmouth bass (Micropterus dolomieu), bluegill (*Lepomis macrochirus*) and juvenile largemouth bass (*Micropterus salmoides*).

Introduction

Lake assessments are typically based on trophic state indicators (i.e., TSI secchi water clarity, TSI phosphorus and TSI chlorophyll), macrophyte surveys, plankton analysis, and sportfish population inventories. Focusing on water quality is understandable given the pervasive threats and impacts to the Madison lakes from primarily agricultural phosphorus loading and urban runoff (Kara et al. 2014, Lathrop 2007). However, important ecosystem indicators such as nearshore fish populations are often overlooked in lake assessments.

Nongame fish species are rarely surveyed since they offer no perceived economic benefit compared to more familiar gamefish populations. Some nearshore fish species are very sensitive to environmental degradation and have been described as “canaries in the coal mine” (Gaumnitz 2005). Small nongame fish are important food web links and population declines can reveal environmental stresses that traditional lake monitoring methods overlook. Nearshore fish surveys can also be useful for gamefish management since juvenile stages of popular sportfish are detected in these areas as well.

The status of Lake Mendota nongame fish species was assessed in detail during the early 1980's (Lyons 1989). Eight species appeared to have disappeared since earlier surveys: the pugnose shiner (*Notropis anogenus*), common shiner (*Luxilus cornutus*), blackchin shiner (*Notropis heterodon*), blacknose shiner (*Notropis heterolepis*), tadpole madtom (*Noturus gyrinus*), banded killifish (*Fundulus diaphanus*), blackstripe topminnow (*Fundulus notatus*), and fantail darter (*Etheostoma flabellare*). Their disappearance coincided with the colonization and explosive expansion of the invasive aquatic plant Eurasian watermilfoil (*Myriophyllum spicatum*) in the lake in the late 1960's and early 1970's.

Besides invasive plants such as Eurasian watermilfoil, other habitat factors can also affect environmentally sensitive nongame fish. For example, large piers can destroy fish habitat by shading aquatic plants (Garrison et al. 2005, Radomski 2010). Shoreline development and bank armoring can modify the terrestrial-aquatic transition zone to the detriment of nearshore species. Habitat disruption can strongly affect nongame fish species even in lakes without water quality problems associated with cultural eutrophication.

A 2004 survey of 13 southeast Wisconsin glacial lakes, exhibiting mesotrophic conditions, revealed significant declines of a number of small nongame species that inhabit nearshore areas (Marshall and Lyons 2008). The statistically significant declines had occurred in most of the 13 lakes between the 1970s and 2004. Water quality in these lakes did not change significantly over that time frame but rather the amount of shoreline development increased significantly. In some of these lake, Eurasian watermilfoil also reached nuisance levels. Species declines included the banded killifish, State Threatened pugnose shiner, blackchin shiner, blacknose shiner, State Special Concern least darter (*Etheostoma microperca*) and State Special Concern lake chubsucker (*Erimyzon sucetta*). The study demonstrated that native species declines correlated with increased pier densities.

Climate Change has compounded these types of environmental stressors in the Yahara River Watershed with increased precipitation and nutrient loading. Within the backdrop of a lake water levels regime established in the 1970s, increased surface runoff has contributed to severe flooding and habitat changes in nearshore areas. (Chen et al. 2019, Dane County Land and Water Resources Department 2010).

The purpose of this study was to assess the current distribution and status of small-bodied, nearshore fishes in the four main lakes of Yahara Lakes Chain: Mendota, Monona, Waubesa, and Kegonsa. Lakes Mendota and Monona, as well as Lake Wingra, have been regularly sampled for small fishes with beach seines on an annual basis for over 25 years by the University of Wisconsin-Madison Long-Term Ecological Research (LTER) Program, but Waubesa and Kegonsa have seen very few small-fish surveys since the 1940's and 50's. In this study we employed a small tow barge electroshocker while wading, a technique more effective than beach seining for collecting fish in areas with complex habitat and extensive rocks, aquatic plants, or woody debris. Each lake was sampled at multiple sites following with the same equipment, crew, and standardized protocols so that results could be compared within and among lakes and with previous surveys.

Methods

A towed DC electroshocking barge was used for all nearshore fish sampling. The unit was operated around 160 volts and 3.5 amps. Two anodes were employed for sampling Lakes Mendota and Monona. For Lake Kegonsa and Lake Waubesa, a single anode was employed while wading parallel to shore in water less than 4' deep, and an attempt was made to collect all fish observed. Basic information on site conditions consisted of measuring water temperature and dissolved oxygen (YSI Pro ODO optical meter) and specific conductance (Extech). Notes on habitat were recorded for each site including amounts aquatic vegetation and woody debris, etc. Sites were not randomly selected but rather reflected historic nearshore sampling sites, other natural sites, or sites that had to be negotiated within densely populated piers. Electroshocking distances ranged from about 75 meters to 150 meters depending on obstructions, such as piers, or water depths too deep to safely sample. The four lakes are heavily developed with most shorelines armored with either riprap or to a lesser degree seawall. Efforts were made to sample natural shorelines and shallow shoals so that the amount of effort for each habitat type within the lakes is not comparable. Cobble-gravel shoals include areas where water depths gradually increase from very shallow nearshore areas and with substrate composed of natural rock of varying sizes. Sandy shoals, also relatively rare, were not considered in this habitat type. Water depths at riprap sites are typically relatively deep next to shore, sometimes a meter or greater. Other is a term used in this report to reflect sites without riprap that were mostly undeveloped, although water depths were often much greater than found in rocky shoals. Cobble-gravel shoals are uncommon in the Yahara Chain of Lakes and are mostly associated with river inlets and outlets, other small tributaries and parks. Occasionally, riprap was constructed above the waterline and had no direct impact on habitat (Figure 20). In this case, the site was counted as shoal since the water was very shallow. Aquatic plant beds were not often abundant in nearshore areas in any of the lakes likely due to scouring, although we were unable to sample weedy bays because substrates were too soft for wading.

Results

Lake Mendota Findings

Twenty sites were sampled on Lake Mendota July 11, July 25 and July 30, 2017 (map Figure 1). Water levels exceeded the long-term median from about 0.5' to 1.1' during the survey (Figure 2). Water temperatures ranged from 24.3 – 29 C. Dissolved oxygen ranged from 6.7 to 16.3 mg/l with the latter supersaturated concentration a result of a wind driven Cyanobacteria bloom. Specific conductance levels ranged from 459 to 495 uS/cm. Most shorelines were armored with riprap and water depths next to shore were relatively deep. Nearshore water depths all locations were higher than the long-term median values recorded during the survey. Rocky shoals were very scarce in the lake. Figure 3 displays actual water sampling depths per site (bars) along with long-term median water levels (markers) at three- and six-feet distances from the water edge. Woody debris was scarce except along publicly owned undeveloped shorelines.

A total of 12 native species were collected with only three considered small nongame fishes; mottled sculpin, logperch, and bluntnose minnow. Figure 4 displays the relative frequency of occurrence for the top five native species that were collected. Smallmouth bass was found at the most sites. Capture rates of native species around Lake Mendota was generally lower than other three lakes. Species richness was greater within rocky shoals versus riprap and riprap combined with "other" natural sites (Figure 5). Environmentally sensitive species collected from Lake Mendota were rock bass, smallmouth bass and mottled sculpin. Two fish collections of interest included juvenile longnose gar that were found at six sites and abundant young of year common carp. Immature common carp were found at two sites on the north end of the lake, indicating significant recruitment. DNR regulations list both species as "rough fish" but the longnose gar is an important and desirable predator whereas the common carp is a well-established invasive species that continues to pose lake management challenges.

Figure 1: Map of Lake Mendota sampling locations

Figure 2: Lake Mendota water levels during the survey. Stars indicate electroshocking dates.

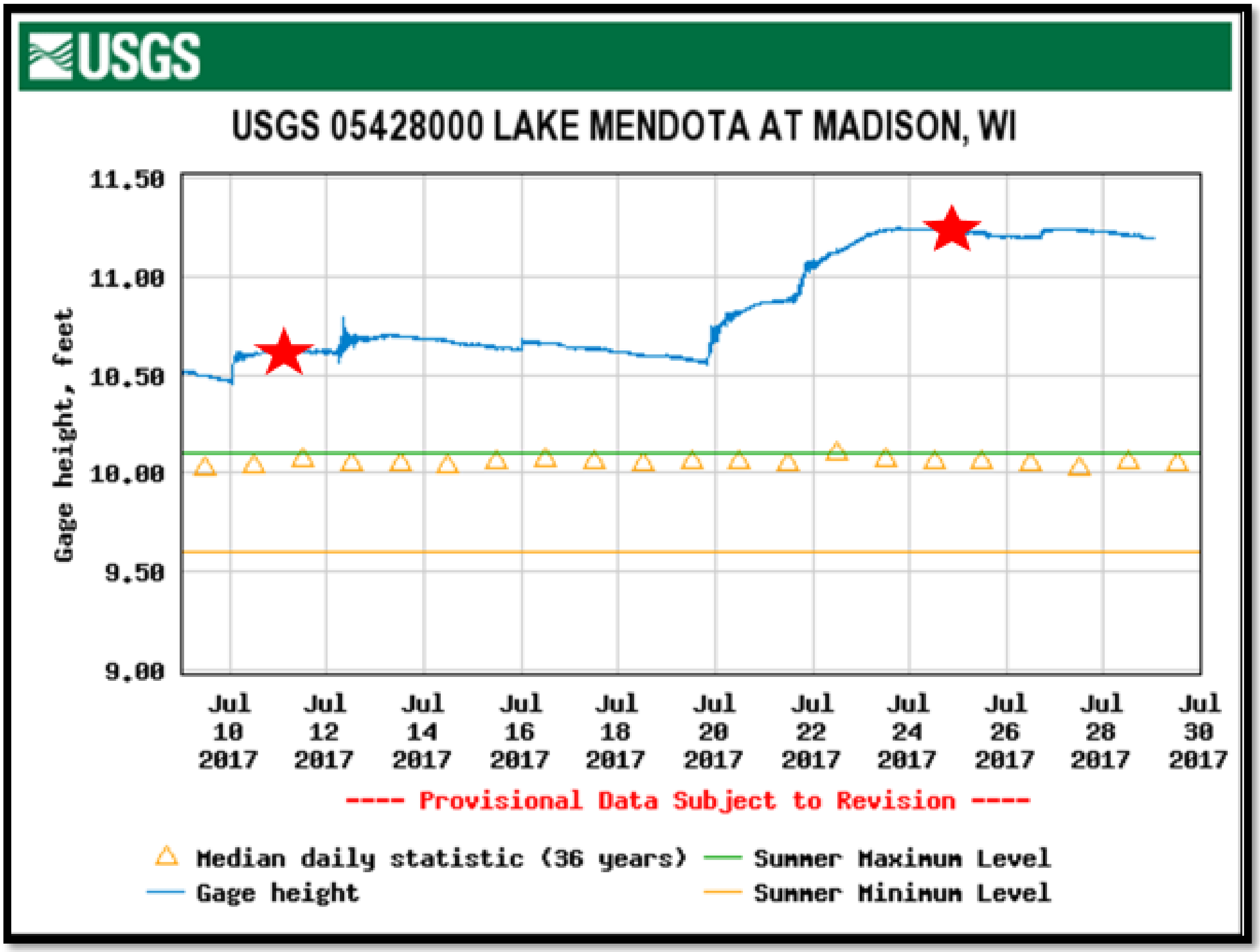


Figure 3: Measured Lake Mendota nearshore depths (bars) at sampling sites compared with markers adjusted for long term median water levels

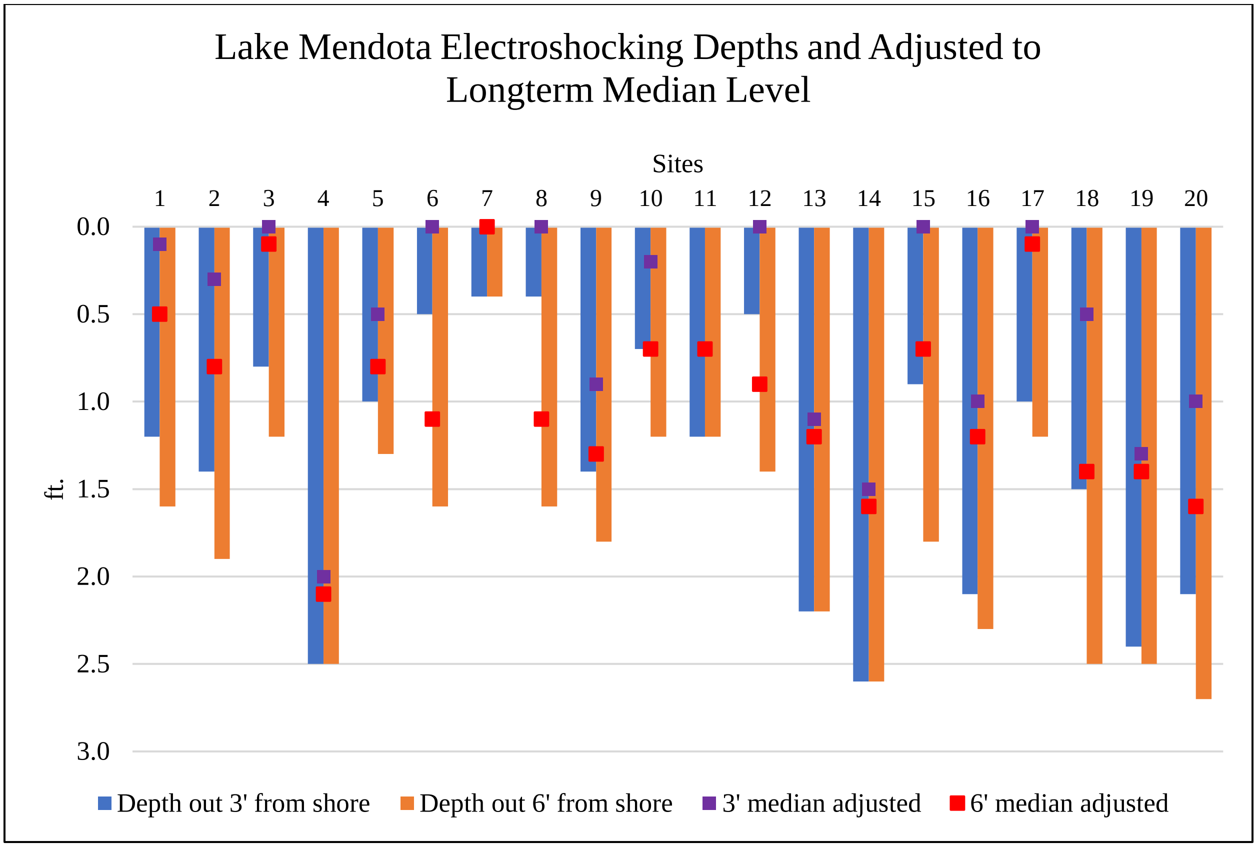


Figure 4: Dominant nearshore fishes in Lake Mendota July 2017

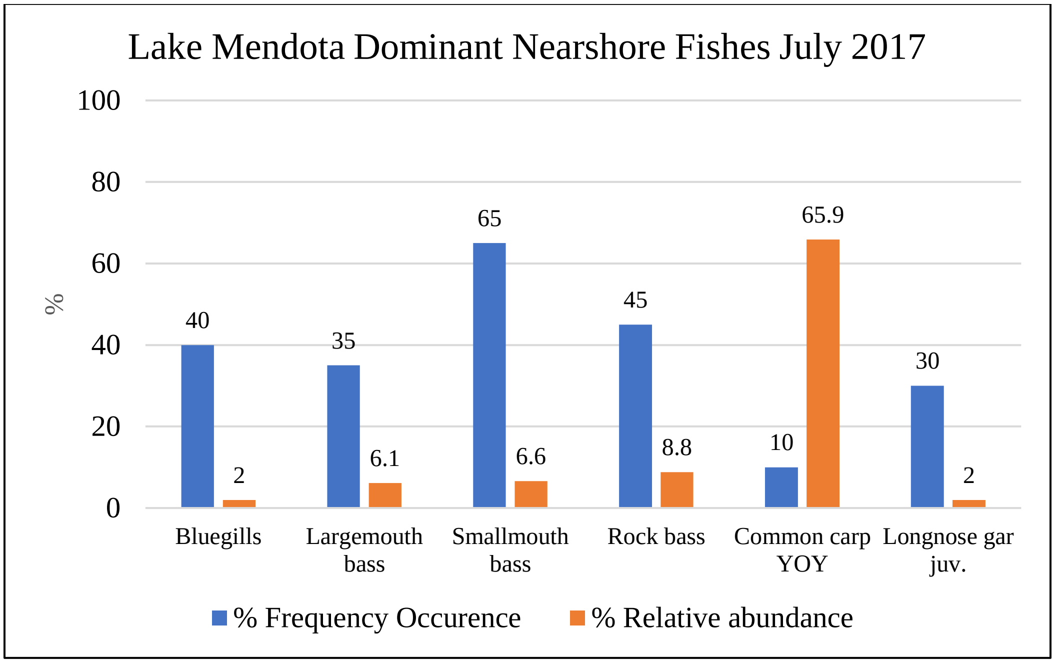
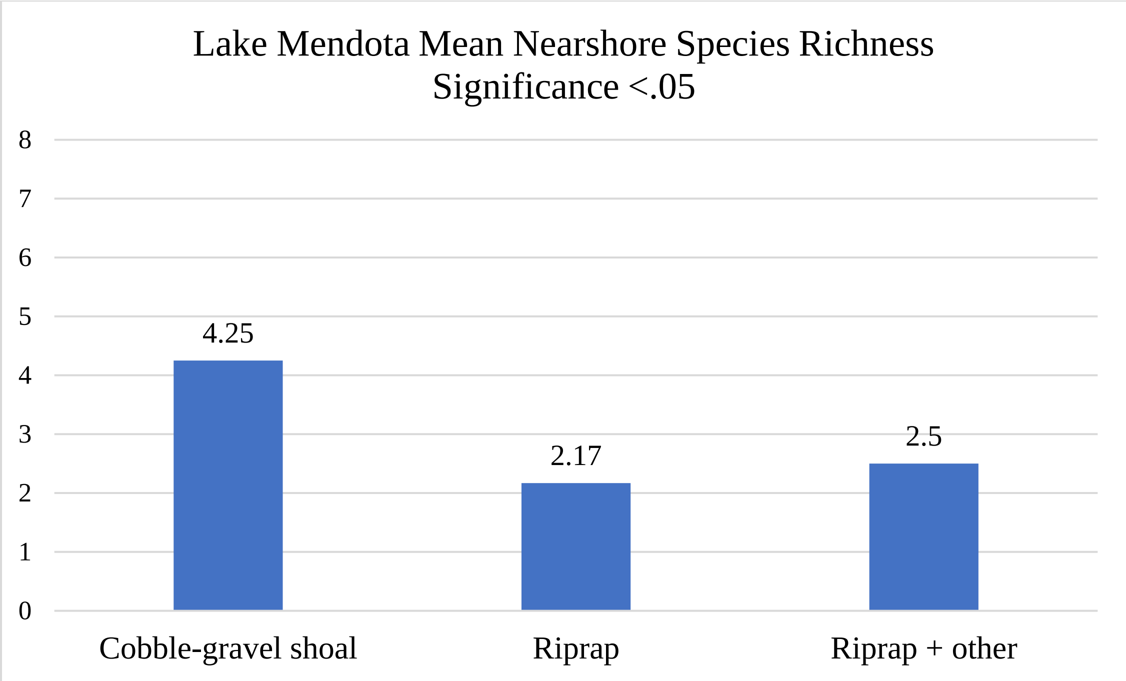


Figure 5: Native species richness among habitat types



Shoal (N = 4) versus riprap (N = 6): t = 2.68221, p = .027831, $p < .05$ significant

Shoal (N = 4) versus riprap + other sites (N = 16): t = 2.56796, p = .019358, $p < .05$ significant

Lake Monona Findings

Lake Monona was sampled on June 21 and 27, 2017 at 20 sites (map Figure 6). Water levels exceeded the long-term median levels by about 0.7' during the surveys (Figure 7). Water temperatures ranged from 20.3 – 24.1 C. Dissolved oxygen levels ranged from 7.7 to 16.1 mg/l with the latter supersaturation measurement recorded during a major Cyanobacteria bloom. Specific conductance levels ranged from 495 to 596 *u*S/cm. Shorelines at most sites were heavily armored with riprap and one site included a seawall. No fish were found along the seawall section at that sampling station. Nearshore cobble-gravel shoals were very scarce around the lake. A total of sixteen species were collected from Lake Monona nearshore zones during two survey dates. We found six small nongame fish species including mottled sculpin, Iowa darter, spotfin shiner, bluntnose minnow, Johnny darter, and logperch. These fish were primarily found in shallow rocky areas along the south shoreline. Woody debris was scarce except along public shorelines. Five captured species are designated environmentally sensitive; muskellunge (but this fish had been stocked), rock bass, smallmouth bass, mottled sculpin and Iowa darter. Figure 8 displays the site frequency of the top five species sampled. The results demonstrate the abundance of bluegills in the lake. Figure 9 demonstrates greater species richness within cobble-gravel shoals compared with riprap that otherwise dominates the remainder of the nearshore habitat. A major fish kill occurred in June just prior to the survey, taking common carp, drum, white bass, largemouth bass and panfish near the Yahara River inlet. The fish kill was caused by a major Cyanobacteria bloom.

Figure 6: Map of Lake Monona nearshore electroshocking sites

Figure 7: Lake Monona Water Levels with stars indicating survey days

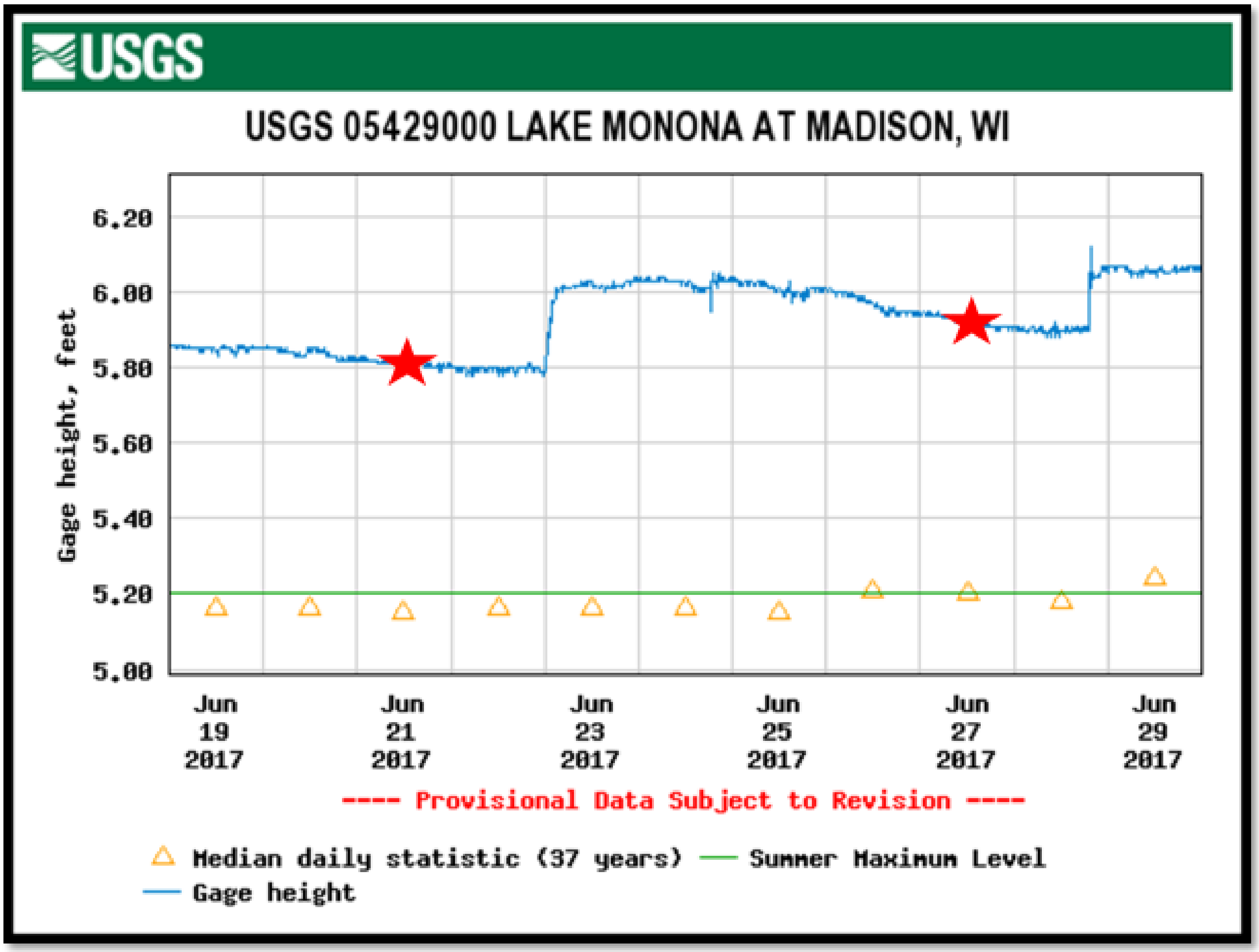


Figure 8: Dominant nearshore fishes in Lake Monona June 2017

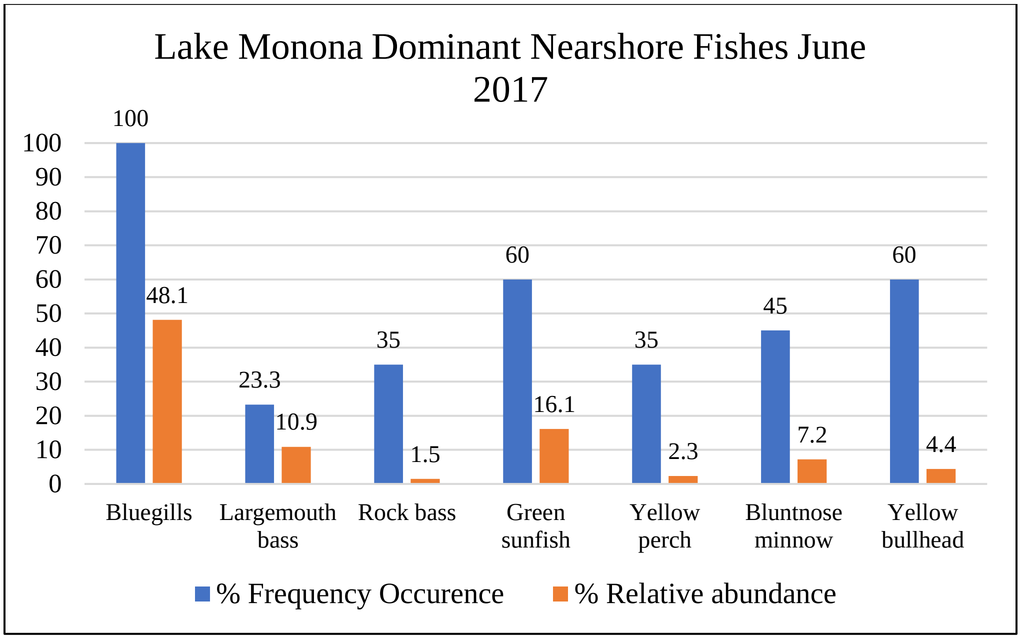
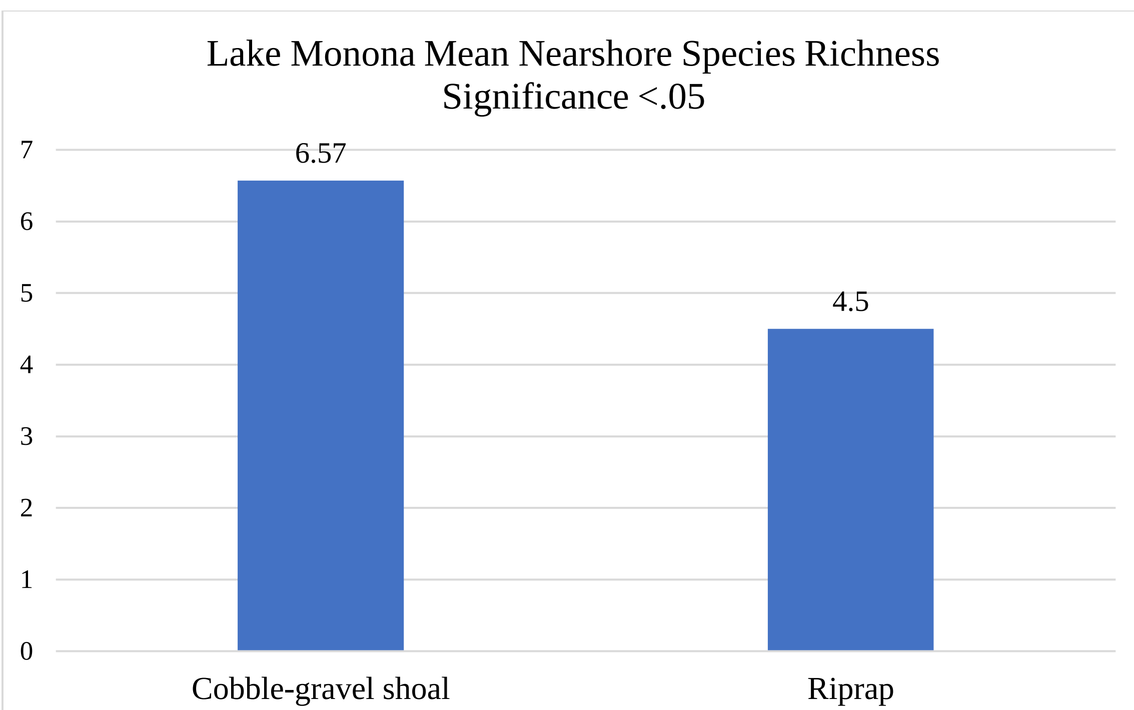


Figure 9: Native species richness at cobble-gravel shoals and riprap



Shoals (N = 7) versus riprap (N = 13): T = 2.57294, p = .019754, $p < .05$ significant

Lake Waubesa Findings

Nearshores on Lake Waubesa were electroshocked on September 13 and 14, 2020 at 18 sites (map Figure 10). Water temperatures ranged from 16.4 – 20.7 C. Dissolved oxygen levels ranged from 4.2 to 9.4 mg/l and specific conductance from 520 to 560 *u*S/cm. The lowest dissolved oxygen level was found at Site 3 along the south marsh that was too deep and mucky to safely sample with wadable electroshocking gear. These conditions prevented an intended survey of the south wetland complex. Water levels remained well above the long-term median and established summer maximum levels (Figure 11).

The survey captured 16 fish species. Similar to Lake Monona, bluegills were very abundant and were present at all sampling sites. The dominant six species found in Lake Waubesa are displayed in Figure 12. Another common feature shared with the other lakes was that cobble-gravel shoals supported more species, particularly the small nongame species. The highest number of native species (11) was found around the Babcock Park island. Many "other" natural shorelines were much deeper and produced fewer species. However, the natural shorelines with large treefalls also supported adult largemouth bass whereas most riprap sites support juvenile-size basses. Figure 13 displays fish species richness at shallow cobble-gravel shoals versus riprap and other shorelines. Two environmentally sensitive fish species collected in the lake were smallmouth bass and Iowa darter.

Figure 10: Map of Lake Waubesa sampling sites

Figure 11: Lake Waubesa levels during the September 13 and 14, 2020 survey – stars

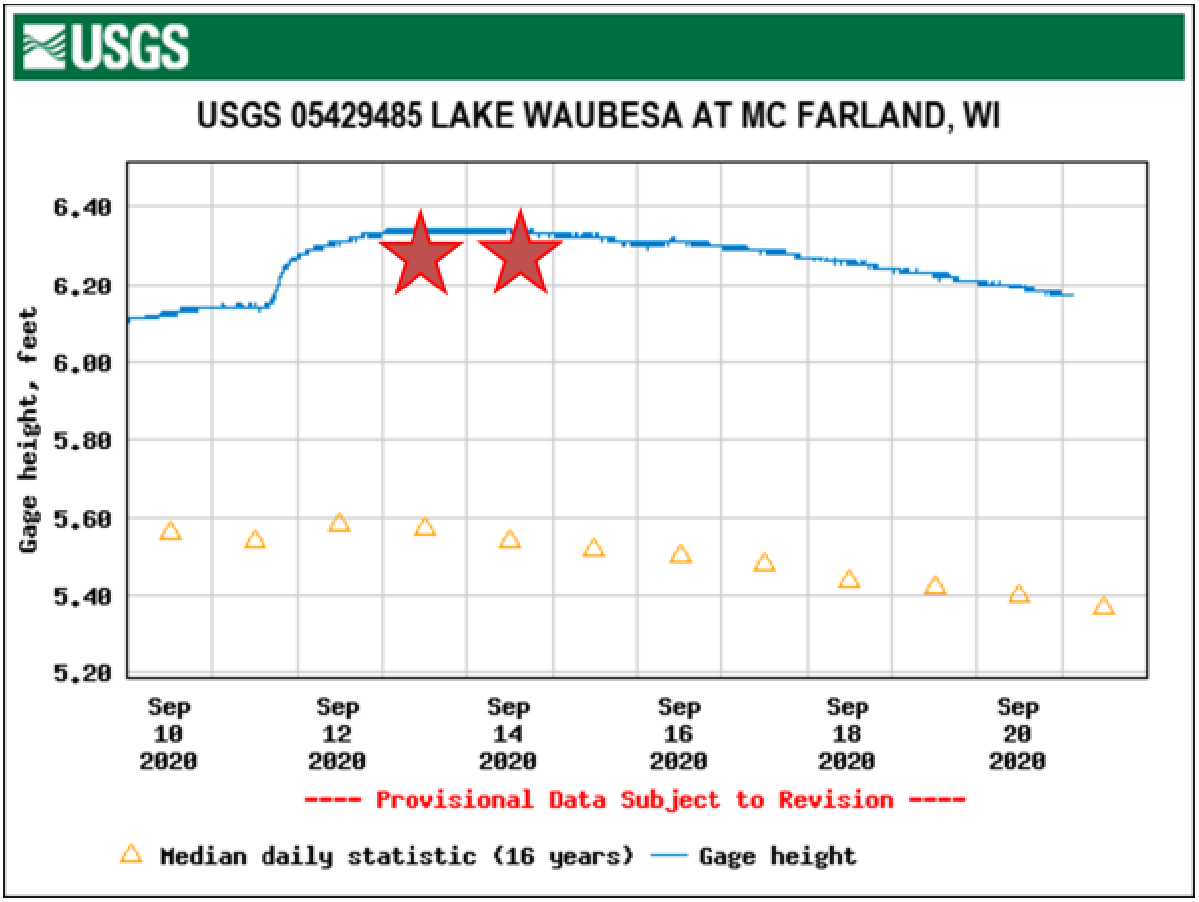


Figure 12: Dominant Lake Waubesa nearshore fishes September 13 and 14, 2020

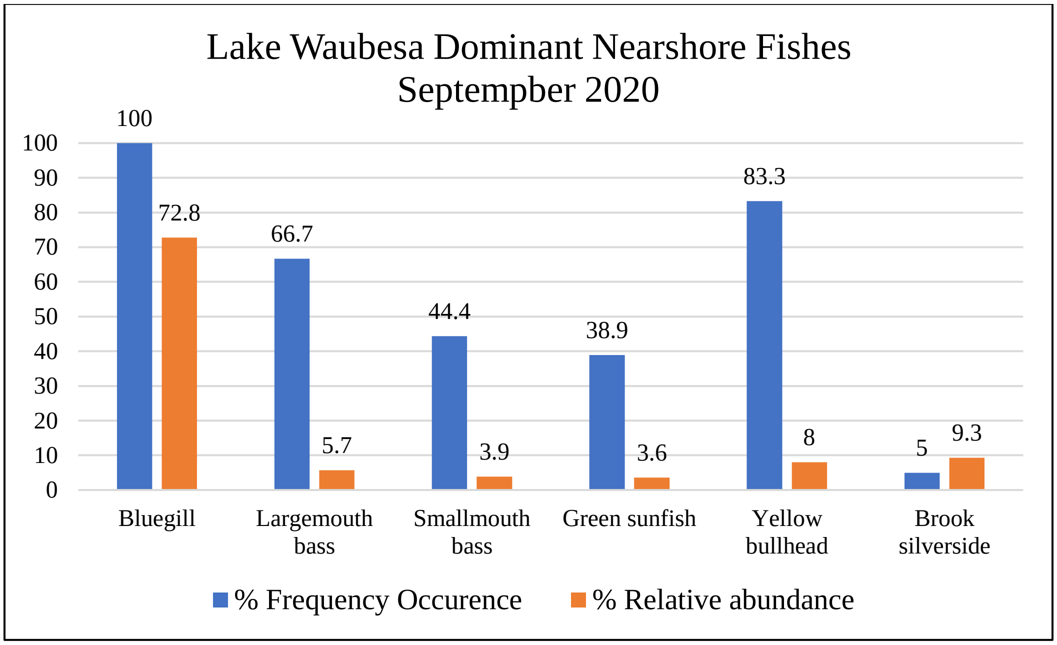
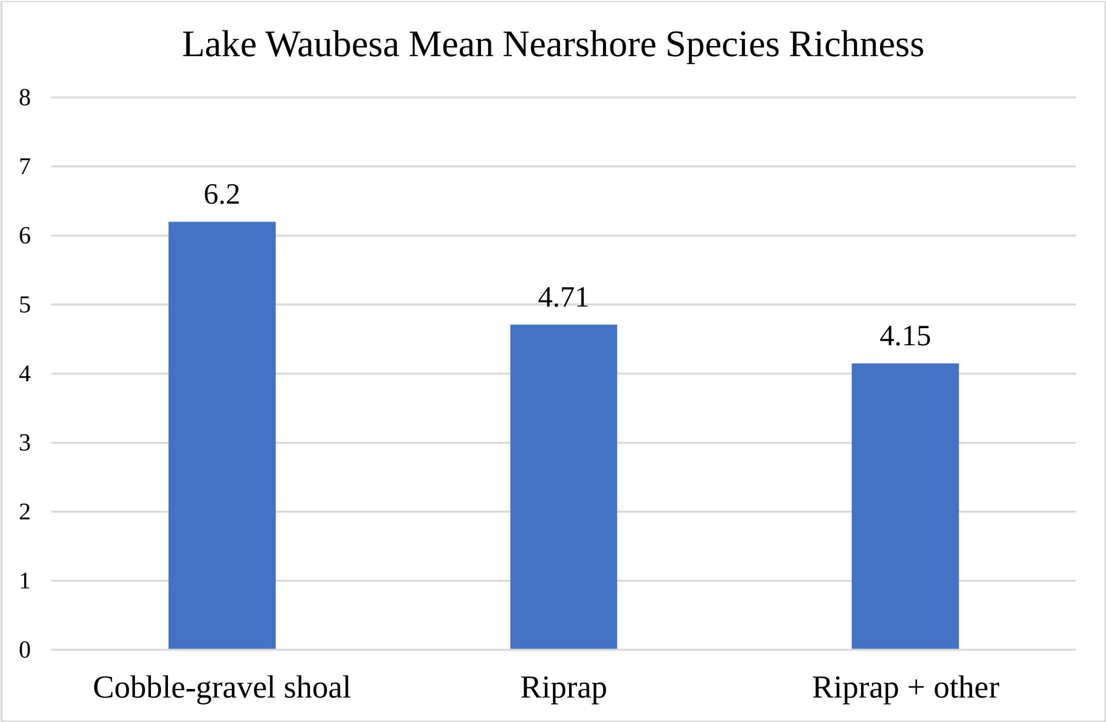


Figure 13: Native species richness at cobble-gravel shoals, riprap and other shores



Shoals (N = 5) versus riprap (N = 7): t = 1.37146, p = .200217, $p < .05$ not significant

Shoals (N = 5) versus riprap + other shores (N = 15): t = 2.33172, p = .033111, $p < .05$ significant

Lake Kegonsa Findings

Lake Kegonsa was sampled on July 30 and August 1, 2019 at 20 sites (map Figure 14). Water temperatures ranged from 23 – 27.4 C. Dissolved oxygen levels ranged from 7.2 - 14.4 mg/l and specific conductance levels ranged from 542 - 587 *u*S/cm.

A total of 18 fish species were collected. Common carp YOY was the most common species found in the nearshore areas. It was collected in 14 of the 18 sites, mostly within rock riprap. Three environmentally intolerant species, smallmouth bass, Iowa darter, and mottled sculpin, were collected. At Site 17, over 200 Iowa darters were collected within a shallow rocky shoal along Lake Kegonsa State Park. Lake Kegonsa had by far the most Iowa darters among the four lakes even though it has historically been the most eutrophic. Cobble-gravel shoals are more common around Lake Kegonsa than the other three lakes, although it was sampled during a year when chronically high-water levels were less severe than when the other lakes were sampled (Figure 15). The only site with mottled sculpin was at the mouth of a cool-cold transitional tributary (Site 7). The tributary water temperature was 16.1 C (61 degrees F). In recent decades tadpole madtoms have only rarely been collected in the Yahara Chain of Lakes, but three individuals were found at two sites in Lake Kegonsa. Figure 16 displays the dominant fish species found in the lake. In general, sections of the lake near the inlet and outlet and shallow cobbler-gravel shoals provided the most favorable habitats for most small nongame fish. Habitat was also generally poor around densely packed piers. Riprap provided habitat for some species, including immature common carp, along sandy shorelines. Consistent with the other three lakes, cobble-gravel shoals supported greater numbers of species and nongame fish in general (Figure 17).

Figure 14: Map of Lake Kegonsa sampling sites.

Figure 15: Water levels during the late July early August 2019 survey

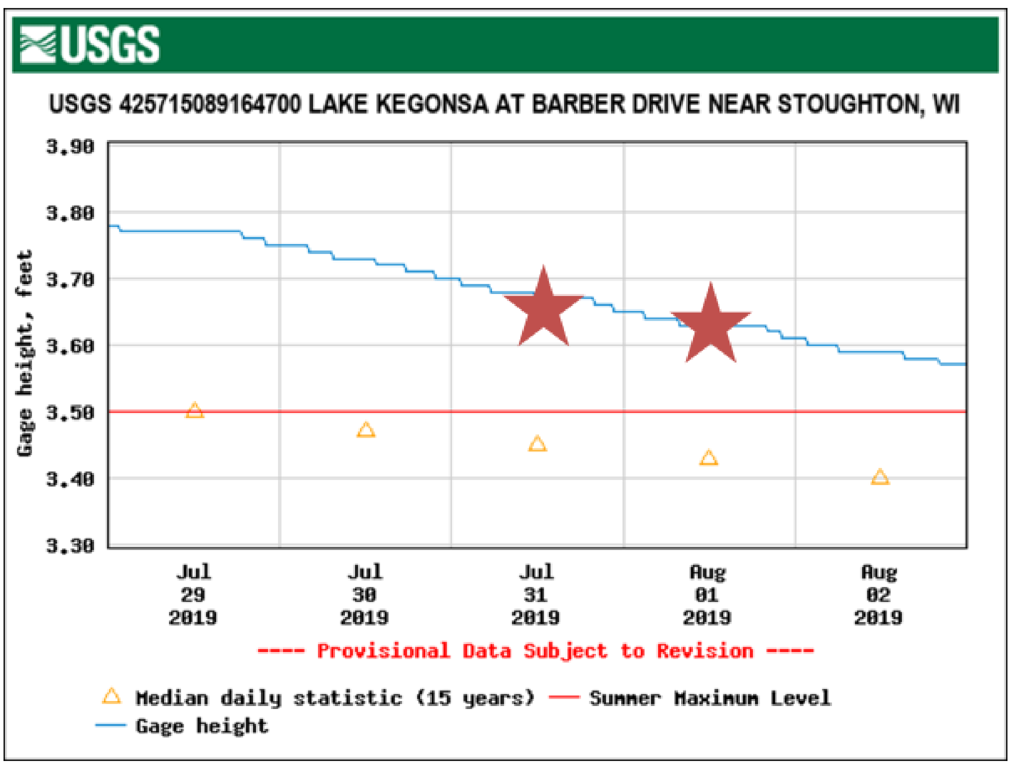


Figure 16: Dominant nearshore fishes in Lake Kegonsa July 31 and August 1, 2019

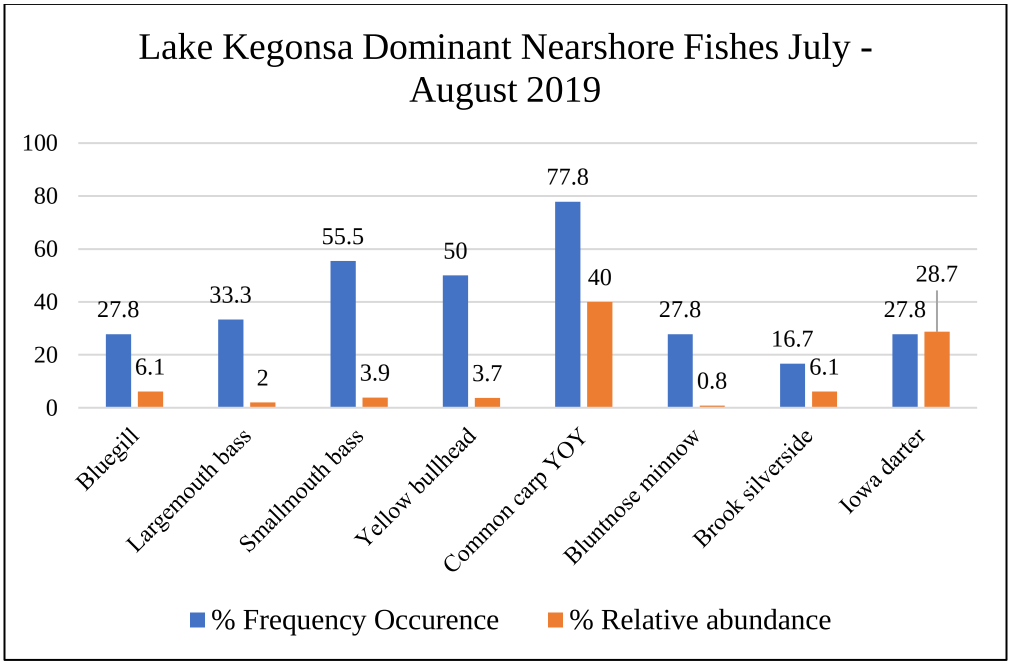
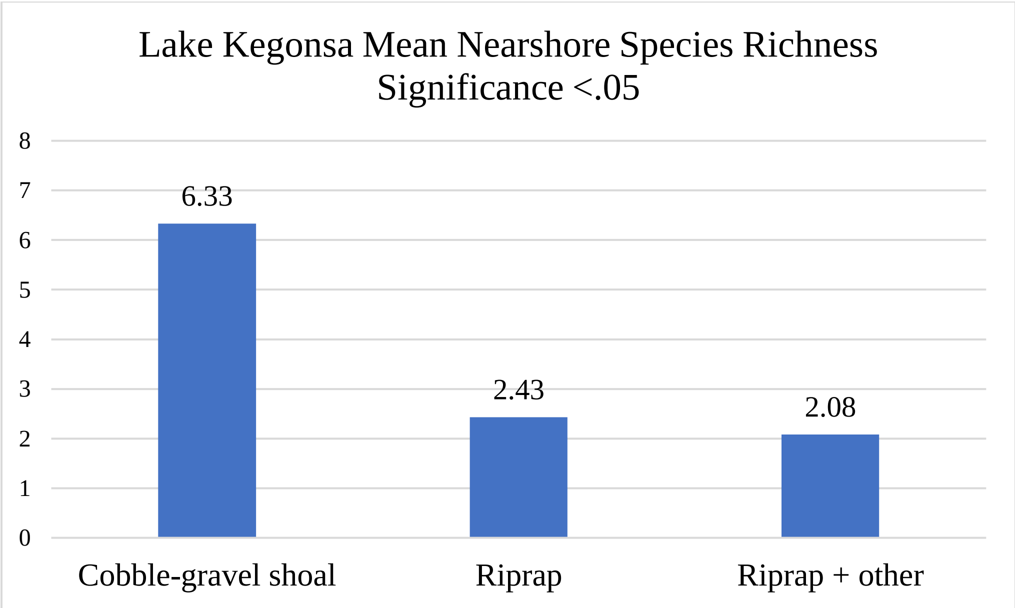


Figure 17: Native species richness at cobble-gravel shoals, riprap and other shorelines



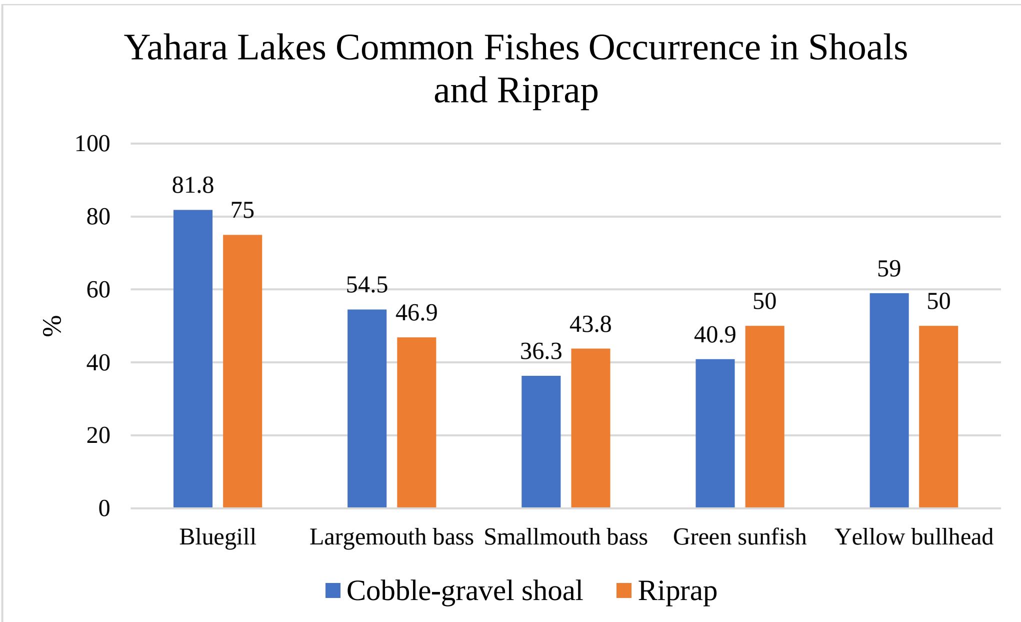
Shoals (N = 6) versus riprap (N = 7): t = 4.04924, p = .001918, $p < .05$ significant

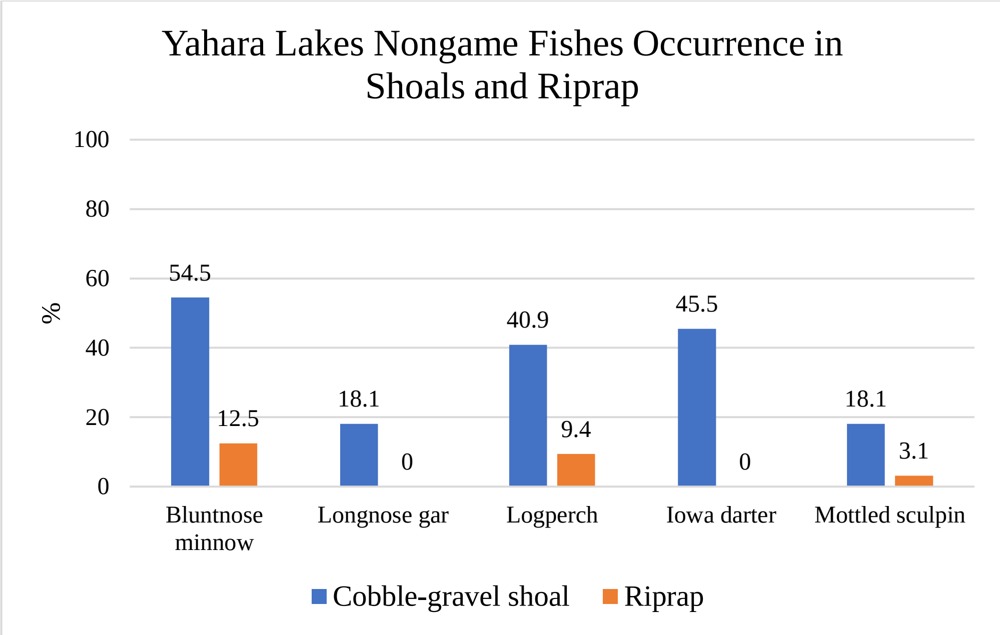
Shoals (N = 6) versus riprap + other shores (N = 14): t = 5.23077, p = .000082, $p < .05$ significant

Discussion

Considering the four lakes collectively, Figure 18 demonstrates that the frequency of occurrence for common sunfishes and yellow bullhead at cobble-gravel shoals and riprap was similar in the first histogram. In the second histogram, nongame species are compared for both habitat types. The data suggest that riprap selects for sunfishes and yellow bullhead but may not provide more habitat than shoals for this fish guild. Otherwise, cobble-gravel shoals are clearly important for nongame fishes. Figure 19 demonstrates that most nongame fish inhabit cobble-gravel shoals or other natural shorelines.

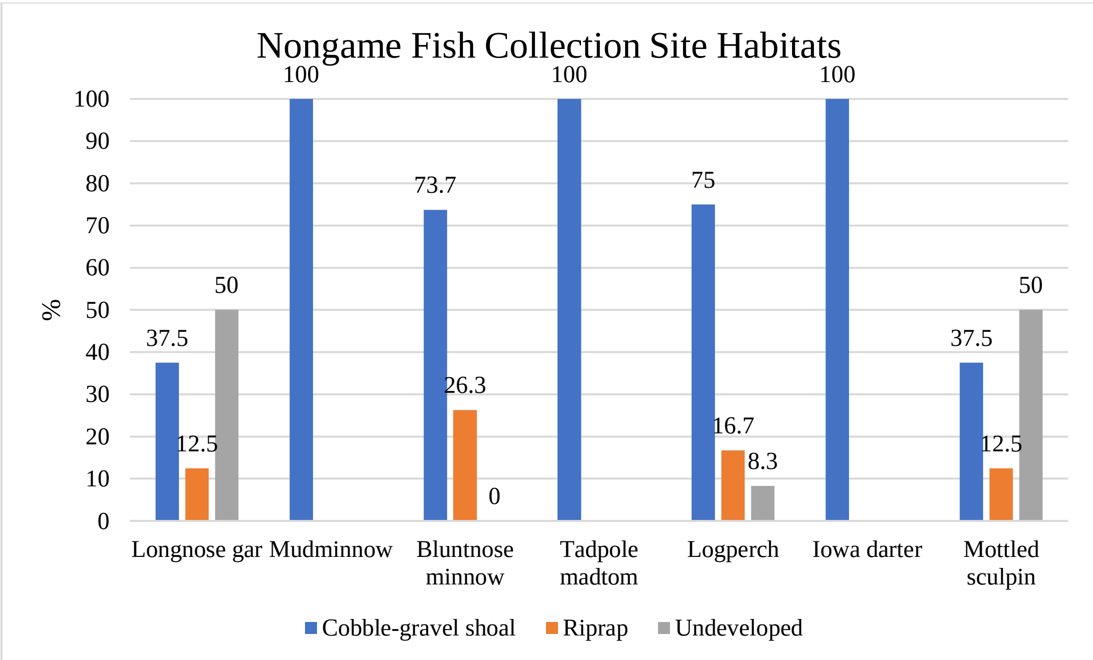
Figure 18: Comparing the frequency of occurrence for 10 Yahara lakes fish species.





Shoals N = 22, Riprap N = 32,

Figure 19: Comparing habitats where nongame fish species were collected



The original goal of the surveys was to assess species richness and distribution of nearshore fish populations, with particular interest in rare and declining small nongame fishes. The sampling locations were not selected randomly. Sample locations were a combination of historic sample sites, accessible natural shorelines and riprap areas. The more widespread riprap shorelines may have been underrepresented. Sampling some riprap areas was prohibitive due to dense pier clusters. We also had an interest in sampling diverse habitat types regardless of relative abundance. While the survey goal was not designed to directly compare riprap with cobble-gravel shoals, the data suggest significant habitat differences.

It is important to note that our survey used a sampling technique, wading electrofishing, that was optimized to capture small species that lived in areas of "cover", rocky substrate, rip rap, woody debris, piers and other structures, and aquatic plants. It was not as effective as a beach seine, as used by LTER, for species that swam off the bottom in open, unobstructed water. For example, the brook silverside, a schooling open-water species, has been the most commonly captured small fish from lakes Mendota and Monona by LTER, although we caught few. Neither our electrofisher or a beach seine is effective in weedy bays that have bottoms too soft for wading, such as parts of University Bay in Lake Mendota and the Waubesa Wetlands in Lake Waubesa. Here, other techniques, such as minnow traps or small-mesh fyke nets, would need to be employed to collect the small fishes present.

Our findings indicate that high-quality habitat important for small nongame fish species, particularly native minnows (Cyprinidae) and darters (Percidae), is relatively scarce in the lakes. Most shorelines are now armored with riprap that often increase shoreline depths. Deeper water that is typically associated with armored shorelines has been amplified by recent record rainfalls, and lake levels are also regulated and maintained higher than historic levels. The most recent water level orders were established during the 1970's, establishing higher minimum levels (Dane County Land and Water Resources Department 2010). It remains unclear what the specific reasons contributed toward the massive development of shoreline armoring. Perhaps eroding shorelines reflected a combination of higher regulated water levels with increased precipitation associated with Climate Change.

The 1970s, WDNR lake water level orders were designed, in part, to sustain higher lakes levels to improve northern pike access to spawning habitats. The decisions at that time preceded significant research on fluvial geomorphology, including floodplain aggradation. Euro-American settlement had increased soil deposition across floodplains, with incised channels that became unconnected with their floodplains (Knox 2006). The goal to maintain higher lake levels for northern pike spawning would unlikely compensate for elevated floodplains and incised stream channels.   In addition to floodplain aggradation, wetlands declined about 50% in the Yahara watershed (Lathrop et al. 1992). Maintaining higher lakes levels will also unlikely compensate for historic wetland losses.

The existing lake water level orders preceded information on Global Warming with predicted increased precipitation as a consequence. The Dane County Board adopted 2018 RES-227 establishing a Technical

Work Group to investigation causes for the severe flooding that occurred in 2018 and find remedies. Final recommendations included actions such as dredging and aquatic plant harvesting to increase river discharge rates from the lakes. The recommendation did not include changing the existing seasonal Lake Mendota water level regime. Chen et al (2019) applied models to determine that reducing the minimum Lake Mendota water level could reduce flood magnitude and frequency. An ecological benefit to reduced lake levels is the likely expansion of shallow shoals in Lake Mendota, where few now exist.

Not all riprap areas resulted in the same degree of habitat change. In Figure 20, the photo of a heavily developed riprap shoreline appears to be a drastic change from natural habitat. However, at this site the riprap was actually constructed above the water line and the nearshore habitat was a cobble-gravel shoal that supported Iowa darters. Figure 21 demonstrates the extent of shoreline modifications that had occurred along Lake Mendota and Lake Monona. The impact of shoreline modifications, such as dredging, grading and riprap, can vary based on fetch and other factors.

Two species of interest are the tadpole madtom and Iowa darter. Lyons (1989) reported that the tadpole madtom had not been found in Lake Mendota for decades. Fortunately, a few remain in the system including a single specimen found in Cherokee Marsh (2016) and three individuals found at two sites in Lake Kegonsa. Lyons (1989) also listed Iowa darters as "uncommon" in Lake Mendota. We did not find any in Lake Mendota, but the other three lakes had them. Numerous individuals were found in Lake Kegonsa where the nearshore water is generally shallower than in the other three lakes.

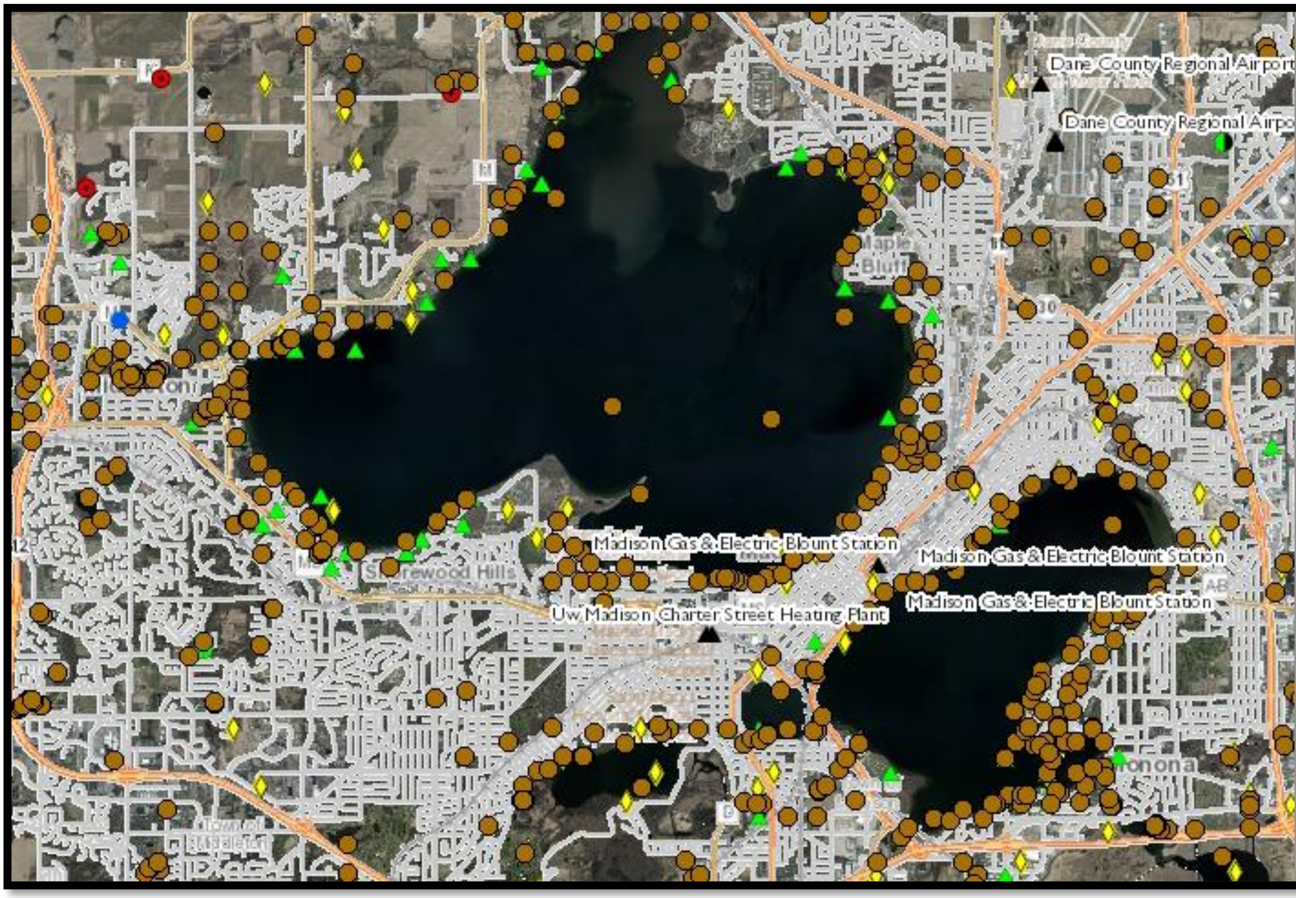
Iowa darters are considered "secure" in Wisconsin (Lyons et al. 2000). However, they are listed as S2 or "imperiled" in Illinois, Pennsylvania and New York. Across their range they are generally considered vulnerable as their distribution is declining. In the Yahara Lakes Chain their uncommon distribution also suggests they are vulnerable within this watershed.

The common threats to associated with nongame species include Eurasian watermilfoil invasions, development of piers and other nearshore structures, and eutrophication. The severe Cyanobacteria bloom and fish kill in 2017 was clearly a demonstration of water quality threats. However, all four lakes still support self-sustaining environmentally sensitive species (smallmouth bass, rock bass, mottled sculpin and Iowa darter). The continued survival of these environmentally intolerant species may suggest that habitat loss may be a greater threat. Now that Eurasian watermilfoil has significantly declined and in many areas has been replaced with wild celery (*Vallisneria americana*) (Dane County unpublished data), the dearth of shallow rocky shoals appears to be a significant impairment for the survival of small bottom-dwelling nongame species such as tadpole madtoms and Iowa darters. Their disappearance would represent another incremental loss of nature from these historic glacial drainage lakes.

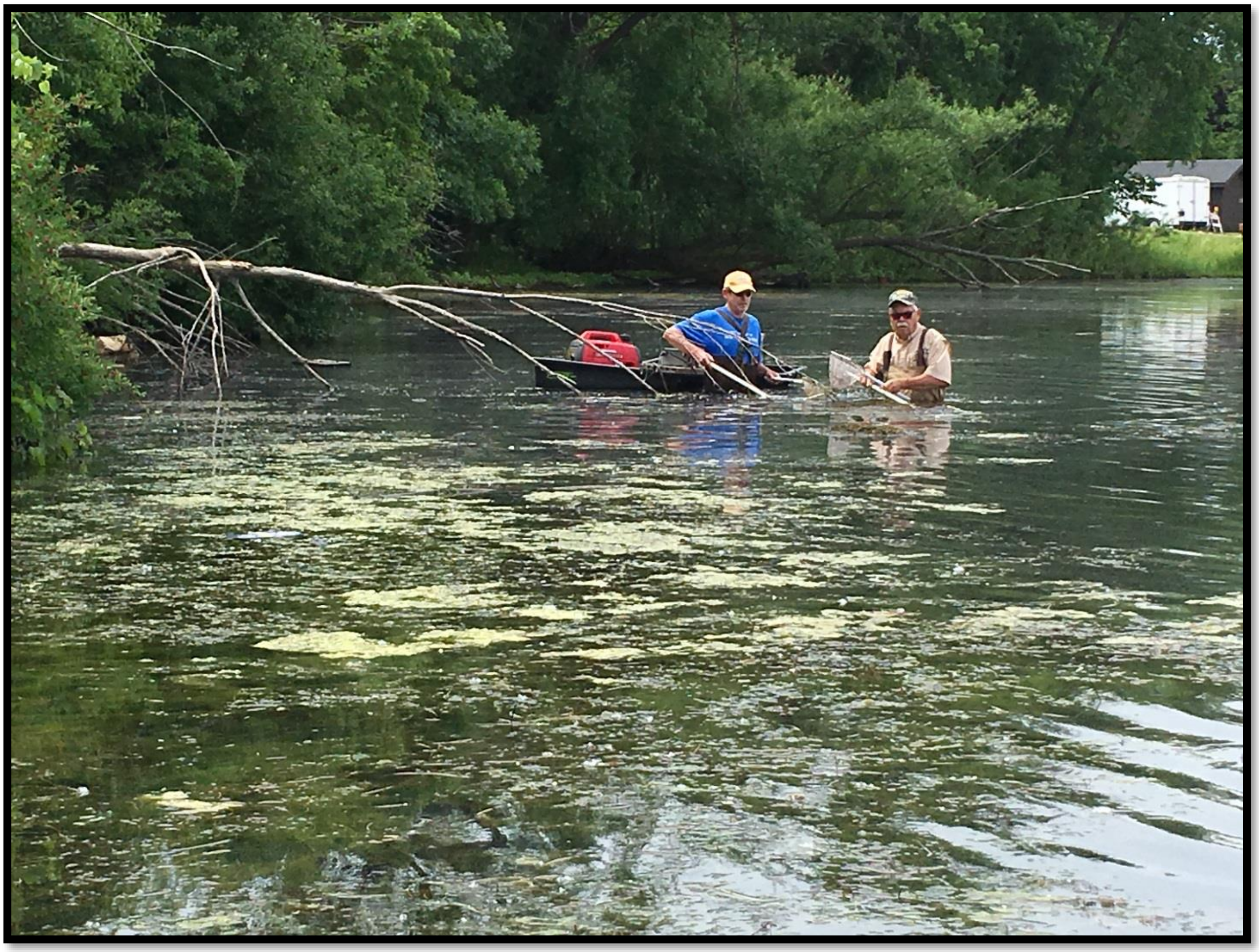
Figure 20: Photo of heavily developed site with dry riprap and existing shallow shoal

This heavily developed site offers little in the way of cover for adult panfish or gamefish. But it is a rocky shoal in front of dry riprap and supports Iowa darters. Perhaps other riprap sections of the lakes could be restored to cobble-gravel shoals under lower water level regimes?

Figure 21: WDNR Surface Water Dataviewer locations of shoreline wetland modifications in Lake Mendota and Lake Monona



Along Lake Mendota shorelines, the dots indicate riprap, seawalls, armoring repair/replacements, dredging, miscellaneous etc. Between 2004 – 2020, DNR records indicate 22 riprap, 2 seawall, 33 riprap repair/replacements, and 4 seawall repair/replacement permits.



This photo demonstrates the frequent deep water “bathtub” conditions close to shore in Lake Monona.

Immature longnose gar sampled in Lake Mendota (2017)

Young of year common carp were abundant near Governor's Island in Lake Mendota (2017) and at numerous locations within Lake Kegonsa riprap

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Appendix 1: Lat-Long site locations.

Mendota sites: 1 (43.09067-89.47957), 2 (43.10811-89.47302), 3 (43.10974-89.45734), 4 (43.12352-89.43843), 5 (43.14009-89.42523), 6 (43.13302-89.40919), 7 (43.12583-89.40093, 8 (43.12649-89.39818), 9 (43.12889-89.38086), 10 (43.11149-89.37188), 11 (43.0939-89.37219), 12 (43.08685-89.37765), 13 (43.0786-89.41414), 14 (43.08039-89.42507), 15 (43.08554-89.42471), 16 (43.0873-89.41996), 17 (43.08973-89.42442), 18 (43.09268-89.43087), 19 (43.09093-89.43642), 20 (43.0888-89.44125)

Monona sites: 1 (43.07471-89.37605), 2 (43.07753-89.3681), 3 (43.08562-89.35352), 4 (43.08977-89.34317), 5 (43.09038-89.3373), 6 (43.08866-89.33226), 7 (43.07773-89.32767), 8 (43.0719-89.33771), 9 (43.05483-89.34753), 10 (43.05621-89.33826), 11 (43.05032-89.35036), 12 (43.0477-89.35777), 13 (43.04518-89.36743), 14 (43.04802-89.37065), 15 (43.05231-89.36817), 16 (43.0534-89.37296), 17 (43.05861-89.38396), 18 (43.05725-89.38909), 19 (43.05809-89.39828), 20 (43.06355-89.39299)

Waubesa sites: 1 (43.0003-89.3392), 2 (42.99697-89.34042), 4 (42.9896-89.3405), 5 (42.9916-89.3297), 6 (42.9962-89.3272), 7 (43.0034-89.3149), 8 (43.0032-89.3064), 9 (43.0081-89.3048), 10 (43.0174-89.3041), 11 (43.02715-89.30923), 12 (43.03035-89.3183), 13 (43.03038-89.32785), 14 (43.02277-89.32712), 15 (43.02035-89.32895), 16 (43.0186-89.33208), 17 (43.01482-89.33243), 18 (43.00882-89.33283), 19 (43.00245-89.3345)

Kegonsa sites: 1 (42.96469-89.2226), 2 (42.95402-89.23232), 3 (42.94987-89.23834), 4 (42.94920-89.24991), 5 (42.94946-89.26005), 6 (42.9516-89.26759), 7 (42.95138-89.27419), 8 (42.95472-89.27902), 9 (42.96126-89.28033), 10 (42.9620-89.27573), 11 (42.96716-89.28117), 12 (42.97496-89.27679), 13 (42.98108-89.26434-89.26434), 14 (42.98269-89.26086), 15 (42.98181-89.25378), 16 (42.9758-89.24078), 17 (42.9697-89.2268), 18 (42.96852-89.22299)

Appendix 2: Nearshore species abundance per site.

Common name	Abbreviation in other tables	Scientific name	Origin	Classification	Tolerance
Gar Family		Lepisosteidae			
Longnose gar	Ln gar	*Lepisosteus osseus*	Native	Rough	Intermediate
Minnow family		Cyprinidae			
Spotfin shiner	Spotfin sh	*Cyprinella spiloptera*	Native	Minnow	Intermediate
Common carp	C carp	*Cyprinus carpio*	Introduced	Rough	Tolerant
Golden shiner	Golden shiner	*Notemigonus crysoleucas*	Native	Minnow	Tolerant
Emerald shiner	Emerald sh	*Notropis atherinoides*	Native	Minnow	Intermediate

Bluntnose minnow	Bluntnose	*Pimephales notatus*	Native	Minnow	Tolerant
Fathead minnow	Fathead min	*Pimephales promelas*	Native	Minnow	Tolerant
Catfish family		Ictaluridae			
Black bullhead	B bullhead	*Ameiurus melas*	Native	Game	Tolerant
Yellow Bullhead	Y bullhead	*Ameiurus natalis*	Native	Game	Tolerant
Channel Catfish	C catfish	*Ictalurus punctatus*	Native	Game	Intermediate
Tadpole madtom	Tadpole mad	*Noturus gyrinus*	Native	Minnow	Intermediate
Mundminnow family		Umbridae			
Central mudminnow	C mudminnow	*Umbra limi*	Native	Minnow	Tolerant
Pike family		Esocidae			
Muskellunge	Musky	*Esox masquinongy*	Introduced	Game	Intolerant
Silverside family		Atherinidae			
Brook silverside	Br silverside	*Labidesthes sicculus*	Native	Minnow	Intermediate
Sculpin family		Cottidae			
Mottled sculpin	M sculpin	*Cottus bairdii*	Native	Minnow	Intolerant
Sunfish family		Centrarchidae			
Rock bass	Rock bass	*Ambloplites rupestris*	Native	Game	Intolerant
Green Sunfish	Gr sunfish	*Lepomis cynanellus*	Native	Game	Tolerant
Pumpkinseed	Pumpkinsd	*Lepomis gibbosus*	Native	Game	Intermediate
Bluegill	Bluegill	*Lepomis macrochirus*	Native	Game	Intermediate
Smallmouth bass	Sm bass	*Micropterus dolomieu*	Native	Game	Intolerant
Largemouth bass	Lm bass	*Micropterus salmoides*	Native	Game	Intermediate
Black crappie	B crappie	*Pomoxis nigromaculatus*	Native	Game	Intermediate
Perch family		Percidae			

Iowa darter	Iowa darter	*Etheostoma exile*	Native	Minnow	Intolerant
Johnny darter	Johnny d	*Etheostoma nigrum*	Native	Minnow	Intermediate
Yellow perch	Y perch	*Perca flavescens*	Native	Game	Intermediate
Logperch	Logperch	*Percina caprodes*	Native	Minnow	Intermediate

Lake Mendota species abundance per site. Total 12 native species caught.

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Ln gar					1	1	2	2				2				1				
Bluntnose						2	8													
C carp						1		300												
Y bullhead								1												
C catfish								1												
Bluegill		2		1	1		1	1			1		1							
Gr sunfish	1				2	2									1					
Hybrid sunfish		2																		
B crappie														2	1					
Rock bass	1			3							1	2	8			1		13	23	10
Lm bass	2					5	12	3			1			4	1					
Sm bass		5	1	2	5	3				2	1	2	1			1	2		4	1
Logperch											1									
M sculpin												1						13	18	
Total native	3	3	1	3	4	5	4	5	0	1	5	4	3	2	3	3	1	2	3	2
Habitat	R	R	O	R	S	S	S	S	R	R	O	O	R	O	O	O	O	O	O	O

R = riprap, S = Cobbler-gravel shoal, O = other habitat

Lake Monona species abundance per site. Total 16 native species caught.

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Musky										1										
C carp									1	5										
Bluntnose		1		3			3		3		8	2			8	14	2			
Spotfin sh												2	4							
Y bullhd	1	5	1			2	2		4	1	1			1		1			4	6
B bullhd														1			1		2	
Bluegill	2	20	5	9	12	33	11	5	2	31	6	1	36	35	26	56	1	11	9	8
Pumpkinsd													6	2	1				2	
Gr sunfish	8	9	2		1	1		2	11	1						5		14	19	25
Hybrid sunfish												2		2						
Rock bass	1	1	2					1	1						1	2				
Lm bass		2				1	2	10	2		2	11	9	5	10			6	1	3
Sm bass											2									

Y perch		2	1	1		2	1			6		1	6							
Logperch							1				3	3			1					
Iowa darter											3				1					
Johnny d															1					
M sculpin									2		2	2			1					
Total native	4	7	5	3	2	6	7	4	7	5	8	7	5	5	9	5	3	3	6	4
Habitat	R	R	R	R	R	R	S	R	R	S	S	S	S	R	S	S	R	R	R	R

R = riprap, S = cobbler-gravel shoal

Lake Waubesa species abundance per site. Total 15 native species caught.

Species	1	2	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
C mudminnow								1										
Emerald sh							1											
C carp								1							1			
Bluntnose						4		4			1							
Y bullhead	4	1		15	5	5		10	1	1	2		2	4	1	3	15	8
B bullhead							1	3	2									
Br silverside								90										
Bluegill	5	55	137	32	11	13	7	151	3	33	32	94	51	45	23	1	1	7
Gr sunfish	10	2		4				2			1						4	12
Pumpkinseed	1		1					4		2						1		2
Hybrid sunfish		1		4														6
B crappie			1															
Lm bass	4	9	3		4	3		24				1	1	2	1			2
Sm bass				10	7	6	1	5		2						1		
Y perch													1			2	5	
Logperch										1	1						4	1
Iowa darter								7	3		10							
Total native	5	5	4	4	4	5	4	11	4	5	6	2	4	3	3	5	5	7
Habitat	R	O	O	R	R	S	R	S	S	S	S	O	O	O	O	R	R	R

R = riprap, S = cobbler-gravel shoal, O = other habitat

Lake Kegonsa species abundance per site. Total 18 species caught.

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
C mudminnow													1					
Common carp	12	4			72	25	19	45	32	28	6	2			2	19	19	29
Bluntnose			3					1					1				2	1
Golden shiner													5					
Fathead min																	1	
Y bullhead						3	1	4	4	4				1	4	6	4	
B bullhead									1			4						
Tadpole mad																2		1
Br silverside											11	50					50	
Bluegill						4		1					38	4	5			
Gr sunfish						1		4									6	1
Pumpkinseed						1							1					

B crappie													1					
Lm bass	1		1							1			11	1	3			
Sm bass			1	1		13	2	8	1	2						2	2	1
Y\perch													2					
Logperch													2				4	4
Iowa darter								2		1						27	200	14
M sculpin*							4*											
Total native	1	0	3	1	0	5	2	6	3	4	1	2	9	3	3	4	7	6
Habitat	O	R	R	R	O	R	R	S	R	S	O	R	S	O	O	S	S	S

R = riprap, S = cobbler-gravel shoal, O = other habitat

*collected within mouth of cool cold transitional tributary