Spread Eagle Chain of Lakes (Florence County, Wisconsin)

Zebra Mussel Population Monitoring Report

This is a product of a WDNR Early Detection & Response Grant awarded to:

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WHITE WATER ASSOCIATES, INC.

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INTRODUCTION

The zebra mussel, an aquatic invasive species (AIS), was confirmed in North Lake in 2012. North Lake is part of a chain of eight lakes known as the Spread Eagle Chain of Lakes in Florence County, Wisconsin. Zebra mussels were first observed in the Great Lakes system in the mid-1980s and have spread throughout the Great Lakes and into inland streams, lakes, and reservoirs in the Midwest. There are several zebra mussel infested waters within a short drive time of North Lake and the Spread Eagle Chain of Lakes. Exhibit 1 shows zebra mussel distribution in the Menominee River watershed as of 2012 (since then a population has been discovered in Fortune Lakes in Iron County, Michigan). Zebra mussels can cause significant ecological impacts and economic costs.

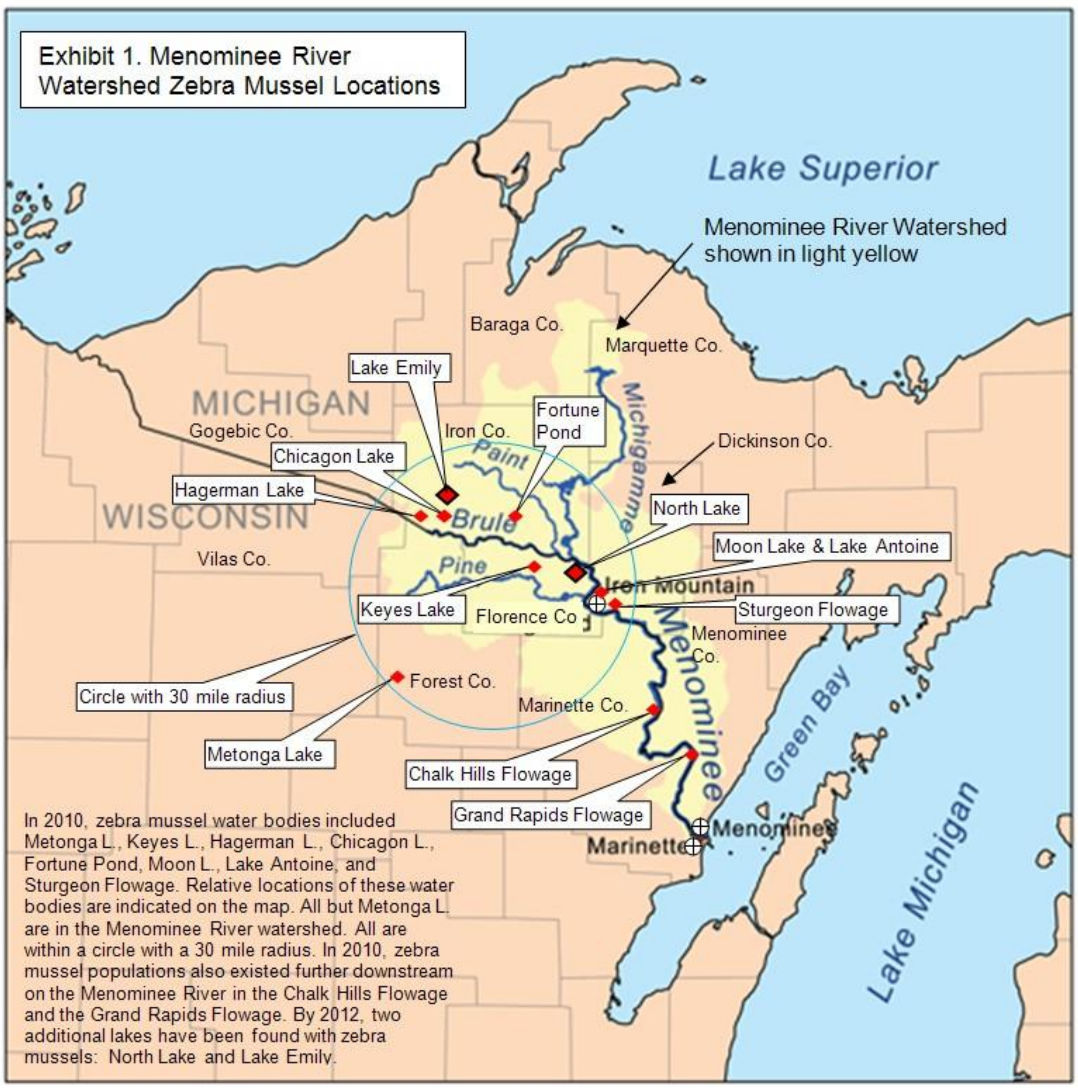


Exhibit 1. Menominee River Watershed Zebra Mussel Locations

The North Lake zebra mussel population was discovered during a Wisconsin Department of Natural Resources (WDNR) Early Detection Monitoring field inspection. On Sept. 5, 2012, WDNR staff discovered both Eurasian watermilfoil and zebra mussels in North Lake. At that time, the Spread Eagle Chain of Lakes Association (SECOLA) was conducting a study on North Lake under a large-scale lake planning grant. A product of that grant was the *North Lake Adaptive Management Plan* (Premo *et al* 2014). The adaptive management plan addressed the zebra mussel population. The subsequent early detection and rapid response grant project awarded to SECOLA stems from the adaptive management plan and represents part of its implementation. The SECOLA is a very active lake stewardship organization and there is high concern and interest regarding the zebra mussel population and other AIS.

Among other activities, the early detection and rapid response grant specified that zebra mussel population monitoring would take place throughout the SECOL. The field effort took place in 2016. Prior to this effort, the Florence County Land Conservation Department surveyed part of North Lake and the adjacent Middle Lake for zebra mussels to document the early state of colonization (FCLCD 2013). As part of her graduate research Maureen Ferry studied zebra mussels in North Lake in 2012 (Ferry 2013).

A Strategic Plan to Address Zebra and Quagga Mussels in the Menominee River Watershed (Premo and Stine, 2013) established a systematic protocol for responding to zebra mussels in the Menominee River Watershed. It augments this report. This monitoring report focuses on the SECOL because understanding the population dynamics in this system is of interest to local lake stewardship. This knowledge also benefits the broader region.

The North Lake zebra mussel find is distressing to the SECOLA, the Florence County Lakes and Rivers Association (FCLARA), resource agencies, and other stakeholders that care for the SECOL and all surface water resources in the northern Wisconsin and Michigan. The zebra mussel is particularly insidious in that no suitable lake-wide means is currently available to control or eradicate this species once it has infested a lake. Nevertheless, monitoring the population and its impacts, trying to reduce some of the specific impacts, and containing the zebra mussel infestation are achievable and worthwhile goals.

We organize this report in six sections (including the Introduction). In the next section (Zebra Mussel Biology), we summarize the species' biology. The Methods section details our approach to monitoring zebra mussels in the SECOL. Findings are reported in the Results section and the Discussion section describes impacts, mitigation, containment, and monitoring of the SECOL zebra mussel population. A Literature Cited section cites supporting literature.

ZEBRA MUSSEL BIOLOGY

The zebra mussel (*Dreissena polymorpha*) is a freshwater bivalve mollusk. “Bivalve” means the shell composed of two halves, a characteristic shared by native mussels (sometimes called “clams”). Zebra mussel shells are variable in size and color, but as adults are usually about the size of a thumbnail and marked with the light and dark bands (Exhibit 2). A closely related species, the quagga mussel (*Dreissena bugensis*), is also variable in morphology and color, but can be slightly larger than the zebra mussel and the shell is usually paler toward the end of the hinge. The zebra mussel tends to be more triangular in shape, whereas the quagga mussel is rounder. The zebra mussel shell will sit flat if placed on its bottom side, but the quagga mussel shell will fall over. Native to the Ukraine and Russia, zebra mussels were first discovered in North America in 1988 in Lakes St. Clair and Erie. Quagga mussels were discovered in some of the Great Lakes three years later. Both species have spread rapidly and can reach exceptionally high population levels in newly colonized habitats. Both exist in the Menominee River Watershed although zebra mussels are in more lakes at the present time.

The rapid spread and great abundance of zebra mussels is in part due to their reproductive cycle. They often are sexually mature at age 1 and a single female can produce a million eggs each season. Eggs and sperm are released simultaneously into the open water where fertilization takes place. The fertilized eggs hatch into free-swimming microscopic larvae called “veligers.” The veligers swim, drift, and feed as part of the plankton in the water column. After 1-5 weeks, the veligers settle onto substrates and those that land on a suitable hard surface become attached by sticky threads. These juveniles begin filter feeding, growing, maturing, and eventually reproducing for the remainder of their life of three to six years.

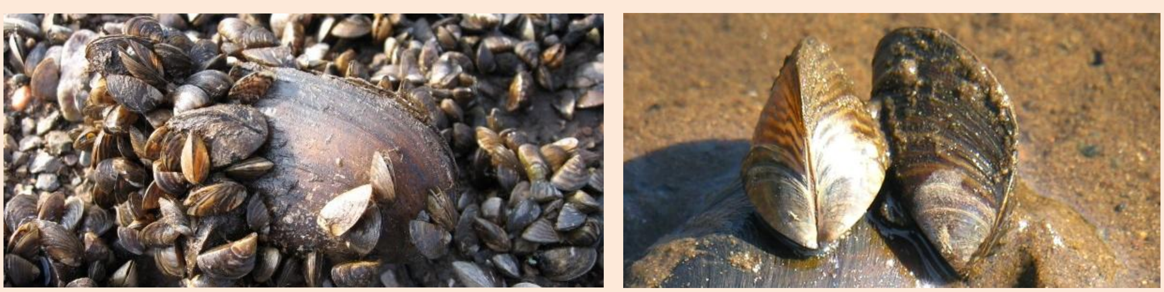


Exhibit 2. Zebra mussels from the Menominee River. The left photo shows zebra mussels on gravel substrate (some attached to a native mussel). The right photo shows two adult zebra mussels attached to a native mussel shell.

METHODS

We developed the monitoring methodology used on the SECOL in consultation with Maureen Ferry (Aquatic Invasive Species Monitoring Lead, Bureau of Water Quality, WDNR). Ferry's firsthand experience conducting field research on zebra mussels of this region (including on North Lake) was invaluable in creating an efficient and meaningful approach to systematically monitoring zebra mussels in the SECOL. Over the past several years the entire SECOL has been the subject of point-intercept aquatic plant surveys. The formal WDNR point-intercept survey assesses the plant species composition on a grid of several hundred points distributed evenly over the entire lake. Points on the grid are typically about 30 meters apart. Using latitude-longitude coordinates and a handheld GPS unit, scientists navigate to the points and collect a sample. This systematic survey provides baseline data about the lake that is accurately repeatable in future surveys. These point-intercept sampling points were appropriate for the zebra mussel monitoring.

Past work in the region (Ferry 2013) reported that zebra mussels tend not to occur on substrates that exist below the thermocline. For example, if the thermocline typically occurs at 25 feet, zebra mussels would not typically colonizes substrates in water beyond that depth. We used this information to filter the grid of existing points for each of the eight lakes in the SECOL, omitting from sampling those plots deeper than the thermocline in each lake. Once that filter was accomplished, we randomly selected ten of the sampling plots from each lake to be subject to our sampling for zebra mussels. On a handful of occasions in the field, the randomly selected point was too deep (ie., below the thermocline). In these instances we moved the point toward shore from the original point at a water depth less than the thermocline depth. The newly selected sampling point was then documented with latitude and longitude coordinates using a hand-held GPS unit.

Once in the field, we navigated to each sampling point and recorded the depth reading from a sonar device. Next, we dropped a Petite Ponar® Grab sampler (Exhibit 3) over the side of the boat and allowed it to strike the lake bottom. Pulling on the attached rope to retrieve the dredge closes it on a lake bottom sample and allows it to be hauled on board the boat. The collected sample contains substrate, plants, zebra mussels, snails, and other materials. On the rare occasion when the dredge only partially closed because a rock or stick was caught in its jaws, an incomplete sample was obtained. In these cases, we redeployed the dredge and collected a complete sample. The jaw opening of the Pygmy Ponar dredge is 14.1 cm by 16.8

cm. The area sampled by each deployment was 237 cm^2 (about 0.26 ft^2). To convert counts of zebra mussels per one dredge sample to count per square meter (m^2), the count is multiplied by a factor of 42.2.

Once on board, the dredge was emptied into a stainless steel bowl for initial processing. We made an estimate of the type of substrate contained in the dredge (including plant material). Using a colander and lake water, we removed debris from each sample and picked all zebra mussels we could discern. These were preserved in alcohol for later processing at the laboratory. When the sample was preserved and labeled as to sample plot number and lake, we proceeded on to the next sampling plot. In all, 80 plots were sampled over the course two days in the field (August 23 and 26, 2016).

In the laboratory, each sample was processed by determining length and age (by examining annual growth rings) of each zebra mussel encountered and recording this information on a data sheet. Field and laboratory data were entered into a spreadsheet for analysis.

Exhibit 3. Petite Ponar® Grab sampler

RESULTS

We documented zebra mussels in the sampling plots in seven of the eight lakes in the Spread Eagle Chain of Lakes. We did not observe zebra mussels in South Lake sampling plots, although we did observe zebra mussels on the bridge separating East Lake from South Lake so zebra mussels are almost certainly present in South Lake. Over the entire SECOL we observed zebra mussels in 35 of the 80 sampling plots (44% of the plots). Exhibit 4 shows a map of the SECOL with the location and depth of the 80 sampling plots along with zebra mussel presence. Table 1 shows the percentage of sampling plots occupied by zebra mussels for each lake. Ferry (2013) studied eight zebra mussel lakes in the region and found that zebra mussel presence in the square meter sampling quadrats ranged from about 2% to 99% (with an overall average of 63%).

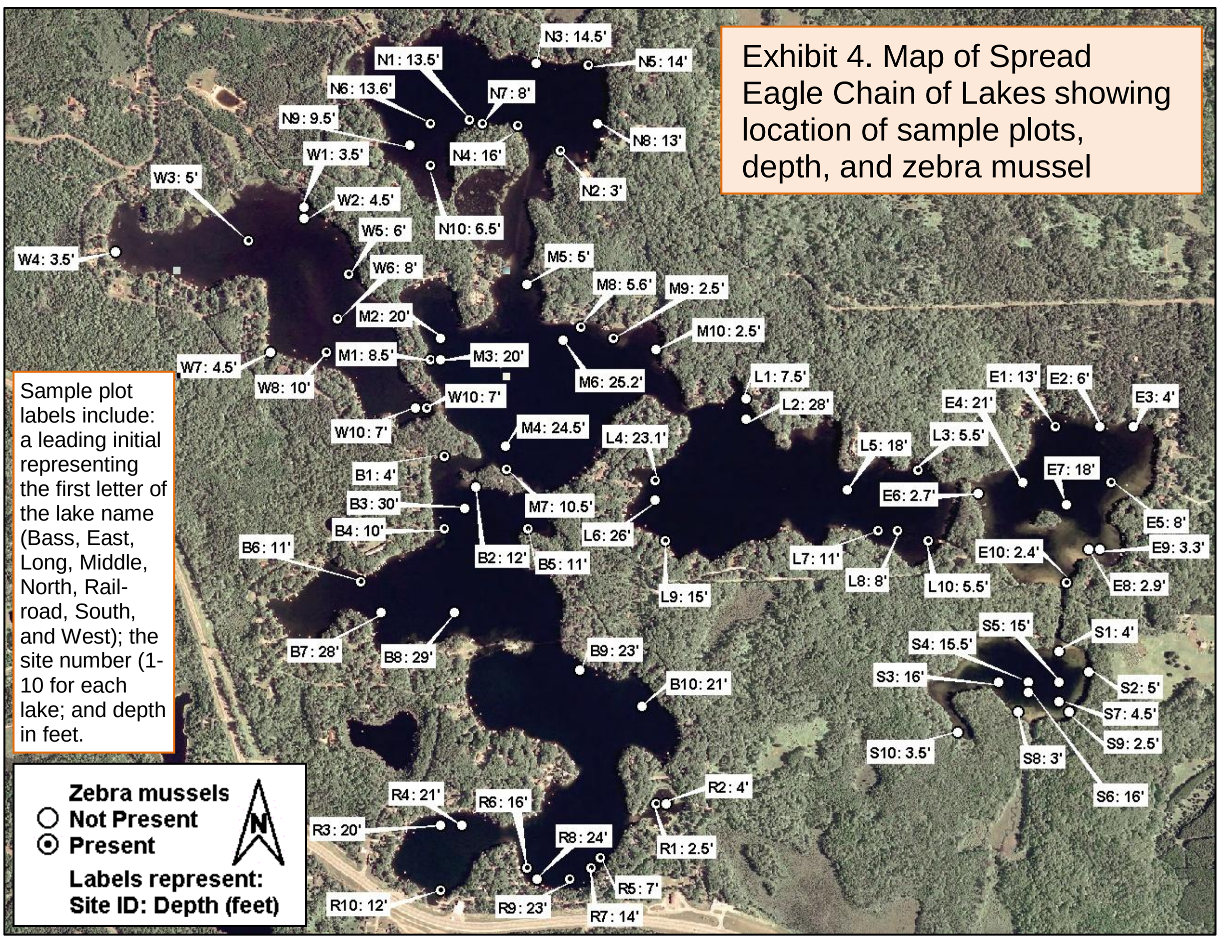


Exhibit 4. Map of Spread Eagle Chain of Lakes showing location of sample plots, depth, and zebra mussel

Table 1. Percent of Sampling Plots Occupied by Zebra Mussels	
Lake Name	Percent Sampling Plots with Zebra Mussels
Bass	40
East	30
Long	60
Middle	40
North	70
Railroad	60
South	0
West	50
Mean value for all 8 study lakes	44
Mean value for 7 zebra mussel lakes (not including South Lake)	50

A total of 905 zebra mussels were processed from the sampling plots. The mean number per plot (by lake) is provided in Table 2 and shown graphically along with the 95% confidence intervals in Exhibit 5. The variability is quite high among the sampling plots and the resulting broad 95% confidence intervals indicate that differences in mean numbers among the seven lakes are not statistically significant. Table 2 also presents the number of zebra mussels per sampling plot extrapolated to zebra mussels per square meter. Ferry (2013) provided estimates of zebra mussel density in nearby Keyes Lake (8 miles west of the SECOL) over a one year period starting one year after zebra mussels were first detected in the lake (see data in footnote of Table 2). These data indicate the dramatic increase in population size in Keyes Lake over that relatively short period of time. The densities calculated for the Spread Eagle Chain of Lakes are for the fourth year after they were detected in 2012.

Exhibit 5. Mean Number of Zebra Mussels per Sample Plot by Lake

(Includes all sample plots, including those with no finds. Does not include South Lake.)

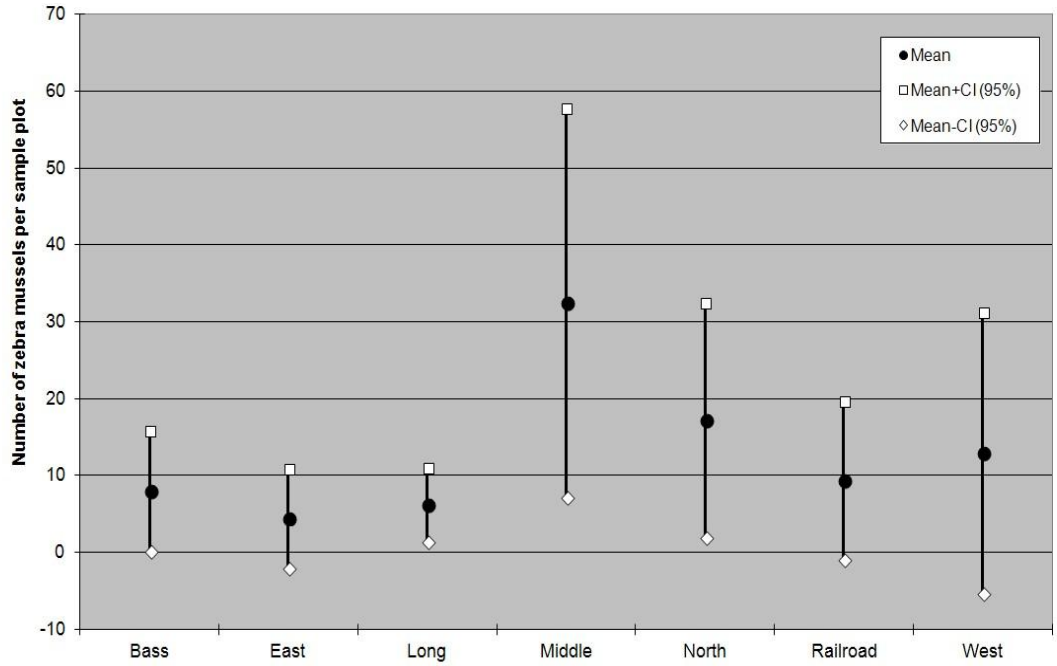


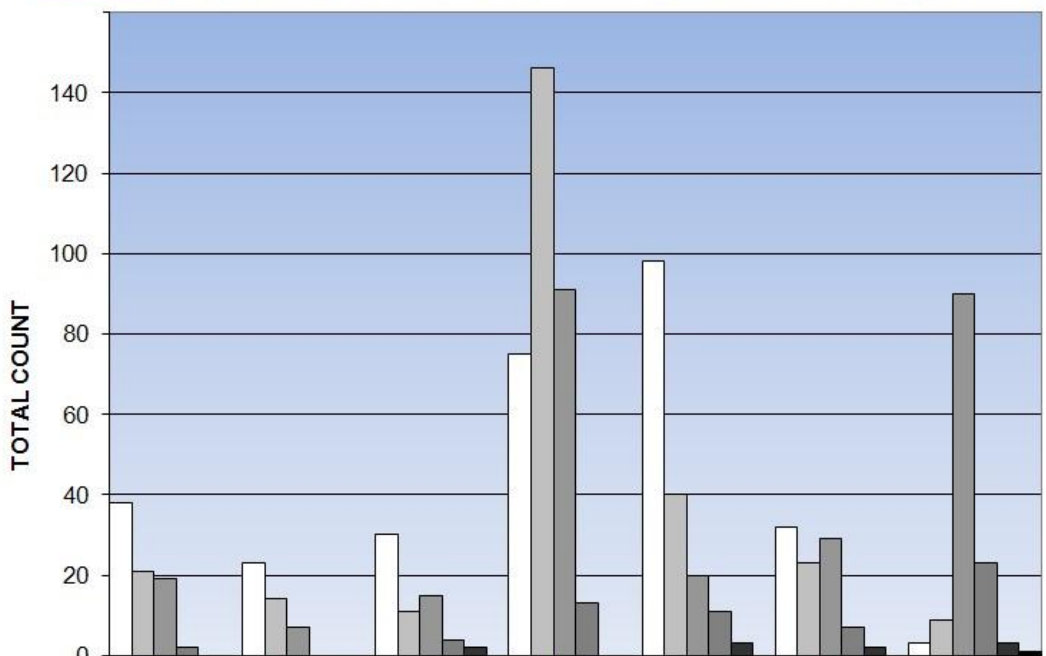
Table 2. Mean Number of Zebra Mussels Per Sampling Plot in SECOL		
Lake Name	Mean Number of Zebra Mussels Per Plot (incl. plots with zero)	Number of Zebra Mussels Extrapolated to per Square Meter[1, 2]
Bass	8.0	337.6
East	4.4	185.7
Long	6.2	261.6
Middle	32.5	1371.5
North	17.2	725.8
Railroad	9.3	392.5
South	--	--
West	12.9	544.4

[1]*Zebra mussels per square meter of that portion of lake where depth is less than depth of the thermocline.*

[2] *For comparison, Ferry (2013) estimates zebra mussel density in Keyes Lake (8 miles west of the SECOL) over a one year period starting one year after zebra mussels were first detected in the lake. These per square meter densities were: 2.3 (August 2011), 140 (June 2012), and 6,876 (August 2012).*

Exhibit 6 shows the distribution of age classes of zebra mussels collected from sample plots. The age categories are consistent with Ferry (2013). For example, age group "0" represents individuals that are less than one year old, whereas age group "1" are least 1 year old, but less than two. South Lake sample plots had no zebra mussels. Age groups 0, 1, and 2 were represented in all seven zebra mussel lakes. Age group 3 individuals were in samples of Bass, Long, Middle, North, Railroad, and West Lakes. Age group 4 zebra mussels were in samples from Long, North, Railroad, and West Lake. Age group 5 zebra mussels were found only in West Lake samples. Age group 0 numerically dominated in samples of all lakes except West and Middle. Age group 1 was numerically dominant in Middle Lake samples and age group 2 was numerically dominant in West Lake samples.

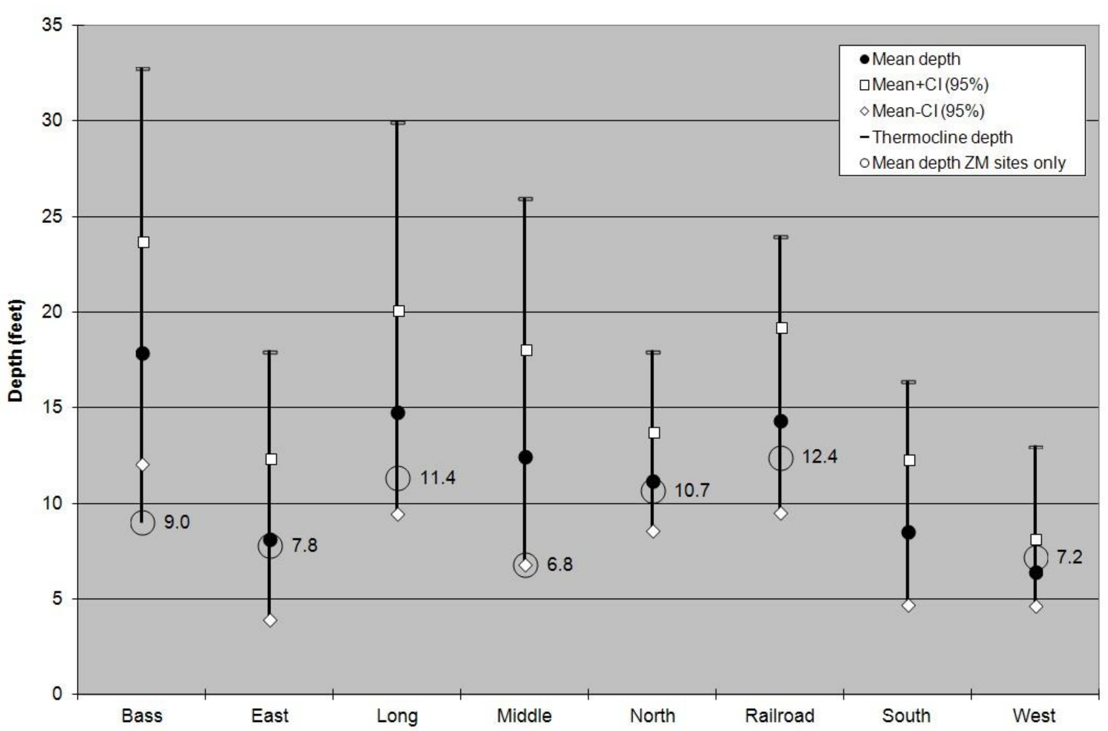
Exhibit 6. Counts by Age Class for Zebra Mussels in Spread Eagle Chain of Lakes



	Bass	East	Long	Middle	North	Railroad	West
0 year	38	23	30	75	98	32	3
1 year	21	14	11	146	40	23	9
2 year	19	7	15	91	20	29	90
3 year	2		4	13	11	7	23
4 year			2		3	2	3
5 year							1
Total ZM by Lake	80	44	62	325	172	93	129

Our data allow examination of zebra mussel distribution and lake depth. Sample plots with zebra mussels ranged in depth from 2.4 feet to 23.1 feet (one 23 foot deep plot on Long Lake and one on Railroad Lake). Exhibit 7 shows mean depth of all ten sample plots in each lake along with thermocline depth and mean depth of sample plots where zebra mussels were found. Thermocline depth varied from lake to lake (ranging from 13 feet in West Lake to 32.8 feet in Bass Lake) and mean depth of sample plots also varied (ranging from 6.4 feet in West Lake to 17.9 feet in Bass Lake). This is not surprising since thermocline depth was part of our sample plot selection. Mean depth of plots where zebra mussels were found, however, varied considerably less and ranged from 6.8 feet (Middle L.) to 12.4 feet (Railroad L.). In six of the seven zebra mussel lakes, mean depths of sample plots where zebra mussels were present was less than mean sample plot depth. In Bass and Middle Lakes, mean depths of zebra mussel plots were considerably less than mean depths of sample plots. Ferry (2013) found zebra mussels in North Lake in a band around the perimeter of the lake with few occurrences in shallow water (<1m) and absent beyond 4m (13 feet). Our North Lake data generally agree, although as noted above, we did document zebra mussels as deep as 23 feet two other lakes.

Exhibit 7. Mean Depth of Sample Plots and Zebra Mussel Plots by Lake



Muck was the most commonly encountered substrate at our sample plots, occurring on 70 of the 80 points (88%). Sand and gravel were less frequently recorded at sample plots. Thirteen points had sand (16%) and fifteen had gravel (19%). Sand and gravel were almost always present together (all 13 plots where sand was present also had gravel present). Gravel was nearly always represented by only a small amount at any given sample plot. Aquatic macrophytes (plants) were recorded at 34 of the 80 sampling plots (42%) and were always associated with muck.

Our substrate data does not elucidate clear habitat preferences of zebra mussels in the Spread Eagle Chain of Lakes, but some generalities are worth mentioning. Thirty-six of the 80 sample plots had muck as the only substrate, but only five of these (14%) had zebra mussels present. The 34 sample plots where plants were recorded were always associated with muck substrate and zebra mussels were present at 23 of these plots (68%). Presence of sand and/or gravel also seemed to predict zebra mussel presence. Ten of 13 sample plots with sand had zebra mussels (77%). Eleven of 15 plots with gravel had zebra mussels (73%). Ferry (2013) found that zebra mussels consistently selected for hard substrates (rock, wood, and mussel shells), avoided soft substrates (silt, organic, and sand), and used macrophytes in proportion to their availability. Given her findings, it seems likely that the association we observed between zebra mussels and sand substrate was actually an association with gravel (since sand and gravel were so closely associated as a substrate in the Spread Eagle Chain of Lakes). Exhibits 8 through 15 graphically display substrate records for each lake.

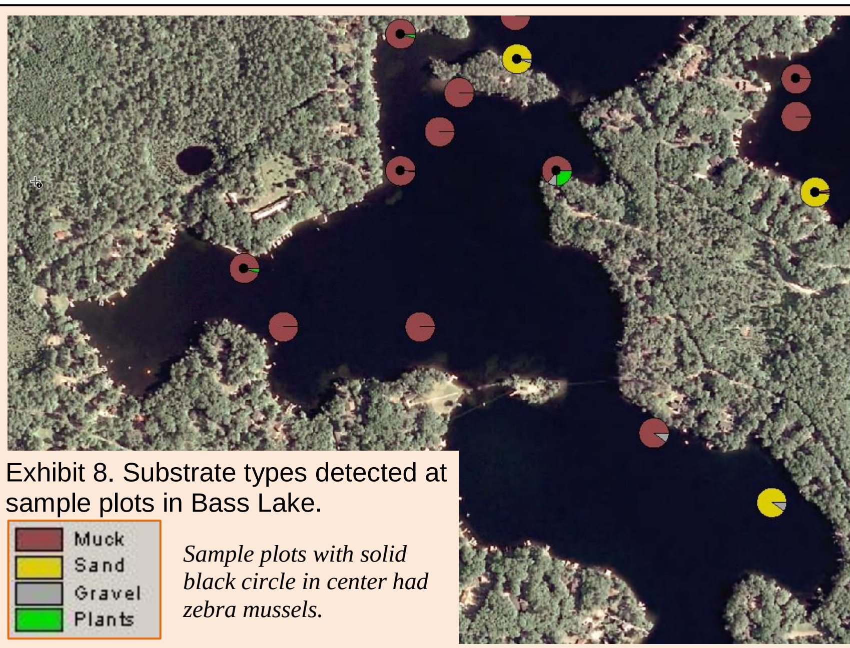


Exhibit 8. Substrate types detected at sample plots in Bass Lake.

Sample plots with solid black circle in center had zebra mussels.

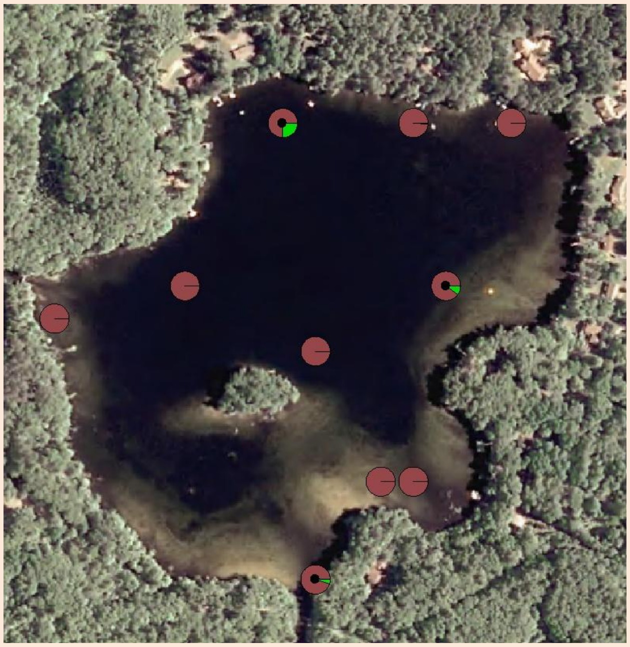


Exhibit 9. Substrate types detected at sample plots in East Lake.

Muck
Sand
Gravel
Plants

Sample plots with solid black circle in center had zebra mussels.

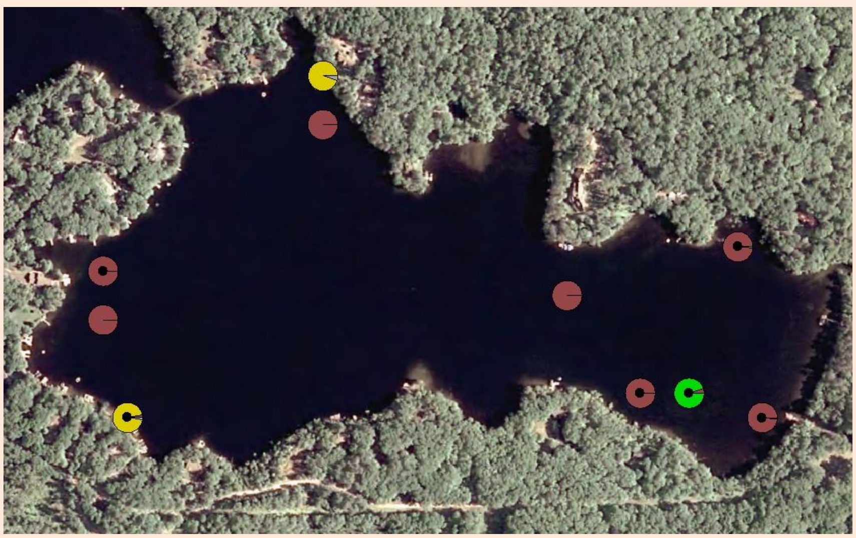


Exhibit 10. Substrate types detected at sample plots in Long Lake.

Muck
Sand
Gravel
Plants

Sample plots with solid black circle in center had zebra mussels.

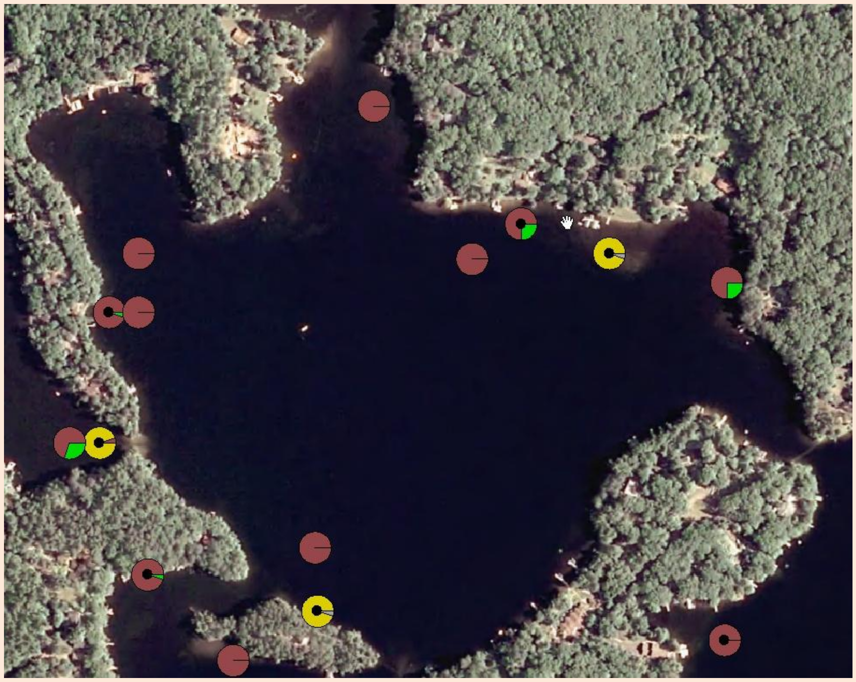


Exhibit 11. Substrate types detected at sample plots in Middle Lake.

Muck
Sand
Gravel
Plants

Sample plots with solid black circle in center had zebra mussels.

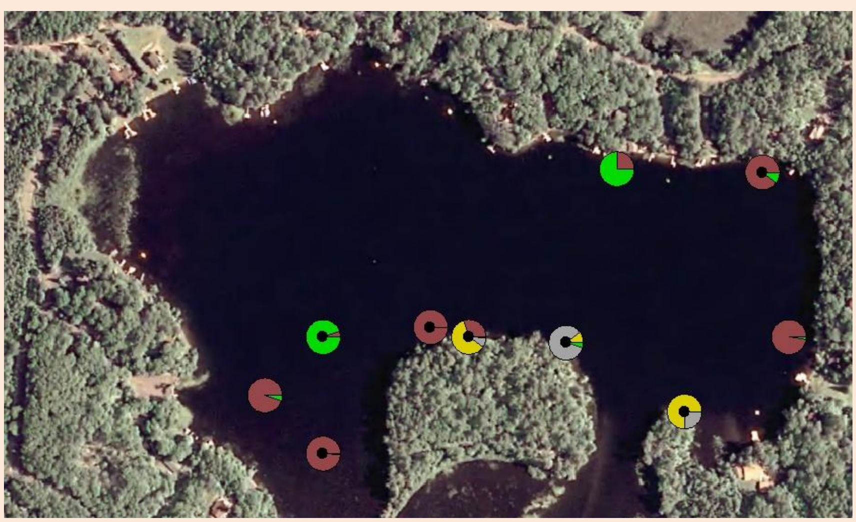


Exhibit 12. Substrate types detected at sample plots in North Lake.

Muck
Sand
Gravel
Plants

Sample plots with solid black circle in center had zebra mussels.

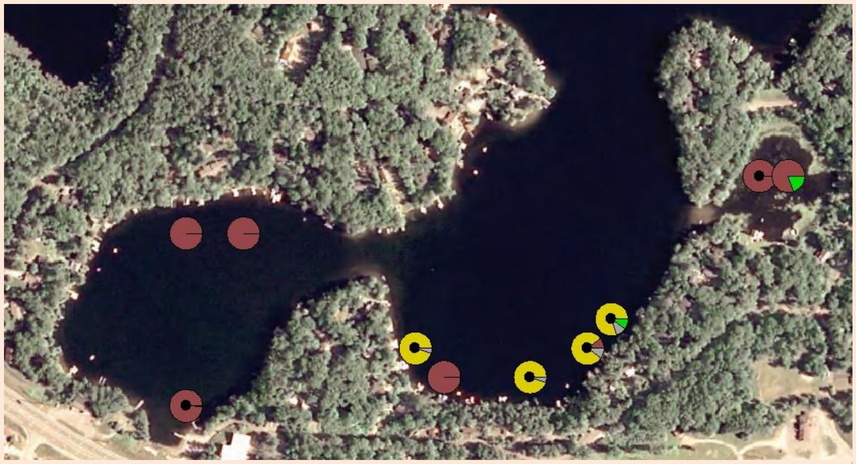


Exhibit 13. Substrate types detected at sample plots in Railroad Lake.

Sample plots with solid black circle in center had zebra mussels.

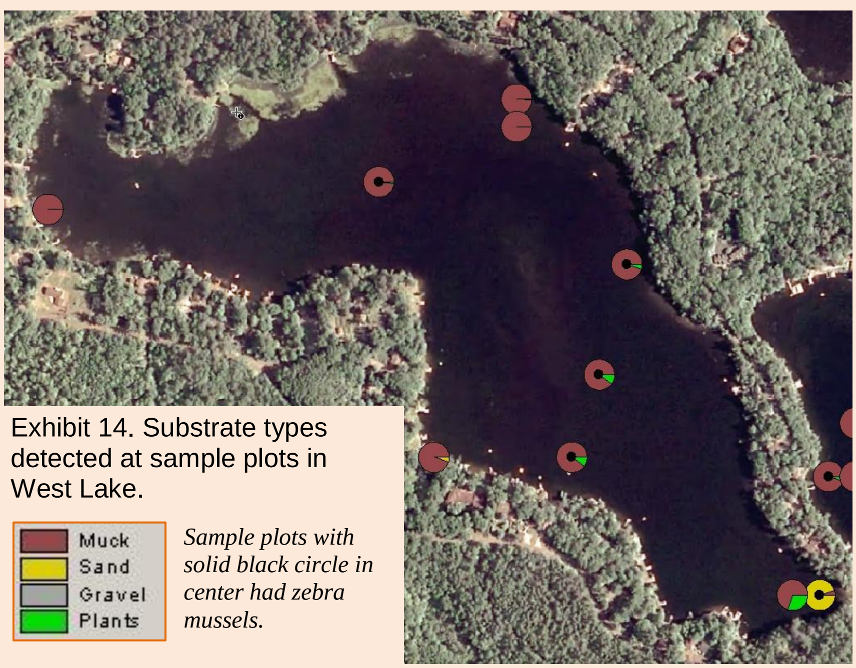


Exhibit 14. Substrate types detected at sample plots in West Lake.

Sample plots with solid black circle in center had zebra mussels.

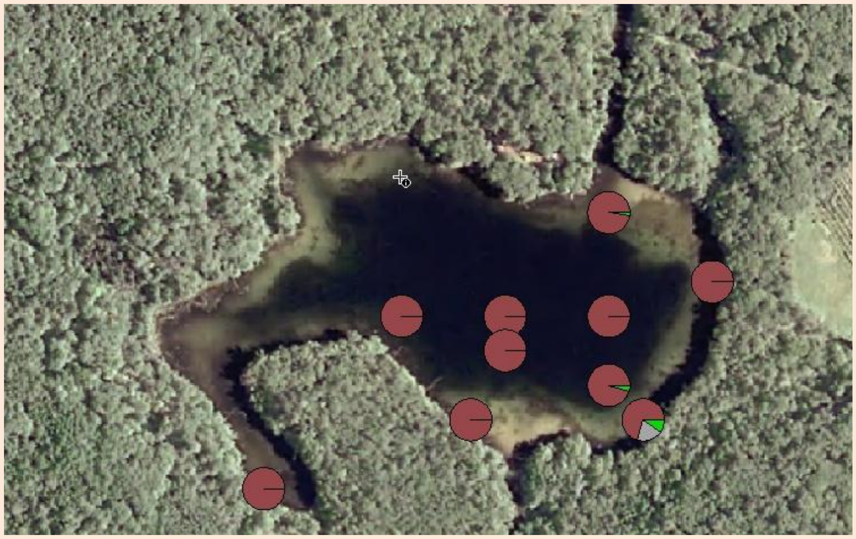


Exhibit 15. Substrate types detected at sample plots in South Lake.

Sample plots with solid black circle in center had zebra mussels (no zebra mussels were found in sample plots in South Lake).

DISCUSSION

Zebra mussels can attach to any hard non-toxic surface (e.g., rock, wood, metals, vinyl, glass, rubber, fiberglass, plants, turtles, and native mussels). Zebra mussels primarily live in warm, shallower water and can reach high densities. Zebra mussels feed by drawing water into their bodies and filtering out most of the suspended microscopic plants, animals, and debris. An individual can process 1 liter of water per day. Their great densities and feeding behaviors are the reasons for their ecological and economic impacts. How these potential impacts may manifest in the Spread Eagle Chain of Lakes remains to be seen. In this Discussion section we outline potential impacts, mitigation, containment, and monitoring of the Spread Eagle Chain of Lakes' zebra mussel population.

Zebra mussels alter freshwater ecosystems in both obvious and subtle ways. The impacts that especially concern the Spread Eagle Chain of Lakes include the following:

- Altering and redirecting food web pathways
- Depleting the food supply for native organisms (including fish)
- Altering the natural substrate and habitat used by native organisms
- Fouling the environment with waste products and depleting oxygen levels
- Physically encrusting native mussels and causing their decline and/or extinction
- Competing with native mussels for food source
- Creating conditions favorable to noxious blue-green algal blooms
- Causing increase in water clarity and thereby affecting the aquatic plant community
- Increasing the concentrations of microsystin (a toxic product of blue-green algae) by selective feeding that discriminates against blue-green algae
- Through bioaccumulation, increasing wildlife exposure to pollutants and viruses.

Economic impacts of zebra mussels are experienced by industries, agencies, and individuals. Potential impacts most germane to the SECOL include the following:

- Colonizing docks, breakwalls, boat hulls, engine outdrives to the point of damage or reduced effectiveness
- Fouling beaches and creating hazards to those with unprotected feet (shells are sharp)
- Spoiling recreational opportunities because of reduced fish populations, algal blooms, and concern for equipment
- Reduced property values.

Native freshwater mussels are imperiled in many parts of the world (Williams et al., 1993; Ricciardi and Rasmussen, 1999). They have been exploited by humans and have been impacted by siltation, channel modification, pollution, and dam construction. Zebra mussels also impact native freshwater mussels (Williams et al., 1993; Ricciardi et al., 1995; Ricciardi and Rasmussen 1999). Zebra mussel attachment to native mussel shells interferes with the freshwater mussel movement, feeding, physiology, and growth (Strayer, 1999; Strayer and Malcom, 2006). Following zebra mussel establishment, native mussel populations have declined significantly in Lake St. Clair, Lake Erie (Schloesser and Nalepa, 1994), the St. Lawrence River (Ricciardi et al., 1996), and the Hudson River (Strayer and Smith, 1996).

Because of the economic and ecological importance of zebra mussels, their control has been an enormously active area of research. Despite this attention, no zebra mussel control technique has yet been discovered that can feasibly be applied to a whole lake system.

With each new zebra mussel infestation, the risk to other water bodies increases. Since control measures for zebra mussels are limited, the best option for protecting other water bodies is to contain existing populations of zebra mussels. Not only do the SECOL stakeholders have to care for the zebra mussel-stressed Chain of Lakes, they carry the additional responsibility of protecting other lakes from the SECOL zebra mussels. This depends on educated lake users. They must know about AIS transport and clean their boats and gear upon entering and leaving the SECOL. This behavior will address multiple AIS.

A Strategic Plan to Address Zebra and Quagga Mussels in the Menominee River Watershed (Premo and Stine, 2013) discusses a strategic response to zebra mussels in the watershed, but has information and references of interest in the context of the Spread Eagle Chain of Lakes. Various vectors facilitate the transporting of zebra mussels along human-influenced pathways. Boats, canoes, kayaks, engines, and boat trailers are the more obvious. Less obvious vectors include aquatic plant fragments, live bait containers, anchors and ropes, fishing equipment, snorkeling and SCUBA gear, water skis and wakeboards, research equipment (such as plankton nets and aquatic plant rakes), fish management equipment (such as nets, trucks, and hoses for planting fish), float planes, rocks or driftwood collected from an infected lake, aquarium water, and even pets that might swim in an infected lake. Zebra mussel veligers, juveniles, and even adults are sensitive to exposure to air and sunlight. Short transportation distances increase the likelihood of a viable introduction to a new water body.

The Clean Boats Clean Waters (CBCW) program has been active for many years in Wisconsin. Boaters are getting the message about draining water from their boats and looking for aquatic plants and animals before leaving the landing. Improvement needs to occur in the following areas: disposing of unwanted live bait, drying boats for at least five days if another form of decontamination is not used, going out of your way to find a boat wash station, and flushing the motor's cooling system with tap water after each use.

For the Spread Eagle Chain of Lakes residents, be aware of the pathways for zebra mussels to leave the Chain of Lakes and reach other water bodies. If you sell a boat, pier, raft, or other water-based equipment, make sure it is disinfected or thoroughly dried for at least ten days before it is installed elsewhere. If you enter or leave the SECOL, disinfect your watercraft by going to the boat wash station or thorough drying in the sun.

The Spread Eagle Chain of Lakes will benefit from several kinds of monitoring efforts. First and foremost is to monitor the lake for early indicators of new AIS. Second, it is important to monitor the variety of ecosystem effects caused by the zebra mussel population. Third, it will be instructive to monitor the zebra mussel population itself as it grows and finally comes into some kind of equilibrium state in the Spread Eagle Chain of Lakes. These are distinct kinds of monitoring, each requiring specific skills, equipment, and motivation.

The zebra mussel population in the Spread Eagle Chain of Lakes is in a growth phase and the increasing numbers will potentially influence several attributes of the ecosystem. Water clarity may increase and this can be monitored by a regimen of water transparency checks (using a Secchi disk) throughout the open water season. Water chemistry data should continue to be collected. These are valuable means to evaluate lake changes. With possible zebra mussel-induced water clarity and nutrient changes in the lakes, the aquatic plant community may change in terms of its composition and geographic distribution. A future point-intercept plant survey would help determine such changes. Since zebra mussels consume planktonic algae, this community may also change as the zebra mussel population increases. Algae could be monitored as well as the food web that is dependent on these algae (zooplankton and fishes). WDNR fish surveys could address the numbers and state of health of planktivorous fish populations. It is important to be vigilant for bluegreen algae blooms (a possible side effect of zebra mussel presence).

The SECOL is an ecosystem under stress from zebra mussels. It is important for stakeholders to minimize other potential stressors. They should prevent additional AIS, maintain and create good shoreland buffer zones to prevent additional nutrients from entering the lakes, and maintain good aquatic habitat in the SECOL. The SECOLA can work with others to build interest, volunteers, and funding to make this happen.

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