Management Plan for Control of Asian Clam (*Corbicula fluminea*) in the Mukwonago River Watershed

Crooked Creek Preserve, Mukwonago River Watershed
(Conservancy, 2014).

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Introduction

The Mukwonago River is one of the most pristine and biologically diverse streams in southeastern Wisconsin (River, n.d.). Since 2008 the river and its associated tributaries, which lies within Waukesha, Walworth, and Jefferson counties (Figure 1), has witnessed the introduction of an aquatic invasive species known as the Asian clam (*Corbicula fluminea*; henceforth referred to as *Corbicula* or Asian clam). The infestation was first discovered in the Mukwonago River unit of the Southern Kettle Moraine Forest and has since been sighted in water bodies throughout the watershed (Schneider, unpublished data). The proliferation of *Corbicula* in these inland waters has prompted action from the Friends of the Mukwonago River (FoMR), The Nature Conservancy, and the Wisconsin Department of Natural Resources (WDNR).

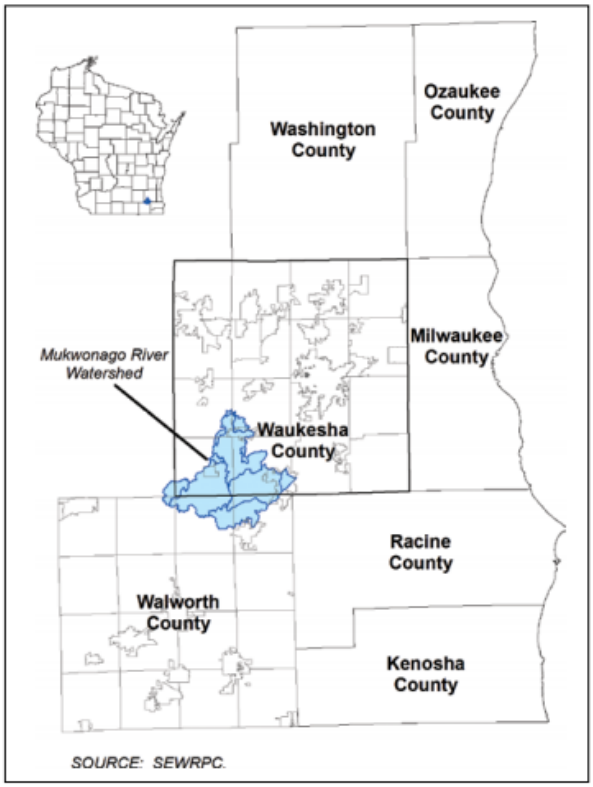

Figure 1. Overview of Mukwonago River Watershed location.

The landscape of the Mukwonago River Watershed is extremely heterogeneous. The Mukwonago River transitions between urban areas, undeveloped areas, and natural areas and flows in and out of lakes and wetlands (River, n.d.). Accessibility varies based on location. This diversity demands management techniques be adapted to each site. With heterogeneity in mind, it is essential to develop a long-term and comprehensive management plan to control the spread of Asian clam.

Figure 2. Map of Mukwonago River Watershed. The watershed is bordered by Lulu Lake to the west and the Fox River to the east. Notable reaches include: Lulu Lake to Eagle Spring Lake, Jericho Creek, Wetlands between Eagle Spring and Phantom Lake, and Phantom Lake to Fox River (also referred to as the Lower Reach).

Background

Mukwonago River Watershed

The Mukwonago River Watershed, which is situated 35 minutes southwest of Milwaukee, WI, contains over 50 miles of rivers and covers 86 square miles with 52 square miles (61% of the watershed) occupying Waukesha county with smaller portions reaching into Walworth and Jefferson counties (Figure 1 and 2). The area is a mixture of agricultural (36%), residential (19%), woodlands (15%), and wetlands (9%) but could be considered relatively undeveloped when compared to the adjacent suburban sprawl and cityscape of metropolitan Milwaukee (Conservation, 2012). Once glaciated, the landscape is dominated by the weathered soils of glacial till parent material (University of Minnesota, 2009) and dolomite, shale, and limestone rock (Grace, Selb, & Yassin, 1996). Groundwater recharge rates are significantly high

due in part to the glacial soils. Water quality in the Mukwonago River is also high due to vast stretches of wetlands which provide habitat for diverse hydrophytic plants and other aquatic species (River, n.d.). The ecological significance of the watershed is evident through the efforts and land ownership by the Wisconsin DNR (southern unit of the Kettle Moraine State Forest and the Lulu Lake State Natural Area) and The Nature Conservancy with the watershed being one of their highest priority areas in Wisconsin.

The southern unit of the Kettle Moraine State Forest is a 970 acre area which straddles both Waukesha and Walworth counties. It is a popular area for outdoor recreation, environmental education, and is known for its biological diversity and high quality aquatic habitats (Resources, Kettle Moraine, 2014). The Lulu Lake State Natural Area (Figure 3) contains diverse habitats including former glaciated uplands, wetlands, rivers, and lakes. The area is defined by the 95 acre, 40 foot deep Lulu Lake which is fed by the Mukwonago River. Designated a state natural area in 1977 and owned by the WDNR and The Nature Conservancy, Lulu Lake is a pristine water resource which is home to a diverse array of aquatic species and is extensively used for recreational purposes (Resources, Lulu Lake, 2014).

Figure 3. Lulu Lake State Natural Area

North and west of Lulu Lake are spring-fed wetlands which contain an amalgamation of calcareous fens, shrub carr, and sedge meadows. Prairies, bogs, oak woodlands, and tamarack forests scatter the rest of the site (Resources, Lulu Lake, 2014). The various habitats that compose the Mukwonago River Watershed contain a plethora of diverse species. The Mukwonago River alone is habitat to over 50 species of freshwater fish and 15 species of

freshwater mussels. The Mukwonago River is home to ten of the eleven species of sunfish in Wisconsin and all three species of topminnow along with various shiners and darters which provide an indication of good water quality (River, n.d.). Prominent threatened species include the longear sunfish (*Lepomis megalotis*), slipper shell mussel (*Alasmidonta viridis*)**,** and ellipse mussel (*Venustaconcha ellipsiformis*) as well as the endangered starhead topminnow (*Fundulus dispar*) *and* rainbow shell mussel (*Villosa iris).* The river also provides habitat for diverse reptiles, amphibians, insects, waterfowl, and aquatic plants. The overall ecosystem quality is excellent (River, n.d.).

Native Unionid Mussels

The ellipse, slipper shell, and rainbow shell mussels are present in running water reaches of the Mukwonago River (Figure 4). They are found exclusively in the river and not Lulu Lake or any impounded lakes. Both the ellipse and slipper shell are present from the river mouth to Lulu Lake. The ellipse is most commonly found between impounded lakes and downstream of the Village of Mukwonago Dam between Lower Phantom Lake and the Fox River, whereas the rainbow shell is most commonly found in just that lower reach (Figure 2). More refined locations for both the slipper shell and rainbow shell are not available due to lack of records (Lisie Kitchel, personal communication, Nov. 24, 2014).

A 

B 

C 

Figure 4. Native Unionid Mussels: A) Ellipse Mussel B) Slipper Shell C) Rainbow Shell

Corbicula fluminea

The invasive Asian clam (*Corbicula fluminea*) was first discovered in the Mukwonago River in 2008 and five years later it was found upstream in Lulu Lake (Schneider, unpublished data). This was the first instance of Asian clam proliferation into Wisconsin inland waters. While the method for introduction is unknown, typical modes of transport of aquatic invasive species include boating (stowaway in ballast tanks), bait bucket disposal, and aquarium release (SEWISC, 2013).

Figure 5. *Corbicula fluminea* at various sizes compared to a dime. Clams on the left are adult and clams on the right are juvenile.

Asian clams are small, light-colored bivalves with concentric shell ornamentation (Figure 5), anterior and posterior lateral teeth with many fine serrations, and are less than 50 mm in diameter - not to be confused with native fingernail clams (Sphaeriidae) which look similar but grow smaller and have thinner shells without ridges. They are hermaphroditic and can reproduce twice per year, spring and fall, resulting in upwards of 70,000 young per year (SEWISC, 2013). *Corbicula* thrive in warm waters above 36 degrees Fahrenheit (2.2 degrees Celsius) and reproduce at temperatures above 61 degrees Fahrenheit (16.1 degrees Celsius) (Clearinghouse, 2009).

In general, invasive species often cause a number of problems for the environment. Depending on the species, they can carry and pass on devastating diseases, prey on and outcompete native species, prevent native species from reproducing, and even cause changes to the ecosystem's food web by replacing or reducing native food sources. Additionally, they have

been known to change ecosystem conditions, such as soil chemistry, and can decrease the biodiversity of the ecosystem ("Invasive Species", n.d.). *Corbicula* mussels can cause problems similar to those caused by most invasive species. Sheer numbers may allow them to out-compete native *Unionidae* mussels and become a major factor in benthic nutrient and energy cycling. The clams can release phosphorous and nitrogen (increase algal blooms) which in turn may also affect native aquatic species. The clam can also block grates in water pipes (biofoul) for irrigation systems, water treatment plants, or power plants and clog intakes and outputs (SEWISC, 2013).

Preliminary Assessment

Though the presence of *Corbicula* in the Mukwonago River is cause for concern, more information is required to determine the significance of its threat to the ecosystem and the vulnerable or endangered organisms within. Mussels are often the greatest source of filtration in the riverine ecosystem, having large impacts on nutrient availability downstream. The addition of the new mussel, *Corbicula* that feeds and reproduces at a much higher rate than native mussels, could spell massive changes for the stream system (Strayer et al., 1999). *Corbicula* have been observed as having relatively low direct detrimental impacts on healthy adult colonies of unionid mussels in some U.S. streams (Vaughn & Spooner, 2006). However, they tend to be located in disturbed habitat where presence of native mussels is low or in some cases (Clarke, 1988; Miller & Payne, 1994; Vaughn & Spooner, 2006; Strayer, 1999). Also, when compared to many unionid mussels, *Corbicula* have a greater demand for food due to their high metabolism and requirements of stable and specific water temperatures for survival, leading to selection against certain habitats as well as die-offs when ideal conditions are altered (Williams & McMahon,

1985). *Corbicul*a have been known to have a preference for silty or sandy substrates, where Unionids are often found in gravel and cobble (McMahon & Bogan, 2001).

The best management strategies for *Corbicula* in the Mukwonago River should be based on how *Corbicula* interact with the surrounding organisms within the stream system (Sousa et al., 2008(2)). Though it is well understood that the Mukwonago River provides habitat for species of threatened and endangered status, negative impacts on these organisms from *Corbicula* have yet to be observed. Therefore, it is of utmost importance to assess the distribution and abundance of the Asian clam and native mussels, to determine which stream reaches are considered most biologically diverse or valuable, and to understand how *Corbicula* interacts within the Mukwonago River system through professional observations and assessment. If *Corbicula* are found to be a persistent and a serious threat to the stream ecosystem, then involved management strategies should be implemented in an attempt to prevent further damage or restore what has been lost.

Problem

Corbicula fluminea have rapidly spread throughout the United States since its deliberate introduction in the late 1800s (McMahon, 1982; Counts, 1986). Through high growth rates and rapid reproductive capabilities, *Corbicula* have been known to rapidly invade, colonize, and dominate non-native aquatic habitats to which it has been introduced (Yavelow et al., 1976; McMahon & Bogan, 2001; Sousa et al., 2008(2). Human interactions, abiotic factors such as direction of water flow, and species migration have perpetuated the spread between water bodies.

In the event that direct intervention is required for the preservation of the endangered organisms within the Mukwonago River, action is limited by the special regulations and

permissions set by the DNR as well as the Endangered Species Act (Sullins, 2001). Water quality and environmental conditions cannot be violated in habitats containing endangered or protected organisms, while the organisms themselves cannot be harmed, removed, or manipulated without professional interaction and/or permission. The stretch between Phantom Lake and the Fox River is of great concern because it provides habitat for the endangered rainbow shell mussel as well as other native Unionids and fingernail clams. Currently, sampling has not found *Corbicula* in this reach (Schneider, unpublished data).

If the *Corbicula* threat is severe, then native unionids face local extinction. Sophisticated actions that may potentially violate DNR and ESA rules (example: relocation of native mussels) could be the only means of preventing extirpation. These actions would need to be coordinated with professional scientists, volunteers, and the DNR, respectively.

Based on Matt Schneider's research in the summer of 2014, *Corbicula* are present in three sites along the Mukwonago River. Highest densities were found at Jericho Creek (County Road E), followed by Rainbow Spring Bridge, and lower densities at Beulah Road Bridge (Schneider, unpublished data). In addition, no quantitative data was collected on lakes, however *Corbicula* were observed in both Lulu Lake and Eagle Spring Lake. A strategic management plan should be put in place in order to reduce these densities and prevent them from spreading to the rest of the watershed.

If drastic actions are not deemed ethical, the only viable plan for management of *Corbicula* would involve manual removal. The complete removal of the species from the river system is near impossible with this method. The effectiveness of manual removal as a control for *Corbicula* is unknown in the Mukwonago River. *Corbicula* have been observed as having one or two breeding seasons within a year, where dispersal of young and colonization can occur very

rapidly (Hornbach, 1992). Management planning would be made most effective by large-scale removal projects before breeding occurs, limiting the breeding populations.

For the workers involved, identification becomes very important as volunteers will need to be capable of distinguishing between species as well as trained in handling both native and non-native mussels. All removed *Corbicula* specimens would need to be disposed of appropriately while all equipment would need to be properly dried and sanitized to avoid unintentional spread.

Strategic management plans can be expected to culminate as the severity of the *Corbicula* threat is determined. Practical actions with the greatest benefits should be the aim of any management plan and as new evidence and information is brought to light, the decision on how to act will be made clearer.

Goals and Objectives

Goals (1) through (3) are adapted from the DNR Aquatic Invasive Species (AIS) grant narrative. The goals of this management plan are to:

(1) Develop a *Corbicula* removal plan that outlines options with varying levels of impact and effort that FoMR can tailor to their own financial and volunteer resources. When this removal plan is enacted it should produce data on the quantity of *Corbicula* removed that can be compared to the assessed levels of *Corbicula* from Goal (2). From this data a level of effectiveness could be elucidated as well as a logical conclusion on the feasibility of undertaking future, large scale removal of *Corbicula.*

(2) Develop an outline to monitor *Corbicula* populations throughout the Mukwonago River Watershed during and after removal procedures are enacted. Monitoring would begin at

Lulu Lake (the original identified location of *Corbicula*) and spread throughout the watershed. This will help FoMR understand *Corbicula* movements and life cycles.

(3) Develop a list of partners (including grants for potential funding) for volunteer work and educational purposes that will aid in the removal of *Corbicula* and future monitoring and assessment. FoMR will be able to utilize this list to create partnerships with people who will hopefully gain knowledge and appreciation about efforts relating to aquatic/terrestrial invasive species and their removal.

Management Strategies

Prevention

It is important to prevent the spread of *Corbicula* throughout the watershed. Even though preventative actions can sometimes be time consuming and cost prohibitive, most are common sense and cost effective. Making smart prevention choices are well worth the effort.

Corbicula can be transported to other areas by bait buckets (SEWISC, 2013), as well as general recreational equipment. It is vital that fishermen prevent cross contamination from bait buckets and other fishing equipment. If a bait bucket is used in more than one lake, it should be rinsed thoroughly in the area that it was used before being transported ("New York Boaters Guide", n.d.).

Boats also have the possibly of spreading *Corbicula* (SEWISC, 2013). It is important that when boaters leave a lake they drain all water from their boat, live wells, bait wells, bilge pumps, and motors. Water should also be drained from all fishing gear and watersport equipment. A top to bottom inspection is also necessary to insure that all mud, weeds and other materials on the boat are removed ("New York Boaters Guide", n.d.).

As part of this inspection, it can be helpful to wipe down the boat with a damp towel that has been soaked in bleach to disinfect any remaining invasive species ("New York Boaters Guide", n.d.). This can be more easily accomplished when boats are on dry dock. Letting the boats and equipment dry off are very effective ways to reduce the spread of *Corbicula.* The typical drying time for a medium sized boat is anywhere from five to seven days during the summer months, and a month or more during moist and winter months. If the boat is to be used before the drying period is up, it would be advantageous to use disinfectants to clean the boat before using it ("New York Boaters Guide", n.d.).

Using hot water is the best way to dispose of *Corbicula.* Clams submerged in water at 140 degrees Fahrenheit (60 degrees Celsius) or hotter for ten seconds is lethal to *Corbicula.* Most household water does not reach these temperatures, so the use of a steamer may be necessary ("New York Boaters Guide", n.d.).

It is important to disinfect every piece of equipment to ensure transportation of invasive species to other locations does not occur. A bleach water mixture is a suitable substitute when disinfecting your equipment (see Disposal section). It is important to rinse equipment thoroughly, such as waders and tools, and make sure disinfection is done on site. A final scrubbing of all equipment with a brush will ensure that all invasive species are removed (Schneider, unpublished data).

Education and Outreach

Since human activity is a major factor in the spread of *Corbicula*, education is extremely important when it comes to prevention. People who use the streams and lakes for recreation, work, or otherwise should be taught to clean their boats and equipment before moving on to another water body. It is also important to teach people not to release mussels, or any other

organism, into the wild from aquariums or bait buckets. Laws that enforce these measures and prohibit the introduction of these invasive mussels would be of further benefit, considering not all people would voluntarily go through these steps (Kramer-Wilt, 2008).

Interventions

Managing invasive species is a complex issue that requires multiple interventions that vary in time and spatial scales. The most effective management plans are multifaceted and comprehensive. The following management plan created for the Mukwonago River Watershed includes strategies to reduce the number of *Corbicula* in lakes and in rivers as well as strategies that vary in levels of effort and impact.

A variety of control methods for *Corbicula* are available, however many of them are not suited for the Mukwonago River Watershed. Thermal regulation can be used by heating water in pipes to 98.6 degrees Fahrenheit (37 degrees Celsius) or higher, that is lethal for Asian clams. This method is not appropriate for Mukwonago River Watershed because Asian clams are not impacting intake pipes. Chemical methods, such as adding chlorine or bromine to the water system could be effective (*Corbicula fluminea*, 2005). However, this could lead to depletion of the water quality. In extremely impacted areas, draining and refilling the affected lake has been utilized. This would not be a reasonable solution because the lakes in the watershed are not impacted to that extent. The most viable management methods for the watershed are mechanical measures such as benthic barriers, suction harvesting, and manual removal.

The timing and placement of implementing the strategies is crucial for successful *Corbicula* management. *Corbicula* reproduce in the spring, after the water temperature rises above 60 degrees Fahrenheit (15 degrees Celsius) (Wick & Young, 2013). In the Mukwonago

River, that occurs in April and May (Figure 6) ("Mukwonago River Watershed", 2009). The strategies should be implemented before the first reproductive cycle to limit the number of *Corbicula* that need to be removed. Strategies should be implemented from areas of least impact to areas of highest impact. This will limit the spread of *Corbicula.* Based on Matt Schneider's research, strategies will start at Beulah Bridge and work west towards Eagle Spring Lake and Lulu Lake (Schneider, unpublished data).

Different strategies will be applied in lakes and rivers. Eagle Spring Lake and Lulu Lake have no native mussels (Lisie Kitchel, personal communication, Nov. 24, 2014), so more drastic controls can be used in the lakes compared to the rivers. Two strategies, benthic barriers and suction harvesting, will be described in this management plan for lakes. Manual removal techniques will be described for use in the Mukwonago River and its tributaries.

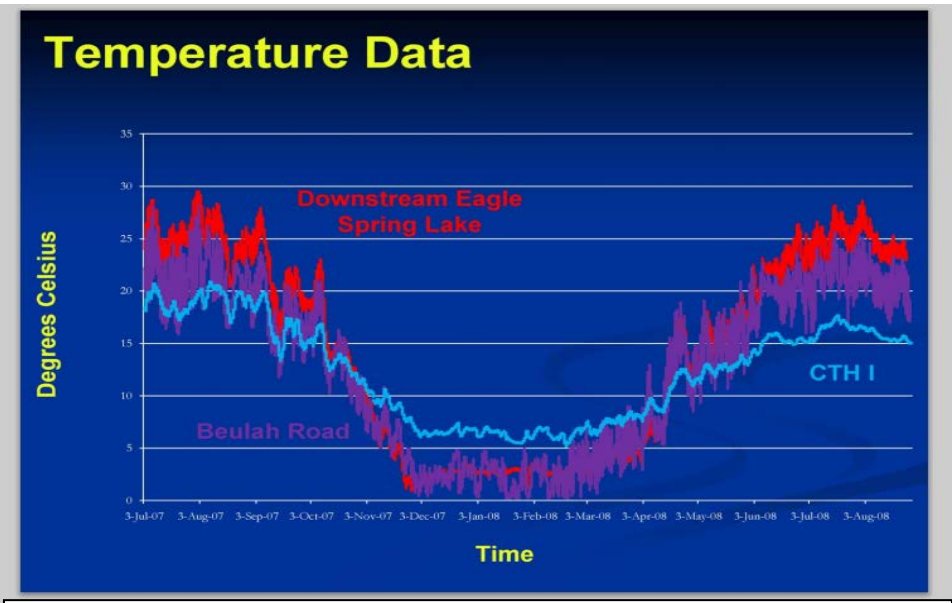

Figure 6. Water temperature graph of Downstream Eagle Spring Lake, Beulah Road Bridge, and County Highway I. Image obtained from SEWRPC's Mukwonago River Watershed Protection Planning Program, 2009.

Lakes

Benthic Barriers

Method

Areas in the lakes with high densities of *Corbicula* will be treated with benthic barriers. Further research needs to be done to determine the distribution of *Corbicula* in the lakes in order to identify high priority areas. Benthic barriers lay on top of the lake bottom and suffocate the clams by cutting off access to dissolved oxygen (DO) (Wick & Young, 2013).The most successful type of benthic barrier is ethylene propylene diene monomer (EPDM) barrier that is 1.14 mm thick (Figure 7). Marla Bay, which is on the southeast edge of Lake Tahoe, used mats that were 30 x 3 m to cover an area of 64 x 30 m, although any dimensional size would be sufficient for this purpose (Wittmann et al., 2012b). It proved to be successful to have the mats overlap one foot on all edges of the mats. In order to weigh down the mats, steel reinforcement bars were used by placing them along the edges and in the middle of the mats ("Plan to Eradicate", 2011).

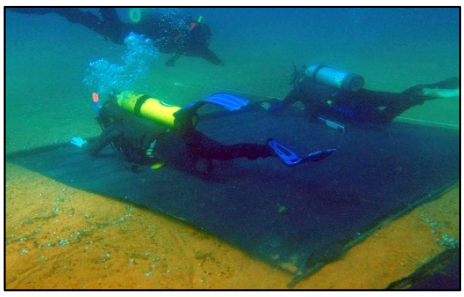

Figure 7. Benthic barrier mats being installed in Lake George.

Trained divers will install and monitor the barriers. The DO level beneath the mats should also be monitored throughout the time period to ensure it is low enough for it to cause mortality. An effective range of lethal DO levels was 0 -1 mg/L (Wittmann et al., 2012b).

Time Line

Barriers should be installed as early as possible after the ice melts, preferably by the end of April ("Plan to Eradicate", 2011). The barriers will stay in place for at least 28 days and no

more than 56 days. In Marla Bay, Wittmann et al. found no difference in results for the range of 28-56 days (Wittmann et al., 2012b).

Effectiveness

In Marla Bay this method was successful, causing 98% mortality rates for *Corbicula* under the benthic barriers. This method of benthic barrier use proved to have successful long term effects. A year after barrier removal, the areas that were treated had 90% fewer *Corbicula* than control areas (Wittman et al., 2012b).

The expenses for Marla Bay's Initiative were not available, but Lake George's initiative also successfully used benthic barriers. Their expenditure for benthic barriers totaled $57,489 (Coffey et al., n.d.).

It should be noted that benthic barriers will cause death to vegetation and other mussels and macroinvertebrates. However, after barriers are removed there is a significant amount of growing season left for native vegetation to regenerate given the amount of starchy reserves the plants have in their roots ("Plan to Eradicate", 2011). Also, threatened native mussels are not distributed in Lulu Lake and Eagle Spring Lake (Lisie Kitchel, personal communication, Nov. 24, 2014) so the barriers will not harm those populations.

Suction Harvesting

Method

Suction harvesting is an effective method to us near the shoreline. Benthic barriers do not work well near the shore because of wave action. Suction harvesting removes the top six inches of near shore sediment (Figure 8) ("Plan to Eradicate", 2011). A trained technician operates the suction dredge apparatus while the pump is on a barge (Wittmann et al., 2012a). Suction harvesting will take place up to 25 feet out from the shoreline and underneath and around docks

("Plan to Eradicate", 2011). Removed sediment should be disposed of in a local designated area. For instance a zebra mussel removal project disposed of the muscles in a local landfill (Grant, 2005). The suction harvesting area should overlap the benthic barrier area for maximum results ("Plan to Eradicate", 2011).

Figure 8. Suction harvesting on the shoreline of Lake George.

Time Line

The suction harvesting should begin as early as possible in April and end in early May ("Plan to Eradicate", 2011).

Effectiveness

There are mixed results regarding suction harvesting. The method was successful for Lake George and Lake Tahoe, however it was less successful for Lake Champlain ("Plan to Eradicate", 2011). More Asian clams were present in areas of Lake Champlain after the suction harvesting compared to before it. The rate went from 36% to 59% of areas that had Asian clams present. Researchers hypothesize that recovered sediment that was re-deposited back in the lake assisted with spreading the clams. Also, suction harvesting can be expensive. The Lake Champlain Initiative spent $84,528 on this method (Coffey et al., n.d.). It was one of the most expensive portions of their initiative.

Rivers

Manual Removal

Method

While the lakes within the Mukwonago River Watershed can allow for procedures such as the benthic barriers and suction harvesting due to the minimal numbers of native mussels (Lisie Kitchel, personal communication, Nov. 24, 2014), this is not the case for the Mukwonago

River and its tributaries. The Asian clam and native mussels share the river habitat, so the removal strategy must be appropriately applied to preserve the native and endangered species. The shallow and accessible sections of the river allow for the less disturbing, but still effective, technique of manual removal.

Matthew Schneider, a student of University of Wisconsin-Waukesha, has demonstrated and conducted manual removal within the Mukwonago River (Figure 9). The removal method he applied involved using a GPS to coordinate different plots including a control plot, constructing PVC square plot markers, and scooping 1-2 inches of substrate with a colander for easy sorting. Schneider found it most useful and successful to only have two people within a site to provide the best coverage and would be the least disruptive to the ecological habitat. In accordance with Wisconsin State Law, any native mussel found was counted and placed back into its original plot (Schneider, unpublished data). For laws and regulations that govern clamming refer to Section 29.537, Wis. Stat., and Chapter NR 24, Wis. Admin. Code as well as Section 29.604, Wis. Stat., and Chapter NR 27, Wis. Admin. Code for requirements pertaining to threatened and endangered species (Resources, Clamming, 2014). In the course of manual removal it is likely that other invasive species will be discovered, specifically the Zebra mussel *(Dreissena polymorpha)* (Resources). These non-native species, if encountered, should also be removed and discarded in a similar process as the *Corbicula.* After the sorting and removal process it is pertinent that disinfection steps are completed to prevent transport upstream or downstream of invasive species. A simple

Figure 9. Matthew Schneider manually sorting and removing *Corbicula* in the Mukwonago River.

bleach and water mixture should be used to submerge or spray all equipment after use to effectively eliminate any remaining non-native mussels.

As previously stated, the areas of least impact should be addressed first to prevent the further spread of *Corbicula.* The initial manual removal and research completed by Matthew Schneider began at the Eagle Springs South Discharge, within the Mukwonago River Watershed, where no mussels were found (Schneider, unpublished data). County Road I and Highway 83 Bridge also showed no sign of *Corbicula*. Schneider ultimately identified three sites where *Corbicula* were present within the watershed: Mukwonago River at County Road E, Rainbow Springs Bridge, and Beulah Road Bridge (Figure 10). Further inspection and removal should continue at the site of least impact indicated in his research starting with Beulah Road Bridge and continue west. Inspection should also occur at certain other high priority areas such as the stretch of the Mukwonago River below the dam between Phantom Lake and the Fox River. This area in particular has been known habitat for a variety of threatened mussels (Lisie Kitchel, personal communication, Nov. 24, 2014). This type of coverage can further predict and eradicate the spread of *Corbicula*.

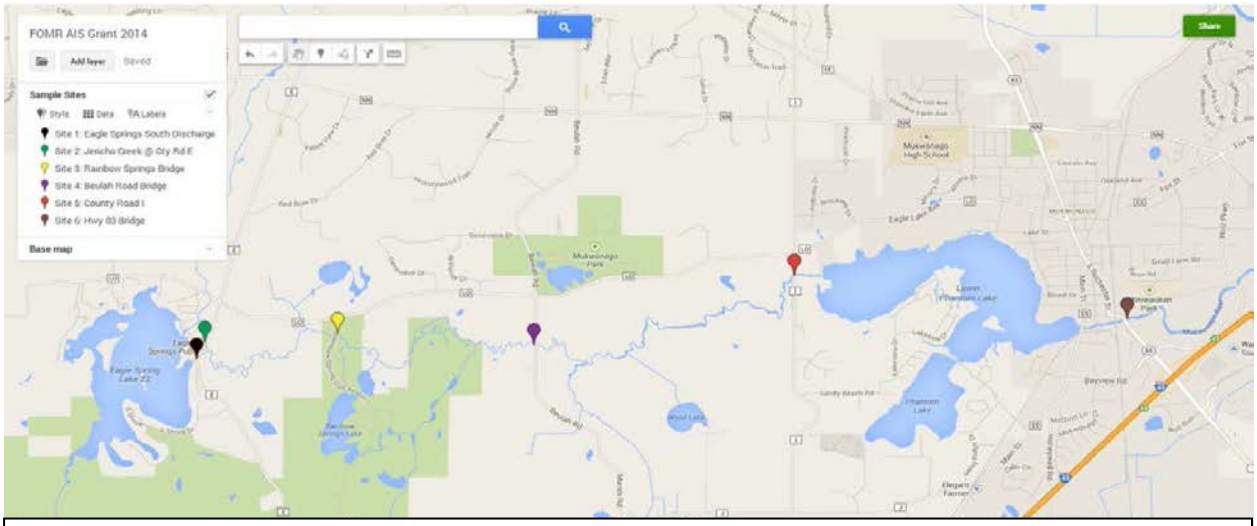

Figure 10. Sample sites along the Mukwonago River that Matthew Schneider worked in during the summer of 2014. *Corbicula* were present at Jericho Creek at County Road E(green), Rainbow Springs Bridge (yellow), and Beulah Road Bridge (purple).

Community partners can be utilized to conduct citizen monitoring and assist in *Corbicula* removal. These partners can be in the form of grade schools and universities, corporations focused on environmental stewardship, or non-profit organizations like the Friends of the Mukwonago River. Grants and awards can help fund these volunteer endeavors by purchasing equipment and educating the participants on *Corbicula* and other mussels common in Wisconsin waterways. A list of different organizations and grants can be found in appendices A, B, C, and

Disposal

Bleach, salt, and Virkon® can all be used to kill *Corbicula* mussels after removal with varying degrees of success. Virkon® is an aquatic disinfectant, commonly used to clean fishing gear. Virkon® uses potassium monopersulphate to kill viruses, bacteria, and fungi. Of the three chemicals tested in the study by Barbour et al. (2013), the Virkon® solution had the greatest effect on the mortality of *Corbicula*. The most effective variation was immersion of the mussels for five minutes in a solution of 2% Virkon®, which resulted in a mortality rate of 93.3%. Both bleach (10%) and salt (70 grams/Liter) solutions were more effective than the control groups, with mortality rates of 76.7% and 13.3% in 60 minutes respectively, but neither were as effective as the Virkon® solution. The length of the immersion times had no significant effect on mortality for neither the salt nor the bleach solutions (Barbour et al., 2013). When used or disposed of improperly, all three chemical solutions can have negative impacts on both the environment and the equipment being cleaned. Corrosion of equipment can occur based on the material. For example, hypochlorites such as bleach can degrade fabrics and silicone sealants, and can also corrode metals (Croud, n.d.). Releasing large or highly concentrated amounts of any of these solutions could kill non-targeted organisms and cause degradation to the watershed.

It is important to dispose of *Corbicula* in a biosecure manner (Ireland, n.d.). Biosecurity takes measures to prevent the spread of harmful biological agents (Encyclopædia Britannica, 2014). When looking at disposal methods for other aquatic invasive species such as Zebra mussels, it is advised that the mussels be disposed of in landfills (Grant, 2005). Lisie Kitchel, WDNR mussel biologist, agrees with this for claim specifically for *Corbicula* (Lisie Kitchel, personal communication, Dec. 4, 2014). The residual organic material could also be utilized as mulch in private gardens (Grant, 2005). It is suggested that the FoMR contain the deceased mussels in inexpensive garbage bags and dispose of them through the town of Eagle refuse collection (Eagle, 2014). FoMR could also store the shells and allow the public to take them for use in their own private compost or mulch (Grant, 2005), but there would always be the risk that these citizens would throw them back into another waterbody or onto the landscape. The safest method of disposal would be to bag and landfill the shells.

Timeline

The manual removal of *Corbicula* should be executed in the months prior to reproduction to limit the growth of the population. Research shows that Asian clam typically reproduce twice a year in spring and fall. To have the maximum effect, removal should occur prior to ensure the least amount of young are produced, which can sometimes reach over 70,000 a year (SEWISC, 2013). This timeline will also allow for better visual identification of fully maturated *Corbicula* during removal process. Waiting until after the reproduction stage might hinder the removal given the similar juvenile size of the *Corbicula* in relation to native mussels, and the rapid increase in population will result in a less time efficient and effective process.

Effectiveness

The manual removal of *Corbicula* and other invasive species is limited in effectiveness due to labor, time, and the intensive nature of the problem at hand. The Asian clam has the ability to reproduce faster than the time in which it takes for removal, thus making complete removal likely impossible. Management of *Corbicula* is a more viable option. This scope of management should include continual monitoring and control methods, as well as multiple manual removal sessions throughout the year to maintain feasible numbers and prevent a larger spread of the Asian clam.

No Action Plan

If all methods of eradication prove too costly, time consuming, or unsuccessful, a no action plan should be implemented for the management of *Corbicula* within the Mukwonago River and its tributaries. The no action plan will result in the inevitable spread of this debilitating invasive species throughout the watershed (Beasley et al., 2003; Counts, 1986; McMahon, 1982; Sousa et al., 2008).

The effects of a no action plan will be evident in a multitude of facets. The potential for *Corbicula* to outcompete the native and endangered mussels will increase throughout the watershed if left with no action. *Corbicula* also contribute to algal blooms by secreting significant amounts of inorganic nutrients like nitrogen (Asian Clam, 2012). In excess, this can significantly decrease the water quality. Apart from ecological impacts, industrial businesses have witnessed and have been affected by the growth of *Corbicula* in the clogging or interruption of water intake pipes (Lucy et al., 2012). *Corbicula* have also been deemed responsible for historically costing the power industry over one billion dollars annually due to the biofouling of municipal, agricultural, and power stations hydrological access (Matthews &

McMahon 1995). The overall biological integrity and industrial use of the watershed would be manipulated and altered if a no action plan is implemented, thus making this option the least desirable.

However, Vaughn and Spooner (2006) found that areas where adult native unionid mussel densities were high, *Corbicula* densities were never high. When looking at the data from an entire stream reach they did not see a negative relationship between *Corbicula* numbers and adult unionid numbers. This could mean that in the Mukwonago River where unionid mussel densities are moderate to high, the *Corbicula* density could have a limited population density growth potential. Suggested explanations for this observation were lack of space for *Corbicula* to colonize and lack of available food. They did find that *Corbicula* had adverse effects on the growth of juvenile unionid mussels (Vaughn & Spooner, 2006). This is a major concern because reducing juvenile populations will have negative long term effects on adult unionid populations.

Monitoring and Assessment

A management plan without a mode for determining the effectiveness of the chosen actions is unethical and often a waste of time and resources. Monitoring and assessment of the various reaches and habitats will provide data concerning both the quality of management strategies as well as the colonization habits of the various mussel's species. Certain reaches have also yet to report Asian clam presence (Downstream of Phantom Lake Dam & Eagle Springs Lake Discharge), where routine sampling of these areas can determine if it is capable of invading. It is entirely possible that *Corbicula* may be selective in habitat preference based on benthic characteristics, water temperature, and availability of food (Williams & McMahon, 1985;

Vaughn & Spooner, 2006). Further observation can evaluate the degree to which these variables affect *Corbicula* distribution.

Benthic barriers, suction harvesting, and manual removal can all be assessed through visual observations and sampling following management action. Multiple dates should be planned throughout the year for gathering data concerning the conditions of the removal sites as well as downstream reaches where colonization can occur following *Corbicula* breeding seasons. It is vital that prior data is acquired before management action is taken so that quality comparisons can be made to help determine overall change and effectiveness. If a "no-action" plan is adopted, observation and sampling should still continue to determine if the severity of the threat changes. If data supports the idea that management hasn't made significant impacts, then revisions to the management plan can be made in light of the analysis.

Resources

The removal of aquatic invasive species can vary greatly in cost and effort depending on the species in question and the size of the removal area. FoMR and organizations such as The Nature Conservancy and the WDNR can rally volunteer resources to remove *Corbicula*, but utilizing these groups is only logically applicable in easy to access shallow lotic areas such as in the Mukwonago River and associated tributaries. Deeper lentic areas such as Lulu Lake would require volunteers to have additional expertise such as scuba/diver skills that most of the general public, especially children, probably would not have. It cannot be assumed that FoMR, The Nature Conservancy, or the WDNR will provide funding for these cost-intensive measures.

There are a number of grants that could be completed that can be used to meet the management goals. A list of possible grants was compiled after investigation of multiple

websites including the Environmental Protection Agency (EPA), the Wisconsin Department of Natural Resources (WDNR), and private grants. This list would be publically available for anyone to use to help fund *Corbicula* removal in the Mukwonago River Watershed (see Appendix A).

Lotic areas have the highest possibility of using volunteer resources to control *Corbicula*. Volunteers including children, adolescents, and adults would not need special skills to aid in restoration. All that is needed is some practice identifying Asian clams, experience in swimming, and a strong work ethic. Funding from grants would be used to purchase waders, buckets, and other associated materials volunteers could not bring themselves or be provided by FoMR.

There are many local businesses in the area that have volunteer programs that could provide employees for *Corbicula* removal. A list of business and their contact information is provided to help expedite the volunteering process (see Appendix B). Possible businesses include R.W. Baird, Liberty Mutual, Orbis, Target, Kohl's, and GE. A list of local public and private schools (see Appendix C) is also provided to get young people active in aquatic invasive species removal and education. FoMR could also coordinate with local and regional environmental organizations that could provide assistance and help organize volunteer events (see Appendix D).

Conclusion

Significant management strategies have to be implemented in order to make lasting changes and help control the spread of the invasive Asian clam (*Corbicula fluminea)* in the Mukwonago River. The spring-fed nature of much of the river, coupled with extensive areas of

sandy substrate and optimal breeding water temperatures has resulted in the proliferation of *Corbicula* throughout the watershed. Field studies by Matt Schneider have yielded initial results on the specific numbers and spread of *Corbicula* and have provided vital information with regards to future management. The preceding plan outlines *Corbicula* assessment, management, prevention, and outreach that the Friends of the Mukwonago River (FoMR) can utilize. Management strategies including benthic barriers, suction harvesting, and manual removal vary in levels of effectiveness and effort which FoMR can optimally tailor to their specific funding and resources. While the ultimate goal would be to eliminate all *Corbicula* in the watershed, these actions have to be realistically viewed as continuous maintenance. Especially when dealing with the sensitivity of native mussel and fish species which preclude the use of more aggressive chemical management strategies. However, as long as FoMR, its associates, and volunteers are willing and able to take action, they should do so in order to maintain a pristine Mukwonago River watershed for generations to come.

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Figure References

Figure 1: http://mukwonagoriver.org/friends/wp-content/uploads/2013/02/Planning-for-Protection-in-SE-Wisconsin.pdf

Figure 2: http://dnrmaps.wi.gov/Geocortex/Essentials/4_1_1/REST/TempFiles/Export.jpg?guid=712da203-2255-404a-ba40-f84556e0d6d9&contentType=image%2Fjpeg

Figure 3: http://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/wisconsin/placesweprotect/lulu-lake-preserve.xml

Figure 4: A) http://dnr.wi.gov/topic/endangeredresources/animals.asp?mode=list&grp=19 B) http://dnr.wi.gov/topic/endangeredresources/animals.asp?mode=list&grp=19 C) http://dnr.wi.gov/topic/endangeredresources/animals.asp?mode=list&grp=19

Figure 5: http://www.lakegeorgemirrormagazine.com/wp-content/uploads/2011/04/asianclam1.jpg

Figure 6: http://www.sewrpc.org/SEWRPCFiles/Environment/MukwonagoRiver/2009-04-09-meeting-presentatio.pdf

Figure 7: http://www.stoptheasianclam.info/2011_11_01_archive.html

Figure 8: http://www.stoptheasianclam.info/2011_11_01_archive.html

Figure 9: Schneider, M. (2014). *Method of the manual removal of the Asian Clam (Corbicula Fluminea) as an invasive species in the Mukwonago River - Summer 2014*. Unpublished working paper, University of Wisconsin Waukesha, Waukesha, WI.

Figure 10: Schneider, M. (2014). *Method of the manual removal of the Asian Clam (Corbicula Fluminea) as an invasive species in the Mukwonago River - Summer 2014*. Unpublished working paper, University of Wisconsin Waukesha, Waukesha, WI.

***Appendix A*: Grants –** Grant information has been taken verbatim from the associated grant funding websites.

Wells Fargo Environmental Grants
Eligibility and Purpose: Wells Fargo makes contributions to organizations with tax-exempt status under Section 501(c)(3) of the U.S. Internal Revenue Code, as well as to qualified tribal and governmental agencies, including public school systems. We offer two environmental grant programs - focused on addressing local environmental priorities in our communities and providing support that fosters innovation to help accelerate a "green" economy.
Maximum grant amount: based on need
Match requirement:
Contacts: environmental.affairs@wellsfargo.com please reference Environmental Grant Program in the subject line of your email.
Deadlines: The deadline for the Environmental Solutions for Communities grant program falls in early-mid December of each yea **If the deadline date falls on a weekend or holiday, we will extend the deadline to the next business day (i.e. if 8/31 is a Saturday, the program would extend to accept applications through the following Monday)
Website: https://www.wellsfargo.com/about/csr/ea/environmental-giving

Aquatic Invasive Species (AIS) Prevention and Control Grants
Eligibility & Purpose: Aquatic Invasive Species Prevention and Control Grants help prevent and control the spread of aquatic invasive species in the waters of the state.
Maximum grant amount: Education, Prevention and Planning projects = $150,000; Established Population Control projects = $200,000; Early Detection and Response projects = $20,000; Research and Development = annual funding limit of $500,000; Maintenance and Containment = permit fee reimbursement
Match Requirement: 25 percent
Contact: DNR Regional Lake Coordinator or Kathleen Hanson, 608-266-9426
Deadlines: AIS Education, Prevention and Planning - December 10; Established Population Control - February 1; Research and Development - year-round; Early Detection and Response - year-round; Maintenance and Containment - year-round
Website: http://dnr.wi.gov/Aid/SurfaceWater.html

River Protection Planning and River Protection Management Grants
Eligibility & Purpose: River Protection Planning grants assist in the formation of a qualified river management organization or in strengthening an existing organization; protection or improvement of rivers and their ecosystems; river improvement education projects; assessments and plan development. River Protection Management grants are available for purchasing land or conservation easements, local ordinance development, installation of nonpoint source pollution

control practices and river restoration activities. They may also be used for education, planning and design activities necessary for completion of a management project.
Maximum grant amount: Planning = $10,000; Management = $50,000
Match requirement: 25 percent
Contact: DNR Regional River Coordinator or Kathleen Hanson, 608-266-9426
Deadlines: River Protection Planning - December 10; River Protection Management - February 1
Website: http://dnr.wi.gov/Aid/SurfaceWater.html

Citizen-based Monitoring Partnership Program
Eligibility & Purpose: To expand citizen and volunteer participation in natural resource monitoring by providing funding and assistance with high priority projects. Qualifying topics include monitoring of aquatic and terrestrial species, natural communities and environmental components such as water, soil and air.
Maximum grant amount: $4,999
Contact: Owen Boyle, 608-261-6449
Deadline: request for proposals in the spring
Website: http://wiatri.net/cbm/Partnership/

Streambank Protection (Stewardship)
Eligibility & Purpose: The Streambank Protection Program protects water quality and fish habitat in Wisconsin by establishing buffers along high-priority waterways. This grant program is part of the Knowles-Nelson Stewardship Program.
Website: http://dnr.wi.gov/topic/stewardship/grants/applyNCO.html

Patagonia
Eligibility & Purpose: is action-oriented

- builds public involvement and support
- is strategic
- focuses on root causes
- accomplishes specific goals and objectives
- Our funding is limited to: United States, Canada, Japan, Chile, Argentina, United Kingdom, The Netherlands, Switzerland, Sweden, Spain, Norway, Luxembourg, Italy, Ireland, Germany, France, Denmark, Belgium, Austria, Australia and the Czech Republic.

Patagonia funds only environmental work. We are most interested in making grants to organizations that identify and work on the root causes of problems and that approach issues with a commitment to long-term change. Because we believe that the most direct path to real change is through building grassroots momentum, our funding focuses on organizations that create a strong base of citizen support.

Maximum grant amount: $12,000
Contact: Patagonia

259 W Santa Clara st
Ventura, CA 93001
(805) 643-8616
Deadline: April 30 (all applications received in April will receive a response by the end of August)
August 31 (all applications received in August will receive a response by the end of January)
Website: http://www.patagonia.com/us/patagonia.go?assetid=2942

National Environmental Education Foundation

Bartlett Award
DoD Legacy Award
Everyday grants for non-profit groups

Eligibility and Purpose: Based on application and need
Maximum grant amount: Based on need
Contact: National Environmental Education Foundation, 4301 Connecticut Avenue NW, Suite 160 | Washington, DC 20008
Deadline: Based on grant
Website: http://www.neefusa.org/grants/every_day_grants.htm

Captain Planet Foundation
Eligibility and Purpose: Be project-based; Projects must be performed by youth; and Projects must have real environmental outcomes. Provide hands-on environmental stewardship opportunities for youth; Serve as a catalyst to getting environment-based education in schools; Inspire youth and communities to participate in community service through environmental stewardship activities.
Maximum grant amount: $500-$2,500
Contact: Captain Planet Foundation 133 Luckie Street, 2nd Floor | Atlanta, GA 30303 404-522-4270 | 404-522-4204 Fax
Deadline: September 30th- typically for spring and summer projects
January 31st- typically for fall and winter projects
Website: http://captainplanetfoundation.org/apply-for-grants/

***Appendix B*: Businesses**

Business: R.W. Baird
Volunteer Program: "Baird Gives Back Week"
Volunteer Website: http://www.rwbaird.com/who-we-are/community-involvement
Contact Information:
Nick Herff
Baird Public Relations: 414-298-7094

Business: Kohls
Volunteer Program: "Kohl's Cares – Associates in Action"
Volunteer Website: http://www.kohlscorporation.com/communityrelations/Community04.htm
Contact Information:
Email: AssociatesinAction@kohls.com
Human Resources: 262-703-7000

Business: Liberty Mutual Insurance
Volunteer Program: "Liberty Mutual Foundation"
Volunteer Website:
http://www.libertymutualgroup.com/omapps/ContentServer?pagename=LMGroup/Views/LMG&ft=4&fid=1138356732820&pid=1210356374865
Contact Information:
Corporate Headquarters: 617-357-9500

Business: Orbis
Volunteer Program: "Community Action Team"
Volunteer Website: http://www.orbiscorporation.com/About-Orbis/Giving-Back#.VGUBa8t0zIU
Contact Information:
Corporate Headquarters: 800-890-7292
Email: info@orbiscorporation.com

Business: Target
Volunteer Program: "Volunteer Match"
Volunteer Website: http://www.volunteermatch.org/volunteers/
Contact Information:
Main Office: Phone: 415-241-6868

Business: GE
Volunteer Program: "GE Foundation"
Volunteer Website: http://www.ge.com/careers/culture/life-at-ge/community-service

Contact Information:

Customer Service: 888-348-7563

Contact Website: http://www.ge.com/contact/general

Appendix C: Public and Private Grade Schools

School: Mukwonago High
Website: http://www.masd.k12.wi.us/mhs/
Phone: 262-363-6200

School: Park View Middle
Website: http://www.masd.k12.wi.us/pvms/
Phone: 262-363-6292

School: Big Bend Elementary
Website: http://www.masd.k12.wi.us/bbes/
Phone: 262-363-4401

School: Clarendon Avenue Elementary
Website: http://www.masd.k12.wi.us/ces/
Phone: 262-363-6286

School: Eagleville Elementary Charter
Website: http://www.masd.k12.wi.us/eves/
Phone: 262-363-6258

School: Prairie View Elementary
Website: http://www.masd.k12.wi.us/pves/
Phone: 262-392-6310

School: Rolling Hills Elementary
Website: http://www.masd.k12.wi.us/rhes/
Phone: 262-363-6318

School: Section Elementary
Website: http://www.masd.k12.wi.us/ses/
Phone: 262-363-6260

School: Natures Classroom Institute and Montessori School
Website: http://www.nciw.org/
Phone: 800-574-7881

St. James Catholic School
Website: http://www.stjamesmukwonago.org/

Phone: 262-363-7615

St. Johns Evangelical Lutheran School
Website: http://www.stjohnslutheran-muk.org/site/default.asp?sec_id=180013131
Phone: 262-363-4999

Mukwonago Baptist Academy
Website: http://www.mukwonagobaptist.org/ministry/academy/
Phone: 262-363-1731

Appendix D: Environmental Organizations

Organization: Caledonia Conservancy
Website: http://www.caledoniaconservancy.org/
Phone: 262-498-4993

Organization: Cedar Lakes Conservation Foundation
Website: http://clcfinfo.wordpress.com/
Phone: 262-353-4866

Organization: Milwaukee Riverkeeper
Website: http://www.mkeriverkeeper.org/
Phone: 414-287-0207

Organization: Kettle Moraine Land Trust
Website: http://kmlandtrust.org/
Phone: 262-949-7211

Organization: Milwaukee Audubon Society
Website: http://www.milwaukeeaudubon.org/
Phone: 414-352-2437

Organization: River Alliance of Wisconsin
Website: http://www.wisconsinrivers.org/
Phone: 608-257-2424

Organization: Sierra Club – Wisconsin John Muir Chapter
Website: http://wisconsin.sierraclub.org/
Phone: 608-256-0565

Organization: Southern Wisconsin Trout Unlimited
Website: http://www.swtu.org/
Email: Admin@SWTU.org

Organization: Urban Ecology Center
Website: http://urbanecologycenter.org/
Phone: 414-964-8505 (Riverside Park)

Organization: Waukesha County Environmental Action League
Website: http://www.weal.org/