Integrated Pest Management for Nuisance Exotics in Michigan Inland Lakes

Water Quality Series: WQ-56

MICHIGAN STATE UNIVERSITY EXTENSION

Integrated Pest Management for Nuisance Exotics in Michigan Inland Lakes

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New, June 2000

Acknowledgements

We would like to thank the following for their help:

Mark Coscarelli

S. Jerrine Nichols

This publication was produced through a grant from the Office of the Great Lakes, Michigan Department of Environmental Quality (DEQ), pursuant to a Comprehensive State Management Plan to Control Aquatic Nuisance Species.

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Preface

This manual is for waterfront property owners and other citizens concerned about and interested in the prevention and control of nuisance aquatic exotic plants and animals. Some of these species such as zebra mussel, Eurasian milfoil, purple loosestrife, round goby and ruffe, can be very damaging to the environment. They can disrupt the diversity and abundance of native species and threaten the ecological integrity of a lake or stream ecosystem as well as irrevocably damage local industry and commerce. Once introduced into a lake or stream their eradication is nearly impossible.

Although eradication may not be achievable, research and technology can inhibit introduction and maintain existing pests at acceptable levels by employing a philosophy of control called *Integrated Pest Management* (IPM). This management philosophy takes a holistic approach to pest suppression by researching and evaluating all environmental conditions, species interactions, management options and control tools. A plan results which employs the best management options and control tools to economically and ecologically restrict, reduce and maintain the pest at levels of insignificant impact, while minimizing danger to the environment, human health and the economy.

It is the purpose of this manual to introduce citizens to the management philosophy of IPM and how it can be employed at their lake to reduce the impact of nuisance exotic species and produce a healthy and diverse lake environment for all users.

Section I – Introduction

Aquatic Exotics

Michigan's aquatic ecosystems have been invaded by more than 140 exotic species. An exotic species is an organism that is not native to the environment it inhabits. These organisms become part of the fabric of our environment and we are learning to live with them.

Some exotics, such as the Pacific salmon, were purposely stocked in the Great Lakes. They are still "exotic" because they are not native to our area, but they are not a nuisance. Other exotic species, however, such as the sea lamprey and the zebra mussel, are invasive nuisances.

When aquatic nuisance invasions result from human activity, we can call this "biological pollution". There are many sources of biological pollution. Ocean-going ships that exchange their ballast water in Great Lakes ports have caused serious damage to the ecosystem. A growing number of our lakes and streams suffer invasive infestations when boaters fail to clean their equipment as they move from lake to lake. There are many suspected pathways for biological pollution, including aquarium dumping, aquaculture escapes and bait bucket transfers. Boaters and anglers should be especially careful to help prevent the spread of nuisance species by these pathways.

Zebra mussels (*Dreissena polymorpha*) attached to native clam

Invasive exotics often outcompete native species for space and food. Population explosions and crashes cause immediate and tangible ecological and economic difficulties around lakes, and the long-term loss of biodiversity (loss of the abundance and variety of plants and animals present in an environment) casts a shadow on the future. During the zebra mussel's first decade in North America, municipal and industrial water users spent an average of $10 million per year controlling zebra mussels. Preventing biological pollution is now recognized as one of the great challenges facing not only the ecology of the Great Lakes Basin but its economic and social structure as well. The National Invasive Species Act and Michigan's Aquatic Nuisance Species State Management Plan were adopted in 1996 in response to the problems caused by invasive exotic species.

Scientists have identified 139 exotic species introduced in the Great Lakes Basin between 1800 and 1993, but most aquatic invaders never come into the public spotlight. In the years between the sea lamprey (*Petromyzon marinus*) and the zebra mussel (*Dreissena polymorpha*) invasions, many exotic newcomers arrived, but few have done as much as these two pests to raise public awareness and understanding of aquatic nuisance species. Some introduced species that are considered particularly threatening to Michigan's inland waters are Eurasian milfoil (*Myriophyllum spicatum*), purple loosestrife (*Lythrum salicaria*), curly-leaf pondweed (*Potamogeton crispus*), Eurasian ruffe (*Gymnocephalus cernuus*), round and tubenosed gobies (*Neogobius* spp.) and two water fleas (*Bythotrephes cedarstroemi* and *Cercopagis pengoi*).

The Lake as an Ecosystem

A lake is not just a depression in the landscape filled with water—it is a living ecosystem. Fish, aquatic mammals, reptiles, insects, microcrustaceans, amphibians, waterfowl and shorebirds interact with plants to create a web of life. These animals and plants not only interact with one another but also are influenced by the chemistry of the water and physical elements. A lake's biological, chemical and physical properties continually combine and interact to produce a living ecosystem. The forces shaping this underwater world are not confined to the lake.

Far from the shoreline, the land and activities occurring on it can change the life within the lake in profound ways. Urban and agricultural development and other land uses may expose soil to rain and running water. Soil particles carrying nutrients, pesticides and heavy metals can be transported across the land, down rivers and into the lake. These newly introduced elements change the chemistry and physical quality of the lake, which in turn affect the plants and animals living there. These land activities are the forces that bring about long-term changes in the lake.

People come to the lakeshore to enjoy the lake's beauty and take pleasure in the recreational opportunities that the lake provides. Sometimes, however, the shore is too muddy, the plants too abundant, the water too turbid. Powerful management tools of modern technology are brought in to change the lake so that it better conforms to expectations. Unfortunately, people too often don't understand or consider the lake's complex, delicate web of life before initiating action. The results can be counterproductive and even devastating to the plant and animal communities that live there.

When people understand that the lake is a living ecosystem, not merely a pool of water, they can use management tools as precision instruments rather than as indiscriminate, disruptive controls. Knowledge about the lake, its interactions, human influences and management tools can be used to produce a plan that will maintain the lake's environmental integrity and enhance recreational opportunities.

Integrated Pest Management

Integrated pest management (IPM) is a strategy used by farmers and environmental managers to plan and implement pest controls. IPM uses a logical sequence of events—gathering data, disseminating information, making decisions, taking action and monitoring results—to control a target pest. Using the IPM strategy maximizes pest control while minimizing damage to the environment, including native plants and animals. IPM strategies that have worked well in agricultural and urban settings can be used by lake associations to manage exotic pests that threaten their lake while protecting native plants and animals.

Sea lamprey on lake trout

The introduction and establishment of the sea lamprey resulted in the first usage of IPM strategies for controlling aquatic species. The alewife (*Alosa pseudoharengus*) and the parasitic sea lamprey arrived in Michigan waters from the Atlantic coast after the opening of the Welland Canal around Niagara Falls. The sea lamprey was largely responsible for the crash of important Great Lakes fisheries in the middle of the 20th century. The subsequent lack of predatory fish resulted in a boom in alewife populations. Eventually, the alewife population also crashed. Anyone who visited the Great Lakes shore in the prime of the alewife/lamprey population boom and bust cycles observed the unsightly, decomposing alewives and took home a vivid lesson in the value of preventing biological pollution. Our native ecosystems are changed forever. Lamprey suppression now costs Great Lakes taxpayers several million dollars per year. Biologists are searching for efficient alternatives to chemical control of the lamprey. Integration of controls such as sterile-male and natural pheromone releases show promise.

Section II – An Integrated Pest Management (IPM) Strategy for Your Lake

Use of the IPM strategy in a lake to manage an exotic plant or animal should proceed through a series of logical, well thought-out actions or steps. The precise sequence will vary, depending on the lake and the exotic species involved, but it should include the following actions:

1. *Form a committee or board to coordinate IPM efforts*—Keeping exotic species out of the lake or managing them once they are in the lake will involve a moderate to significant effort. One person should not be overwhelmed trying to implement the IPM program alone. The local citizens' action group or lake association should form an exotic species control committee that can assume responsibility for education, monitoring, decision making, implementing and overseeing action, and funding. If the control/management program will be extensive and require significant annual cost, consideration should be given to creating a taxing special assessment district (SAD). A SAD for lake management may be established with a lake board under part 309 of the Natural Resource and Environmental Protection Act (Public Act 451 of 1994) or through the township using the Township Public Improvements Act (Public Act 188 of 1954).

Learning about lakes and exotic invaders

Using a plankton net to understand the microscopic life of the lake

2. *Know the potential threats*— Exotics can cause serious environmental damage to the lake ecosystem by destroying or overrunning native species habitat. Exotic species are sometimes able to outcompete native plants and animals because the natural enemies (diseases, parasites, herbivores, predators) that limited the exotic species in its home environment are not present in the new environment. The lack of control agents allows the exotic population to expand wildly. This can have a serious impact on your lake. Native fish populations could decline because of competition from a non-native species. An exotic pest could change shoreline areas and reduce recreational opportunities and boat access. The cost of controlling the exotic can also be significant. An exotic plant or animal's life history and growth

habitats may hold important keys on how best to prevent it from reaching the lake or controlling it once it's established there. Knowing which exotic species could invade your lake is your first line of defense.

3. *Monitor for potential threats*—A monitoring program for exotic species can provide an early warning system. If an invader is detected early, it may be possible to eradicate it or keep its population small through a continual control program so it never reaches nuisance levels.

4. *Implement preventive measures*—Many exotics are not easily controlled once they're introduced, so the best management tool available is to make sure that everything possible is done to keep them out of your lake. For some exotic species this may be the only IPM strategy available. Proper use of preventive measures will protect your lake from many exotic species. Preventive measures are general practices such as proper cleaning of boating equipment, which decreases the chance of exotics being introduced.

5. *Positively identify the exotic*—Many exotic invaders look similar to desirable native species. Before beginning control measures, be certain you are targeting an exotic and not a native plant or animal. Use the photographs and drawings in this manual to find out whether you have an exotic in your lake. If you are unable to determine whether it is an exotic species, preserve the organism and contact an expert who can identify it. You can preserve an animal by putting it in a plastic bag and freezing it; you can preserve a plant by pressing it in an old phone book or between two newspapers and boards weighted down with a brick. For further assistance, consult your local county Extension office.

6. *Collect data on exotic and native populations*—The aquatic exotic and native populations need to be measured to determine their abundance and distribution throughout the lake. The size and complexity of the lake can make assessing these populations difficult, but it is important if you want to control the exotic with minimal damage to the native species. A few publications are available on methods for assessing exotic population sizes, but the lake association may want to contact an expert to obtain a population estimate. After a population estimate has been obtained, use this manual or consult an expert to determine what control methods are best for your lake.

7. *Select appropriate control methods*—Ideally, the control methods selected will give maximum control of the exotic with minimal damage to the native plants and animals. Every lake ecosystem is different, and a control method that is recommended for one lake may not be as effective in another lake. Control techniques may include biological, chemical or physical methods used independently or in combinations. Control methods may be selective or broad-spectrum.

   Selective controls—A control method may be selective or effective only on the target organism and cause limited damage to non-target organisms. Examples of selective controls include an insect that feeds only on the target plant or a pesticide that kills the target organism while causing minimal damage to most of the other plants and animals.

   Broad-spectrum controls—The opposite of selective controls are broad-spectrum controls, which kill or damage many organisms when used. Many pesticides are broad-spectrum in their impact. Physically altering the lake level may control an exotic pest but can kill and damage many plants and animals. Though they're less desirable than selective control methods, broad-spectrum controls can be useful in managing exotic species. If the exotic's life history and growth characteristics are well known, they may provide information on critical times and places where intensive use of

broad-spectrum controls will provide maximum destruction of the exotic while causing limited damage to other organisms.

This manual identifies several exotic plants and animals that could become nuisances in your lake and provides some general control suggestions. An expert in aquatic ecology and/or pest management can provide specific recommendations on control methods for the exotic pest in your lake.

8. *Practice maintenance control*—It is important to introduce a management philosophy known as maintenance control. This philosophy is used in agriculture, medicine and other industries to minimize the negative effects of diseases, parasites and pests. It recognizes that the eradication of a pest is not likely, so to minimize the pest's impacts, its populations are maintained at the lowest possible levels by continual application of controls. Maintenance control uses continual monitoring to identify the location and density of a target nuisance organism. Once it is identified, selective control techniques are immediately employed to check the pest before it can spread and cause major damage. This practice keeps the pest organism at low levels and minimizes the amount of pesticide or other control agent needed. Because the pest is never eradicated, this practice must be employed repeatedly, thus the term "maintenance control." It is more cost effective to treat 2 acres of a pest every year rather than waiting until the pest occupies 400 acres, when control will be very expensive and perhaps impossible.

9. *Maintain healthy native populations*—Certain control methods can have detrimental effects on native species populations. It is extremely important to know what native species are present in your lake. When a control method is chosen, you need to be aware of how that method will affect the native species populations. Reducing a native species population by the control may significantly change the entire lake ecosystem. This could lead to undesirable changes in your lake. Additionally, damaging or reducing native populations may allow the exotic to become more abundant and become permanently established.

10. *Review the control program for effectiveness*—Sometimes it is impossible to ascertain what control methods will work best for a lake ecosystem before you begin. Once the control strategy has been implemented, it is important to continue to monitor your lake. You need to evaluate the control strategy's effectiveness to see if you have met the desired goal. Aquatic exotic pest populations may be most effectively controlled through a series of several different control methods.

    It is important to note that, even if the control strategy did have the desired effect, the exotic pest may return. The lake will need to be monitored regularly to determine when and where to treat again.

    Native plant and animal populations should also be assessed to determine if the control had a negative impact on their populations. You should expect some slight annual changes in plant and animal populations due to differences in climate, so you should look at longer term trends in populations. The lake association may decide that the control method was effective or that a different approach needs to be taken. Lake ecosystems continually change, so it is important to realize that an IPM plan also needs to evolve with the situation.

Section III – Aquatic Exotics in Michigan Lakes

Many aquatic exotics have invaded Michigan inland lakes and watershed areas. The following species are some of the more objectionable ones.

Zebra Mussels (*Dreissena polymorpha*)

Invasion history

- Zebra mussels are native to the Ukraine and Russia. They were introduced into Lake St. Clair and Lake Erie in the mid-1980s and discovered in 1988. A transatlantic freighter coming from eastern Europe is believed to have introduced them into North America when it dumped its ballast water in the Great Lakes. Since then, zebra mussels have continued to spread throughout all of the Great Lakes as well as the Mississippi, Tennessee, Hudson and Ohio river basins, and they most likely will spread farther south and west.

- Within 10 years of their discovery in Lake St. Clair, zebra mussels spread through a variety of pathways—including currents, bait buckets and recreational boats—into more than 100 inland lakes throughout the Lower Peninsula of Michigan. Veligers, the free-swimming microscopic larval stage, can drift downstream or be transported in water that accumulates in the bottoms of boats or in bilge pumps and bait buckets. Adults can attach to boat hulls, engines, aquatic plants or other objects that people move from lake to lake.

Problems

- Zebra mussels feed by filtering from the water large amounts of microscopic algae, which are an integral part of Michigan's inland lake food chain. Scientists are concerned about the environmental impacts that zebra mussels are having on native species and their habitat. These problems could include killing native clams and crayfish by attaching to their bodies, increasing aquatic plant growth by increasing water clarity, and competing with larval fish and other aquatic organisms for food. Besides environmental impacts, they can clog water intake pipes and foul beaches and boating facilities.

Physical description

- Zebra mussels are fairly easy to identify and quite different from native mussels and snails in shape and color. They are triangular with a sharp ridge where the sides meet the bottom of the shell. They grow sticky filaments called byssal threads, which they use to attach themselves to almost any hard surface. Their shells are usually dark-colored and commonly have lighter stripes, thus the common name "zebra mussel". They grow rapidly to a maximum size of a little over 2 inches; the average is about 1 inch.

Zebra mussels (*Dreissena polymorpha*)

Life history

- Adult zebra mussels begin spawning when water temperatures reach 54 degrees F but are most prolific between 64 and 76 degrees F. A mature

female may produce up to 1 million eggs per season. The eggs and sperm are released from the adults, and eggs are fertilized in the water. Within a few days, the fertilized eggs develop into larval veligers, which float freely for three to four weeks, drifting with the currents. Eventually they settle down on a hard surface and attach with their sticky byssal threads. Once attached to a hard surface, they become juveniles and begin to filter feed. Zebra mussels grow rapidly and typically become sexually mature in their second year of life.

IPM strategies

- Every lake should have an exotic IPM program, including education, prevention, monitoring and control (see pages 5-7). The IPM program will help prevent the introduction of exotic aquatic plants and animals and, if necessary, direct the control of introduced populations.

- The only accepted IPM strategy for controlling zebra mussel populations is prevention. Once a population has been established, there are no known effective control methods. The prevention strategy may include the following practices:

  – Check for and remove any aquatic vegetation attached to a boat's hull, propeller, trailer and all equipment. This vegetation could be harboring zebra mussels.

  – Flush any compartments where water may be stored (engine cooling system, live wells and bilge) with hot water. Any surface of the boat and trailer that is wet should also be rinsed with hot water (110 degrees F kills veligers and 140 degrees F kills adults). Parts that need attention are trailer frames, safety light housings, boat decking and the lower portion of the motor cooling systems. If hot water is not available, use tap water to rinse your boat and trailer and allow them to dry for at least five days before entering another lake. Zebra mussels are very hardy and adults can survive out of water for a long time.

  – Check the boat hull for attached adult zebra mussels if it has been docked in infested waters. The hull should be cleaned or allowed to dry for at least five days if adults are found or the exterior is covered with algae. Do not move the boat to uninfested waters until these precautions have been taken. Adult mussels scraped off the hull should be placed in a garbage bag and discarded. Do not dump mussels back into the lake.

  – A "gritty" feeling on any boating equipment could be young zebra mussels. Scrub any gritty equipment and rinse with hot water before using in another lake.

  – Bait should not be used in another lake if you dipped your bait bucket in a lake that might be infested with zebra mussels. Although adult mussels can be seen, the veligers are too small to be observed. Empty your bait bucket on land to prevent live bait and veligers from being released into lakes or streams.

Ruffe (*Gymnocephalus cernuus*) and Round Goby (*Neogobius melanostomus*)

Invasion history of ruffe

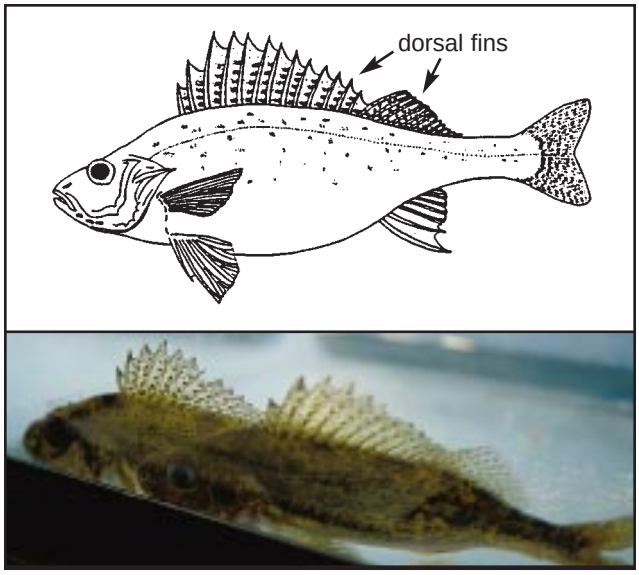
- The ruffe was introduced into Lake Superior in the mid-1980s and was discovered in the Duluth/Superior harbor in 1986. It became the most abundant fish in the area within a few years of discovery. This fish is native to Europe and Asia and was most likely transported to the Great Lakes in the ballast water of transatlantic freighters. In Europe, the ruffe is found in waters varying from fresh to brackish and lakes ranging from deep, cold and clear to shallow, warm and nutrient-rich.

Problems associated with ruffe

- Ruffe populations can grow rapidly, often resulting in less food and habitat for native species. Young ruffe eat the same food and compete for the same habitat as native yellow perch, walleye and a variety of other species. Because of this, ruffe can have a serious impact on perch and walleye fisheries.

Physical description of ruffe

- The ruffe is a member of the perch family. It is a small species with an average length of 4 to 6 inches and a maximum of 10 inches. It has two spiny dorsal fins with rows of dark spots between the spines; the front one has hard spiny rays and the back one has soft rays. The two dorsal fins on the ruffe are connected to form one continuous dorsal fin that makes it quite distinct from its relatives, the yellow perch and the walleye (their dorsal fins are not connected). The mouth of the ruffe is slightly downturned and it has no scales on its head.



Ruffe (*Gymnocephalus cernuus*)

Yellow Perch (*Perca flavescens*)

Walleye (*Stizostedion vitreum*)

Life history of ruffe

- Ruffe normally mature in two to three years in their native Eurasian habitats, though they have been known to mature in a year if the temperature is warm enough. They spawn between April and July, depending on the water temperature, location and preferred habitat. An average female can produce 13,000 to 200,000 eggs per season. The maximum life span for ruffe is up to 11 years for females and 7 years for males.

Invasion history of round goby

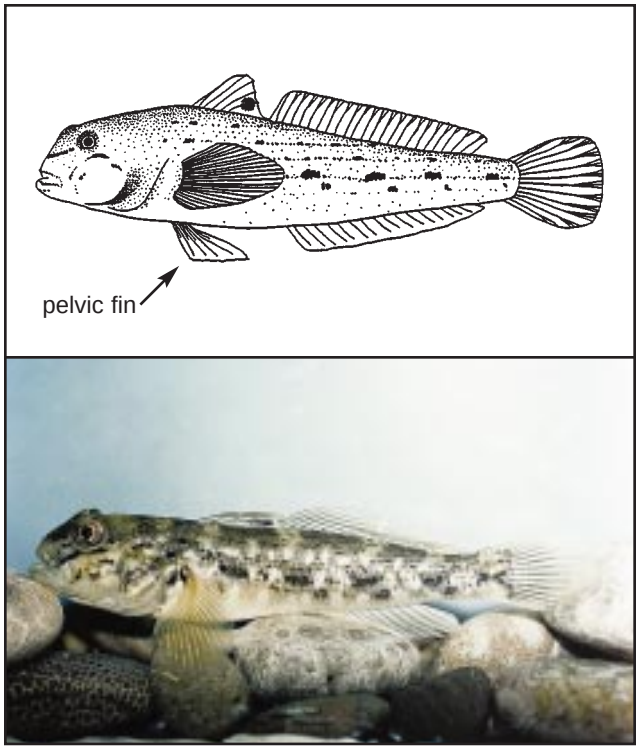
- The round goby was discovered in the St. Clair River in 1990. It was most likely introduced in the late 1980s via ballast water of transatlantic freighters. The round goby is native to the Ukraine and Russian regions. By 1995, the round goby was found in Lake St. Clair, Lake Michigan, Lake Erie, Lake Superior and many tributaries to these lakes. Because of the round goby's ability to adapt to a variety of water conditions, it has potential to spread throughout Michigan inland lakes.

Problems associated with round goby

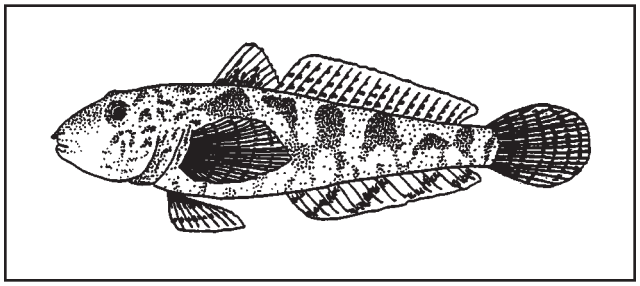
- Round goby populations grow rapidly and compete with populations of native fish such as darters and sculpins. Sculpin populations have been shown to decrease dramatically when round gobies are present. Gobies eat small fish and eggs, such as darters, lake trout eggs, sturgeon eggs and a variety of other native species. Round gobies have a well developed sensory system that allows them to find food in low-light conditions and gives them a major competitive advantage over some native species.

Physical description of round goby

- Round gobies are easy to identify by their single pelvic fin shaped like a scallop. They have gray bodies mottled with black or brown spots.



Round Goby (*Neogobius melanostomus*)



Tubenose Goby (*Proterorhinus marmoratus*)

The round goby has an average length of 3 to 6 inches and a maximum length of 10 inches.

The tubenose goby (*Proterorhinus marmoratus*) is related to the round goby and is also not native to the Great Lakes. It is found in the St. Clair River, Lake St. Clair and Detroit River. The tubenose goby is not considered to be an invasive threat at this time. Two tubes protruding from the head of the fish distinguish the tubenose goby from the round goby.

Life history of round goby

- Round gobies spawn from April to September. One female can produce 300 to 5,000 eggs per season. The male will guard the eggs to reduce the risk of predation. Females mature in one to two years and males mature in three to four years.

IPM strategies for ruffe and round goby

- Every lake should have an exotic IPM program, including education, prevention, monitoring and control (see pages 5-7). The IPM program will help prevent the introduction of exotic aquatic plants and animals and, if necessary, direct the control of introduced populations.

- At this time, the only effective IPM strategy for controlling ruffe and round goby populations is prevention. Once a population has been established, there are no known effective control methods. The prevention strategy may include the following practices:
  - Drain your transom wells, livewells and bilge water before entering a different lake.
  - Empty your bait bucket on land to prevent live bait from being released into lakes or streams.
  - Do not dip your bait bucket into the water if it still has water in it from another lake.
  - Do not transport live fish from one lake to another.
  - Do not transport a live ruffe or round goby and do not throw it back alive. If you catch a ruffe or round goby in a Michigan inland lake, kill it, freeze it and contact Michigan Sea Grant or the Michigan Department of Natural Resources immediately.

Spiny Water Flea (*Bythotrephes cederstroemi*), Fishhook Flea (*Cercopagis pengoi*) and (*Daphnia lumholtzi*)

Invasion history

- *Bythotrephes* has been found in all of the Great Lakes since the 1980s, *Cercopagis* has been found in Lake Ontario since 1998 and Lake Michigan since 1999, and *Daphnia lumholtzi* was found in the Illinois River in 1995 and in Lake Michigan in 1999. It is likely that they were introduced into the Great Lakes through ballast water. All three of these organisms are zooplankters (tiny animals that are an integral part of the food chain) that have potential to become established in Michigan inland lakes.

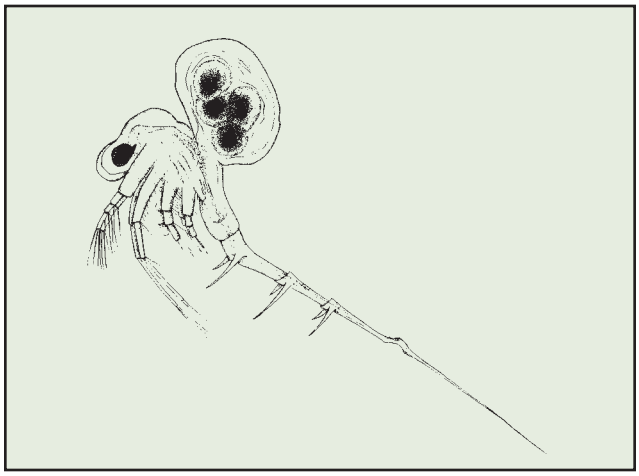
Invasive water fleas can foul fishing gear.

Problems

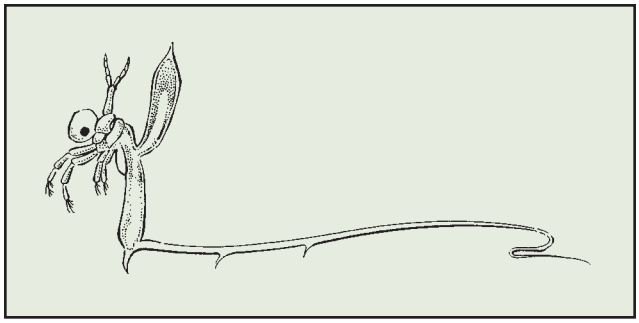
- All three of these zooplankton species are larger than native zooplankton species. In addition, they have long spines that make them hard for young fish to eat. If young fish are unable to consume enough of them, a shift in populations may occur with the exotic species replacing the native populations. This would leave less food for young fish and cause a decrease in native fish populations. *Cercopagis* and *Bythotrephes* also eat smaller native zooplankton, which could also cause a decrease in available food for native fish. These zooplankters also can clog the line guides of fishing poles when their long spines tangle with the fishing line and cause them to be reeled in with the line. They have been known to clog guides so badly that anglers have had to cut their lines. Masses of these zooplankters can feel like wet cotton.

Physical description

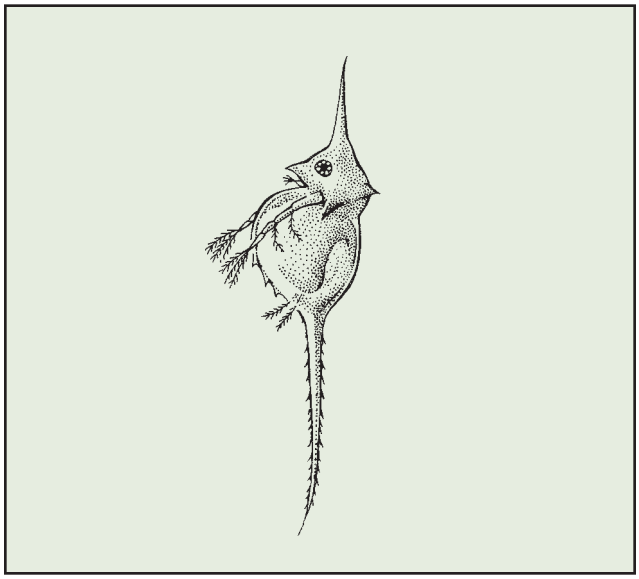
- Zooplankton are so small that it is difficult to see any characteristics without the aid of a microscope. These three exotic species each have a maximum length of about ¼ inch; their long spines can account for more than half of their total body length.



Spiny water flea (*Bythotrephes cederstroemi*)



Fishook flea (*Cercopagis pengoi*)



Daphnia lumholtzi

Life history

- *Bythotrephes*, *Cercopagis* and *Daphnia lumholtzi* can reproduce a few offspring every two weeks when the water temperatures are high enough. All of these zooplankters will continue to reproduce throughout the warmer summer months.

IPM strategies

- Every lake should have an exotic IPM program, including education, prevention, monitoring and control (see pages 5-7). The IPM program will help prevent the introduction of exotic aquatic plants and animals and, if necessary, direct the control of introduced populations.

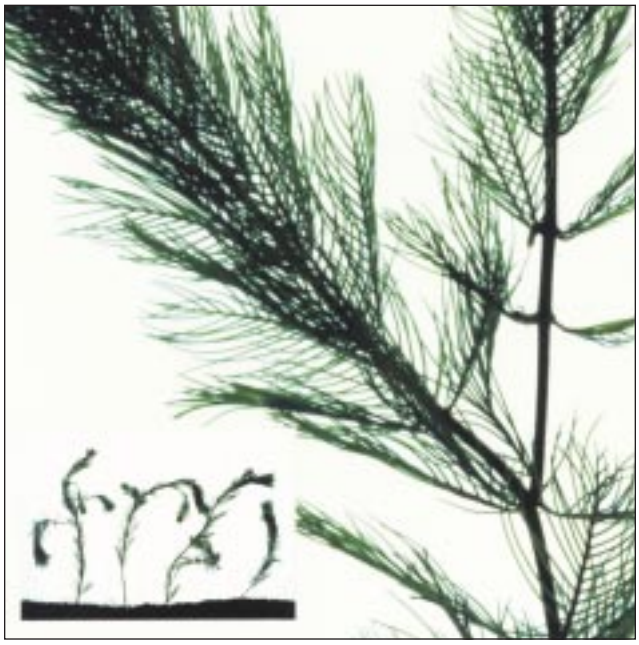
- At this time, the only effective IPM strategy for controlling *Cercopagis*, *Bythotrephes* and *Daphnia lumholtzi* populations is prevention. Once a population has been established, there are no known effective control methods. The prevention strategy may include the following practices:
  - Check for and remove any aquatic vegetation attached to a boat's hull, propeller, trailer and all equipment. This vegetation could be harboring zooplankton.
  - Wash your boat and equipment with hot water (110 degrees F), spray your boat and equipment with a high-pressure hose (250 psi), or allow your boat and equipment to dry for five days before entering another lake.
  - Drain your transom wells, livewells and bilge water before entering a different lake.
  - Empty your bait bucket on land to prevent zooplankton from being released into lakes or streams.
  - Do not dip your bait bucket into the water if it still has water in it from another lake.

Eurasian Milfoil (*Myriophyllum spicatum*)

Invasion history

- Major nuisance colonies of Eurasian milfoil developed in North America in the late 1940s and 1950s and disrupted the ecology of Chesapeake Bay. By the 1990s, Eurasian milfoil had spread across the continent, creating problems in western states and Canadian provinces.

- The first observations of well established growths of Eurasian milfoil in the Great Lakes basin were at Put-in-Bay in western Lake Erie in 1952. It moved into Michigan in the mid-1960s and within 10 years was hindering recreational activities on many southern Michigan lakes. It continued to spread northward, and in the early 1990s it moved across the Straits of Mackinac into the Upper Peninsula.



Eurasian milfoil (*Myriophyllum spicatum*)

Native milfoil (*Myriophyllum* Spp.)

Coontail (*Ceratophyllum demersum*)

- Eurasian milfoil most likely entered Michigan through aquarium releases and on boats and boat trailers. Its rapid spread was aided by the plant's ability to reproduce by stem fragments. A single segment of stem with leaves can develop roots and produce an entire plant. Stem fragments clinging to boats and trailers spread the plant from one lake to another. Waterfowl may also play a role in moving the plant.

Problems

- In many lakes, Eurasian milfoil forms a thick, tangled mat of vegetation. Much of this mat is near or at the water surface and forms a canopy of foliage. Moving over or through the canopy mat can be difficult—swimming, boating and fishing can all be seriously hindered. Under the canopy, conditions deteriorate because of reduced water circulation, decreased light and increased deterioration of native plants.

Physical description

- Eurasian milfoil produces a long, thin stem. Near the water surface, the stem branches many times and twists with the branches of adjoining stems to form a dense, tangled canopy. These branched stems have a pinkish color and a short, reddish flower stalk that sticks out of the water. The leaves are bright green and feathery-looking. Usually 12 or more pairs of leaflets divide off from the one central leaf axis, and four or five leaves grow in a group around the stem. Lower on the stem the leaf groups are farther apart, but higher on the stem they are very close together.

- Many native aquatic plants (including coontail) look like Eurasian milfoil. In fact, Michigan has several species of milfoil that grow here naturally. It is difficult to distinguish native milfoil plants from Eurasian milfoil, but native milfoils are usually lower growing and don't form the dense, tangled canopy. Their leaves usually have 12 or fewer leaflet pairs along the leaf's central axis. In some cases, however, it may be necessary to consult an aquatic plant professional to distinguish between native and Eurasian milfoil.

Life history

- Eurasian milfoil is a perennial plant that can reproduce by seeds or plant fragments. It begins growing early in the spring when water temperatures are still cool (55 to 60 degrees F). This gives it an advantage over native plants, which usually start growing one to two weeks later. It can grow 1 to 3 inches per day, reaching the water surface in a few weeks, even from deeper water. In the autumn, the stems fragment easily and the milfoil spreads to other areas of the lake. Some stems may overwinter in a green, upright condition and resume growth in the spring.

IPM strategies

- Every lake should have an exotic IPM program, including education, prevention, monitoring and control (see pages 5-7). The IPM program will help prevent the introduction of exotic aquatic plants and animals and, if necessary, direct the control of introduced populations.

- Steps to prevent Eurasian milfoil introduction into a lake include:
  - Educating the local community about Eurasian milfoil and how it spreads.
  - Putting up signs at boat access points to encourage the removal of plant fragments from boats and trailers before launching and after retrieving boats.
  - Discouraging the disposal of aquarium plants into surface waters.
  - Establishing an on-going prevention/monitoring program that seeks out and identifies the earliest infestations of Eurasian milfoil.

- The following IPM strategies should be considered in the development of a control program for Eurasian milfoil:
  - Be certain you have a positive identification of Eurasian milfoil.
  - Early identification of Eurasian milfoil infestations may allow the plants to be carefully hand harvested and removed from the lake.
  - Early identification allows control tools to be applied to a small area. This minimizes cost and impact on other plants and the environment.
  - Once Eurasian milfoil is introduced, eradication from the lake is difficult unless the infestation is discovered in the earliest stage. Continual control (maintenance control) will be needed to keep this nuisance plant at the lowest possible level.
  - Avoid using control tools that will spread Eurasian milfoil, such as harvesting machines, unless the plant is already spread over the entire lake. Never use harvesters to remove milfoil if your lake has an outlet that connects to another lake.
  - Use the most selective control tools available and appropriate for the conditions.
  - Some herbicides are reasonably selective for Eurasian milfoil, but if they're misused, they can seriously damage desirable native aquatic plants and defeat the purpose of the chemical's selective qualities.
  - In certain situations, it may be possible to use broad-spectrum herbicides. Plant distribution or timing of herbicide application may allow control of Eurasian milfoil with minimal impact on native plants. Such control may be possible early in the spring or if Eurasian milfoil is the only plant or the dominant plant in an area.
  - All herbicide applications require a permit from the Michigan Department of Environmental Quality (DEQ).
  - Some recent data suggest that a native beetle (*Euhrychiopsis lecontei*) may provide a biological control for Eurasian milfoil. Additional data are needed, but early indications suggest that supplementing and redistributing *E. lecontei* could become part of an IPM strategy.
  - Winter drawdown of lake levels has in certain situations been effective at reducing Eurasian milfoil populations. Milfoil stems exposed to drying and freezing are damaged or killed. Other plants are also killed, but some native plant species actually benefit from the drawdown. Before drawing down a lake, it is important to know what plants and animals are present and how drawdown will affect them. A permit from the DEQ is needed to draw down a lake.

– Maintain a healthy population of native aquatic plants. If native plants are damaged as part of a control program, Eurasian milfoil will likely replace the damaged native plants. In some lakes with abundant native plants, Eurasian milfoil has been present in the lake for years but has never become a problem.

– Adjust the control program on the basis of information generated by the monitoring.

Curly-leaf Pondweed (*Potamogeton crispus*)

Invasion history

- Though reports of curly-leaf pondweed in North America date back to 1807, the earliest verifiable records of the plant are from Wilmington, Del. and Lancaster, Pa., in the 1860s. By early in the 20th century, it was common throughout most of the United States.

- The earliest Great Lakes Basin record of curly-leaf pondweed is from 1879 in western New York. It probably became common in Michigan by the 1890s.

- Curly-leaf pondweed hasn't had to rely on its natural mechanisms for reproduction and spread—the plant was deliberately transported from lake to lake and planted as a food for waterfowl. In the first 50 years of the 20th century, planting aquatic vegetation in lakes to promote fish and wildlife habitat was a common practice undertaken by hunting, fishing and conservation clubs.

Problems

- The scientific literature suggests that curly-leaf pondweed is an aggressively growing species that often expands to nuisance levels when native plants are damaged. Lack of competition from other plants allows curly-leaf pondweed to form dense colonies that can hinder swimming, boating and fishing.

Physical description

- The underwater leaves of curly-leaf pondweed are oblong—about 2 to 3 inches long and ¼ inch wide. The margins of the leaves are wavy and finely saw-toothed, which is a key characteristic for identifying the plant. It has a short, pinkish flower spike that sticks out of the water. Each stem may produce several turions, reproductive vegetative buds that look like small, brownish pine cones.

- A few other members of the pondweed family of aquatic plants native to North America look similar to curly-leaf pondweed—such as clasping-leaf pondweed and variable pondweed—but none have fine saw-toothed leaf margins.

Curly-leaf pondweed (*Potamogeton crispus*)

Clasping-leaf pondweed (*Potamogeton Richardsonii*)

Variable pondweed (*Potamogeton gramineus*)

Life history

- Curly-leaf pondweed grows at cooler water temperatures than most other rooted plants in Michigan lakes. It sprouts in the spring two to three weeks before most native plants. This gives it a competitive advantage—curly-leaf pondweed can grow 4 to 5 feet tall before other plants begin germinating from the bottom sediments. As it grows to the water surface, it produces turions, which will seed the lake for next year's crop. As water temperatures rise in late June and early July, curly-leaf pondweed stems begin to die and break down. What had been a seriously hindering plant population in May and June can be completely gone by early to mid-July. The turions lie dormant on the lake bottom until water temperatures begin to cool in September. At that time there may be mild to moderate regrowth of the plant. Most of the turions will overwinter and sprout the following spring.

- Curly-leaf pondweed tolerates muddy water conditions. It is often found growing in waters too turbid for many native plants. In these situations it beneficially provides physical structure and habitat to the lake or pond, but it could be a source for introduction to other areas.

IPM strategies

- Every lake should have an exotic IPM program, including education, prevention, monitoring and control (see pages 5-7). The IPM program will help prevent the introduction of exotic aquatic plants and animals and, if necessary, direct the control of introduced populations.

- Steps to prevent curly-leaf pondweed introduction into a lake include:
  - Educating the local community about curly-leaf pondweed.

  - Discouraging the disposal of aquarium plants into surface waters.
  - Establishing an on-going prevention/monitoring program that seeks out and identifies the earliest infestations of curly-leaf pondweed.

- The following IPM strategies should be considered in the development of a curly-leaf pondweed control program:
  - Be certain you have a positive identification of curly-leaf pondweed.
  - Early identification of a curly-leaf pondweed infestation may allow the plants to be carefully hand harvested and removed from the lake.
  - Early identification allows control tools to be applied to a small area. This minimizes cost and impact on other plants and the environment.
  - Once curly-leaf pondweed is introduced, eradication from the lake is difficult unless the infestation is detected in the earliest stage. Continual control (maintenance control) will be needed to keep this nuisance plant at the lowest possible level.
  - Curly-leaf pondweed's growth pattern provides an opportunity for control. Broad-spectrum control tools such as harvesting machines and broad-spectrum herbicides that break down rapidly may be employed in May to control curly-leaf pondweed with minimal damage to native plants, which have not yet germinated.
  - Once the native plants have germinated, there are currently no selective tools to control curly-leaf pondweed without harming the native species. Any action undertaken at this time should be planned very carefully to maximize control of curly-leaf pondweed while minimizing the impacts to native vegetation. Such control may be possible if curly-leaf pondweed is the only plant or the dominant plant in the area.
  - All herbicide applications require a permit from the Michigan DEQ.
  - The early summer dieback of curly-leaf pondweed should be considered in the development of a control program. For some lakes, this natural process may be the primary part of the control strategy. Chemical or physical controls may be used in small but high-demand areas while most areas are untreated and the plants are left to die back naturally.
  - Maintain a healthy population of native aquatic plants. If native plants are damaged as part of a control program, curly-leaf pondweed may replace them. In some lakes with abundant native plants, curly-leaf pondweed has been present for years but has never become a problem.
  - In the long term, protecting water quality can help control curly-leaf pondweed. This exotic plant has a competitive advantage over native plants when water clarity is reduced.
  - Adjust the control program on the basis of information generated by the monitoring.

Purple Loosestrife (*Lythrum salicaria*)

Invasion history

- Purple loosestrife is a widespread and serious problem affecting wetlands, waterways and lake edges throughout North America. Though a few varieties of loosestrife are native to the Great Lakes region, they are uncommon and pose no threat to the integrity of native ecosystems. Purple loosestrife arrived in North America from Europe in the early 1800s, probably in ships' ballast and in the fleece of sheep. It was once admired by botanists, beekeepers and gardeners, who helped spread it westward from the East Coast. It is now found in all the contiguous states except Florida. In Michigan, purple loosestrife is present throughout the Lower Peninsula and is expanding its range in the Upper Peninsula.

Problems

- This plant dominates many of the wetlands it has invaded because it tends to outcompete native plants for space and sunlight. Biologists and ecologists are worried about the decrease in wetland biodiversity brought on by the invasion of purple loosestrife. In many cases, loosestrife has changed open-water marshes, which are favored by waterfowl, into habitats dominated by loosestrife in which the stiff plant stems are too dense to be suitable habitat for waterfowl. The whole food web, from tiny native organisms to muskrats and birds, is affected by invasive purple loosestrife. Scientists know very little about the long-term impacts of loosestrife.

Physical description

- Purple loosestrife is very easy to identify during its showy, midsummer flowering phase. This plant requires a lot of water and will most often be found in drainageways and along the edges of streams, ponds and lakes. It also invades moist prairies and mucklands. Each root crown produces 30 to 50 stout stems, which can grow from 3 to 7 feet tall. Small pink-purple flowers begin to bloom in July, first at the tip of the stem. The flowers have five or six petals each, and they will typically cover the top 12 inches of every stem when the plant has fully blossomed. The stems stand pale brown throughout the winter and can be identified by their square cross-section at any time of the year.

Life history

- One of purple loosestrife's competitive advantages in the wild is that it sprouts early in the season. It grows very rapidly, sometimes adding an inch to its height in just one day during May and June in Michigan. A mature plant produces as many as 2.5 million tiny seeds each year, so the soil around every loosestrife plant is usually heavily inoculated with viable seeds. Purple loosestrife also propagates by fragmentation—a tiny piece of loosestrife root can start a new colony.

Purple loosestrife (*Lythrum salicaria*)

IPM strategies

- Every lake should have an exotic IPM program, including education, prevention, monitoring and control (see pages 5-7). The IPM program will help prevent the introduction of exotic aquatic plants and animals and, if necessary, direct the control of introduced populations.
- Before the introduction of biological controls just a few years ago, solutions for managing purple loosestrife were limited and not very effective. Landowners and wetland managers have tried several control methods, including burning, herbicides, digging and cutting, but these have proven to be extremely difficult and impractical on a large scale. Once established, purple loosestrife keeps

returning year after year despite annual treatments. Limited success with some of these annual treatments is reported when an infestation is managed within the first few years.

– Controlled burning of small stands of loosestrife kills the stems and leaves necessary for growth, flowering and seed production. Burning can destroy standing seedheads. Viable seeds in the soil may start new loosestrife plants following removal of mature loosestrife and neighboring plants by burning. The root crown is not usually killed because soil temperatures do not get high enough in controlled burns. Energy stored in the root crown will produce shoots of lower viability each year that the photosynthesis of the plant is restrained by annual treatment. Controlled burning may be practical in some situations. Permits may be needed.

– Herbicides can kill stems and leaves necessary for growth, flowering and seed production and are applied directly to small stands of loosestrife according to label instructions. Viable seeds in the soil may start new loosestrife plants following removal of mature loosestrife and neighboring plants by herbicides. The root crown is not usually killed by application of approved herbicides. Energy stored in the root crown will produce shoots of lower viability each year that the photosynthesis of the plant is restrained by annual treatment. Permits may be needed.

– Digging purple loosestrife is very strenuous work and has not been effective in well established populations, but it can work when the first few invaders appear. Fragments of root, many of them capable of sprouting new plants, are always left behind when loosestrife is uprooted. Small populations of loosestrife—fewer than 50 to 100 established plants—can be seriously damaged by digging. This method is highly recommended when an annual "workout in the wetland" is desired. Annual control by digging can keep a small population from becoming a large infestation. Seedheads will need special handling. Viable seeds in the soil may start new loosestrife plants following removal of mature loosestrife and soil disturbance. Plants should be burned to avoid propagation by fragmentation.

– Cutting the stems of loosestrife before they go to seed is one way to drain the energy from individual root crowns and thereby control the growth of the whole colony. Annual cutting can seriously damage small populations of loosestrife—fewer than 50 to 100 established plants. Clipping the stems and leaves necessary for growth, flowering and seed production will not only prevent the current year's plant production but also permanently weaken the plant's root crown. Energy stored in the root crown will produce shoots of lower viability each year that the photosynthesis of the plant is restrained by annual treatment. Viable seeds in the soil may start new loosestrife plants following removal of mature loosestrife and neighboring plants by area mowing. Seedheads will need special handling. Clippings should be burned to avoid propagation by fragmentation.

– Biological control may be appropriate wherever more than 100 purple loosestrife plants are established. One of loosestrife's natural enemies being used in Michigan is a leaf-eating

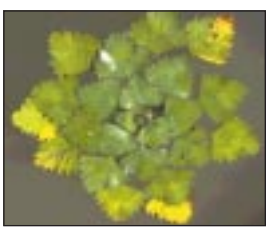
beetle, *Galerucella* spp., imported from Europe in 1990. *Galerucella* is a host-specific beetle—it will not survive without a steady diet of purple loosestrife. Loosestrife-infested wetlands are inoculated with small colonies of beetles. Though it's not always effective, loosestrife density has been reduced by 90 percent in some North American wetlands. Annual maintenance is not required if the beetles keep the loosestrife suppressed. Contact the Michigan State University Extension office in your county for information about biological control and the Purple Loosestrife Project at Michigan State University.

Section IV–Other Exotics That May Invade Michigan Waters

Other aquatic exotics have the potential to move into Michigan lakes. This manual focuses only on the exotics that are considered an immediate threat to Michigan inland lakes. Some of the species to watch for are flowering-rush (*Butomus umbellatus*), European frog-bit (*Hydrocharis morsus-ranae*), European water chestnut (*Trapa natans*) and New Zealand mud snail (*Potamopyrgus antipodarum*). More information about these other exotic species can be found through Michigan Sea Grant, the Office of the Great Lakes or many sites on the Internet, e.g.: <http://infoweb.magi.com/~ehaber/> or <http:// www.anr.state.vt.us/dec/waterq/ans/anslist.htm>.

Flowering-rush is an emergent shoreline plant that flowers throughout the summer. A single flowering stem emerges from the water. The flowers can vary in color from white, to deep pink, to purplish-brown. It is usually found in marshes and shoreline areas of rivers, lakes, streams and ditches. This plant can form thick mats of vegetation that can choke out native plants and be a hindrance to recreation. Flowering-rush can be found in the St. Lawrence River and along the border of Lake Erie in southeast Michigan. It has not spread throughout the state at this time. Flowering-rush has spread mainly through intentional introductions. Awareness of the impact of flowering-rush is important to avoid further intentional introductions. There is little information available on the control of flowering-rush, so it is essential that all possible measures be taken to avoid introducing this invasive exotic plant.

European water chestnut is an aquatic plant that can usually be found rooted in mud. The plant has a submerged stem with a rosette of floating leaves.



European water chestnut (*Trapa natans*)

European frog-bit (*Hydrocharis morsus-ranae*)

White flowers can be found in the center of the rosette. Fern-like leaves grow on the submerged stem. European water chestnut can be found in streams, ponds, estuaries and mud flats. The plant forms dense mats of floating vegetation that grow rapidly and can choke out native plants and be a hindrance to recreation. European water chestnut has not spread to Michigan at this time, but has spread to the southeast shore of Lake Ontario. Federal regulations prohibit the interstate transportation and sale of water chestnut. This plant is most likely spreading through natural expansion. It is important to recognize the potential threat of invasion and take measures to prevent this invasive aquatic exotic from entering Michigan lakes. Mechanical harvesting over a number of years may prove useful in controlling the European water chestnut in small bodies of water, however this does not provide long term control.

The New Zealand mud snail is another invasive aquatic organism of concern. It conserves moisture and can survive extended periods out of the water by covering the opening of its shell with a solid cover made of calcium. The New Zealand mud snail reproduces rapidly once it is introduced into an area. The populations of the snail become

extremely dense and it can compete with native snails and other aquatic organisms for food and habitat. The snail is capable of invading a wide range of habitats from the Columbia River estuary to the Middle Snake River, Idaho. The New Zealand mud snail has recently been found in Lake Ontario. It has not been found in Michigan inland lakes at this time, however it has shown the capability to spread rapidly. There are no known control measures for the New Zealand mud snail. It is important that efforts are made to prevent the introduction of this organism.

European Frog-bit is an annual free-floating aquatic herb with several rounded, heart-shaped leaves that measure about 1¼ inches in diameter. It looks somewhat like a very small water lily. Dense mats of European Frog-bit can cover quiet water inlets, canals, and slow streams by mid-summer when its small white flowers emerge. In addition to blocking the penetration of sunlight, thick mats of Frog-bit may impede the movement of aquatic animals and seriously disrupt aquatic systems. The plant was introduced in 1932 to an experimental farm in Ottawa, Canada and it has been spreading westerly since that time. It was discovered in a canal at the edge of Lake St. Clair in 1997.

Finally, there are many more potential aquatic invaders that have not been covered in this manual. It is important to follow the guidelines presented when setting up an IPM program for your lake. Developing preventive measures for introduction can prevent many invading species.

Section V – Additional Information

Many bulletins, publications and videos on aquatic exotic species are available. These resources can be obtained through your local Extension office, Michigan Sea Grant or other sources.

Lake Management

- *EPA's Watershed Academy 2000.* (Web site.) U.S. Environmental Protection Agency: <http://www.epa.gov/OWOW/watershed/wacademy/acad2000.html>.
- *Lake and Reservoir Restoration Guidance Manual.* Publication number EPA1. North American Lake Management Society, (608) 233-2836.
- *Protecting Inland Lakes—You Can Make a Difference.* Michigan Department of Environmental Quality, (517) 373-8000.
- *What Makes a Quality Lake?* (Video.) IFAS catalog number VT-398. University of Florida/IFAS Center for Aquatic Plants, (352) 392-1764.
- *Your Lake and You.* Michigan Lake and Stream Associations, Inc., (616) 273-8200.

Pond Management

- *Managing Michigan Ponds for Sport Fishing.* Publication E1554. MSU Extension Bulletin Office, (517) 355-0240, or your local county MSU Extension office.

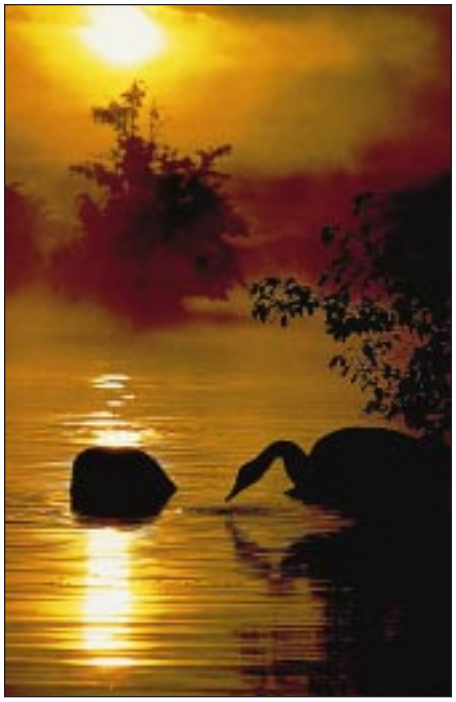
Aquatic Plant Management

- *Aquatic Plant Management in Lakes and Reservoirs.* Publication number A1. North American Lake Management Society, (608) 233-2836, and Aquatic Plant Management Society.
- *A Citizen's Guide for the Identification, Mapping and Management of the Common Rooted Aquatic Plants of Michigan Lakes.* Publication WQ 55. MSU Extension Bulletin Office, (517) 355-0240; your county MSU Extension office; or the Michigan Lake and Stream Associations, Inc., (616) 273-8200.
- *Common Aquatic Plants of Michigan.* Michigan Department of Environmental Quality, (517) 373-8000.
- *Florida's Aquatic Plant Story.* (Video.) IFAS catalog number VT-315. University of Florida/IFAS Center for Aquatic Plants, (352) 392-1764.
- *Lakescaping for Wildlife and Water Quality.* Publication WQ 57, MSU Extension Bulletin Office, (517) 355-0240 or your county MSU Extension Office.
- *Management of Aquatic Plants.* Michigan Department of Environmental Quality, (517) 373-8000.
- *Nuisance Aquatic Plant Control Using Algicides and Herbicides.* Michigan State University Department of Fisheries and Wildlife, (517) 355-4478.
- *Through the Looking Glass—A Field Guide to Aquatic Plants.* Wisconsin DNR publication FH-207-97, distributed by North American Lake Management Society, (608) 233-2836.
- Identifying Eurasian Watermilfoil. 1997. Vermont DEQ, (802) 241-3777; e-mail: mikeH@waterq.anr.state.vt.us
- Investigations on the Potential Use of an Aquatic Weevil to Control Eurasian Watermilfoil. 1997. Michigan Sea Grant, (734) 764-1118; e-mail: msgpubs@engin.umich.edu
- Purple Loosestrife in Michigan: Biology, Ecology and Management. 1997. Michigan Sea Grant, (734) 764-1118; e-mail: msgpubs@engin.umich.edu
- Purple Loosestrife Project: Cooperators Handbook. 1999. Michigan Sea Grant College Program, (734) 764-1118; e-mail: msgpubs@engin.umich.edu

Continued on next page

Zebra Mussels and Other Invasive Animals

- Boaters: Take Action Against Zebra Mussels. 1996. Ohio Sea Grant College Program, (614) 292-8949; e-mail: banicki.1@osu.edu
- Zebra Mussel Distribution in the Inland Waters of Michigan. Michigan Sea Grant College Program, (734) 764-1118; e-mail: msgpubs@engin.umich.edu
- Detecting Zebra Mussels: A Monitoring Program for Citizens. 1996. (Brochure describing loanable equipment and instructions.) Michigan Sea Grant College Program, (734) 764-1118; e-mail: msgpubs@engin.umich.edu
- Control of Zebra Mussels in Residential Water Systems. 1996. New York Sea Grant, (800) 285-2285 or (716) 395-2516; e-mail: zmussel@cce.cornell.edu
- The Zebra Mussel (*Dreissena polymorpha*): An Unwelcome North American Invader. 1991. New York Sea Grant, (800) 285-2285 or (716) 395-2516; e-mai: zmussel@cce.cornell.edu
- Ruffe: A New Threat to Our Fisheries. 1997. Minnesota Sea Grant Exotic Species Information Center, (218) 726-8712; e-mail: djensen@e.umn.edu
- The Ruffe: A Small Fish— Big Problems. (Video.) 1993. Minnesota Sea Grant Exotic Species Information Center, (218) 726-8712; e-mail: djensen@e.umn.edu
- Round Gobies Invade North America. 1995. Illinois-Indiana Sea Grant College Program, (217) 333-9448; e-mail: goettel@uiuc.edu
- Gobies: Cyberfish of the ‘90s. 1996. (4-page fact sheet about impact on native benthic fish.) Michigan Sea Grant College Program, (734) 764-1118; e-mail: msgpubs@engin.umich.edu
- Effects of Spiny Tailed *Bythotrephes* on Great Lakes Fish. 1997. Michigan Sea Grant College Program, (734) 764-1118; e-mail: msgpubs@engin.umich.edu
- A Field Guide to Aquatic Exotic Plants and Animals. 1992. Minnesota Department of Natural Resources, (612) 296-2835; e-mail: debbie.hunt@dnr.state.mn.us
- Rusty Crayfish: A Nasty Invader. 1995. Minnesota Sea Grant Exotic Species Information Center, (218) 726-8712; e-mail: djensen@e.umn.edu
- *Daphnia lumholtzi:* The Next Great Lakes Exotic? 1999. Illinois-Indiana Sea Grant College Program, (217) 333-9448; e-mail: goettel@uiuc.edu
- *Cercopagis pengoi* Invades Lake Ontario. 1998. Minnesota Sea Grant Exotic Species Information Center, (218) 726-8712; e-mail: djensen@e.umn.edu



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Issued in furtherance of Extension work in agriculture and home economics, acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture. Arlen Leholm, Extension director, Michigan State University, E. Lansing, MI 48824. •

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