Biology, Ecology and Management of

Eurasian Watermilfoil

(Myriophyllum spicatum L.*)*

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MONTANA STATE UNIVERSITY | EXTENSION

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Cover photo of Eurasian watermilfoil in Pend Oreille River near Cusick, Washington, 2007 by John Madsen.
Inset cover photo by Alison Fox, University of Florida, bugwood.org

MONTANA STATE UNIVERSITY EXTENSION

Eurasian watermilfoil is a submersed aquatic plant that forms dense tangled beds that can competitively displace submersed native plant communities, reduce recreational qualities of water bodies, reduce water flow, clog industrial, agricultural, and drinking water supplies, and negatively impact fish and wildlife. It was first reported in Montana in Noxon Reservoir (Sanders County) in 2007. Plants primarily spread through stem fragmentation. Water recreation (primarily boats and boat trailers) is the predominant vector of long distance spread. After prevention, early detection and immediate action to contain and eradicate infestations are the most important management actions for Eurasian watermilfoil in Montana.

PLANT BIOLOGY

Identification

Eurasian watermilfoil (*Myriophyllum spicatum* L.), hereafter referred to as EWM, is a submersed, aquatic perennial in the Haloragaceae family that roots to the bottom of water bodies. The fibrous roots are slender and fragile. Leaves, whorled in groups of four at the stem nodes (Figure 1), are 0.8 to 1.8 inches (2 to 4.5 cm) long, and have 14 to 24 pairs of thread-like divisions giving the leaf a feather-like appearance. Stems emerge from root crowns, are smooth and hairless (glabrous), and grow up to 21 feet (7 m) to the water surface, where they branch profusely. Lower stem leaves die and fall off as abundant stem branches form near the surface.

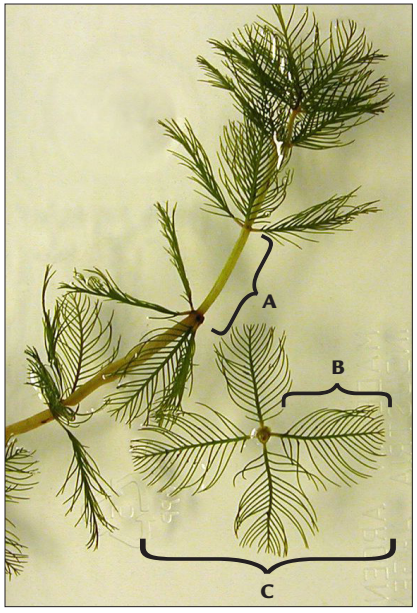

FIGURE 1. Eurasian watermilfoil foliage. A) An internode, the distance between leaf whorls; B) Leaf, pinnately divided with 14 or more paired leaflets; C) Whorl, a group of 3 or more leaves (typically four in EWM) that emerge from the same point on the stem. (photo by John Halpop)

Flower spikes emerge above the water surface growing two to eight inches (5-20 cm) long. Male and female flowers are separate on the stem and whorled in groups of four. Female flowers, located at the lower half of flower spikes, lack sepals and petals but have a four-lobed pistil. Male flowers, located at the upper half of flower spikes, have four pink petals that drop off early in development, and eight stamens. The fruits are globelike in shape, less than 1/8 inch long, with four long narrow grooves, and four seeds. The stem width widens below the flower spike, often doubling in width. The spike is erect when in flower, but bends as fruit set to be parallel to the water surface.

In Montana there are a number of native aquatic plants with fine, feathery leaves in whorls that may be confused with EWM. For example, Coon's tail (Figure 2, *Ceratophyllum demersum* L.) looks similar, but leaves do not have a central midrib with paired leaflets, lacking the symmetry of the milfoils (Figures 3.1F-3.3F). Additionally, Coon's tail leaves have small teeth on the midrib, giving the plant a rough feel when pulled through the hand.

Two native species of watermilfoil are much more difficult to distinguish from EWM (Figure 3.1): shortspike (also known as northern) watermilfoil *(Myriophyllum sibiricum*, Figure 3.2), and whorl-leaf watermilfoil *(Myriophyllum verticillatum*, Figure 3.3). See "SpeedyWeed ID" on page 6 for information on how to differentiate among watermilfoils of Montana.

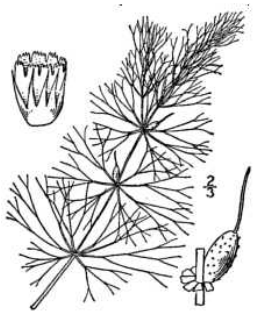

FIGURE 2. Coon's tail *(Ceratophyllum demersum)*. From Britton, N.L., and A. Brown. 1913. *An illustrated flora of the northern United States, Canada and the British Possessions.* Vol. 2: 75. Courtesy of the Kentucky Native Plant Society.

FIGURES 3.1-3.3. A) leaf bract; B) male flower; C) female flower; D) flower spike; E) growth habit; F) leaf (dotted lines emphasize differences in leaf shape); G) winter buds (turions), present in both native species (not EWM) from fall to spring. Winter buds of whorl-leaf watermilfoil may be more club shaped, or wider at the tip than shortspike watermilfoil. (illustrations by Hilary Parkinson)

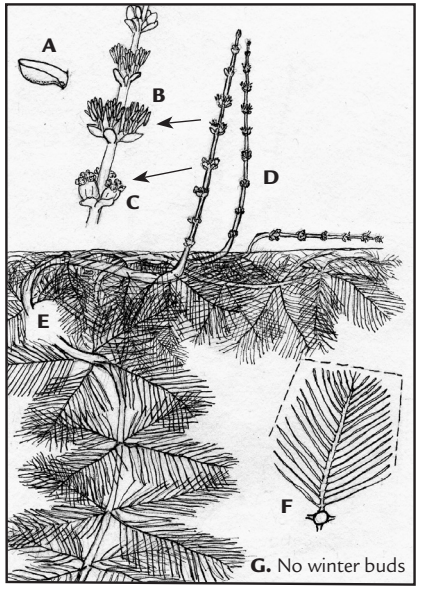

FIGURE 3.1. Eurasian watermilfoil.

Life History

EWM can overwinter under the ice, and begins growth rapidly in the spring as the water warms and light intensity increases. As stems grow, they branch densely near the surface, and slough off lower leaves. Plants can flower from June to September, but flowering has been observed mostly in late July to September in Montana. The female flowers (seed producing) ripen first as the inflorescence spikes emerge from the water, well ahead of the male flowers (pollen producing), favoring cross pollination. Fruits have a stony surface that inhibits seed germination, giving seeds a prolonged dormancy (7 years). Germination is erratic, and seedlings are considered rare in nature. While flowering may be prolific (Figure 4), most reproduction is asexual from root crown buds and stem fragments. Stem fragments form due to natural wave action and recreational activities such as boating. However, unlike the native milfoil species, stem fragmentation can also be initiated by the plant. Self fragmentation occurs in EWM by specialized cells that aid in stem breakage, which typically form after flowering.

FIGURE 4. Flowering spikes emerging from dense stands of EWM on Hayden Lake, Idaho. (photo by Ryan Wersal)

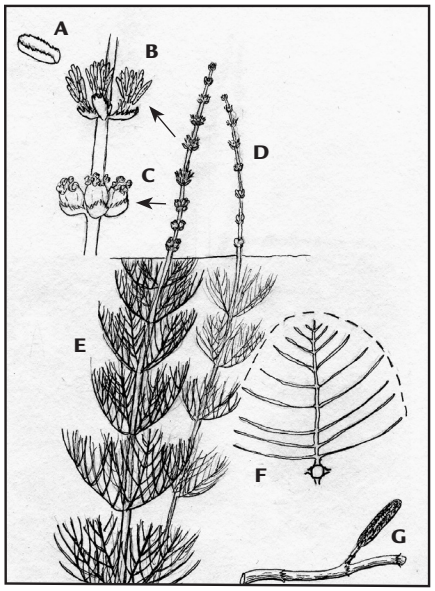

FIGURE 3.2. Shortspike watermilfoil.

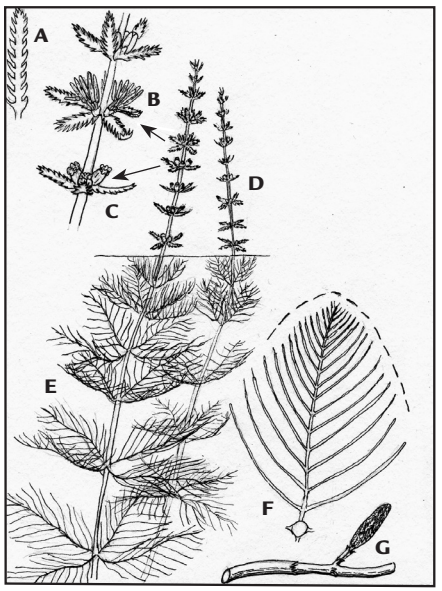

FIGURE 3.3. Whorl-leaf watermilfoil.

SpeedyWeed ID

If you think you've found EWM, check for the characteristics described below. Investigate a whorl of leaves from the middle of a stem.

Which watermilfoil is it?

(1) If flowering spikes are present, continue below. If no flower spikes are present, go to (2):

- If the bracts are longer than the flowers, and are highly dissected (see Figure 3.3A, B), it's whorl-leaf watermilfoil.
- If the bracts are equal to or shorter than the flowers with smooth or toothed margins (Figure 3.1B, 3.2B) it could be EWM or shortspike watermilfoil.

  It's likely EWM if more than 14 leaflet pairs; it's likely shortspike watermilfoil if less than 14 leaflet pairs.

(2) If no flower spikes are present:

- 14 or more leaflet pairs?
  - Yes: EWM or whorl-leaf
  - No: shortspike
- Leaflet length mostly equal?
  - Yes: EWM (square shape)
  - No: native milfoil (rounded)
- Apical meristem (growing point) flat or rounded?
  - Flat: EWM
  - Rounded: native milfoil
- Does foliage collapse when removed from water?
  - Yes: EWM
  - No: native
- Are winter buds present in the fall and winter?
  - Yes: native
  - No: EWM
- Is there dense branching near the water surface?
  - Very: EWM
  - Sparse: native (especially in waters deeper than 3')

Note: Identification is even more difficult by the potential for EWM and shortspike watermilfoil to hybridize. Leaf characteristics overlap those of both parents, but the plants may have winter buds. Hybrids can only be distinguished using molecular analysis. SpeedyWeed ID is designed for Montana only as other states may have additional water milfoil species not covered here.

EWM can maintain a large amount of biomass throughout the winter which aids in rapid and early seasonal growth in the spring. EWM is adapted to use bicarbonate as a carbon source for photosynthesis. This allows more efficient carbon utilization in the low carbon, submersed environment.

CURRENT DISTRIBUTION AND STATUS

The details on the introduction of EWM to North America are unclear, but it may have been introduced near Maryland around 1940, possibly through the aquarium trade. It is now one of the most widely distributed non-indigenous aquatic plants; its presence is confirmed in all the lower 48 states, except for Wyoming, and in the Canadian provinces of British Columbia, Ontario and Quebec. In Montana, EWM was not confirmed until the summer of 2007 when two populations were found in Noxon Rapids and Cabinet Gorge reservoirs (Figure 5). Inventory data collected in 2008 found it in 247 acres in Noxon Reservoir and 117 acres in Cabinet Gorge. In 2010 additional populations were found in Fort Peck Reservoir, the upper Missouri River, and the lower Jefferson River. Regionally it is listed as noxious in Montana, Colorado, Idaho, Nevada, Oregon, Washington, and Alberta, Canada. Nationally, it's listed as noxious, or has special status in Alabama, Connecticut, Florida, Maine, Massachusetts, New Hampshire, New Mexico, North Carolina, South Carolina, Texas and Vermont.

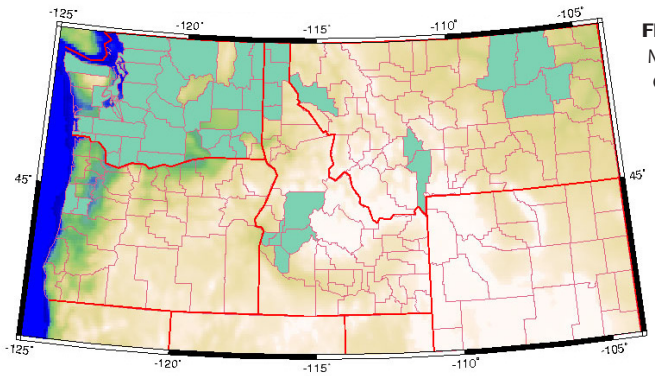

FIGURE 5. Counties in Montana, Wyoming, Idaho, Oregon and Washington where EWM has been reported. (Rice, P.M. INVADERS Database System, Division of Biological Sciences, University of Montana. http://invader.dbs.umt.edu)

If you think you've found Eurasian watermilfoil, please call Montana Fish, Wildlife and Parks Aquatic Nuisance Species (ANS) coordinator at (406) 444-2449, the Montana Department of Agriculture at (406) 444-3140 or your county Extension agent or weed coordinator for more assistance.

ECOLOGY

Habitat

EWM can be found on every continent except Antarctica, and it is native to Europe, Asia and northern Africa. It colonizes rivers, lakes and other water bodies. It can tolerate moving water, and water currents and wave action facilitate fragmentation. It is considered an indicator of eutrophic (low levels of dissolved oxygen, high levels of organic matter) conditions. High growth rates and dominance in hard, alkaline waters is common. It grows vigorously in salinities up to 10 parts per thousand (ppt) and survives at 20 ppt salinity.

EWM will tolerate a wide range of sediment types, but root anchoring may be impeded by coarse substrates like sand and gravel, and also by particularly fine sediments or loose and fluffy substrates. Research has found colonization of new sites by fragments is greatest during the late summer in shallow water (1.6 feet deep) and in rich organic sediments.

Once established, the optimum depth for growth ranges from 3 to 13 feet (1 to 4 m). Growth is limited by light, preventing colonization of deep waters or water with high suspended particles. However, EWM can grow in water up to 24 feet deep if it is very clear with high light penetration.

Spread and Establishment Potential

Transport on boating equipment likely plays the largest role in introducing fragments to new water bodies (Figure 6). Following introduction, spread may be rapid. For example, in Currituck Sound, North Carolina, EWM spread from approximately 1.5 to 103 square miles (400 ha to 26,800 ha) in one growing season.

FIGURE 6. Boat trailer with Eurasian watermilfoil fragments. (photo by David J. Eagan)

However, declines in EWM populations have been recorded following invasions, and the reasons for these declines are not understood. For example, explosive growth in the Chesapeake Bay in the 1950s was followed by a dieback in the 1960s. Unfortunately, populations that died back rebounded following disturbances. The Chesapeake Bay populations that decreased in the 1960s increased following a hurricane and tropical storm in the 1970s. Sharp increases in other lakes were attributed to major human or natural disturbances.

With the introduction in Montana relatively new, early detection is the top priority for management of EWM. Predicting where it will colonize can focus surveys to susceptible water bodies. A Wisconsin study found lakes with a public boat launch were 21 to 28 times more likely to become infested than lakes without a boat launch because of higher potential to move vegetation from lake to lake. Wind, waterfowl, water flow between water bodies, motor boats and boat trailers are believed to be the main mechanisms of fragment dispersal.

Damage Potential

EWM is associated with negative impacts on native aquatic plants, waterfowl and some mammals, fish, and water quality. The dense weed beds formed by EWM have adverse effects on native aquatic vegetation that are important food sources for waterfowl and some mammals. EWM has multiple impacts on fish; dense foliage has been associated with increases in the survival of young fish, but reduces foraging space for large predator fish and requires them to expend more energy to obtain prey. Dense foliage also lowers the abundance and diversity of invertebrates, reducing food for fish. Lower branches and leaves constantly slough, adding nutrients to the water column throughout the growing season. The release of nitrogen and phosphorus can be rapid, and can be a significant source of internal nutrient loading to a lake. The function of water ecosystems are altered, including biomass turnover and nutrient cycling. Dense mats of EWM cause reduced levels of dissolved oxygen and are associated with changes in water temperature.

MANAGEMENT ALTERNATIVES

Prevention is the most important management option for EWM in Montana. Routine and thorough inspection and sanitation of recreational equipment will prevent spread. Any aquatic plant debris on boats, trailers, livewells, boat bilges, and fishing equipment should be disposed of away from lakes, ponds and rivers (Figure 7). Inspections must be thorough: a study by researchers in Denmark found fragments that were less than 1 inch long (2 cm) and with only two nodes are able to develop roots and colonize.

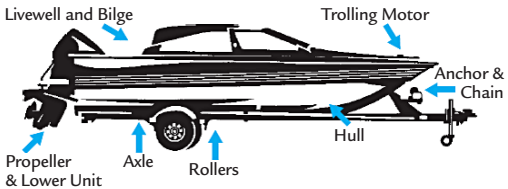

FIGURE 7. Arrows indicate locations that may store and transport EWM and other invasive aquatic species. Boats, trailers and other equipment should be washed, dried and inspected thoroughly before entering a new body of water.

Establishing washing stations at water-based recreational sites is recommended and their use is expanding. For example, Henry's Fork Lake, Idaho offers free boat and float tube washes. Such efforts will not only help prevent the introduction of EWM, but will also reduce the spread of other aquatic nuisance species like whirling disease, quagga mussel or zebra mussel.

After prevention, early detection of new infestations is critical. An aggressive surveying strategy is recommended for water bodies considered to be at risk. Survey methods include divers trained in EWM identification; routine surveys of boat ramps, access points, and other high use areas; shoreline surveys; and collections of plant samples by dragging a rake along the bottom of a lake or pond. Ideal times to survey are July through September when the water is calm. If a new infestation is found, a specimen should be saved, and the infestation reported to the Montana Department of Fish, Wildlife and Parks at (406) 444-2449 and/or the Montana Department of Agriculture at (406) 444-3140.

Chemical Control

Herbicidal control of EWM requires direct application of herbicides to water. Use only herbicides approved for aquatic use by the U.S. Environmental Protection Agency. Carefully follow label instructions and use restrictions. ***In Montana, applicators need a 308 permit from the Montana Department of Environmental Quality before applying aquatic herbicides to water*** (http://agr.mt.gov/weedpest/pdf/aquatic.pdf).

Herbicides are widely used for long-term control of EWM across the United States. Applications of all herbicide formulations are made to the water; therefore the concentration of the herbicide in the water and the exposure time before herbicides dissipate are critical for predictable control.

Diquat and endothall are fast-acting contact herbicides that quickly break down the stems standing in the water. Since the translocation of the herbicide into the roots is minimal, plants will grow back after a contact treatment. These herbicides, however, require only a short contact time, and the effects are localized in the area of actual treatment.

Triclopyr and 2,4-D require an intermediate length of contact time. They provide selective control of EWM without harming most native species. However, native watermilfoil species are susceptible to 2,4-D and triclopyr. Probably the most widely used herbicide for controlling EWM is 2,4-D, both for its selectivity and its relative low cost.

TABLE 1. Herbicides recommended for managing Eurasian watermilfoil.

Active ingredient	2,4-D		Diquat	Endothall		Fluridone		Triclopyr	
Formulation	Liquid	Granular	Liquid	Liquid	Granular	Liquid	Granular	Liquid	Granular
Application Rate[a]	1.42 to 2.84 gallons per acre-foot[b]	100 to 200 lbs. per acre	4 lbs. ae per acre	1.3 to 2.6 gallons per acre-foot	8.8 to 17.6 lbs. per acre-foot	0.42 to 3.8 ounces per acre-foot	0.27 to 2.5 lbs. per acre-foot	0.7 to 2.3 gallons per acre-foot	14 to 67 lbs. per acre-foot
Herbicide type	Selective auxinic systemic		Broad spectrum contact	Broad spectrum contact		Broad spectrum systemic		Selective auxinic systemic	
Notes	Best results in spring to early summer during early growth stage. Acts in 5-7 days, up to 14 days.		Do not apply to muddy water. Acts in 5-7 days.	Trade names Aquathol K® and Aquathol Super K® are safe for fish, but Hydrothol® is not. Acts in 7-14 days.		Acts in 30-90 days		Acts in 7-10 days, up to 14 days.	
Typical waiting period, in days, following chemical treatments (maximum allowable concentration):									
Swimming	1		1	1		No restrictions		No restrictions.	
Drinking: humans[c] (and water tolerance)	Typically 21, but highly variable (0.03 ppm)		3 (0.05ppm)	7-25 depending on ppm (0.5 ppm)		0 (150 ppb)		Variable (less than or equal to 0.4 ppm)	
Drinking: livestock[d]	Highly variable		1	7-25 depending on ppm		No restrictions		No restrictions	
Irrigating	Typically 21, but highly variable		3	7-25 depending on ppm		Variable based on water body and crop. See product label		120 or when concentration drops to 1.0 ppb or less	

[a] This table is not designed to replace product labeling, but serves as a brief overview for comparison: always refer to product labels. Specific amounts will vary based on trade names.
[b] Acre-Foot = Length (ft.) x Width (ft.) x Avg. Depth (ft.) ÷ 43,560.
[c] Recommendations can vary depending on distance of application from potable water intake.
[d] Additional restrictions typically apply for lactating dairy animals.

Fluridone, a broad-spectrum herbicide, has been used in many states for whole-lake control of EWM. Fluridone requires a very long contact time (on the order of 60 days) and may require repeated treatments or applications of several different granular formulations with differing release characteristics. Many active ingredients are currently undergoing the registration process for aquatic use, so in the near future a number of additional herbicides may be available to control EWM.

Consult your county Extension agent and/or weed district for more information on herbicidal control of EWM. Application rates vary depending on water depth. Control is best when applied in early spring or early summer, when water temperatures are above 60°F. Reapplications may be needed and should be applied before mid-August.

Mechanical Control

Repeated mechanical harvests have been successful in reducing stem densities of EWM. Equipment has been developed to mechanically remove milfoil in large areas. A hand rake can be used for small areas (around docks, swimming areas). However, the risk of spread by stem fragments is high. Fragment barriers around harvest operations have been developed to reduce spread. For single harvests, it should be done just prior to when peak biomass is obtained. However, if mechanical harvesting is considered, managers should ideally plan to do it repeatedly within a growing season, and for more than one year. Areas harvested only once can quickly re-colonize to pre-harvest levels in less than one year.

Hand harvesting or diver operated suction harvesting has been successfully used to control scattered individual plants. These techniques are particularly valuable for early stages of infestation, but are not appropriate for any dense beds of EWM.

Benthic barriers (bottom-covering material that inhibits plant growth) anchored to lake bottoms have been used to kill or reduce EWM. This may be particularly helpful near boat ramps, and other areas frequently disturbed and at high risk of infestation. For example, a study conducted by the University of Idaho on Coeur d'Alene Lake showed benthic barriers applied in mid-spring and left on for eight weeks controlled EWM. Four weeks after removal of the benthic barrier EWM had not grown back, but native plants had begun to regrow. Barriers should be installed as early in the spring as possible, prior to EWM growth. Barriers must be monitored for sediment accumulation and cleaned because sediments deeper than 1.5 inches (4 cm) will facilitate rooting of EWM fragments on top of the barriers.

Water drawdown followed by exposure to freezing temperatures for 96 hours will kill plants and has also reduced infestations.

Biological Control

Currently, there are no viable biological controls available for EWM. However, two insects – watermilfoil moth *(Acentria ephemerella),* native to Europe, and the milfoil weevil *(Euhrychiopsis lecontei)*, native to North America – are associated with EWM declines. More testing is needed to determine their effectiveness and host specificity.

INTEGRATED WEED MANAGEMENT (IWM)

Prevention is the most important goal in any IWM strategy, but especially important in Montana where invasion is relatively recent. People who boat or fish throughout the Intermountain West play an important role in preventing the spread of EWM. Clean boats, trailers and watercraft on dry land, carefully inspecting all areas likely to have accumulated Eurasian watermilfoil fragments (see Figure 7). Pump the bilge of the boat before entering another body of water; EWM can stay alive in bilge water for many days.

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ADDITIONAL RESOURCES

Eurasian Watermilfoil Identification and Management in Idaho. Includes diagrams of watermilfoil species native to Idaho. Also includes a risk assessment of water bodies susceptible to invasion as well as cost estimates associated with different control options. http://info.ag.uidaho.edu/pdf/CIS/CIS1108.pdf

Key to aquatic plants of British Columbia. This Web site provides an easy to use dichotomous key for amateur or more experienced botanists interested in identifying aquatic species. http://www.env.gov.bc.ca/wat/wq/plants/plantkey/key.html

Helpful guidelines to protect your waters and stop aquatic hitchhikers designed by the Aquatic Nuisance Species (ANS) task force. http://www.protectyourwaters.net/

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If you believe you've encountered Eurasian watermilfoil, please contact the Montana Department of Agriculture at (406) 444-3140, the Montana Fish, Wildlife and Parks Aquatic Nuisance Species Coordinator at (406) 444-2449 or use the following Web site to report the encounter:

- http://fwp.mt.gov/fishing/guide/ANS/aisSighting

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