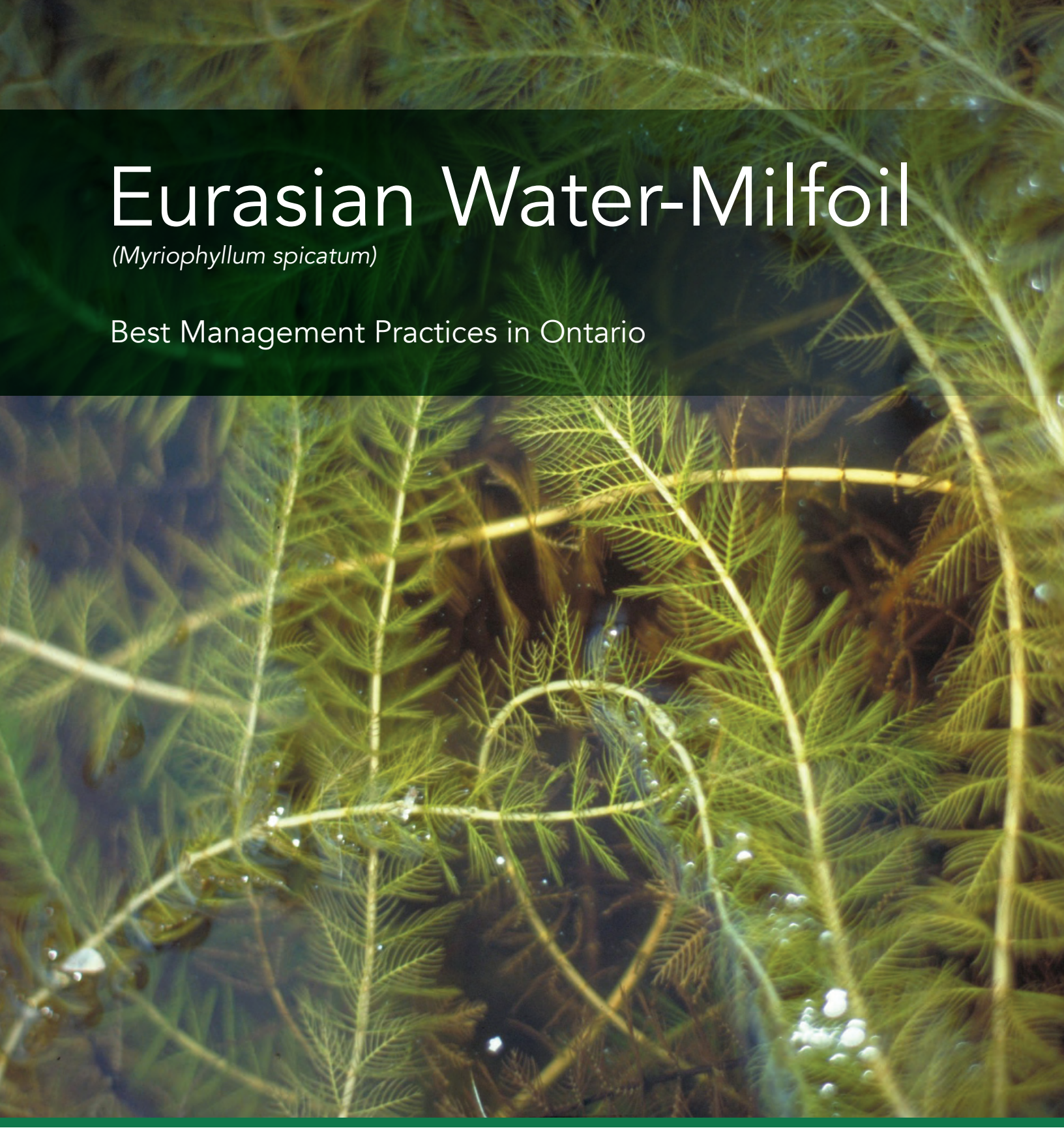
Eurasian Water-Milfoil

(Myriophyllum spicatum)

Best Management Practices in Ontario



ONTARIO INVASIVE PLANT COUNCIL

Foreword

These Best Management Practices (BMPs) provide guidance for managing invasive Eurasian water-milfoil (*Myriophyllum spicatum*) in Ontario. Funding and leadership for the production of this document was provided by Environment and Climate Change Canada, Canadian Wildlife Service – Ontario (CWS-ON). These BMPs were developed by the Ontario Invasive Plant Council (OIPC) and its partners to facilitate invasive plant control initiatives by individuals and organizations concerned with the protection of biodiversity, agricultural lands, infrastructure, crops and species at risk in Ontario.

The intent of this document is to relay specific information relating to aquatic invasive plant control practices that have been recommended by leading professionals across Ontario. This document contains the most up-to-date, effective, and environmentally safe control practices known from research and experience. It complies with current provincial and federal legislation regarding pesticide usage, habitat disturbance and species at risk protection. It is subject to change as legislation is updated or new research findings emerge. The information provided in this BMP is not to be considered legal advice. The timing windows suggested will differ throughout Ontario and by management activity and should be tailored to your region. Interested parties are advised to refer to the applicable legislation to address specific circumstances. Check the website of the OIPC (https://www.ontarioinvasiveplants.ca/) for updates.

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For more information on invasive plants in Ontario, please visit the following websites:
www.ontarioinvasiveplants.ca, www.ontario.ca/invasivespecies, www.ontario.ca/page/remove-invasive-aquatic-plants, www.invadingspecies.com, or www.invasivespeciescentre.ca

Front and back cover photo courtesy of Alison Fox, University of Florida, Bugwood.org.

Table of Contents

Eurasian water-milfoil.

Photo courtesy of: Robert Canning, Severn Sound Environmental Association.

Preface

Aquatic Invasive Plants

Native aquatic plant communities play an important role in sustaining healthy aquatic environments for both humans and wildlife. They provide food and shelter to a variety of animal species. Many invertebrates, fish, birds, and mammals use aquatic plant cover to escape from predators, and the shelter of aquatic plants provides nursery habitat for fish, frogs, and salamanders. Sturdy emergent plants provide nesting material for birds and mammals, and building supplies for humans who construct baskets, mats, boats and dwellings from cattail, rush and bulrush stems. Aquatic plants help to prevent shoreline erosion, assist in nutrient cycling, and provide calm areas for sediment to settle to the lake bottom, increasing water clarity.

A number of aquatic invasive plants threaten Ontario's waterways. These are non-native species, which were introduced to Ontario from outside of their normal range by human activities and threaten the environment, economy, or society. Once established they can out-compete native plants, threaten Species at Risk, inhibit recreational uses of waterways (like boating, swimming or angling), disrupt storm drainage or hydro-electrical generation, increase flood probability, and in some cases, impact water quality. In recognition of the damage these aquatic invasive plants can cause, Ontario has developed an Aquatic Invasive Plant List which currently lists 19 aquatic invasive plants. Eight of these species threaten Ontario's wetlands, lakes and waterways making up the "Watch List", while 11 are already causing a significant impact to Ontario's aquatic ecosystems.

There are eight aquatic invasive plants that make up Ontario's Aquatic Invasive "Watchlist":

- Brazilian elodea (*Egeria densa*) *
- Hydrilla or waterthyme (*Hydrilla verticillata*)*
- Parrot's feather (*Myriophyllum aquaticum*)*
- European Lake Sedge (*Carex acutiformus*)
- Rough mannagrass (*Glyceria maxima*)
- Common water hyacinth (*Eichhornia crassipes*)
- Water lettuce (*Pistia stratiotes*)
- Watermoss – Salvinia species (*Salvinia molesta, S. auriculata, S. minima, S. natans*)

Eleven aquatic invasive plants already found in the province are causing a significant impact on Ontario's wetlands, lakes and waterways. They include:

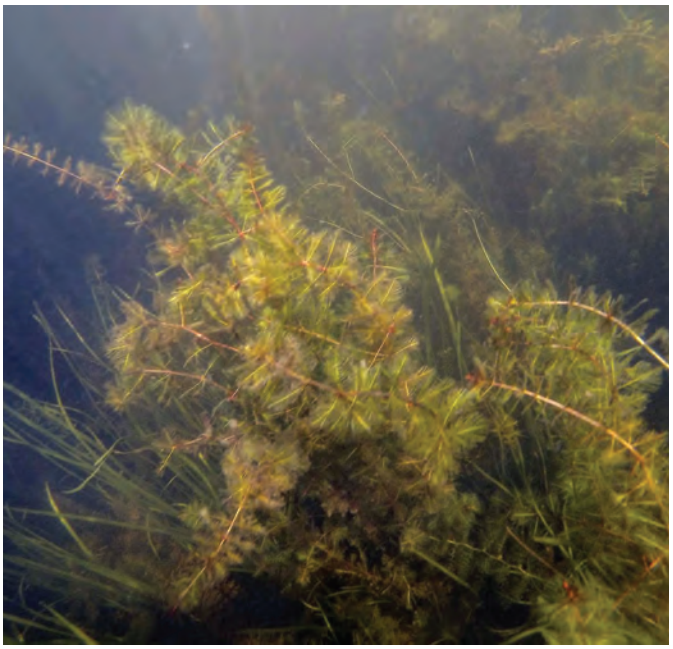
- European water chesnut (*Trapa natans*)*
- Water soldier (*Stratiotes aloides*) *
- Invasive Phragmites or Common reed (*Phragmites australis*) **
- European frog-bit (*Hydrocharis morsus-ranae*)***
- Carolina fanwort (*Cabomba caroliniana*)***
- Yellow floatingheart (*Nymphoides peltata*)***
- Curly-leaved pondweed (*Potamogeton crispus*)
- Eurasian water-milfoil (*Myriophyllum spicatum*)
- Flowering rush (*Butomus umbellatus*)
- Hybrid water-milfoil (*Myriophyllum spicatum x M. sibiricum*)
- Purple loosestrife (*Lythrum salicaria*)
- Yellow iris (*Iris pseudacorus*)

Aquatic invasive plant species regulated as prohibited (*) or restricted (**) under the Invasive Species Act *(2015) as of January 1st, 2018. In Ontario, it is illegal to import, possess, deposit, release, transport, breed/grow, buy, sell, lease or trade these species. The prohibited (*) species are also listed in the Great Lakes and St. Lawrence Governors and Premiers "least wanted" aquatic invasive species list, as they pose an imminent threat to the Great Lakes – St. Lawrence River region.*

**** Aquatic invasive plant species under review for addition to the* Invasive Species Act *(2015) as of February 2020.*

Aquatic Plant Types

There are three types of aquatic plants: submerged, floating-leaved, and emergent. Submerged aquatic plants grow entirely underneath the water. Floating-leaved aquatic plants have leaves that float on the top of the water, and may be free-floating (the roots hang in the water and are not attached to substrate) or be rooted in the sediment at the bottom of the lake. Emergent aquatic plants usually grow in shallow water and the flowers or stems grow above the water. Control methods will differ for each plant and plant type.



Submerged aquatic plant.

Photo courtesy of: Robert Canning, Severn Sound Environmental Association.

Floating-leaved aquatic plant.

Photo courtesy of: Eric Snyder, Ministry of the Environment, Conservation and Parks.

Emergent aquatic plant.

Photo courtesy of: Alex Yakovlev, inaturalist.org/observations/37955352, licensed under CC-by-NC 4.0.

Eurasian water-milfoil forms a dense canopy at or below the water's surface.

Photo courtesy of: Kyle Borrowman, Ducks Unlimited Canada.

Introduction

Eurasian water-milfoil, or spiked water-milfoil is a submerged aquatic perennial of the Holoragaceae (Water-milfoil) family. Native to Europe, Asia and northern Africa, it was introduced to the USA in the 1940s and has since become one of the most widespread and problematic aquatic invasive species in North America due to its competitive growth habits and ability to spread vegetatively by plant fragments. Once established, Eurasian water-milfoil is able to form dense underwater mats of vegetation that can negatively impact the ecosystem of a waterbody, including displacing native plant species, altering food-web structures, reducing macroinvertebrate abundance and diversity, and degrading the quality of fish habitat. These thick mats also reduce the aesthetic appeal of a water body, decrease property values and impact recreational activities such as swimming and boating, and can clog industrial and power generation water intakes.

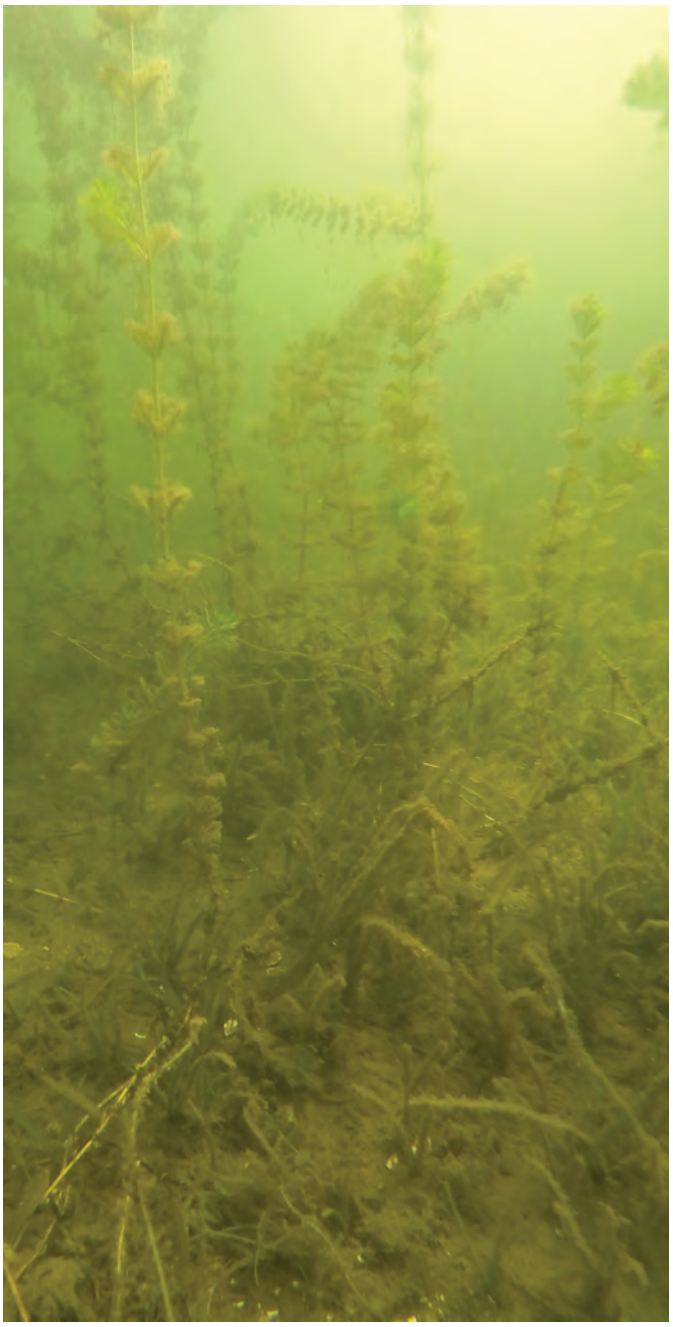
The exact timing and location of Eurasian water-milfoil introduction are unclear; however, it is thought to have been accidently introduced to North America in the late 19th century through shipping ballast or as an ornamental for aquatic gardens. It was first collected in 1942 from the Chesapeake Bay area. The first record in Canada was from an herbarium specimen collected in 1961 at Rondeau Provincial Park on Lake Erie. Subsequent specimens were collected from several sites along the St. Lawrence seaway during the 1960s. It was not regarded as a nuisance until the early 1970s when it became problematic in some areas of Ontario, such as the Kawartha Lakes. Eurasian water-milfoil spreads primarily to new waterbodies through recreational boating activities. Like many aquatic species, Eurasian water-milfoil can reproduce both sexually through seed and asexually through vegetative reproduction, by fragmentation of the plant and stolon formation. The ability for parts of the plant to break off and be transported to new areas and reestablish as a new plant has led to its nickname "Zombie Plant". Eurasian water-milfoil can also hybridize with a native milfoil species, northern water-milfoil (*Myriophyllum sibiricum*), which can lead to a more aggressive invasive species. This hybrid milfoil expresses a trait called hybrid vigor, which is the expression of superior qualities of both parents.

This document was developed to help guide the effective and consistent management of invasive Eurasian water-milfoil populations across Ontario.

Description

Height:

Submergent; typically in water depths between 1 - 4 m, up to a depth of 10 m. Once the plant reaches the water surface it branches extensively, forming dense canopies.

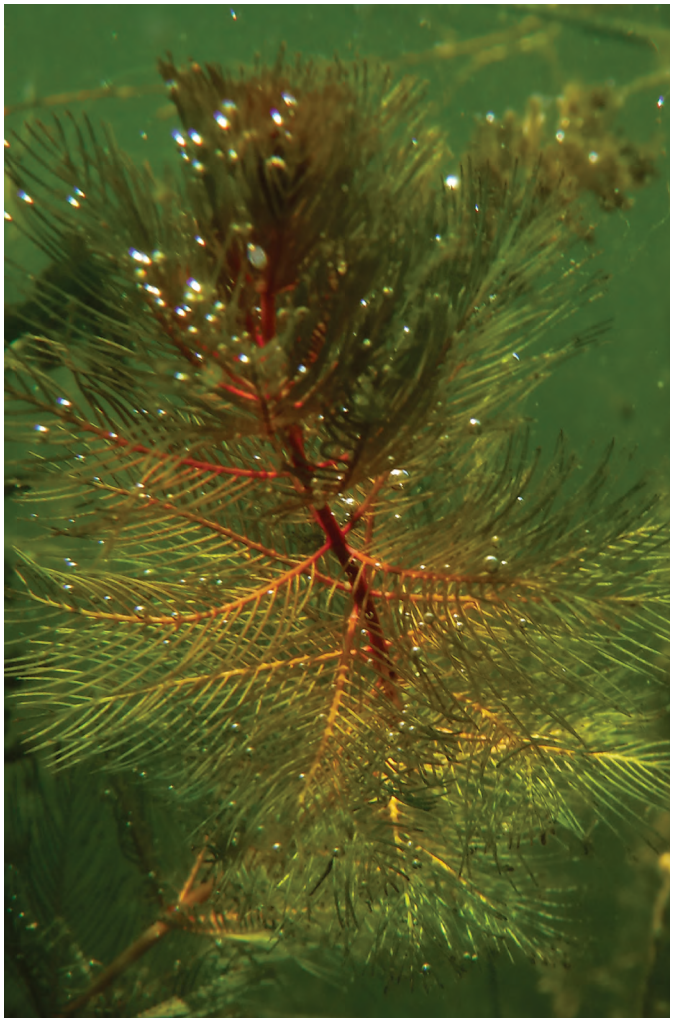


Eurasian water-milfoil can be found in water depths up to 10 m.

Photo courtesy of: Robert Canning, Severn Sound Environmental Association.

Leaves and Stems:

The leaves are arranged in whorls (circles) which center around nodes along the stem, with 3 - 6 (typically 4) leaves per node. The nodes are spaced 1 - 3 cm apart. Each leaf has 12 - 24 filiform or threadlike divisions, giving the leaves a feather-like appearance. As canopies of milfoil expand, the lower leaves are shaded and become leafless. The stem is a leafy shoot, and can be long and spaghetti-like, from 0.5 – 7 m long. There are many branches, particularly at the water's surface, and the tip of the stem is usually reddish in colour.



Whorls of 3-6 (typically 4) leaves around each node. The tip of the stem is reddish in colour.

Photo courtesy of: Jean-Pierre Thonney.

Description

Flowers:

The flowers are a pink–red hue, arranged in whorls (circles) on a terminal spike. The terminal spike is 5 - 20 cm long and borne above the water surface. The plant flowers between late July to early August; upper flowers are male, the lower flowers female. The spike is parallel to the water surface at fruit set.

Flowers are arranged in whorls on a terminal spike that is borne above the water surface.

Photo courtesy of: Robert Canning, Severn Sound Environmental Association.

Roots:

Roots are not essential for survival, although Eurasian water-milfoil grows best when rooted to the sediment, allowing it to access nutrients. Eurasian watermilfoil does not produce overwintering structures such as turions, although small buds may be present and develop from a single root, initially at the base. Root crowns persist through the winter and stems begin to grow when water temperatures approach 15°C.

Roots of Eurasian water-milfoil.

Photo courtesy of: Brant Lake Association.

Northern water-milfoil (*Myriophyllum sibiricum*).
Photo courtesy of: Severn Sound Environmental Association.

Lookalikes

Eurasian water-milfoil can resemble other water-milfoil species in Ontario; there are six native and one additional invasive species of milfoil in Ontario, all with variable leaf counts and many with similar appearance, which may cause confusion when attempting to accurately identify this species. Eurasian water-milfoil hybridizes with the native northern water-milfoil (*M. sibiricum*), which may cause further confusion. Northern water-milfoil can be distinguished from Eurasian water-milfoil by having fewer threadlike leaf divisions and the presence of turions.

Of the six native *Myriophyllum* species, some common species that might be seen include variable-leaved water-milfoil (*M. heterophyllum*), whorled water-milfoil (*M. verticillatum*), alternate water-milfoil (*M. alterniflorum*), and Farwell's water-milfoil (*M. farwellii*). The other invasive milfoil species is parrot's feather (*M. aquaticum*), which has distinct leaf petioles and small white flowers on the axils of emergent leaves; Eurasian water-milfoil lacks petioles or has short petioles < 2 mm and pink flowers. Parrot's feather also has distinct emergent leaves that are greener and longer than submergent leaves, which distinguishes it from other *Myriophyllum* species. Native coontails (*Ceratophyllum demersum*, *C. echinatum*) have leaves that are split into two thread-like segments.

The most reliable method of identifying any milfoil species (i.e. confirming Eurasian vs. hybrid water-milfoil) is through molecular testing using the plants' DNA.

Table 1. Eurasian water-milfoil and its Look-alikes.

	Eurasian water-milfoil *(Myriophyllum spicatum)*	**Northern water-milfoil** *(Myriophyllum sibiricum)*	**Hybrid water-milfoil** *(Myriophyllum spicatum x M. sibiricum)*
			
Plant Type	Submerged	Submerged	Submerged
Stem	• 0.5 - 7 m long • Leafy shoot, many branches • Stem tips usually reddish; stem diameter double in width immediately below the terminal spike	• 0.5 - 7 m long • Leafy shoot, sparsely branched • Stem tips usually green, can be red in some spots; stem diameter immediately below the terminal spike is the same as lower stem	• 0.5 - 3 m long • Leafy shoot, branching repeatedly (tends to branch more than Eurasian and northern water-milfoil) • Stem diameter can vary
Leaves	• Arranged in whorls of 3-6 (typically 4), feather-like, pinnately divided, with greater than 12 threadlike divisions per leaf (usually 12-20) • Leaves arranged in whorls (circles) of 3 to 6 (usually 4) around each stem • Leaves are limp when out of water	• Arranged in whorls of 4-5, feather-like, pinnately divided, with less than 11 threadlike divisions per leaf (usually 5-11) • Leaves arranged in whorls (circles) of 4 to 6 (usually 4) around each stem • Leaves are usually rigid when out of water	• Arranged in whorls of 4-5, feather-like, pinnately divided, with varying number of threadlike divisions per leaf • Leaves arranged in whorls (circles) of 4 to 6 around each stem
Flowers/ Fruit	• Emergent, on terminal spike above water, 5 – 20 cm long • Upper flowers male and lower flowers female • Pink or white (frequently white), arranged in whorls; flowers larger than bracts; bracts have smooth margins • Flowers between late July and early August	• Emergent, on terminal spike above water, 4 – 15 cm long • Upper flowers male and lower flowers female • Pink in colour, arranged in whorls; flowers small; bracts equal to or slightly longer then female flowers and have serrated margins • Flowers between late July and early August	• Flowers and fruit can look intermediate or like either parent plant • Flowering frequently throughout growing season
Turions	• Does not form winter buds (turions)	• Does form winter buds (has turions) towards the end of the growing season • Egg-shaped and form along submerged stems	• Can appear with or without winter buds

Eurasian water-milfoil can spread by disturbance such as boating activities.

Photo courtesy of: Matt Vardy, Ontario Federation of Anglers and Hunters.

In the early fall, plant pieces begin the process of auto fragmentation, and some plants die back to their root crowns.

Photo courtesy of: Kyle Borrowman, Ducks Unlimited Canada.

Biology and Life Cycle

Eurasian water-milfoil is capable of spreading sexually by seed as well as vegetatively through stem fragmentation and stolon growth. Most reproduction occurs through stem fragmentation caused by disturbance such as boat motors, or naturally through a process called autofragmentation. Stem fragmentation is the most important means of dispersal over long distances and the main method by which it colonizes new habitats. Water-milfoil can also expand locally through underground stems called stolons, which grow horizontally from the parent plant, just above the sediment.

In the Great Lakes region, Eurasian water-milfoil begins to break dormancy in early spring and initiate growth as water temperatures approach 15°C (Smith and Barko, 1990). It can be established by April, well before other aquatic macrophytes, and this longer growing season gives it a competitive advantage. Flowering spikes emerge above the water line once the plant has reached the surface, typically June to July. Fruits develop later in July or August and continue until September.

The plant reaches its peak growth and biomass shortly after flowering, when milfoil stems begin to branch and form dense clusters, blocking available sunlight to other submerged plants. Soon after this peak biomass in late summer to early fall the plant begins a natural process called autofragmentation, whereby small branches begin to develop roots, break away from the parent plant, and float until they lose buoyancy, at which point they sink and root in the sediment, ultimately forming new plants.

Towards the end of the growing season, some plants die back to their root crowns, while others overwinter intact in an evergreen form. Unlike other species of water-milfoil, Eurasian water-milfoil lacks specialized structures called turions, which are overwintering buds that store starch to be used for growth. Reserves are stored instead in overwintering roots and shoots.

Eurasian water-milfoil forms a dense canopy at or below the water's surface.

Photo courtesy of: Kyle Borrowman, Ducks Unlimited Canada.

Habitat

Eurasian water-milfoil is able to adapt to a wide range of environmental conditions. It tends to prefer slow-moving waters such as ponds, marshes and lakes with little disturbance, or along sheltered portions of streams (i.e. coves, inlets) where the current is slow or stagnant. It is able to rapidly colonize areas that have experienced some form of disturbance; disturbance can result in fragmentation and spread.

It can tolerate a range of nutrient conditions from high nutrient (eutrophic) to low nutrient (oligotrophic), although it tends to grow most abundantly in medium (mesotrophic) to mildly eutrophic lakes. In eutrophic lakes, overabundant algae and phytoplankton reduce light levels and water-milfoil growth is inhibited (Menninger, 2011). In oligotrophic lakes, growth tends to be limited and restricted to areas where sediment and nutrients accumulate such as near the mouth of tributary creeks and in areas of heavy public use. It tends to grow best on fine textured, inorganic sediments as they have the highest nutrient availability, and grows poorest in highly organic sediments and coarse substrates. The most important source of nutrients (i.e. phosphorus, nitrogen) is the sediment. The best predictor of Eurasian water-milfoil dominance is water column total phosphorus (Madsen, 1998). In Ontario, hybrid water-milfoil appears to be restricted to high alkaline lakes with carbonate bedrock, such as lakes within the Kawartha Lakes, Trent-Severn Waterway and Rideau Canal system (Borrowman *et al.*, 2014). It can grow in a wide range of depths, from 1 - 10 m, although the most common depth is between 0.5 - 4 m. In shallow water (less than 1 m), growth is restricted, likely due to greater fluctuations in water levels and temperatures, and ice along the shore may also limit its long-term growth in shallower areas. The depth and clarity of the water determines the rooting depth and growth form of the plant. In shallower and more turbid waters, plants have shallower rooting depths, with horizontal stems at the surface that tend to mat profusely. In deeper and clearer waters, milfoil grows to deeper depths and is able to grow into long strands and will not reach the surface or form dense canopy stands (Smith and Barko, 1990).

Eurasian water-milfoil has a wide pH tolerance (pH 5.4 – 11) although growth is most optimal in alkaline waters and less optimal in low alkaline waters. It can tolerate salinities of up to 15 parts per thousand (half the concentration of sea water), although at high salt concentrations it shows lower invasive success. It can also grow over a broad temperature range (15 – 35°C), with maximum growth under higher water temperatures (30 – 35°C) (Smith and Barko, 1990).

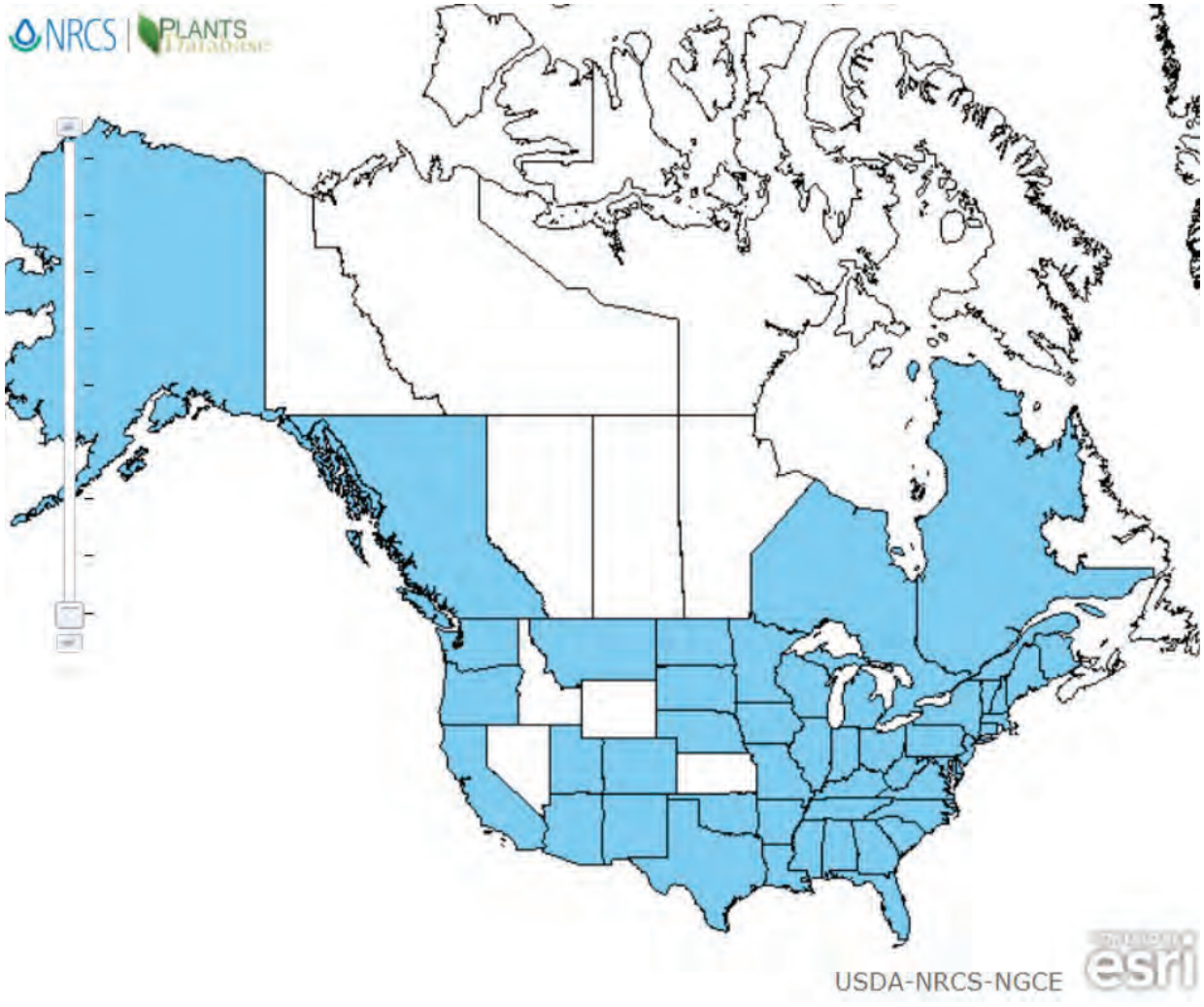
Pathways of Spread and Distribution in Ontario

Eurasian water-milfoil spreads between waterbodies via plant fragments, which can be transported long distances by boats, boat trailers, fishing gear, and other aquatic equipment, as well as naturally by water currents, wind and waterfowl. It spreads through waterway connections in cases where lakes are connected by rivers and canals, such as the Trent-Severn Waterway.

In Ontario, Eurasian water-milfoil has spread through the Great Lakes, southern and eastern Ontario, to coastal Georgian Bay. It is most notable in the inland lakes in southern Ontario, including the Kawartha Lakes region of the Trent-Severn Waterway, as well as the Rideau Lakes system and the Greater Sudbury Area. It is also found in Quebec, New Brunswick, Prince Edward Island, Manitoba and British Columbia.

It is widespread throughout most of the United States and has spread across every continent except Antarctica.

For up-to-date distribution maps, please visit www.EDDMapS.org/ontario or www.iNaturalist.ca .



Eurasian water-milfoil is found throughout most of Canada and the United States.

Map courtesy of: United States Department of Agriculture, Natural Resource Conservation Science.

Once established, Eurasian water-milfoil forms expansive monocultures that displace native aquatic vegetation.
Photo courtesy of: Tom McNabb, Aquatechnex.

Impacts

Ecological:

Large overwintering biomass and early spring emergence gives Eurasian water-milfoil a competitive edge, allowing it to displace other native submergent aquatic plants. Dense underwater mats of vegetation form on the water's surface blocking available light, and its extensive root system reduces space and access to nutrients in the sediment for other plant species. As a result, significant declines in native submergent plant species richness and abundance has been observed in infested lakes. These mats can be so thick that waterfowl and frogs are able to rest and travel over its surface.

Although aquatic plants play an important role in providing shelter for many macroinvertebrate and fish species, not all species are equal. Dense mats of Eurasian water-milfoil support significantly fewer species and fewer numbers of macroinvertebrates compared to dense mats of native vegetation (Menninger, 2011). In Lake Opinicon, Ontario for example, Eurasian water-milfoil beds were found to support fewer invertebrate species per square meter than did mixed beds of pondweeds and wild celery (Aiken, 1979). This may in part be due to chemicals released from Eurasian water-milfoil plant stems that inhibit the growth of algae, on which many macroinvertebrates feed. This inhibitory effect on algae appears to have some benefit in preventing algal blooms (Menninger, 2011). The altered habitat structure and macroinvertebrate prey abundance, may in turn negatively impact fish abundance, composition and diet. Dense Eurasian water-milfoil beds may lead to an overpopulation of forage fish like bluegill, while predatory fish like largemouth bass decrease in numbers, as they have more difficulty accessing fish prey hidden in the vegetation. Thick beds also create stagnant conditions, which alter water quality and reduce dissolved oxygen levels, a situation that can be lethal to fish. Sensitive fish species such as salmonids are particularly impacted by Eurasian water-milfoil,

as thick beds reduce spawning success by covering suitable open gravel areas for spawning (Menninger, 2011). In Ontario, juveniles and adults of the pugnose shiner are known to utilize Eurasian water-milfoil as shelter, although high densities of Eurasian water-milfoil are detrimental, and have led to local extirpations in Wisconsin (Doherty *et al.*, 2012). Waterfowl have been observed to favor native submerged aquatic vegetation (i.e. pondweed, smartweed, wild celery) as food over invasive Eurasian water-milfoil, which they rarely consume (Aiken, 1979). Although it is not known whether Eurasian water-milfoil decreases habitat value for waterfowl, thick beds displace native submerged aquatic plants.

Economic:

Dense stands of Eurasian water-milfoil impact recreational activities such as boating, swimming and angling. Thick mats are considered unsightly and decrease the aesthetic value of beachfront properties, creating stagnant conditions ideal for mosquitos. Several studies in the USA have demonstrated that Eurasian water-milfoil can significantly reduce lakefront property values. In King County, Washington, mean property sale values lakes decreased by as much as 19% (Olden and Tamayo, 2014). Excessive growth can also clog industrial and power generation water intakes and restrict the operation of flow metering devices in flood control channels.

Table 2. Species listed under the federal *Species at Risk Act* for which Eurasian water-milfoil is highlighted as a threat in Ontario.

Species at Risk	Status	Habitat/Details	Primary Threat from Eurasian water-milfoil
Bent spike-rush (*Eleocharis geniculata*)	Endangered	• Small, tufted annual sedge • Found on wet, sandy to muddy soil in open flats along the shores of Lake Erie	• Competition from invasive plants may make the habitat unsuitable by creating shaded conditions and reducing open areas • Invasive plants also compete for resources, such as light, space and nutrients, leading to a reduction in population size and possibly local extirpations • Eurasian water-milfoil and other invasive plants have been found alongside bent spike-rush in a shallow interdunal depression on the south shore of Long Point • Invasive species, particularly *Phragmites*, are a main threat in Ontario
Ogden's pondweed (*Potamogeton xogdenii*)	Endangered	• Historically found at only three locations in south-eastern Ontario. Has not been observed in over 20 years in any of these three locations • Found in shallow, alkaline waters of clear, slow-moving streams, beaver ponds and lakes	• Speculated that non-native aquatic plants such as Eurasian water milfoil could create unsuitable habitat • Eurasian water-milfoil can grow very thickly and block available light, outcompeting native species for available nutrients

Robert Canning, Severn Sound Environmental Association.

Applicable Legislation

Requirements, such as permits, that could apply to aquatic invasive plant control activities will depend on the location of removal in Ontario, as well as the timing and type of activity (e.g. mechanical/manual or chemical) being undertaken. This document does not provide an exhaustive list of permits or rules that may apply to every situation where control is being undertaken. It summarizes some of the agencies that may need to be contacted prior to aquatic vegetation removal, depending on the species, location, and activity. It is the responsibility of the individual undertaking the control activities to comply with any applicable legislation. In the event that there is a discrepancy between the information provided and the legislation, the legislation shall prevail.

Aquatic Invasive Plant Removal in Provincial Crown Land and Shorelands (Mechanical/Manual Control)

In Ontario, the beds of most waterbodies are provincial Crown land. The Ministry of Natural Resources and Forestry (MNRF) manages these lands under the *Public Lands Act*. The *Public Lands Act* applies to the use of provincial Crown land and shore lands. The Act does not apply to federal lands and water bodies, for example protected heritage areas managed by Parks Canada (National Parks, National Marine Conservation Areas and National Historic Sites including the Rideau Canal and Trent-Severn Waterway) or by Environment and Climate Change Canada (e.g. National Wildlife Areas) and certain isolated waterbodies on private lands.

According to the Regulations prescribed in O. Reg. 239/13 under the *Public Lands Act*, a person may remove invasive aquatic plants such as Eurasian water-milfoil by mechanical means or by hand without a permit if they follow all of the rules for removing aquatic invasive plants (https://www.ontario.ca/page/remove-invasive-aquatic-plants). These rules include following the In-Water Work Timing Window Guidelines (https://www.ontario.ca/document/water-work-timing-window-guidelines) established to protect fish from impacts during spawning, migration and other critical life stages.

If you cannot meet all of the prescribed rules or want to conduct control or removal activities outside of the timing window guidelines, you will need a work permit to remove Eurasian water-milfoil. Information on how and when you need a work permit for projects on Crown land and shore lands as well as permit applications can be obtained online or by contacting your local MNRF office (see Table 3).

Aquatic Invasive Plant Removal in Federal Lands and Waters

Parks Canada:

Rideau Canal or Trent-Severn Waterway

For federal waters under the authority of Parks Canada, authorization is required from the Parks Canada Agency for any plant removal activity in these waters. If there is critical aquatic species at risk habitat on Parks Canada land, Fisheries and Oceans Canada (DFO) might also be involved. Within the Ontario Waterways (Rideau Canal and Trent Severn Waterway), permit applications and guidelines for aquatic plant removal can be obtained online (see Table 3 for contact information). Depending on the scope of the project, a permit for control work might involve one of two pathways. For residential or smaller projects, please see policies for In-water and Shoreline Works and Related Activities. https://www.pc.gc.ca/en/docs/r/poli/page01, or for larger projects please see policies under the Research and Collection Permit http://www.pc.gc.ca/apps/rps/page1_e.asp.

Federal waters that are not regulated by Parks Canada are generally under the authority of DFO, and information about requirements related to projects near water can be obtained online. The requirements under Ontario's *Invasive Species Act* would still apply to any designated plants transported off federal lands (i.e. for disposal).

Other Federal Lands & Waters

Other federal lands and waters include national wildlife areas, national marine conservation areas, some migratory bird sanctuaries, First Nations reserve lands, federal ports, harbours, anchorages, aquatic sites under the Federal Contaminated Sites Program, and other waters within federally-owned land.

Aquatic Species:

Federal waters that are not regulated by Parks Canada are generally under the authority of DFO when it comes to aquatic invasive species. Activities such as the removal of aquatic plants, may require authorization(s) from DFO if fish or fish habitat and/or aquatic species at risk may be impacted. DFO is responsible for administering the *Fisheries Act*, federal legislation that provides protection of all fish and fish habitat. Under the *Fisheries Act*, no one may carry out work which would lead to the death of fish, or to the harmful alteration, disruption or destruction of fish habitat without a permit. If a removal project might impact an aquatic species at risk, then authorization from DFO is required prior to undertaking any projects. A Request for Review form outlining the project and the potential impact on fish and fish habitat would need to be submitted to fisheriesprotection@dfo-mpo.gc.ca. A biologist would then review the project to determine if a *Fisheries Act* Authorization or Species at Risk permit is required. For more information, visit: http://www.dfo-mpo.gc.ca/pnw-ppe/index-eng.html.

Terrestrial Species:

Environment and Climate Change Canada is responsible for issuing permits involving terrestrial species at risk for federal lands and waters not regulated by Parks Canada. The *Species At Risk Act* (SARA) contains prohibitions against the killing, harming, harassing, capturing, taking, possessing, collecting, buying, selling or trading of individuals of threatened, endangered, and extirpated species listed in Schedule 1 of the Act. The Act also contains a prohibition against the damage or destruction of their residences (i.e. nest or den).

These prohibitions apply to individuals of such SARA-listed species that are:

- found on federal lands in a Province, or on lands in a Territory under the authority of the Minister of the Environment and Climate Change or Parks Canada;
- migratory birds protected by the *Migratory Birds Convention Act*, 1994 (MBCA), anywhere they occur, including private lands, lands in a province, in a territory, or federal lands; and,
- aquatic species anywhere they occur, including private lands, lands in a Province and lands in a Territory.

For further information on *Species at Risk Act* permitting and when a SAR permit is required, visit: https://www.canada.ca/en/environment-climate-change/services/species-risk-public-registry/permits-agreements-exceptions/general-questions-answers.html.

Any further questions can be directed to the appropriate Environment and Climate Change Canada regional office: https://www.canada.ca/en/environment-climate-change/services/species-risk-public-registry/permits-agreements-exceptions/contact-coordinator-regional-offices.html#Ontario.

Small Craft Harbours

If your property is located in a small craft harbour (https://www.dfo-mpo.gc.ca/sch-ppb/index-eng.html), you must contact DFO before controlling aquatic plants such as European water-milfoil (http://www.dfo-mpo.gc.ca/pnw-ppe/index-eng.html).

Aquatic Invasive Plant Removal Using Herbicides

Under the federal Aquatic Invasive Species Regulations, the use of herbicides may be authorized by Fisheries and Oceans Canada, Parks Canada or the Ontario Ministry of Natural Resources and Forestry to prevent the introduction or spread of, or to control or eradicate non-native aquatic plants. You can apply for an authorization here: https://www.dfo-mpo.gc.ca/species-especes/ais-eae/applyappliquer/page01-eng.html. In addition, if you plan to use herbicides to control aquatic invasive plants anywhere in Ontario, approval is also required from the Ontario Ministry of the Environment, Conservation and Parks (MECP). Information on requirements for aquatic herbicide applications can be obtained by contacting a MECP regional office to discuss plans and what pesticide permits may be required: https://www.ontario.ca/page/ministry-environment-conservation-parks.

You must not undertake any in-water work during fish spawning season or during the time of other critical fish life stages. The following link contains information on when in-water work is restricted within Ontario: https://www.ontario.ca/document/water-work-timing-window-guidelines.

Table 3. Contact Information (Summary)

	Location	Activity	First Contact	Contact Information
Federal	Rideau Canal or Trent-Severn Waterway	Manual/Mechanical	Parks Canada	**TSW:** 705-750-4900 or Ont.Trentsevern@pc.gc.ca **Rideau:** 613-283-5170 or RideauCanal-info@pc.gc.ca
Federal	Federal waters other than the Rideau Canal or Trent-Severn Waterway	Manual/Mechanical	Environment and Climate Change Canada, Canadian Wildlife Service	905-336-4464 or https://www.canada.ca/en/environmentclimate-change/services/species-riskpublic-registry/permitsagreements-exceptions/contact-coordinatorregional-offices.html#Ontario
Federal	Federal waters other than the Rideau Canal or Trent-Severn Waterway	Manual/Mechanical	Fisheries and Oceans Canada, Fish and Fish Habitat Protection Program	1-855-852-8320 or http://www.dfo-mpo.gc.ca/pnw-ppe/contact-eng.html 905-336-4464 or https://www.canada.ca/en/environment-climate-change/services/species-risk-public-registry/permits-agreements-exceptions/contact-coordinator-regional-offices.html#Ontario
Federal	Small Craft Harbour	Manual/Mechanical	Fisheries and Oceans Canada, Small Craft Harbours Division, Regional Director	204-983-5721 or https://www.dfo-mpo.gc.ca/contact/sch-ppb-eng.html
Provincial	Crown Land (in Ontario the beds of most water bodies are Crown land)	Manual/Mechanical	Ontario Ministry of Natural Resources and Forestry	1-800-667-1940 or www.mnr.gov.on.ca/en/contactus
Both	All locations in Ontario	Chemical	Ministry of the Environment, Conservation and Parks	1-800-565-4923 or https://www.ontario.ca/page/ministry-environment-conservation-parks

Other Information

Table 4. Summary of legislation involving aquatic plant removal

Legislation & Regulating Body	Summary of Purpose	Application to Management	For More Information
Constitution Act/ British North America Act (Ontario and Canada share responsibility for protecting fish) Ministry of Natural Resources and Forestry (Ontario) Fisheries and Oceans Canada (Canada)	Protection of Fish	**In-Water Work Timing Window Guidelines:** In-water work is restricted during fish spawning season of other critical fish life stages. A work permit is required for the removal of any aquatic invasive plants within a timing window.	In-Water Work Restrictions: https://www.ontario.ca/document/water-work-timing window-guidelines
Federal			
Department of Transport Act Historic Canals Regulations		If located within **Rideau Canal** or **Trent-Severn Waterway**, a permit from Parks Canada will be required for any aquatic invasive plant removal.	Rideau Canal: http://www.rideau-info.com/local/local_legislation.html
Fisheries Act Fisheries and Oceans Canada	Protection of Fish and Fish Habitat	No one can carry out work which would lead to the death of fish, or the harmful alteration, disruption or destruction of fish habitat. If there is risk of harm to fish or their habitat, authorization from DFO is required prior to undertaking any projects.	Fisheries and Oceans Canada Regional Offices: http://www.dfo-mpo.gc.ca/regions/contact/index-eng.htm To remain in compliance with the *Fisheries Act* and the SARA consult the guidance found at the following websites: projects near water http://www.dfo-mpo.gc.ca/pnw-ppe/index-eng.html and permitting https://www.canada.ca/en/environment-climate-change/services/species-risk-public-registry/permits-agreements-exceptions/general-questions-answers.html
Fisheries Act – Aquatic Invasive Species Regulations Fisheries and Oceans Canada	Protection of Fish and Fish Habitat	The use of herbicides may be authorized to prevent the introduction or spread of, or to control aquatic invasive plants that may cause harm to fish, fish habitat or use of fish.	Apply to prevent, control or eradicate an aquatic invasive species https://www.dfo-mpo.gc.ca/species-especes/ais-eae/apply-appliquer/index-eng.html

Legislation & Regulating Body	Summary of Purpose	Application to Management	For More Information
Species at Risk Act (SARA) Environment and Climate Change Canada	Protection and Recovery of Species at Risk and their Habitats	Permits are required by those persons conducting activities such as aquatic invasive plant management that may affect species at risk or damage habitat. For activities that may affect species listed on Schedule 1 of SARA and for activities which contravene SARA's general or critical habitat prohibitions, permits may be required. The SARA applies to terrestrial lands including federal lands, parks, national marine areas for aquatic critical habitat.	For more information on species at risk, critical habitat, or obtaining a permit, consult: https://wildlife-species.canada.ca/species-risk-registry/sar/permit/permits_e.cfm
Migratory Birds Convention Act (MBCA) & Regulations Environment and Climate Change Canada	Protection of Migratory Birds, and their Nests and Eggs	No person or vessel shall deposit a substance that is harmful to migratory birds, or permit such a substance to be deposited, in waters or an area frequented by migratory birds or in a place from which the substance may enter such waters. Permits are not issued for waterbodies where migratory birds may be present.	Learn more about the MBCA Act: https://www.canada.ca/en/environment-climate-change/services/migratory-birds-legalprotection/convention-act-regulations.html
Provincial			
Lakes and Rivers Improvement Act (LRIA)		The *Lakes and Rivers Improvement Act* (LRIA) regulates the design, construction, operation, maintenance and safety of dams in Ontario. LRIA approval may be required when constructing a new, or altering an existing, dam, water crossing, channelization, enclosure, and/or pipeline or cable. Proponents should be aware of the LRIA during the approval and permitting process for works that may need to be reviewed against this legislation.	LRIA administrative guide: https://www.ontario.ca/page/lakes-and-rivers-improvementact-administrative-guide
Conservation Authorities Act		Under the *Conservation Authorities Act*, conservation authorities regulate activities in and around areas affected by water-related natural hazards, such as flooding and erosion. These areas include watercourses, wetlands and shorelines. A permit may be required from your local CA for activities in these areas, including aquatic invasive plant removal. Contact your local CA to find out if your project requires a permit.	Find your local CA: http://www.conservation-ontario.on.ca/

Invasive Management Planning

Early detection and rapid response is key to preventing impacts on biodiversity, the economy, and society.
Photo courtesy of: Matt Vardy, Ontario Federation of Anglers and Hunters.

Management Considerations

Preventing the establishment and spread of aquatic invasive plants like Eurasian water-milfoil is more cost-effective than eradicating or managing populations once established in a water body. Early detection and rapid response is key to preventing negative impacts on biodiversity, the economy, and society. For tips on prevention, see "Preventing the Spread" on page 35.

Once Eurasian water-milfoil has been confirmed at a location, a control plan should be developed based on infestation size, site accessibility, potential for spread and the risk of environmental, economic or social impacts. Site-specific conditions such as native plant richness and diversity, wildlife usage and water table fluctuations should also be considered when developing control plans. A detailed inventory of each site is strongly recommended before starting control efforts to help ensure proper methods and timing are used to minimize negative impacts to wildlife and native plant species. In addition it is important to use a control plan that incorporates integrated pest management (IPM) principles. IPM is a decision-making process that helps control invasive species effectively, economically, and in an environmentally sound manner. Knowledge of the pest species (i.e. biology of the plant and timing of the life cycle) and its surrounding environment along with a variety of control methods are used to prevent and fight infestations.

Learn how to recognize Eurasian water-milfoil in your pond or wetland.

Photo courtesy of: Leslie J Mehrhoff, Bugwood.org.

Mapping – For Landowners:

As a landowner it is important to be aware of invasive plants that can threaten your property. One of the first steps is to learn how to recognize aquatic invasive species like Eurasian water-milfoil that might be present in bodies of water on your property. While land managers such as Conservation Authorities or municipalities might hire or recruit contractors to conduct an ecological survey, private landowners with smaller properties may be able to conduct their own survey. If you know you have Eurasian water-milfoil in one area of your property, ensure you map the rest of the property to identify other infestations and to document its current and potential future distribution. For detailed information on mapping techniques consult the Landowners Guide for Managing and Controlling Invasive Plants in Ontario here: http://www.ontarioinvasiveplants.ca/resources/technical-documents.

To see what might already be in your area, visit EDDMapS Ontario: http://www.eddmaps.org/ontario/. To report an invasive species, see "Tracking the Spread" on page 36.

Landscape Level Management – For Land Managers:

The establishment and spread of an invasive aquatic species can be curtailed by following a management plan that applies a coordinated, integrative approach across a landscape rather than at the scale of a single waterbody or individual landowner. Vander Zanden and Olden (2008) have suggested a "smart" prevention approach to management that integrates landscape-level thinking with a science-based prioritization scheme. This involves assessing the vulnerability of sites across a landscape to aquatic invasive species invasions, by integrating knowledge about the primary pathways of introduction, ecological conditions that promote establishment, and the impacts an invader will have once established. This knowledge can then be

used to target management and prevention efforts towards areas most vulnerable to invasion, such as areas of high boat traffic. A strategic and integrated landscape approach to management also serves to bring partners, landowners, and land managers together to work towards a common goal.

Once established, effective management and control of Eurasian water-milfoil will require ongoing treatments and a combination of control measures. It's not always realistic, especially for large infestations, to try and eliminate the infestation all at once. Determine the desired plant community and the land use objective, and then develop an appropriate IPM strategy.

Setting Priorities

Establishing your highest priority locations for control prior to management will help to determine your best course of action. Therefore, when developing a management strategy, it's important to take into account the following considerations to help inform control decisions:

1. If you have limited resources, try to remove the outlying populations (isolated plants or satellite populations) first, to prevent further spread.
2. If you have more resources, working into larger "core" populations of Eurasian water-milfoil can reduce dispersal and spread into uninfested areas. In many cases, resource limitations may prohibit immediate removal of entire core populations. Under these circumstances, core areas should be prioritized and addressed strategically.
3. Concentrate on preventive strategies in high-priority areas such as boat launches or where Eurasian water-milfoil is most likely to establish and cause the greatest impact, such as sensitive wetland ecosystems or areas of fluctuating water levels such as irrigation canals.
4. Protect federally, provincially and regionally rare species and communities by removing invasive plants and ensuring rare species are not negatively impacted by control efforts.
5. Review the different control options and costs with considerations to surrounding water, habitat, time of year and type of land use i.e. high-traffic recreational areas, agriculture.
6. Ensure all landowners have been identified and consulted before control takes place.
7. Consider dedicating a certain time each year to control efforts and make it a joint effort with neighbouring landowners/land managers.
8. Follow-up monitoring is crucial to remove new plants that may emerge after initial control efforts.

Prioritizing within a Control Area

(This section is modified from The Landowners Guide to Managing and Controlling Invasive Plants, published by Credit Valley Conservation).

1. Focus on large blocks of un-invaded areas and keep them free of invaders.
2. Control small, younger, outlier (satellite) populations first.
3. Reverse the invasion, expand the cleared area outward and ensure that un-invaded areas are kept free of invasive plants (with regular monitoring).

This flow chart can help land managers choose where to first focus their control efforts, if the decision has been made to control only satellite populations due to limited resources:

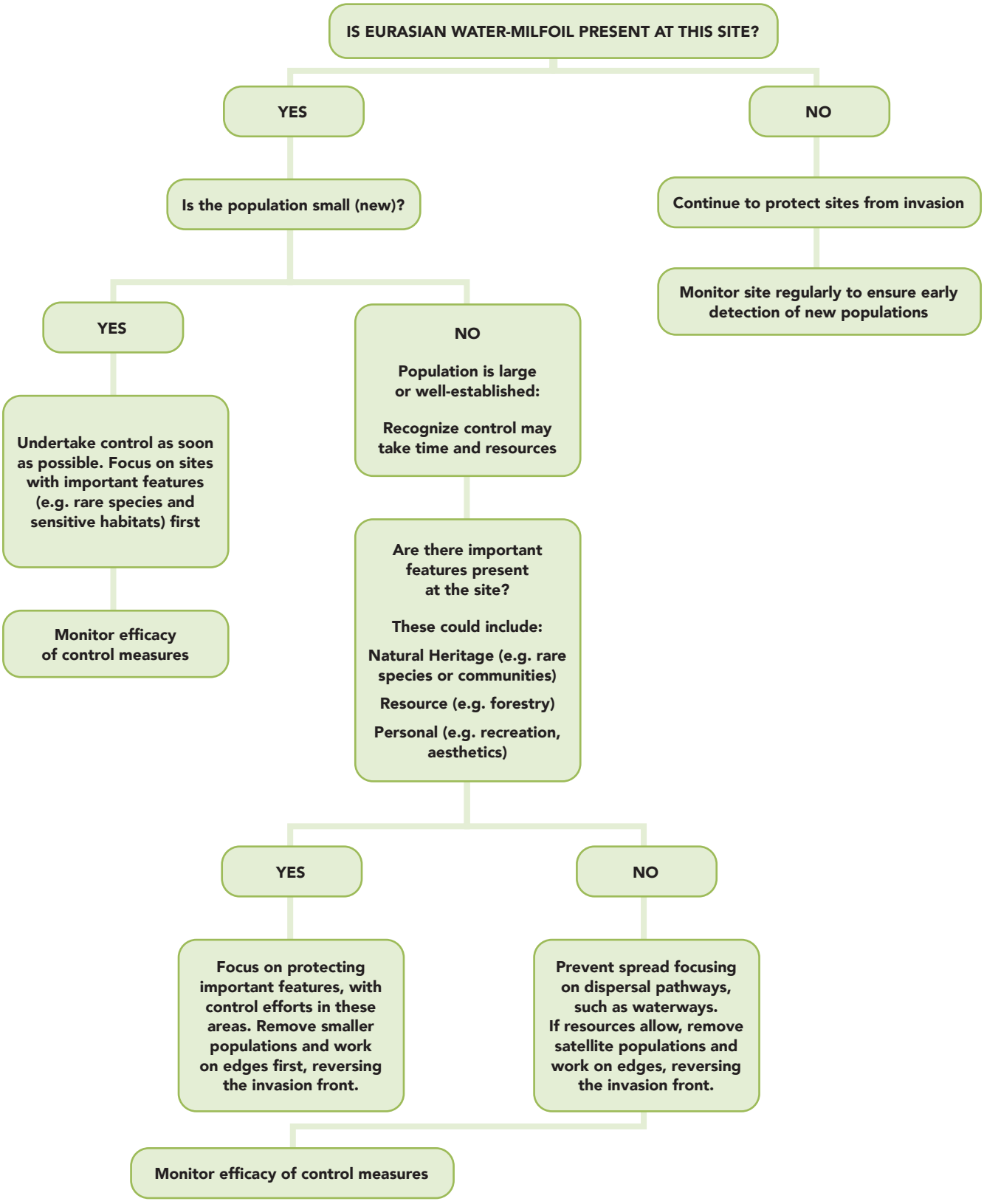


Figure 1: How to prioritize Eurasian water-milfoil sites for effective control.

Long-term Management and Monitoring

Because of the persistent and aggressive nature of Eurasian water-milfoil, a long-term management and monitoring plan should be created prior to the implementation of control efforts. Monitoring will enable assessment of the initial control measures, including their effectiveness, as well as the types of follow-up treatments that are necessary. Ongoing management is critical to the success of a project; after removal, a site remains at risk of reinvasion by nearby populations, or another invasive species.

Monitoring could be as simple as taking photos or performing a visual inspection, or it could be more complex and include extensive surveys. In general, annual treatment is imperative and should focus on selectively removing isolated populations as they appear. Follow-up spot treatment will help to ensure the invasive population remains under control and allows for the regeneration of native plant species. For more information on monitoring see the Landowners Guide for Managing and Controlling Invasive Plants in Ontario here: http://ontarioinvasiveplants.ca/resources/technical-documents.

After Management: Assessing Regeneration vs. Restoration

Consider the following factors:

1) **Level of disturbance at the site:**
    a. Was this a heavily invaded site (i.e. was much disturbance caused during control measures)?
    b. Will it continue to be disturbed (e.g. through beach use or trail use/management)?
2) **Biology of the invasive species removed:**
    a. Is there a seed bank to consider?
    b. Are their seedbanks from other invasive plants in the area?
3) **Re-invasion risk:**
    a. Are there invasive species nearby which could re-invade the site from nearby trails, watercourses or other pathways of introduction?
4) **Existing native vegetation:**
    a. Will any native vegetation that still exists on the site regenerate quickly?
    b. Does it need help? Species with specific habitat requirements or reproductive strategies resulting in low fecundity, including species at risk, may require re-introduction. The majority of plant species should be able to recover naturally, especially if healthy populations exist adjacent to the controlled area.

If you answered **Yes** to most of the questions under 1 to 3, it is most likely that (a) the site will be re-invaded before it has a chance to regenerate on its own, or (b) Eurasian water-milfoil will continue to invade and be present among the native species so that annual control of milfoil may be required. Restoration will be needed to reduce the risk of re-invasion.

Control Measures

Control of Eurasian water-milfoil is most effective when an integrated pest management approach is applied, that combines education and prevention strategies with multiple control strategies. Efforts should be site-specific, taking into consideration factors such as substrate type, water depth, and plant density. Start by conducting an aquatic plant inventory to ensure you have properly identified Eurasian water-milfoil as your primary concern.

If an Eurasian water-milfoil infestation is identified early and populations are small, it is possible to successfully eliminate it by hand removal. Once established, management approaches can help to reduce Eurasian water-milfoil biomass and percent cover in the short-term (weeks to a few years) but will not completely eradicate populations. For example, intensive management efforts to remove Eurasian water-milfoil in Upper Saranac Park were undertaken from 2004-2006, including dive teams removing plants from the entire littoral zone at least two times in a season (June – August) for three years. Eurasian water-milfoil cover had been significantly reduced to less than 5% cover, and stem densities declined in transects from 1,650 stems/ha to 63 stems/ha. However milfoil plants still re-emerged in treated areas, indicating that control would need to be ongoing (Kelting and Laxson, 2010). In another study involving ongoing physical techniques from 1986 – 2010 to control populations in Lake George, the number of locations with Eurasian water-milfoil continued to increase. Due to its ability to fragment and re-root, physical removal methods can enhance the rate of spread. Therefore, it is important to consider using containment measures where possible during control, such as the use of floating booms. These prevent the movement and spread of floating plant fragments by hanging floating curtains in areas where water flow is minimal. It is important to note that any left-over plant material will regrow regardless of control type, therefore extra care should be taken to remove all plant pieces.

To ensure that the native seed bank has a chance to establish and effectively compete with Eurasian water-milfoil, control ideally should begin in mid- to late June. Timing control during carbohydrate storage low points may also help maximize treatment efficacy by limiting growth post-treatment, particularly for chemical and mechanical control (Menninger, 2011; Madsen, 1997). These low points occur in May through July. However, before any work is done in water, ensure that you are avoiding fish spawning season and abide by the In-Water Work Timing Window Guidelines (see Table 4, pg. 20). Generally, this means that any type of control work will not be permitted until early July. It is also important to be aware of the importance of aquatic plants in providing shelter for macroinvertebrates and fish species. Controlling too late in the season should also be avoided as in the fall (September – October), Eurasian water-milfoil becomes brittle and can fragment easily. Controlling too late in the season can also impact native plant populations.

A management strategy is more effective when multiple control methods are combined. For example, in Big Cedar Lake, Kawartha Lakes region of Ontario, an area was raked to reduce milfoil density prior to installing a benthic barrier. Next, native plants were collected from neighboring areas where they were plentiful and transplanted into the benthic mats in order to reduce the potential for milfoil plants to return following the benthic mat removal (Amanda Cooper, personal communication).

Control measures for hybrid water-milfoil are similar to that of Eurasian water-milfoil; however, as the hybrid is a more aggressive plant (increased hybrid vigour), it is more resistant to control efforts such as chemical control (LaRue *et al.*, 2013).

Manual

Hand Removal:	
Infestation Size:	Individual plants, small populations or isolated water bodies.
Goal:	Eradication in small areas; prevent further spread.
Timing:	After fish spawning (July 1st) and before fall when milfoil becomes more brittle.
Treatment Frequency:	Continue to monitor and remove plant material throughout the summer.
Best Practice:	First mark and/or map milfoil locations using a boat or by snorkeling so that the location can be found again and regularly monitored. The plant can be removed by snorkeling in shallow water or scuba diving and works best when paired with a partner on a raft who can observe for plant fragments, collect pulled plants and observe for hazards. The divers should focus on removing the entire plant, including all roots and rhizome fragments that may break off during removal. Fragments that are left behind can root in the sediment and grow new plants. Remove plants carefully; larger plants or firmer sediment require the person to work their fingers into the sediment to help loosen the plant. Slowly remove the plant from the sediment and gently shake it to reduce sediment from clouding the water. The divers should keep the plant in front of them to watch for fragments that may break off during removal. Larger plants can be wrapped around the hand into a ball to prevent breakage and then placed into a fine mesh net held by a partner on the raft. Diving on cloudy days or when the sun goes down can help improve visibility underwater. Continue to monitor the area for several years for new plants growing from root or plant fragments and repeat hand removal, as needed. For more information on manual control see https://www.youtube.com/watch?v=JGNVecrpHil and https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5373240.pdf.
Regulatory Considerations:	*Constitution Act/British North America Act, Fisheries Act, Endangered Species Act, Department of Transport Act, Conservation Authorities Act, Public Lands Act.*
Advantages:	Simple, effective and selective with minimal impact on native aquatic plants. Can reduce biomass and percent cover. Potential for increased community awareness and involvement.
Disadvantages:	Not always effective as it is very difficult to remove all plant material; does not eradicate. Time consuming and labor-intensive, only practical for isolated patches.

Raking:	
Infestation Size:	Individual plants, small populations or isolated water bodies.
Goal:	Supplement hand removal.
Best Practice:	In certain situations (i.e. deeper water) raking may be combine with hand pulling to try and remove all floating plant fragments. In deeper water, guide the rake along the plant and spin the rake so the stems get wrapped around the rake before pulling it up from the water. For a video demonstration, see https://www.youtube.com/watch?v=JGNVecrpHil.

Photo courtesy of: Farlain Lake Community Association.

Photo courtesy of: Farlain Lake Community Association.

Photo courtesy of: Amanda Cooper.

Eurasian water-milfoil on Farlain Lake: A biodegradable burlap barrier was installed along the lake bottom to cover a mono-culture of Eurasian water-milfoil plants, that had been cut by divers prior to installation.

Benthic Barriers:

Benthic barriers, bottom screens, or benthic mats are covers laid on the bottom sediment of a water body to block sunlight, preventing plants from photosynthesizing and suppressing their growth. These barriers target the rhizome, the main method of spread, and can restrict growth in small, localized areas. They are best used for small, dense populations of plants or around docks or swimming areas, or as part of a larger IPM strategy, not as a stand-alone technique. Barriers should be made of a material such as geotextile that is permeable to prevent gas bubbles from forming. This will reduce the likelihood of the barrier floating to the water surface. The best material is biodegradable and does not require removal. When left in the water, these mats will accumulate sediments, allowing new plants to root on top of them which essentially buries the milfoil and it eventually decomposes. Plant decay will occur within 30 days and root decomposition within 60 days. However, this method is considered low efficacy as it is expensive, difficult to install, laborious and requires routine monitoring and maintenance throughout the growing season. Further, barriers are a non-selective control measure, potentially negatively affecting the growth of native aquatic plants and impacting fish spawning and nursery habitats. In Lake George, Eurasian water-milfoil was found to recolonize the area that had been covered within 30 days after barrier removal (Menninger, 2011). This technique must therefore also consider neighboring milfoil populations that can re-populate the area. Consider transplanting species into the treated area in order to reduce the potential for milfoil or another nuisance species such as algae from taking over. Regulatory restrictions must also be considered. Benthic barriers are not permitted by Parks Canada for use in the Trent Severn Waterway or Rideau Canal. For projects on Provincial Crown Land, placement of these materials requires MNRF approval under the Public Lands Act; they do not fall under the provincial rules for removing invasive or native aquatic vegetation in Ontario.

Mechanical

Mechanical Harvesters provide direct relief and immediate results but are a non-selective control measure.

Photo courtesy of: Robert Canning, Severn Sound Environmental Association.

Mechanical Harvesting:	
Infestation Size:	Large areas of infestation only.
Goal:	Clear large infestations to address navigation or safety concerns.
Timing:	After the fish spawning season (July 1st).
Treatment Frequency:	Needs to be repeated several times during a growing season.
Best Practice:	Only recommended for large areas where Eurasian water-milfoil has become widespread and needs to be cleared for navigation purposes or safety concerns. Used to clear infested areas around docks, landings, and swimming areas (Menninger, 2011). Only recommended when other control methods cannot be used. Harvesters involve a machine that cuts milfoil at a certain depth below the water's surface and bundles the plant material for removal and transport. Some mechanical harvesters can be fitted with a deep cutting bar for depths up to 5 m. Cut material is either transported directly onto a conveyer belt and stored on the harvester for later disposal or floats on the surface and is raked up by a trailing machine.
Regulatory Considerations:	*Constitution Act/British North America Act, Fisheries Act, Department of Transport Act, Species at Risk Act, Public Lands Act, Conservation Authorities Act.*
Advantages:	Direct relief and immediate results. Effective when repeated, moderately inexpensive; removes plant biomass in the short-term (weeks to months) and can reduce plant growth the following year.
Disadvantages:	Labour intensive. Non-selective control measure, will indirectly harvest other plant, fish, and macroinvertebrate species. Harvesters can also fragment rhizome pieces, contributing to further spread. Any fragments left behind are at risk of re-rooting and growing. This problem can be mitigated by containing and removing fragments during mechanical harvesting. Milfoil can also return at a faster rate than untouched areas due to nutrient release during dredging and aeration of the bottom.

Dredging or Suction Harvesting:	
Infestation Size:	Small populations.
Goal:	Prevent further spread.
Timing:	After fish spawning season.
Treatment Frequency:	Needs to be repeated for optimal results.
Best Practice/Rationale:	In suction dredge harvesting, divers remove whole milfoil plants (stems, roots, leaves) from the substrate using a dredge hose connected to an industrial engine that creates suction.
Regulatory Considerations:	*Constitution Act/British North America Act, Fisheries Act, Species at Risk Act, Department of Transport Act, Conservation Authorities Act, Public Lands Act.*
Advantages:	Longer-term solution.
Disadvantages:	Disruptive; Very limited areas, usually small areas within larger waterbodies. Slow, expensive. Increases water depth. Milfoil can return at a faster rate than untouched areas due to nutrient release during dredging and aeration of the bottom. Algal blooms can also result from nutrient release. Non-selective; water quality impacts.

North American weevil (*Euhrychiopsis lecontei*), adult.

Photo courtesy of: Tom Alwin, Michigan Department of Environment, Great Lakes, and Energy (EGLE).

Adult milfoil weevil on Eurasian water-milfoil fragment. Weevils must reach high enough densities in order to be effective.

Photo courtesy of: Amanda Cooper.

Biological

Biological control is the use of an herbivore, predator, disease or other natural enemy to reduce established populations of invasive species. Most invasive species have no natural enemies in their new habitats. Biological control aims to re-establish an ecological balance between the invasive species and its natural enemies by selecting highly host-specific natural enemies from the country of origin and moving them to the country where the invasive species is a problem. This is only done after extensive host-range testing in the country of origin or under quarantine, to ensure that the potential biocontrol agent is host-specific to the targeted invasive species. This method has been used successfully for aquatic invasive plants in North America, including purple loosestrife (*Lythrum salicaria*), water lettuce (*Pistia stratiotes*), and common water hyacinth (*Eichhornia crassipes*).

Three native North American species have been considered for Eurasian water-milfoil control, including a native midge (*Cricopopus myriophylii*), a naturalized pyralid moth (*Acentria ephemerella*), and a North American weevil (*Euhrychiopsis lecontei*) (Newman, 2004). The most successful biocontrol agent thus far has been the North American weevil, an aquatic beetle from the Curculionideae family that feeds exclusively within the milfoil genus *Myriophyllum*. Within a few short generations this weevil has shifted from its original host plant, Northern water-milfoil (*Myriophyllum sibiricum*) to feeding almost exclusively on the invasive Eurasian and hybrid water-milfoils (Newman 2004). The adults feed on the stems and leaves of the plant, while the larvae bore into and feed on the inside of the stem, thus causing the plants to lose buoyancy and sink. Much of the impact is from larval feeding, adults eat very little in comparison. However, since natural densities are not usually high enough to significantly impact milfoil density, it is necessary to stock or augment weevil populations to levels that can cause significant declines (Borrowman *et al.*, 2014). Research has indicated there needs to be 1 or more weevils per stem to adequately control milfoil. Unfortunately, although past attempts at weevil release in parts of Ontario such as Big Cedar Lake and lakes in the Greater Sudbury area resulted in initial declines of milfoil and success in some lakes, there was no impact on others, and often densities were not high enough to cause significant damage, even with augmentation (Cooper *et al.*, 2018). Studies are mixed on the effectiveness of the weevil on the hybrid water milfoil, with some studies showing reduced developmental performance (Newman, 2004) while other studies don't indicate this (Borrowman *et al.*, 2014).

Chemical

The management of pesticides is a joint responsibility of the federal and provincial governments. Before a pesticide can be sold or used in Ontario, it must be registered under the federal *Pest Control Products Act* by Health Canada's Pest Management Regulatory Agency (PMRA) and be classified under the provincial *Pesticides Act* by the Ministry of the Environment, Conservation and Parks (MECP).

It is important that herbicides be applied in accordance with all label directions. The label is a legal document and prescribes how the herbicide may be legally used. Ensure you have the most current label and are aware of any re-evaluation decisions.

For an up-to-date list of herbicides labelled for aquatic invasive plant control, visit the Pest Management Regulatory Agency's web site product label search at http://pr-rp.hc-sc.gc.ca/ls-re/index-eng.php. For more information about pesticide use in Ontario, visit: http://www.omafra.gov.on.ca/english/crops/resource/using-pesticides.htm#regulation and https://www.ontario.ca/page/pesticides.

In addition, unless an exemption is granted, any person applying herbicides in water must first obtain a permit issued by the MECP, in accordance with the *Pesticides Act* and Ontario Regulation 63/09. In most cases, an applicator (exterminator) appropriately licensed by the MECP is required to perform the treatment. Permits are reviewed and approved by the MECP with terms and conditions imposed on the use of the herbicide, such as restrictions on timing, location, size of application area, quantity of product used and set back distances from sensitive areas.

Only herbicides specifically labelled for aquatic use may be used to treat plants in water. In Canada, the only herbicide registered for control of aquatic plants that are growing in water is Reward Aquatic Herbicide (diquat, registration number 26271 *Pest Control Products Act*). Another potential aquatic herbicide, Habitat, a formulation for use over water (with the active ingredient imazapyr) is currently under review for registration by the PMRA.

Herbicides and Eurasian Water-Milfoil

In the United States, there are several registered herbicide active ingredients that are known to be effective for Eurasian water-milfoil (Menninger, 2011). Diquat is a rapid-acting photosystem I inhibitor and remains the predominant active ingredient in aquatic applications of herbicides for the mitigation of Eurasian water-milfoil.

Aquatic Herbicide (Diquat):	
Goal:	Eradication.
Timing (season):	After fish spawning season (July 1st).
Treatment Frequency:	One treatment of diquat is permitted annually.
Best Practice:	Diquat is a broad-spectrum contact herbicide that is available in Canada as a restricted herbicide and can only be applied by an exterminator licensed by MECP. It is applied to submerged aquatic vegetation via the water column and can be greatly affected by water exchange processes that may dilute concentrations. For this reason, it works best when the water is cool and still; little or no wind is desirable. High levels of suspended sediment in water can reduce effectiveness. Other environmental factors can influence application and efficacy including water exchange, water temperature, pH, turbidity, conductivity. Undertow, current and other factors need to be considered when applying diquat. There should be no recreational use (boating, fishing) for 24 hours following application and no consumption of the water for five days. In many cases repeated applications in subsequent years can be done as a spot treatment. For more information on herbicides and aquatic vegetation, particularly milfoil control, see Publication 75, Guide to Weed Control: http://www.omafra.gov.on.ca/english/crops/pub75/pub75toc.htm (2016-2017 version: see Table 19-1 Herbicide Treatment for Water Weeds).
Advantages:	Effective and fast acting, requires only a short exposure time, less expensive than mechanical removal.
Disadvantages:	As a broad-spectrum herbicide, diquat can harm many non-target species. In a study that tested the sensitivity of native and non-native aquatic plants such as Eurasian water-milfoil to a range of diquat concentrations (4.7 – 1,153 ug/L), diquat was found to be highly lethal to all plant species. A low concentration of 74 ug/L (below the label recommendation) resulted in 100% mortality of all aquatic plant species. Indirect effects also include lethal effects on invertebrate species using aquatic plants for cover (Sesin *et al.*, 2018). In addition, plant dieback can lead to problems with dissolved oxygen and eutrophication. It is not effective in turbid waters. Areas that have been treated cannot be used for recreation or human consumption for at least five days, which could create a negative public perception. It may also be less effective on hybrid water-milfoil.

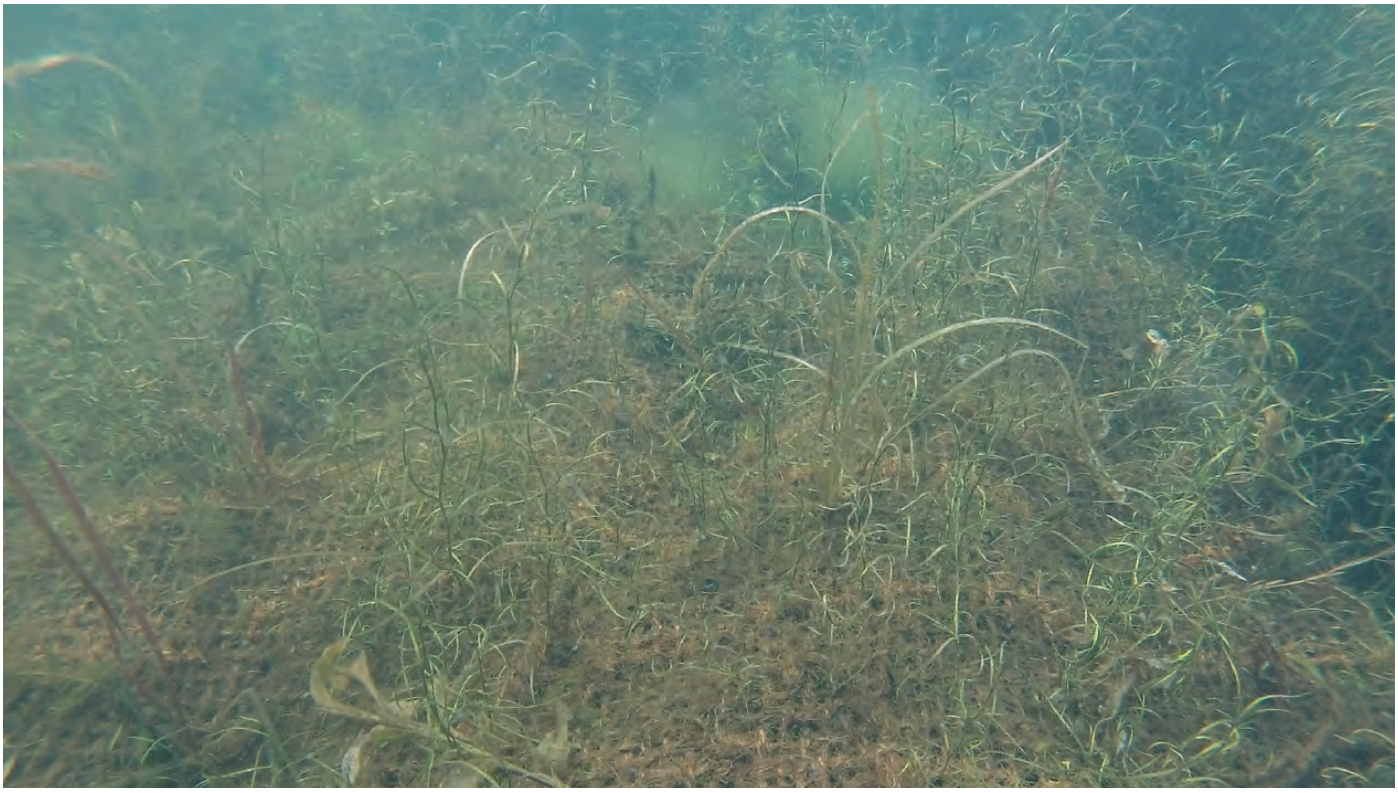
Disposal

Eurasian water-milfoil should be disposed of on dry land, above the high-water mark, to prevent material from re-entering the water. Depending on the amount of plant material removed, disposal methods can vary. Small amounts of biomass can be put on land to dry and then be mulched, buried, composted or left to decompose. Disposal sites should be at least 30 m from the nearest waterbody, preferably in a flat, vegetated area, preventing fragments from inadvertently entering the water through runoff or other means. Gardens or farm fields are excellent disposal sites. Alternatively, plant material can be sealed in a black plastic bag and left in direct sunlight for about one week. These can then be discarded in household garbage. For large amounts you should contact your local municipality to determine if plant material may be disposed of in the landfill.

Restoration

After Control

In some invaded systems, planting a reclaimed area with native vegetation can help prevent the re-establishment of the invasive species. Once an invasive aquatic plant is removed, Eurasian water-milfoil can return or something else can become established. This can be curtailed by planting the treated area with native plants. In one study on Cedar Lake, transplanted species were chosen that would match present species in the lake and cover a large surface area (Amanda Cooper, personal communication).



Native plant species were transplanted onto a benthic barrier to prevent creating bare zones with no vegetation and limit the change of Eurasian water-milfoil taking over. Transplanting is an example of an IPM approach. Big Cedar Lake, Ontario.

Photo courtesy of: Amanda Cooper

Preventing the Spread

Early detection is the most effective tool for controlling the spread of aquatic invasive plants such as Eurasian water-milfoil and everyone can help by following these tips:

☑ Report it.

If you think you see Eurasian water-milfoil or another invasive aquatic plant, take a picture, record the location, and contact the Invading Species Hotline at **1-800-563-7711** or report online at www.eddmaps.org/Ontario or www.iNaturalist.ca. For more information, call the Invading Species Hotline at **1-800-563-7711** or visit www.invadingspecies.com or www.ontarioinvasiveplants.ca.

☑ Watch for it.

Learn what invasive aquatic species look like and then monitor rivers, lakes, streams, and other waterbodies. Early detection of aquatic invasive plants like Eurasian water-milfoil can make it easier and less expensive to remove or control them. To learn how to identify aquatic invasives, see the Invasive Aquatic Plant Species Quick Reference Guide: https://www.ontarioinvasiveplants.ca/wp-content/uploads/2019/04/reducedQuickReferenceGuide_AquaticPlants.pdf

☑ Stop the spread.

Inspect your boat, motor, trailer, and boating equipment such as anchors and fishing gear, centerboards, rollers, and axles. Remove any visible plants parts before leaving the waterbody. **Wash or dry** your boat, tackle, downriggers, trailer, and other boating equipment to kill harmful species not visible at the boat launch.

Some aquatic species can survive more than two weeks out of water. Therefore, it is important to:

1. **Rinse** your boat and any equipment that normally gets wet with hot tap water (greater than 50°C), or
2. **Spray** your boat and trailer with a high-pressure water jet or
3. **Dry** your boat and equipment in the sun for at least 5 days before transporting to another waterbody.

☑ Use native species.

Try to use local native species in your water garden. Don't buy or transplant aquatic invasive plants like Eurasian water-milfoil, and if you have removed them, replace with native species. Encourage your local garden centre to sell non-invasive or native plants. The Grow Me Instead guides list alternatives to plant instead of invasive aquatic species.

Early detection and rapid response is key to preventing establishment.

Photo courtesy of: John F Foster.

Tracking the Spread (Outreach, Monitoring, Mapping)

Several reporting tools have been developed to assist the public and resource professionals to report invasive plant sightings, track the spread, detect it early, and respond to it quickly. These include:

1) **EDDMapS Ontario:** an online reporting tool and FREE mobile application (iPhone and Android) where users can report sightings, review distribution maps, and explore educational resources of aquatic invasive plants and other invasive species. This tool, at www.eddmaps.org/ontario, is free to use.

2) **The Invading Species Hotline:** a toll-free telephone number (1-800-563-7711) where individuals can report sightings verbally.

3) **iNaturalist:** an online reporting tool (www.iNaturalist.ca).

If you suspect you have encountered Eurasian water-milfoil or another invasive aquatic plant, please take a photograph (preferably with the plant out of water and including the leaves, stem, and flowers, if present), mark your location, and call the Invading Species Hotline at 1-800-563-7711.

Additional Resources:

Invasive Aquatic Plant Species: A Quick Reference Guide
https://www.ontarioinvasiveplants.ca/wp-content/uploads/2019/04/reducedQuickReferenceGuide_AquaticPlants.pdf

Ontario Ministry of Natural Resources and Forestry. 2010. Field Guide to Aquatic Invasive Species: 3rd Edition. Ontario, Canada: Queen's Printer for Ontario
http://www.invadingspecies.com/download/field-guide-to-aquatic-invasive-species-3rd-edition/

Ontario Ministry of Natural Resources and Forestry. 2017. Remove invasive aquatic plants. Available at: https://www.ontario.ca/page/remove-invasive-aquatic-plants

Best Management Practices Documents Series from the OIPC

Autumn Olive

Black Locust

European Black Alder

Garlic Mustard

Giant Hogweed

Common (European) Buckthorn

Dog-strangling Vine

Invasive Honeysuckles

Reed Canary Grass

Japanese Knotweed

Multiflora Rose

Phragmites (Common Reed) (EN, FR)

Phragmites (Common Reed) Best Management Practices for Ontario Roadways

Purple Loosestrife

Scots Pine

Spotted Knapweed

White Sweet Clover

Wild Parsnip

White Mulberry

European Frog-Bit

Flowering Rush

Additional Publications from the Ontario Invasive Plant Council

Invasive Terrestrial Plant Species: A Quick Reference Guide

Invasive Plant Technical Bulletin Series

A Landowner's Guide to Managing and Controlling Invasive Plants in Ontario

A Quick Reference Guide to Invasive Plant Species

Clean Equipment Protocol for Industry

Creating an Invasive Plant Management Strategy: A Framework for Ontario Municipalities

Grow Me Instead! Beautiful Non-Invasive Plants for Your Garden, a Guide for Southern Ontario (EN, FR)

Grow Me Instead! Beautiful Non-Invasive Plants for Your Garden, a Guide for Northern Ontario

The Landowners Guide to Controlling Invasive Woodland Plants

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