Aquatic Invasive Plants

Best Management Practices in Ontario

INVASIVE PLANTS OF AQUATIC AND WETLAND HABITATS

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Ontario

ONTARIO INVASIVE PLANT COUNCIL

Foreword

Aquatic Invasive Plants: Best Management Practices in Ontario (BMPs) was developed to provide a useful tool towards efforts to control and manage invasive plants of aquatic and wetland habitats. The intent of this document is to relay information specifically related to control practices that have been recommended by leading professionals across Ontario. This document contains the most effective and environmentally-safe control practices known at the date of publication. Information provided within this document was curated, based on the most recent research, experience, and literature available at this time. It complies with current provincial and federal legislation regarding aquatic invasive plant removal, control activities, 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. Interested parties are advised to refer to the applicable legislation relating to aquatic plant removal and control activities to address specific circumstances.

Check the website of the **Ontario Invasive Plant Council (OIPC)** (www.ontarioinvasiveplants.ca) and the appropriate government agencies for updates.

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For more information on invasive plants in Ontario, please visit the following websites:

www.ontario.ca/invasivespecies, www.ontarioinvasiveplants.ca, www.invadingspecies.com or www.invasivespeciescentre.ca

Front and back cover photo courtesy of Wasyl Bakowsky.

Curly-leaved pondweed forms thick mats of vegetation.

Photo courtesy of Michael Oldham,
www.inaturalist.org/observations/121440997, licensed under CC-by-NC.

Curly-Leaved Pondweed
(Potamogeton crispus)

Regulatory Status under Ontario's ISA: Not Regulated.

Introduction

Type of aquatic plant: Submerged, aquatic plant.

Other names: Member of the Potamogetonaceae (Pondweed) family and is also known as curly pondweed.

Area of origin, introduction date and location: Native to Eurasia, Africa, and Australia. It was first detected in North America in 1841 in the city of Philadelphia and then spread rapidly through Great Lakes regions such as Massachusetts and New York. It was first detected in Canada in Ashbridges Bay, Ontario in 1891.

Identification

Plant Type:

Submerged.

Size and Stem:

Flattened, red-brown, branching stems, which grow to the water's surface, forming thick mats of vegetation. Can grow up to 1 m in length, or longer in deeper water. *Winter form:* flattened, limp, narrow, blue-green leaves, few stems and thin rhizomes. *Spring or summer form:* crisp texture, wavy leaf margins, wider, dark-green and/or red-brown.

Leaves:

Submersed, alternate, oblong, narrow, 2.5 - 7.5 cm long. The leaves have distinct margins that are wavy (resemble lasagna noodles), finely and sharply toothed, rounded at the apex. Prominent mid-vein, stalkless (leaves attached directly to stem). Semi-translucent, olive-green and may turn reddish as they get closer to the water's surface. Leaves become denser at the bottom of the stem. There are no floating leaves. Vegetative buds called turions develop at branch tips and leaf axils.

Flowers:

Emergent, extending above the water in small spikes. Spikes have 3 - 5 whorls of flowers, flowers are small (3 mm wide), white or brownish, each with a 4-parted style surrounded by 4 stamens, each stamen with a green to brown, ladle-shaped, sepal-like appendage. Flowers May to September.

Fruits:

Red-brown, single seeded, 6 x 2.5 mm, with a curved beak 2 - 3 mm long. Fruit is not often formed.

Roots:

Rooted in bottom sediment. Rhizomes are pale yellow or reddish, rooting at the nodes. Many plant stems can be connected to a single rhizome.

Submersed leaves are alternate with distinct wavy margins.

Photo courtesy of Peter Zika, iNaturalist, www.inaturalist.org/observations/216129860.

Leaves are finely and sharply toothed.

Photo courtesy of iNaturalist, www.inaturalist.org/observations/156270078.

Flowers extend above the water in small spikes.

Photo courtesy of Susan Elliott, iNaturalist, www.inaturalist.org/observations/4071242.

Fruits are red-brown, single seeded, with a curved beak.

Photo courtesy of iNaturalist, www.inaturalist.org/observations/121440997.

Curly-Leaved Pondweed and its Lookalikes

	Curly-Leaved Pondweed *(Potamogeton crispus)* **INVASIVE**	**Richardson’s Pondweed** *(Potamogeton richardsonii)* **NATIVE**
	 Photo courtesy of Leslie J. Mehrhoff, University of Connecticut, Bugwood.org.	 Photo courtesy of inaturalist. www.inaturalist.org/observations/131110396.
Plant Type	• Submerged	• Submerged
Leaves	• **Leaf margins wavy, finely and sharply toothed** • **Rounded or blunt at the tip** • **Stalkless (leaves attached directly to stem)** • **Stipules are not fibrous** • Linear-oblong leaves • No floating leaves • Prominent midvein flanked by 1 or 2 pair of lateral veins	• **Leaf margins wavy, toothless** • **Pointed tip** • **Clasp the stem** • **Stipules are fibrous (whitish membranous appendage not connected to the leaf blade, shreds into persistent fibers)** • Lance to egg-shaped leaves • No floating leaves • Prominent midvein flanked by 13 - 33 lateral veins, 3 - 5 of which are more prominent than the rest
Flowers/Fruit	***Flowers:*** • Cylindrical spike held above surface of the water • Spikes have 3 to 5 whorls of flowers, each flower with a 4-parted style surrounded by 4 stamens, each stamen with a green to brown, ladle-shaped, sepal-like appendage ***Fruits:*** • **Dry seed (achene) with knobby keel along back edge, long curved beak (2 - 3 mm long)** • **Presence of turions at branch tips and in leaf axils**	***Flowers:*** • Cylindrical spike held above surface of the water • Spikes have 6 to 12 whorls of flowers, each flower with a 4-parted style surrounded by 4 stamens, each stamen with a green, ladle-shaped, sepal-like appendage ***Fruits:*** • **Dry seed (achene) without keels along back edge, long erect beak (0.4 - 0.7 mm long)** • **Turions are not present**

Biology and Life Cycle

Curly-leaved pondweed can act as a perennial or winter annual, with a unique growth cycle compared to other submersed aquatic plants. Reproduction is almost exclusively vegetative through rhizomes and buds called turions. In the fall, turions break dormancy and begin to sprout new plants. The plants continue to grow through the winter, even under thick ice and snow cover, then grow rapidly in early spring when water temperatures are still cool (10 - 15 °C). In May or early June, plants flower, fruit, form turions, and then die-back. Turions are formed in the leaf axils and branch tips, and each turion can have 2 - 7 dormant buds. Once formed, turions sink to the bottom of the waterbody and lie dormant throughout the summer. Each plant can produce hundreds of turions, which have high germination rates, and can remain viable in the sediment for two or more years.

Habitat

Curly-leaved pondweed prefers alkaline, nutrient-rich, calcareous waters. Its presence is often an indicator of eutrophic conditions, or water bodies with high levels of nitrogen, phosphorous and organic matter. It can be found in disturbed, polluted, or very turbid waters. It can grow in summer and winter conditions. As a cold-tolerant species it will grow through winter, even under ice cover. It typically grows in water that is 1 to 3 m deep but has been found at depths up to 7 m. Its preferred habitat is still water, but it is tolerant of flow. It can be found in almost every type of aquatic environment including freshwater lakes, rivers, streams, marshes, ponds, ditches, and canals, and can root in silt, clay, gravel, or sand sediment.

Distribution

In Ontario, curly-leaved pondweed is currently confined to the southern portion of the province and the Georgian Bay-Severn River area. In Canada, it is found in southwestern Quebec, British Columbia, Alberta, Saskatchewan, New Brunswick, Ontario, Quebec and is also found throughout most of the United States.

For up-to-date distribution information, visit: EDDMapS www.eddmaps.org or iNaturalist www.inaturalist.org.

Pathways of Spread

Curly-leaved pondweed can be spread by plant fragments, rhizomes, or turions that are accidentally transported on boats, trailers or other equipment (i.e., fishing or scuba gear). It is believed that curly-leaved pondweed may have been intentionally spread by humans in the early 1900s to create habitat for waterfowl and wildlife. It may have also spread accidentally as a contaminant in water used to transport fish and fish eggs to hatcheries or released into nearby waterbodies when aquarium contents are discarded into waterbodies. It can also spread over long distances by migratory waterfowl or expand locally in flowing water or flood events.

Impacts

Curly-leaved pondweed is a very effective canopy-forming plant. Its ability to grow through winter and early spring give it a competitive advantage, allowing it to form dense monocultures, outcompete native submersed vegetation and reduce biodiversity. These dense monocultures impede water flow, as well as recreational activities such as angling, boating and swimming, and reduce the aesthetic value of waterfront property and tourism. In mid-summer, thick mats of curly-leaved pondweed begin to die back. This decaying vegetation can affect oxygen levels in the water, negatively impacting fish and other aquatic species. A large amount of phosphorous is also released during decomposition, contributing to algal blooms.

Control Measures

Control for curly-leaved pondweed should take place in spring or early summer, before the flowering stalks appear above the water surface and/or before new turions are produced. Consider its unique life cycle, as the first pondweed to emerge in spring then die back in mid-summer. Before they die, plants form turions which lie dormant during the summer when native plants are growing. The target of control is to reduce the turion bank; removing plants after turions are produced is not effective at reducing curly-leaved pondweed. Turions can lie dormant for a few growing seasons, therefore control efforts should take place for a number of consecutive years.

See the section Applicable Legislation and Permitting Requirements (**page 8**) for more information on permitting requirements. Most of the control options described below will require permits or authorizations, in addition to adherence to rules prescribed under various provincial or federal legislation or regulations. Refer to section Prevent the Spread (**page 6**) for details on how to report and prevent the spread of aquatic invasive plants.

Manual Control

Manual and mechanical control includes raking, hand pulling or cutting, mechanical harvesting, and benthic barriers. Raking and hand cutting remove the plants at the sediment surface while harvesting removes the top 1.5 m of the plant.

Hand Removal:

Hand pulling individual plants or small infestations can prevent the spread of the plant. When hand pulling, focus on removing the buried turions and rhizomes, as well as the plants fragments that may break off. Fragments that are left behind may contain turions and can grow new plants. To reduce the potential of resprouting or seed spread, ensure all plant fragments are removed from the water and away from the bank. This method can be time-consuming and labor-intensive.

Raking:

Raking removes curly-leaved pondweed at the sediment surface, and when conducted early in the season, can assist in preventing turion production. However, raking can cause plant fragments to break off, which can contribute to the spread of the plant. Raking should also be combined with hand pulling to remove buried turions and rhizomes, as well as plant fragments. In a recreational area in Montana, raking a large area or pondweed over a course of three years was effective at reducing infestations.

Mechanical Control

Cutting:

Cutting curly-leaved pondweed can be effective for small areas. Cutting removes curly-leaved pondweed at the sediment surface, and when conducted during the right time of the season, can assist in preventing turion production. Combine with hand pulling to remove buried turions and rhizomes, as well as plant fragments. A three-year, whole lake cutting approach in infested Minnesota lakes found early season cutting at the sediment surface to be effective in preventing turion production.

Mechanical Harvesting:

Mechanical harvesters can be effective in clearing large areas. Early season cutting can prevent turion production. However, it is important to remember that mechanical harvesting only cuts the plant and does not remove the seedbank and is less selective. It is also important to keep in mind the amount of plant material that is going to be removed and disposed of properly.

Benthic Barriers:

Benthic barriers can be effective in localized areas, such as around a dock or a swimming area. The barriers can help to prevent turions from growing new plants. A benthic barrier made of burlap will allow for native plants to grow, but will also decompose within two years. If the barrier is maintained, it can provide long-term control.

Biological Control

There are no biological controls available for curly-leaved pondweed in Canada.

Chemical Control

Contact herbicides with the active ingredient diquat have shown to reduce root biomass and suppress turion production. Herbicide application should take place in early spring in order to reduce the impact of the herbicide on native aquatic plants. There is also another herbicide registered for use on curly-leaved pondweed containing the active ingredient acrolein.

Leaves of curly-leaved pondweed are wavy.

Photo courtesy of iNaturalist, www.inaturalist.org/observations/103472379. Licensed under CC-by-NC.

Eurasian water-milfoil forms a dense canopy at or just below, the water's surface.
Photo courtesy of Alison Fox, University of Florida, Bugwood.org.

Eurasian Water-milfoil (*Myriophyllum spicatum*) and Eurasian and Northern Milfoil Hybrid (*Myriophyllum spicatum* × *M. sibiricum*)

Eurasian water-milfoil status Ontario ISA (2015): Restricted.

Eurasian and northern milfoil hybrid status Ontario ISA (2015): Not listed.

It is illegal to import, deposit, release, breed/grow, buy, sell, lease or trade this restricted invasive species in Ontario. It is also illegal to bring a restricted species into a provincial park or conservation reserve and to possess, transport, deposit or release them in these protected areas.

Introduction

Type of aquatic plant: Submerged, aquatic plant.

Other names: Member of the Haloragaceae (Water-milfoil) family.

Area of origin, introduction date and location: Eurasian water-milfoil is native to Europe, Asia and northern Africa and was probably introduced to North America through the aquarium trade, or in ballast water from shipping in the 1940s. The first record in Canada was from Lake Erie in 1961. The Eurasian and northern milfoil hybrid (*Myriophyllum spicatum* × *M. sibiricum*) is formed when Eurasian water-milfoil (invasive) and northern water-milfoil (native) hybridize where they are present in the same waterbody.

Identification

Plant Type:

Submerged.

Size and Stem:

Submerged; 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. Stem is a leafy shoot, can be long and spaghetti-like (0.5 - 7 m long), branching at water surface. Tip of the stem usually reddish and thin, getting thicker below the flowers.

Leaves:

Whorled, green, feather-like. Whorls (circles) are centered around nodes along the stem, with 3 - 6 (typically 4) leaves per node. Each leaf has 12 - 24 filiform or threadlike divisions.

Flowers:

Emergent, grow on terminal spikes above the water. Arranged in whorls (circles) around spike, pink-red hue, 5 - 20 cm long. Flowers from late July to early August; upper flowers are male, the lower flowers are female.

Fruits:

Red, berry-like.

Roots:

Can be rooted or unrooted to sediment. No overwintering structures (turions). Small buds may be present and develop from a single root, initially at the base.

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

Photo courtesy of John-Pierre Thonney.

Leaves are feather-like with 12 - 24 filiform or threadlike divisions.

Photo courtesy of Aaron Gunner, iNaturalist, www.inaturalist.org/observations/15997885.

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

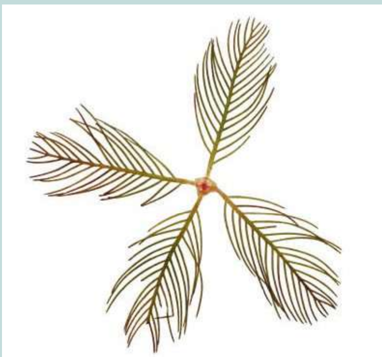
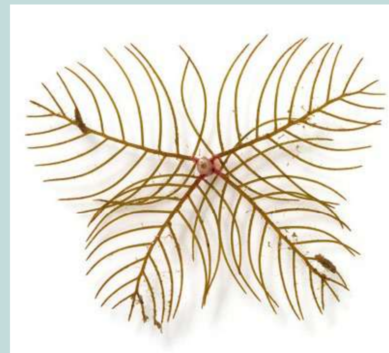
Photo courtesy of iNaturalist, www.inaturalist.org/observations/239342579.

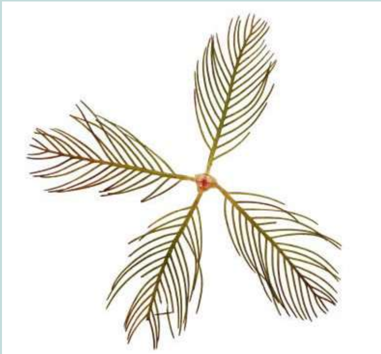
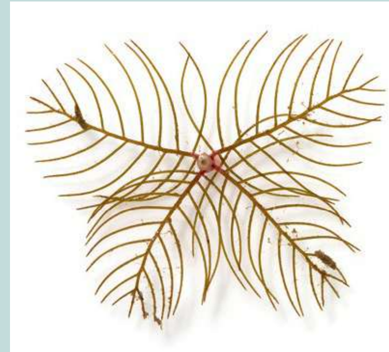
Flowers have a pink-red hue.

Photo courtesy of Holly Young, iNaturalist, www.inaturalist.org/observations/182031654.

Eurasian Water-milfoil and its Lookalikes

Differentiating between Eurasian water-milfoil can be very difficult, as there is considerable overlap in traits, including the number of pairs of leaflets on each leaf. The most reliable method of identifying any milfoil species is through molecular testing using the plant's DNA.

	Eurasian Water-Milfoil *(Myriophyllum spicatum)* INVASIVE  Photo courtesy of Fero Bednar (www.wnp.sk), iNaturalist, www.inaturalist.org/observations/133132060.	**Hybrid Water-Milfoil** *(Myriophyllum spicatum × M. sibiricum)* INVASIVE	**Northern Water-Milfoil** *(Myriophyllum sibiricum)* NATIVE  Photo courtesy of Fero Bednar (www.wnp.sk), iNaturalist, www.inaturalist.org/observations/133132060.
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 (usually 4), feather-like, pinnately divided, with **greater than 12 threadlike divisions per leaf (usually 12 - 20)** • Leaves are limp when out of water	• Arranged in whorls of 3 - 6 (usually 4), feather-like, pinnately divided, with **less than 11 threadlike divisions per leaf (usually 5 - 11)** • Leaves are usually rigid out of water	• Arranged in whorls of 4 - 6, feather-like, pinnately divided, **with varying number of threadlike divisions per leaf**

	Eurasian Water-Milfoil *(Myriophyllum spicatum)* INVASIVE	**Hybrid Water-Milfoil** *(Myriophyllum spicatum × M. sibiricum)* INVASIVE	**Northern Water-Milfoil** *(Myriophyllum sibiricum)* NATIVE
	 Photo courtesy of Fero Bednar (www.wnp.sk), iNaturalist, www.inaturalist.org/observations/133132060.		 Photo courtesy of Fero Bednar (www.wnp.sk), iNaturalist, www.inaturalist.org/observations/133132060.
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 • Arranged in whorls; flowers small; bracts equal to or slightly longer than female flowers and have serrated margins • Flowers between late July and early August	• Flowers and fruit can look like a combination of both parent plants, 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 (turions)

Biology and Life Cycle

Eurasian water-milfoil can spread sexually by seed as well as vegetatively through stem fragmentation and stolon growth. In the Great Lakes region, Eurasian water-milfoil begins to break dormancy in early spring before other native macrophytes and initiates growth as water temperatures approach 15 °C.

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.

Habitat

Eurasian water-milfoil is most commonly found in slow or stagnant waters, such as ponds, marshes, lakes with little disturbance, or along sheltered portions of streams (i.e., coves, inlets). It is able to rapidly colonize areas that have experienced some form of disturbance; disturbance can result in fragmentation and spread.

It is most common in depths of 1 - 3 m but can grow up to depths of 10 m. In shallow water (less than 1 m), growth is restricted, likely due to greater fluctuations in water levels and temperature. 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.

It has been described as a "well-adapted plant" which can grow in a variety of environmental conditions, including nutrient rich (*eutrophic*) and low nutrient (*oligotrophic*) waters. It has a wide pH tolerance (pH 5.4 - 11), although growth is most optimal in alkaline waters. It can also grow over a broad temperature range (15 - 35 °C).

Pathways of Spread

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, as well as autofragmentation. Once established, it can spread to connected waterbodies and through canals such as the Trent-Severn Waterway. This is why it is critical to follow the rules and best management practices for cleaning watercraft and watercraft equipment when boating in waterbodies where Eurasian water-milfoil is present.

Whorls of leaves occur at nodes along stem, 1 to 3 cm apart.

Photo courtesy of Graves Lovell, Alabama Department of Conservation and Natural Resources, Bugwood.org.

Distribution

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, the St. Lawrence River System, 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.

The hybrid water-milfoil is not widely tracked and is difficult to differentiate from the parent plants. However, it is known to be present in Ontario in the Great Lakes and the Kawartha Lakes and in British Columbia. It has also been found in almost every United States state that has Eurasian water-milfoil, including Wisconsin, Minnesota, Oregon, Washington, Idaho, Michigan and Vermont.

For up-to-date distribution information, visit: EDDMapS www.eddmaps.org or iNaturalist www.inaturalist.org.

Impacts

Eurasian water-milfoil forms a dense canopy at the surface of the water or just below, which impedes recreational activities such as angling, boating and swimming. It can also affect water flow and contribute to flooding. Excessive growth suppresses native plant and animal diversity. Eurasian water-milfoil forms dense floating mats of vegetation that can outcompete native aquatic plants and can alter a lake's natural ecosystem. Dense mats block available light and impact water clarity, and its extensive root system reduces space and access to nutrients in the sediment for other plant species. A decline in native plant species richness and abundance leads to reduced macroinvertebrate abundance, altered habitat structure, and negatively impacts fish populations. 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. In addition, reduced oxygen levels caused by the decomposition of plant matter can kill fish and contribute to algal blooms.

Dense stands of Eurasian water-milfoil can also 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 watermilfoil can significantly reduce lakefront property values. Excessive growth can also clog industrial and power generation water intakes and restrict the operation of flow metering devices in flood control channels.

Hybrid milfoil expresses a trait called hybrid vigor, which is the expression of superior qualities of both parents. It has faster growth rates than its parent plant and can out-compete them and other native plants for space and sunlight and is regarded as an invasive plant.

Control Measures

Control of Eurasian or hybrid water-milfoil is most effective when an integrated pest management approach is applied, that combines education and prevention strategies with multiple control methods.

Management approaches can help reduce milfoil biomass in the short term (weeks to a few years) but will not completely eradicate populations.

Due to its ability to fragment and re-root, physical removal methods can facilitate spread if containment measures are not undertaken.

Floating booms can help prevent spread by suspending curtains in the water to capture plant fragments where water flow is minimal. Note that any left-over plant material will regrow regardless of control type, therefore extra care should be taken to remove all plant pieces.

Control ideally should begin by mid- to late June, when the native seed bank has had a chance to establish and effectively compete with Eurasian water-milfoil. Control can also be timed during carbohydrate storage low points (May-July), which can help maximize treatment efficacy by limiting growth post-treatment, particularly for chemical and manual control.

Be aware of the impacts control methods might have on macroinvertebrates and fish species that may be using milfoil and other plants as shelter. 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.

Since hybrid water-milfoil may re-grow more quickly after control is conducted, control may need to be conducted more frequently during the growing season.

See the section Applicable Legislation and Permitting Requirements (**page 8**) for more information on permitting requirements. Most of the control options described below will require permits or authorizations, in addition to adherence to rules prescribed under various provincial or federal legislation or regulations. Refer to section Prevent the Spread (**page 6**) for details on how to report and prevent the spread of aquatic invasive plants.

Manual Control

Hand Pulling

Hand pulling individual plants, small population or isolated water bodies can prevent spread. When hand pulling, focus on removing all fragments that may break off during removal. Fragments that are left behind can root in the sediment and grow new plants. Continue to regularly monitor the site for several years for new plants growing from roots or plant fragments. 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 plant fragments, collect pulled plants and watch for hazards. Continue to monitor and remove plant material throughout the summer. Best after fish spawning (July 1st) and before fall when milfoil becomes more brittle.

Raking:

Raking can be effective in maintaining open water around docks or swimming areas, but is not effective for large areas. Raking can help remove plant material, but it will not eliminate the plant, and in most cases will spread the plant via fragments. In deeper water, raking may be combined with hand pulling to try and remove all floating plant fragments. Plants can also be pulled using a rake by guiding the rake along the plant and spinning the rake so the stems are wrapped around the rake before pulling it up from the water.

Mechanical Control

Mechanical Harvesting:

Mechanical harvesting is only recommended for large areas where Eurasian water-milfoil has become widespread and needs to be cleared for navigation purposes or safety concerns. It is only recommended when other control measures 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. Cut material is either transported directly to a conveyer belt and stored on the harvester for later disposal or floats on the surface and is raked up by a trailing machine. As a non-selective control measure, harvesting will indirectly harvest other plant, fish, and macroinvertebrate species. It can also fragment rhizome pieces, contributing to further spread.

Dredging or Suction Harvesting:

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. This method is best for small areas within larger waterbodies. Harvesting is disruptive as it is non-selective, can impact water quality, promote algal blooms, and cause milfoil to return at faster rate due to nutrient release during dredging and aeration of the bottom.

Cultural Control

Benthic Barriers:

Benthic barriers, benthic mats or bottom screens can control growth in localized areas, such as around boat launches, docks and/or swimming areas, as part of an IPM strategy. When left in the water, mats will accumulate sediments, allowing new plants to root on top of them which essentially buries the milfoil and it decomposes. However, this method is considered low efficacy as it is expensive, difficult to install, laborious, non-selective, and requires routine monitoring and maintenance throughout the growing season. Consider transplanting species onto 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 the Rideau Canal. For projects on Provincial Crown Land and shore lands, placement of these materials requires a work permit from MNR under the *Public Lands Act*; they do not fall under the provincial rules for removing invasive or native aquatic vegetation in Ontario.

Water-level control:

Drawing down the water level can only be conducted in areas where the water levels are controllable. It is not a possibility for public waters but could be used in small landlocked ponds. For this control measure to be effective, water levels must be lowered in the winter to expose the root crowns to freezing temperatures. If exposure is not long enough, the control measure will not be effective.

Biological Control

The North American weevil (*Euhrychiopsis lecontei*) has been used as a biological control for Eurasian water-milfoil and hybrid water-milfoil. 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 plant to lose buoyancy and sink. However, for this method to be successful weevil densities must be high enough to significantly impact milfoil density, requiring continual restocking of beetles to ensure adequate numbers. Unfortunately, past attempts at weevil release in parts of Ontario such as Big Cedar Lake and lakes in the Sudbury area resulted in initial declines in milfoil, but densities of beetles were not high enough to cause significant damage, even with augmentation.

Chemical Control

Diquat is a broad-spectrum contact herbicide available in Canada as a restricted herbicide. It is applied to submerged aquatic vegetation via the water column and can be greatly affected by various water exchange processes that may dilute concentrations. It is effective and fast-acting, requiring only a short exposure time, however as a non-selective herbicide diquat can harm many non-target species. It has lethal effects on invertebrate species using aquatic plants for cover. In addition, plant dieback can lead to problems with dissolved oxygen and eutrophication. Areas that have been treated cannot be used for human recreation or consumption for at least five days.

A newly registered herbicide called ProcellaCOR (PCPA Registration No. 34732) has been piloted in a few Ontario lakes to control milfoil. This herbicide more selectively targets Eurasian water-milfoil and may be a viable alternative to diquat in the future.

See the Ontario Invasive Plant Council's Best Management Practices Guide on Eurasian Water-milfoil **for more information this invasive plant and control methods.**

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

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

Disposal of Aquatic Invasive Plants

Proper removal and disposal of invasive plants and plant parts is absolutely critical to preventing further spread or introductions, and is a requirement not only under the rules for the removal of invasive aquatic plants under the *Public Lands Act* (PLA), but also according to the Prevention and Response plans for the ISA prohibited species European Water Chestnut and Water Soldier. In addition, reasonable precautions to prevent the spread of restricted ISA species during the course of control activities is required in order to be exempt from depositing those species in Ontario.

Aquatic invasive vegetation must be disposed of on dry land, above the high-water mark, at a distance of at least 30 m from any body of water and in a manner that ensures no part of the plant will re-enter the body of water or enter into any other body of water.

In addition, if removed material is being transported to a disposal site it should be ensured that all plants and plant parts be secured in leaf bags and transported in a covered trailer, in closed containers, tarped bins or by another method that ensures the plants do not fall out of a vehicle during transport.

Depending on the amount of plant material removed, disposal methods can vary.

Exercise caution when composting. Most aquatic plants can be safely composted if in an area away from any body of water. If you must compost these types of plants, avoid doing so in backyard composters unless you solarize it first in black plastic bags and then compost the solarized material. Closely examine the plant before composting and avoid composting seeds.

If your municipality has a high-heat compost program, plants can be sent there. Ontario composting facilities are required to routinely monitor the compost process and meet strict, provincially regulated time-temperature parameters for pathogen kill. Consult your local municipality to determine if this is an appropriate course of action.

Do not dump. Many aquatic invasive plants are introduced to new areas through the dumping of aquarium contents or water garden plants into local waterbodies. It is illegal to introduce any aquatic plants or animals into a body of water where it is not native.

Depending on the amount of plant material removed, disposal methods can vary.

Photo courtesy of Diana Shermet, Central Lake Ontario Conservation Authority (CLOCA).

- **Small amounts:** Seal plant material in black plastic bags and leave in direct sunlight for one or more weeks (solarization) to allow the plants to dry out completely. These bags can be discarded in household garbage. Small amounts can also 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.

- **Large amounts:** Contact your local municipality to determine if plant material can be disposed of in the landfill. Large amounts can also be burned where local bylaws permit this.

Tracking the Spread

While some invasive species are tracked carefully, there are many that are not been documented extensively throughout Ontario. There are gaps in our understanding of these species, their provincial distribution, and the scale of their invasion in many locations. Several reporting tools have been developed to assist the public and resource professionals in recording sightings and tracking the spread.

These include:

1. **EDDMapS:** An online reporting tool and **FREE** mobile application (iOS and Android) where users can report sightings, review distribution maps, and explore educational resources of invasive species. This tool, at www.eddmaps.org, is free to use.
2. **The Invading Species Hotline:** A toll-free telephone number **(1-800-563-7711)** administered by the Ontario Federation of Anglers and Hunters through the Invading Species Awareness Program where individuals can report sightings verbally. If you suspect you have encountered an aquatic invasive species, please take a photograph (preferably with the plant out of the water and including the leaves, stem, and flowers, if present), mark your location, and call the **Invading Species Hotline.**
3. **iNaturalist:** An online reporting tool (www.inaturalist.org) where you can report sightings of invasive species in Ontario by searching for the 'Invasive Species in Ontario' project.

HOBART AND WILLIAM SMITH COLLEGES

Starry Stonewort COLLABORATIVE

FINGER LAKES INSTITUTE

Starry Stonewort Management Guide

Control, Monitoring, and Resource Guide

Starry Stonewort Collaborative | Finger Lakes Institute at Hobart and William Smith Colleges,
300 Pulteney Street, Geneva, NY 14456

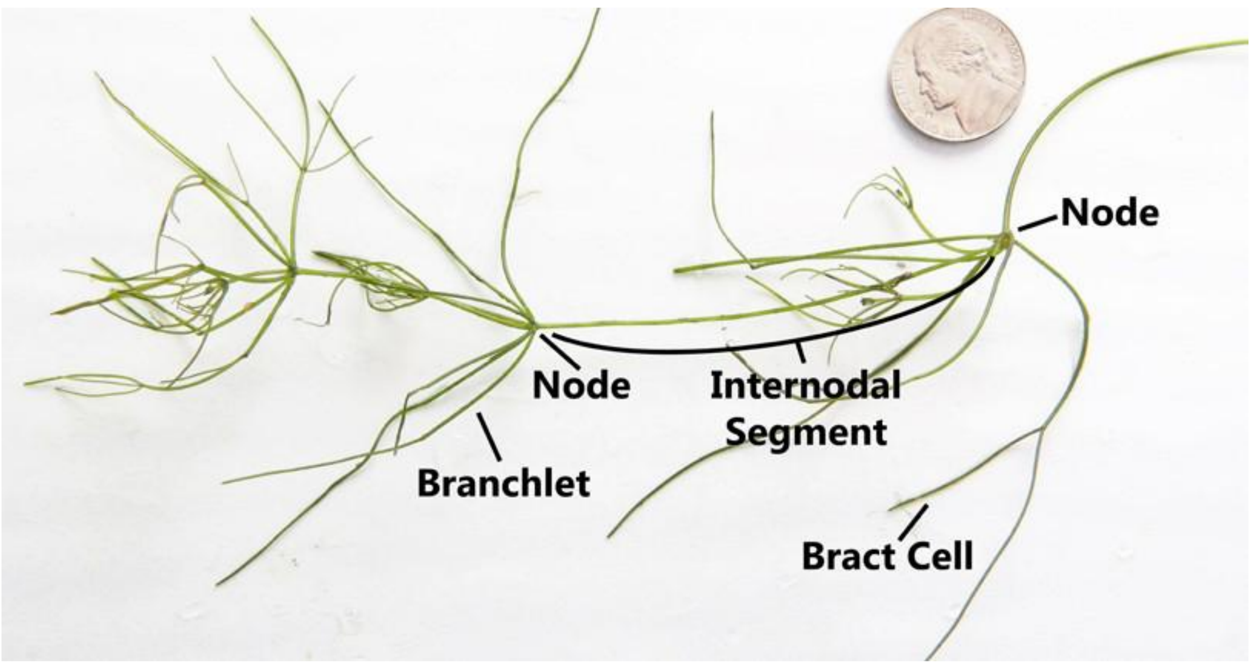
www.starrystonewort.org

INTRODUCTION

Starry stonewort *(Nitellopsis obtusa*) is an invasive species originating in Eurasia, where in some locations it is considered an endangered species. Its exact means and date of entry into North America are unknown, but the oldest records on the continent are from 1974 in the Saint Lawrence River, near Quebec. This first report was likely delivered via the ballast water of large tanker ships (Karol and Sleith 2017). Since then it has spread throughout the Great Lakes basin and beyond, reported as far west as Minnesota and as far East as Vermont (see distribution below for more information). It invades lakes, ponds, and slow-moving water bodies where it attaches to the sediment using rhizomes.

BIOLOGY

Starry stonewort (SSW) is a macroalga from the family Characeae that closely resembles a vascular plant. However, like all macroalgae, it lacks true leaves, roots, or a stem. Instead, it is comprised of a chain of nodes and internodal segments. Whorls of 5-7 branchlets extend from each node, with bract cells growing off branchlets, giving them a forked appearance. Color can vary from a bright green to greenish-brown.



SSW has both male and female individuals. As such, they produce unique reproductive organs, dependent on the individual's sex, at branchlet nodes. For males, this means orange antheridia, while for females it means bright red to light green oogonia. However, only sterile specimens or males have been found in North America thus far (Sleith et al. 2015). Here, SSW reproduces asexually from fragments of the macrophyte or bulbils produced beneath the sediment. Since fragments and bulbils can be small, this allows SSW to spread and reproduce easily.

To anchor themselves to the sediment, SSW uses clear, root-like rhizoids. From the nodesof these rhizoids, white, star-shaped bulbils are produced. It is from these bulbils that the name “starry” stonewort is derived. The star-shaped bulbils are also a distinguishing trait in most cases, asnative macroalgae rarely have them. Additionally, SSW lacks the musky smell of similar looking macroalgae from the family Characeae, also known as muskgrasses.

POTENTIAL IMPACTS

Biological:

Research indicates that SSW may negatively impact the native plants in the invaded range (Brainard and Schulz 2017). Outcompeting them for nutrients, light and space, SSW can kill and replace natives thus reducing biodiversity. Additionally, anecdotal reports suggest animals can be negatively impacted by the invading plant (Pullman and Crawford 2010). Due to the loss of familiar native plants and the excessive density of SSW, many fish species are unable to find refuge or places to spawn.

Economic:

The macroalga has a negative effect on recreational activities. In addition to forming dense mats that cover the bottom of waterbodies, SSW fills the water column vertically. This makes swimming difficult and unpleasant. Boats are also impeded, with thick infestations fouling boat propellers and causing significant drag on the hulls. Additionally, the eviction of native fish species reduces the viable area for fishing while hooks, lures, and other fishing equipment are easily caught in the vegetation.

CONTROL METHODS

PREVENTION

The best management strategy for controlling any invasive species, SSW included, is to prevent them from establishing in the first place. As an invasive species establishes, spreads, and expands its population, it becomes increasingly difficult to eradicate, in terms of both cost and time, a concept known as the "invasion curve". Because there are more individuals, spread out over a larger area, more resources are needed to sufficiently address them all. As prevention precludes this problem, it is the cheapest and most efficient method of invasive species management. Additionally, studies have indicated that SSW's spread is well correlated to human activity. As such, stopping human-facilitated spread may largely contain the macroalga.

Preventative measures can range from efforts to increase public knowledge and awareness of invasive species to more hands-on programs. Examples include: outreach events to inform people on how to identify invasive species and stop their vehicles from becoming vectors of spread; watercraft stewards at boat launches to inspect watercraft and to communicate to the public information concerning the identification, spread, and negative consequences of invasive species; placing signs on billboards and at boat launches to increase public awareness; and providing equipment at boat launches to allow boaters to wash down their boats and dispose of any invasive species.

Early Detection

Early detection efforts can be used to supplement preventative measures. Regular survey programs can detect invasive species that evade prevention efforts while they are still at removable or manageable population levels. Similar to preventative measures, early detection is relatively inexpensive because it ensures that invaders can be dealt with before management becomes much more expensive. Survey programs can include but are not limited to visual surveys, rake tosses, and point intercept surveys.

If SSW is detected, it is imperative that the observer report the location. GPS coordinates and photos clearly indicating the species and identifying features should be submitted to iMapInvasives.org, EDDmapS, or other similar apps for identification confirmation. Most of these applications can be accessed and used with a free user account. SSW populations grow quickly, so it is important to locate them in their early stages, so they are easier to control and require fewer resources for management.

HAND-PULLING

Hand-pulling is a management strategy that involves directly harvesting SSW by hand. Ideally, participants reach a few inches into the sediment and pull the plants up from the sediment, keeping the plant intact and pulling up its bulbils with it. This should be done very carefully to minimize the amount of plant fragments in the water column, as these fragments can easily become established in other areas thus further spreading the species. This method can be done by wading into the water, snorkeling, scuba diving, or from boats/kayaks, depending on the depth and location of the plants. If all parts of the macroalga are removed, along with their bulbils, this will leave them without a way to reproduce and eliminate the infestation. However, it may take several seasons of hand-pulling for complete success. This, along with diver assisted suction harvesting (DASH) are the only methods that can theoretically eradicate SSW (research is ongoing). Other management strategies will leave the bulbils untouched in the sediment, allowing the macroalga to return the next year. Notably however, while reports such as Jurek and Jacobs (2021) suggest hand-pulling to be effective at reducing biomass, they also indicated that it does not eliminate the infestations. In practice, it is too difficult to remove all bulbils and plant fragments.

DIVER ASSISTED SUCTION HARVESTING

As an alternative to hand-pulling, Diver Assisted Suction Harvesting (DASH) can be used. It utilizes a combination of SCUBA or surface-supplied (SNUBA) divers and boat-housed equipment to physically remove whole plants. The divers pull the plants out by hand and feed them into a suction line, which will transport them onto the boat. There, they are collected and the water is allowed to drain back into the waterbody. Like regular hand-pulling, this can be a theoretically effective method for removing infestations due to its ability to remove whole plants, including segments of the plants beneath the sediment. However in practice it is still only successful in reducing biomass because of the difficulty of removing all the bulbils and plant fragments (Jurek and Jacobs 2021). Additionally, the specialty equipment and training needed to perform this management strategy means that it also has an increased cost compared to hand-pulling.

CHEMICAL CONTROL

Chemical treatment involves the application of chemicals designed to kill specific macrophytes where they stand. Copper-based algaecides are commonly used, although any chemicals should be registered with the state and not in conflict with other regulations. The advantages of this method are that it is less labor intensive than physical control and is convenient when infestations are located a distance away from waterway access, which would otherwise make the process of physically removing the plant material difficult. However there may be unintended impacts to non-target species, as these chemicals are not species-specific. Jurek and Jacobs (2021) indicates that native species, especially native macroalgae, are also killed off in the process. The resulting die-off can also cause low dissolved oxygen concentrations by encouraging flurries of decomposer activity. This, in turn, can harm other species in the water and promote algal blooms due to releases of phosphorus that would normally be locked in the sediment. It should also be noted that this method will not eliminate SSW. While it can reduce biomass, and therefore be used to manage the species, it leaves the bulbils in the sediment unharmed, allowing SSW to return afterwards. If native species are killed off in the process, this treatment may exacerbate the problem by clearing SSW competitors, allowing it to become even more dominant.

MECHANICAL CONTROL

Mechanical control of SSW involves the use of an aquatic vegetation harvester, which cuts the plants at a set water depth and removes the cut plants utilizing a conveyor system. The plant cuttings are then taken to shore and dumped, where they can be properly disposed. This method is capable of handling large and dense infestations with relative speed and offers immediate results for boating and other uses of the waterbody.

Studies show mechanical control also works well when followed up with chemical treatments, reducing biomass and bulbil viability (Glisson et al. 2018). However, this method will not eliminate the infestation, as it leaves the bulbils in the sediment intact, allowing SSW to repopulate following the treatment. Even if followed by algaecide treatment, most bulbils will remain viable. Also, it requires appropriate areas to launch and retrieve the harvesters, as well as calm waters deep enough to support a loaded harvester. Fragmentation of the plants may also occur, potentially furthering the spread of the infestation within the waterbody. Additionally, since the harvester is not species-specific, any native species in the area will also be cut down.