Eurasian Watermilfoil (*Myriophyllum spicatum*)
Ecological Risk Screening Summary

U.S. Fish and Wildlife Service, June 2015
Revised, April 2018
Web Version, 5/15/2018

Photo: John Hilty. Licensed under Creative Commons BY-NC. Available: http://www.illinoiswildflowers.info/wetland/plants/eur_milfoil.html. (April 18, 2018).

1 Native Range and Status in the United States

Native Range

From Pfingsten et al. (2018a):

"Europe, Asia, and northern Africa (Patten 1954)."

From CABI (2018):

"It is recorded from at least 57 countries, probably native to all those Palearctic countries in which it occurs, less certainly an exotic in southern Afrotropical countries; […]"

CABI (2018) lists *Myriophyllum spicatum* as present in Bangladesh, Bhutan, Cambodia, China, India, Indonesia, Iran, Israel, Japan, Jordan, DPR Korea, Republic of Korea, Pakistan, Philippines, Taiwan, Thailand, Turkey, Vietnam, Algeria, Egypt, Kenya, Togo, Austria, Belgium, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Iceland, Ireland, Italy, Liechtenstein, Lithuania, Luxembourg, Netherlands, Portugal, Russian Federation, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, UK, and Australia.

Status in the United States

Pfingsten et al. (2018a) list the following states as having nonindigenous occurrences of *Myriophyllum spicatum*: Alabama, Arizona, Arkansas, California, Colorado, Connecticut, Delaware, District of Columbia, Florida, Georgia, Idaho, Illinois, Indiana, Iowa, Kansas, Kentucky, Louisiana, Maine, Maryland, Massachusetts, Michigan, Minnesota, Mississippi, Missouri, Montana, Nebraska, Nevada, New Hampshire, New Jersey, New Mexico, New York, North Carolina, North Dakota, Ohio, Oklahoma, Oregon, Pennsylvania, Rhode Island, South Carolina, South Dakota, Tennessee, Texas, Utah, Vermont, Virginia, Washington, West Virginia, and Wisconsin.

In addition to the states listed by Pfingsten et al. (2018a), GISD (2018) lists *Myriophyllum spicatum* as alien, invasive, and established in Alaska.

From Pfingsten et al. (2018a):

"One of the most widely distributed of all nonindigenous aquatic plants; established in 48 U.S. states (absent in Hawaii and Wyoming), […]"

From Pfingsten et al. (2018b):

"*Myriophyllum spicatum* is a prohibited species in Illinois and Michigan; its hybrids and variants are also prohibited in Minnesota and Wisconsin (GLPANS 2008). In Michigan, a person cannot knowingly possess a live organism (Latimore et al. 2011). In Minnesota, it is illegal to possess, import, purchase, sell, propagate, transport or introduce Eurasian watermilfoil ([Falck et al. 2012])."

According to USDA, NRCS (2018), *Myriophyllum spicatum* is listed as a Class C noxious weed in Alabama; a B list (noxious weeds) in Colorado; as invasive and banned in Connecticut; a Class 1 prohibited aquatic plant in Florida; a noxious weed in Idaho, Nevada, and Texas; an invasive aquatic plant in Maine and South Carolina; a prohibited species in Massachusetts; a Category 3 noxious weed in Montana; a Class A noxious weed in New Mexico; a Class B noxious weed in North Carolina, Vermont, and Washington; a "B" designated weed in Oregon; a quarantine species in Oregon and Washington; a plant pest in South Carolina; and a regulated non-native plant species in South Dakota.

Means of Introductions in the United States

From Aiken et al. (1979):

"In the late nineteenth century, Eurasian watermilfoil was introduced into North America in the Chesapeake Bay area, possibly in shipping ballast. The early spread of this species and a list of annotated herbarium specimens have been recorded by Reed (1977). Eurasian watermilfoil was not considered a weed species until the late 1930's (Springer and Stewart 1959) but it gradually increased in the Chesapeake Bay area to a peak, in 1963, of approximately 80,000 ha (Steenis and King 1964). It was introduced in the Tennessee Valley Authority system in 1953 by a resort owner and reached a peak infestation of 10,000 ha in 1968-1969 (Bates, personal communication)."

From Pfingsten et al. (2018a):

"*Myriophyllum spicatum* was probably intentionally introduced to the United States (Couch and Nelson 1985). Long distance dispersal has been linked to the aquarium and aquatic nursery trade (Reed 1977). Spread occurred as the species was planted into lakes and streams across the country, distributed as far as Mountian [sic] Lake in San Francisco Bay by 1888 (CalFlora 2012)."

"Transport on boating equipment plays the largest role in introducing fragments to new waterbodies. Road checks in Minnesota have found aquatic vegetation on 23% of all trailered watercraft inspected (Bratager [et al.] 1996)."

Remarks

From Aiken et al. (1979):

"Patten (1954) claimed that in New Jersey *M. exalbescens* and *M. spicatum* intergrade, but this was challenged by Löve (1961) because no cytological studies were made and the pollen and seed fertility were not observed. So far, no intergrading or "hybrid" chromatograms have been found in the chromatographic identification research being done on these two species in British Columbia (O. Ceska and P. Warrington, personal communication). Fruit set in an artificial cross between *M. exalbescens* and *M. spicatum* was obtained in 1977 (Fig. 13 [in source material]), and more than 30% of the seeds have germinated."

From Pfingsten et al. (2018a):

"High phenotypic plasticity within the genus *Myriophyllum*, especially among *M. sibiricum* and *M. spicatum*, has been documented under various habitat conditions (Gerber and Less 1994), making identification difficult without flowers or turions."

"Hybridization was documented between *M. spicatum* and *M. sibiricum* [*Myriophyllum spicatum* X *sibiricum*] in Idaho, Michigan, Minnesota, Wisconsin, and Washington (Moody and Les 2002; Moody and Les 2007). The hybrid must be determined by molecular analysis, as morphology is indistinguishable from both parent species."

2 Biology and Ecology

Taxonomic Hierarchy and Taxonomic Standing

From ITIS (2018):

"Taxonomic Status:
Current Standing: accepted"

"Kingdom Plantae
  Subkingdom Viridiplantae
    Infrakingdom Streptophyta
      Superdivision Embryophyta
        Division Tracheophyta
          Subdivision Spermatophytina
            Class Magnoliopsida
              Superorder Saxifraganae
                Order Saxifragales
                  Family Haloragaceae
                    Genus *Myriophyllum*
                      Species *Myriophyllum spicatum* L."

Size, Weight, and Age Range

From Pfingsten et al. (2018a):

"Size: 1-3 meters in length (Aiken et al. 1979)"

Environment

From Pfingsten et al. (2018a):

"*Myriophyllum spicatum* can be found in depths of 1-3.5 m […]. It can grow in a variety of conditions; fresh or brackish water, a wide [water] temperature and a soil pH of 5.4-11 (Benson et al. 2004, IL DNR 2009, Lui et al. 2010)."

From Aiken et al. (1979):

"Eurasian watermilfoil flourishes in eutrophic lakes and in situations where waterways are enriched with nutrients. It has been found in Georgian Bay, Ontario, where phosphorus is relatively low (total P = 3 μg/ *l*) (Wile, personal observation), and in oligotrophic-lakes in British Columbia (Nijman 1976). It will also grow in sand, acidic peat (*p*H = 5.4) (Giesey, personal communication) and in highly alkaline water (*p*H = 9–10). It thrives in water with a salinity of up to l0 parts per thousand, but grows more slowly at a salinity of 15 parts per thousand (Beaven 1960). In Maryland it readily withstands 1-m tides (Steenis and Stotts 1961)."

From CABI (2018):

"*M. spicatum* is a cosmopolitan submerged plant of cool–warm temperate freshwaters; […]"

"There is evidence that *M. spicatum* populations can tolerate quite high heavy metal loadings: a study of polluted waters (receiving sewages and solid wastes from a copper smelter and a copper ore processing plant) in Poland for example revealed plants survived tissue concentrations (mg/kg) up to 1040 Cu, 6660 Mn, and 57 Co (Samecka-Cymerman and Kempers, 2004)."

Climate/Range

From CABI (2018):

"*M. spicatum* is a species of Palaeoarctic (probably European) origin (Faegri, 1982), […]"

Distribution Outside the United States

Native

From Pfingsten et al. (2018a):

"Europe, Asia, and northern Africa (Patten 1954)."

From CABI (2018):

"It is recorded from at least 57 countries, probably native to all those Palearctic countries in which it occurs, less certainly an exotic in southern Afrotropical countries; […]"

CABI (2018) lists *Myriophyllum spicatum* as present in Bangladesh, Bhutan, Cambodia, China, India, Indonesia, Iran, Israel, Japan, Jordan, DPR Korea, Republic of Korea, Pakistan, Philippines, Taiwan, Thailand, Turkey, Vietnam, Algeria, Egypt, Kenya, Togo, Austria, Belgium, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Iceland, Ireland, Italy, Liechtenstein, Lithuania, Luxembourg, Netherlands, Portugal, Russian Federation, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, UK, and Australia.

Introduced

GISD (2018) lists *Myriophyllum spicatum* as alien, invasive, and established in Canada and Swaziland.

From Aiken et al. (1979):

"The first record of *M. spicatum* in Canada is probably a herbarium specimen collected in 196l from Rondeau Provincial Park, Lake Erie: DAO 156348. Eurasian watermilfoil was collected from several sites along the St. Lawrence Seaway during the 1960's. It was not widely recognized as a nuisance until the early 1970's when it became troublesome in the Kawartha Lakes, Ontario, Gatineau Park, Quebec, and the Man and His World site, Montreal, Quebec. It was first observed in the Vernon Arm of Okanagan Lake, British Columbia, in 1970."

CABI (2018) lists *Myriophyllum spicatum* as introduced in Botswana, Namibia, South Africa, Zambia, Zimbabwe, and Canada.

Means of Introduction Outside the United States

From CABI (2018):

"*Myriophyllum* species, like most other invasive aquatic plants, are largely spread between geographically separate regions by human dispersal (mainly by the aquatic plants trade for aquaria). Once established in a new locality their spread is via a range of mechanisms. *M. spicatum* plants are easily spread downstream in the form of vegetative fragments or seed (though the latter seems much less important than the former)."

"Plant fragments are also easily transported attached to ships or boats. In the Nile in Egypt, carriage of *M. spicatum* fragments on ships and other river traffic is the most likely mechanism for the upstream spread of the species in recent years, as far as Aswan in Upper Egypt (Springuel and Murphy, 1991; Ali and Soltan, 1996). Inter-catchment transport via boats and ships using navigable canals is a likely vector where such canal networks exist (e.g. northern USA: Mills et al., 2000). In Canada and elsewhere, quarantine measures have been introduced involving public information campaigns and boat inspections (for example at ferry landing points on Vancouver Island, British Columbia) to try to minimize transfer of plant material to uninfested river and lake systems."

"Finally, the spread of the plants via natural vectors (especially waterfowl, either via the digestive tract or attached to plumage) is always a possible means of transfer."

Short Description

From Pfingsten et al. (2018a):

"*Myriophyllum spicatum* has thin stems, which can be appear green, brown, or pinkish white. The stems grow to 1-3 meters in length and get progressively thinner the further they grow from the main stem (Aiken et al. 1979). There are typically four feather-like, deeply-dissected leaves whorled around the stems with 14 or more uniform (in diameter) leaflets on each leaf (Patten 1954)."

"The small, yellow four-parted flowers rise 5-10 cm above the surface of the water from the terminal spike (Aiken et al. 1979; Patten 1954). Male and female flowers can be found on the same inflorescence. The stem thickness below the inflorescence is almost double that of the lower stem, as well as curved to allow the lower stem to run parallel to the water surface (Aiken 1981)."

"*Myriophyllum spicatum* can easily be confused with native milfoil species that also may have four deeply-dissected leaves per whorl (e.g., *M. heterophyllum*, *M. sibiricum*, *M. verticillatum*). As a general rule, Eurasian watermilfoil typically has more than 14(12-20) leaflet pairs per leaf and reduced bracts on inflorescences, in contrast to native milfoils which have fewer than 14(5-10) leaflet pairs, as in *M. sibiricum*, and bracts at least twice as long as the flowers, as in *M. heterophyllum* and *M. verticillatum* (Aiken 1981; Gerber and Les 1994; Patten 1956). Bud (turion) production distinguishes between the exotic *M. spicatum* and the native *M. sibiricum* and *M. verticillatum*, as the native species produce winter buds, while the exotic does not (Patten 1954)."

Biology

From Pfingsten et al. (2018a):

"*Myriophyllum spicatum* can be found in depths of 1-10 m in lakes, ponds, shallow reservoirs and low energy areas of rivers and streams, and can grow in a variety of conditions; […]"

"*M. spicatum* is a perennial that flowers twice a year, typically mid-June and late-July, followed by autofragmentation of the plant after each flowering (Nichols 1975; Patten 1956). *Myriophyllum spicatum* dies back in the fall, but the root system can survive the winter (Perkins and Sytsma 1987; Titus and Adams 1979). These root crowns begin growing the following spring once water temperatures reach about 60°F (Smith and Barko 1990)."

"Unlike many aquatic plants, this species does not produce turions (dormant vegetative structures that survive the winter) (Patten 1954). Each plant is able to produce approximately 100 seeds per season, but this species is much more successful at vegetative reproduction via fragments and runners (Patten 1956). After flowering, this species can undergo auto-fragmentation; new roots at nodes along the stem, and then the plant will break of *[sic]* at these nodes (Gustafson and Adams 1973; Nichols 1975). Plant fragments can be transported via wind, waves, or by human activity (Kimbel 1982)."

Human Uses

From Aiken et al. (1979):

"Fishermen often consider watermilfoil beds prime locations for bass fishing. Weed beds provide spawning areas and are a habitat for freshwater crustaceans. […] Where Eurasian watermilfoil is removed by harvesting, attempts have been made to use it as a fertilizer (Anderson et al. 1965), as an animal feed (Muztar et al. 1976, Muztar 1976) and as a soil conditioner (Wile et al. 1978) with limited success."

"In February 1978, the Canadian Nuisance Aquatic Plant Committee (IWD) recommended that the importation of *Myriophyllum* into Canada should be banned"

Diseases

From Aiken et al. (1979):

"Lake Venice disease, described as a "severe pathological condition" was discovered during 1962, in Eurasian watermilfoil populations of Maryland (Elser 1969). This disease first appears as a light brownish coating on the leaves, a coating that becomes thicker until it entirely obscures the leaf divisions. The watermilfoil does not flower but gradually becomes weaker and dies. Under a microscope the brown coating shows an amazing variety and quantity of diatoms, sessile protozoans, epiphytic algae and fungi. No pathogen has been found for this disease; but under stress conditions plants become more susceptible to attack by microorganisms (Beau et al. 1973).”

“Northeast disease was first observed in 1964 (Elser 1969). It was thought that the primary pathogen was probably a virus, and gram negative bacilli obtained from diseased milfoil probably represented secondary infections (Bayley et al. 1968). The earliest symptoms seen with the naked eye are broken leaf divisions, and entire leaves reduced in size. The stem and leaves become stiff and remain rigid even when the plant is taken from the water. The petiole flattens and develops wings which fuse outward into flattened and often enlarged basal leaf divisions. Black spots occur along the leaves and stem before the entire plant regresses, and usually fails to flower. Subsequent studies in 1969 failed to show the presence of a virus, and transmission of the disease in the laboratory was not achieved (Bayley 1970).”

Threat to Humans

From Pfingsten et al. (2018b):

“*Myriophyllum spicatum* populations and stagnant water also create habitat for the parasites that cause swimmer’s itch and mosquitoes (Jacobs and Margold 2009, OISAP 2013).”

3 Impacts of Introductions

From Boylen et al. (1999):

“Within three years (1989), the formerly native communities were reduced to only a few stems of native plants under a dense canopy of *M. spicatum*. Species richness declined from an average of 5.5 species per quadrat in 1987 to slightly over two in 1989 (of which one species was always *M. spicatum*). During 1990–1997, *M. spicatum* continued to suppress the native vegetation in this locality with species richness less than two species /quadrat for all years. The total number of species found in the grid (36 m^2) has also decreased linearly over time, from 20 in 1987 to 14 in 1988 and to nine in 1989. Since 1990, the number of species in the grid has leveled out at seven.”

“Not only did *M. spicatum* dominate along the radiating transects beyond the central grid work, the number of species per 0.1 m^2 quadrat measured at 1 m intervals along each transect also decreased (Figure 4 [in source material]). In 1997 the north transect had an average of three species per 0.1 m^2 quadrat, whereas the east, west and south transects had an average of 1.5 species per quadrat. Along the transects, the presence of native species which were abundant before *M. spicatum* became established has diminished considerably. Affected species include *Bidens beckii* Torr., an *Eleocharis* sp., *Elodea canadensis* (Michx) Planchon., *Heteranthera dubia* (Jacq.) MacM., *Juncus pelocarpus* Meyer, *Myriophyllum tenellum* Bigel., *Najas flexilis* (Willd) Rostk. & Schmidt., *Nuphar lutea* (Durand) Beal, *Potamogeton amplifolius* Tuckerm., P. *gramineus* L., *P. praelongus* Wulfen, *P. robbinsii* Oakes, *P. spirillus* Tuckerm., *P. zosteriformis* Fern., *Sagittaria graminea* Michx., a *Sparganium sp., Utricularia vulgaris* L. and *Vallisneria americana* Michx. Species which were infrequent within the native plant community in 1987 (*Myriophyllum alterniflorum* DC, *Najas guadalupensis* (Spreng.) Morong., *Potamogeton* *perfoliatus* L., *P. pusillus* L., *P. vaseyi* Robbins, *Ranunculus longirostris* Godr. and *Utricularia resupinata* B.D.Greene.) had disappeared altogether by 1997."

From Aiken et al. (1979):

"Where Eurasian watermilfoil occurs in Canada it is a vigorous plant that shades out other species including the large leaf pondweed, *Potamogeton amplifulius* Tuck., and the naturalized European *P. crispus* L. Stands become so dense that the tangle of branches near the surface can support the weight of frogs and wading birds. […] In the shallow Kawartha Lakes of Ontario, aquatic plants, primarily *M. spicatum*, have covered 80% of the water surface of some lakes. Such dense stands curtail recreational activities, create habitats favorable for the production of blood-sucking insects and clog industrial and potable water supply systems. Dense Eurasian watermilfoil stands may restrict the operation of flow metering devices in flood control channels, and alter temperature profiles in a lake by as much as 10 Celsius degrees/m in shallow water (Dale and Gillespie 1977). Beach quality is substantially degraded by piles of decaying vegetation and this may add to the cost of beach maintenance. Eurasian watermilfoil is considered to have little value as a waterfowl food (Elser 1969) and furthermore, through competition it can reduce the quantities of desirable duck food species."

"In British Columbia a multimillion dollar program attempting eradication of this weed from the Okanagan Valley was initiated in 1977 and will proceed until 1980 at least (Newroth 1977). This Provincial Government program was initiated because of the high water-based recreational value of the Okanagan lakes. Since 1973 the Ontario Ministry of the environment has budgeted $150,000 per year for the harvesting of aquatic weeds, predominantly Eurasian watermilfoil, in the Kawartha Lakes. An estimated $60,000 per year has been spent privately on the chemical control of weeds in these lakes. Between l96l and l971 over $4 million was expended in direct field costs for the control of Eurasian watermilfoil in the Tennessee Valley Authority reservoirs (Bates, personal communication)."

From Olden and Tamayo (2014):

"The presence of Eurasian milfoil had a significant negative effect on property values; mean reduction in property values was $94,385 USD, ranging from –$92,558 to –$94,670 USD according to the top three competitive models (Table 2). Based on an average sale price of $502,313 across all study lakes, the negative effect of milfoil presence corresponds to a 19% decline in mean property values."

"The presence of milfoil in a lake results in an ''invisible tax'' on the real estate market by substantially reducing property values an average of over $94 thousand USD, translating to 19% decline in value. We note that our estimates did not consider the level of infestation, the implementation of management actions, nor the losses to recreation."

"Similar economic damages have been reported in northern Wisconsin, where waterfront property values in a popular recreational and rural area declined by approximately 8% after milfoil invaded a lake [Horsch and Lewis 2009]. Furthermore, the process of milfoil infestation in five Vermont lakes (USA) resulted in property values that decreased by <1% to 16%

depending on the level of infestation [Zhang and Boyle 2010]. Both these studies examined rural properties containing mostly vacation homes (secondary residences) located in forested landscapes; our study adds to this understanding by demonstrating economic impacts to property values of primary residences in urban settings."

From Pfingsten et al. (2018a):

"Now considered a major nuisance species throughout the Northeast, northern Midwest and Pacific Northwest of the United States (Couch and Nelson 1985; Patten 1956; White et al. 1993) Eurasian water-milfoil competes aggressively to displace and reduce the diversity of native aquatic plants. It elongates from shoots initiated in the fall, beginning spring growth earlier than other aquatic plants. Tolerant of low water temperatures, it quickly grows to the surface, forming dense canopies that overtop and shade the surrounding vegetation (Madsen et al. 1991). Canopy formation and light reduction, are significant factors in the decline of native plant abundance and diversity observed when Eurasian water-milfoil invades healthy plant communities (Smith and Barko 1990; Madsen 1994)."

"Although in small tank experiments the native northern watermilfoil (*Myriophyllum sibiricum* Kom.) appears competitively superior, in the field, however, *M. spicatum* has replaced *M. sibiricum* over much of the temperate range of this species in North America (Valley and Newman, 1998). Both eelgrass (*Vallisneria americana*) and southern naiad (*Najas guadalupensis*) are known to have been displaced by this nonindigenous species in the Mobile Delta of Alabama (Bates and Smith 1994). Its establishment in Lake George, New York, reduced native plants from 5.5 to 2.2 species per square meter, in just two years (Madsen et al 1991). Its presence in the Rio Grande has caused concern for regional irrigation systems (NMAISAC 2008). In the tidal Delaware River, *M. spicatum* can tolerate conditions where salt intrusion and industrial pollution are eliminating native submersed plants (Schuyler et al. 1993)."

"Eurasian water-milfoil has less value as a food source for waterfowl than the native plants it replaces (Aiken et al. 1979). And although fish may initially experience a favorable edge effect, the characteristics of Eurasian water-milfoil's overabundant growth negate any short-term benefits it may provide fish in healthy waters. At high densities, its foliage supports a lower abundance and diversity of invertebrates, organisms that serve as fish food (Keast 1984). Dense cover allows high survival rates of young fish, however, larger predator fish lose foraging space and and *[sic]* are less efficient at obtaining their prey (Lillie and Budd 1992; Engel 1995). Madsen et al. (1995) found growth and vigor of a warm-water fishery reduced by dense Eurasian water-milfoil cover."

"Millions of dollars have been spent nationwide for control efforts (U.S. Congress, Office of Technology Assessment, 1993). In New York state *[sic]* alone, annual costs are estimated at $500,000."

From Pfingsten et al. (2018b):

"Keast (1984) also found that there were 3-4 times as many fish feeding in native plant communities than in beds of *M. spicatum*."

"*Myriophyllum spicatum* populations and stagnant water also create habitat for the parasites that cause swimmer's itch and mosquitoes (Jacobs and Margold 2009, OISAP 2013)."

"Even with control efforts, large infestations of *M. spicatum* can severely limit recreational activities such as boating, fishing, swimming, and/or waterfowl hunting (IL DNR 2009, Jensen 2010). Long stems can get tangled around boat propellers and may cause damage (IL EPA 1996). Large populations of Eurasian watermilfoil are often found to be aesthetically unpleasant (IL DNR 2009). Diminished recreational uses can lead to lost tourism revenue. It is estimated that Eurasian watermilfoil costs Michigan millions of dollars annually in lost tourism revenue (Michigan Sea Grant 2012)."

From CABI (2018):

"Moody (1989) lists *M. spicatum* as a weed of transplanted and deep-water rice in Bangladesh, India and Vietnam, and Napompeth and Bay-Petersen (1994) similarly include it as a rice weed in Thailand."

"Anderson (1993) outlines the various ways in which submerged weeds such as *M. spicatum* can have detrimental impacts. These include interference with flow of irrigation water, transport, hydro-electric power production, fisheries, recreation, and increased risk of flood and associated hazards to human life (e.g. O'Hare et al., 2007)."

"Costs of control of *M. spicatum* in Canada using non-chemical means are quoted by Anderson (1993) as ranging from US $125/ha for shallow-water tillage to US $1200/ha for harvesting, and up to US $26 000/ha for some types of benthic barriers (matting laid on the sediment to prevent growth). Steward (1993) gives a figure of US $252-417/ha for chemical control of water milfoil in South Carolina, USA, and US $254/ha for control using grass carp (at 1990 prices). Eiswerth et al. (2000) place a lower boundary figure for the impact of M. spicatum invasion into the high recreational-value Lake Tahoe watershed (California/ Nevada) at US $0.5M per annum."

4 Global Distribution

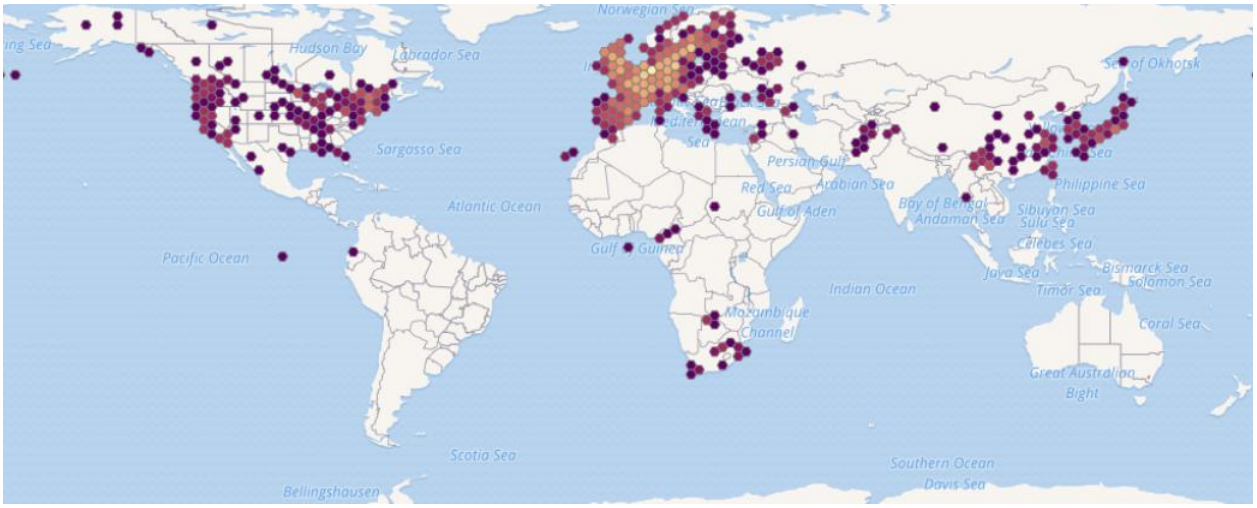

Figure 1. Known global distribution of *Myriophyllum spicatum*. Map from GBIF Secretariat (2018).

The locations in Ecuador, Mexico, Cameroon, and Sudan are from specimens collected in the wild (GBIF Secretariat 2018) and were used as source points in the climate match.

The location off the western coast of South America is in a marine environment and no locality information was given in the record (GBIF Secretariat 2018). It was not used as a source point for the climate match.

The location off the central western coast of Africa is the result of coordinate issues with a specimen collected in California (GBIF Secretariat 2018). It was not used as a source point for the climate match.

The location in Myanmar is the result of a record with significant missing information, including the basis of record (GBIF Secretariat 2018). It was not used as a source point for the climate match.

5 Distribution Within the United States

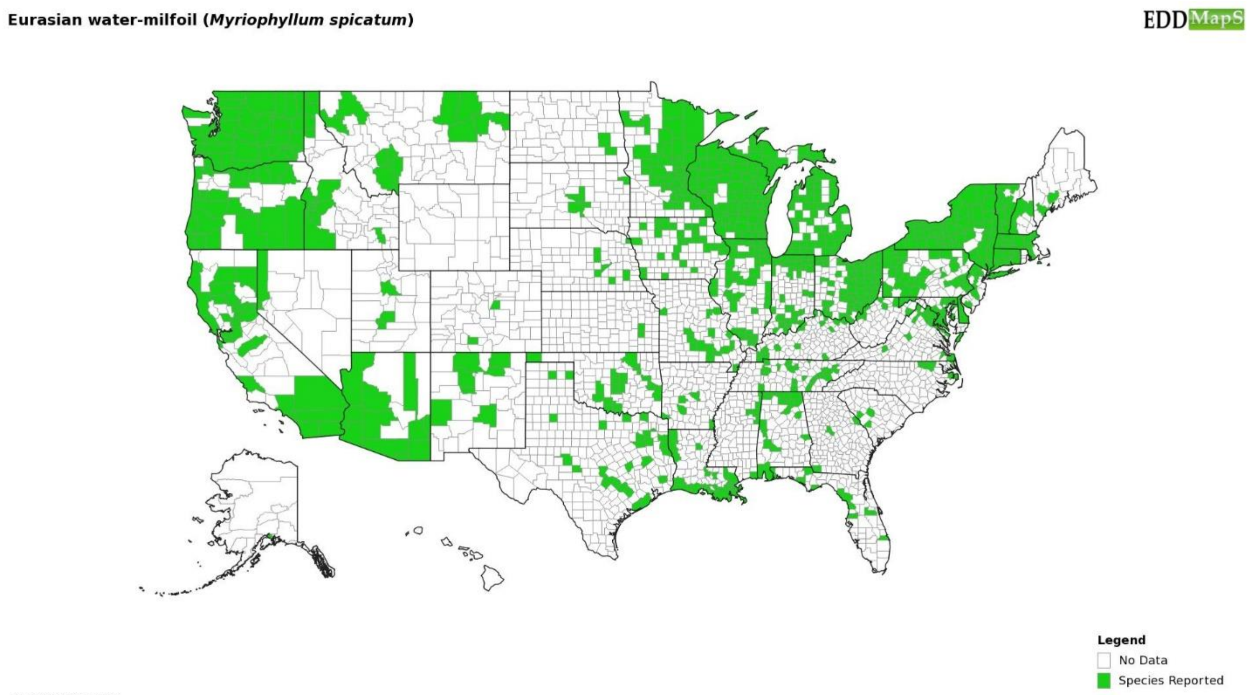

Figure 2. Known distribution of *Myriophyllum spicatum* by county in the United States. Map from EDDMapS (2018).

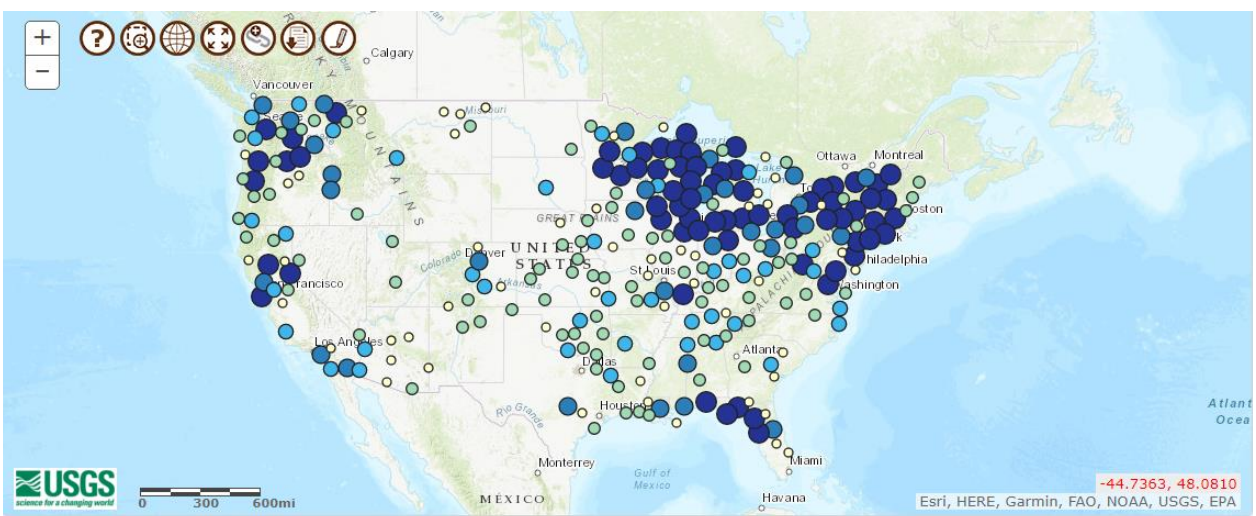

Figure 3. Known distribution of *Myriophyllum spicatum* in the contiguous United States. Map from Pfingsten et al. (2018a).

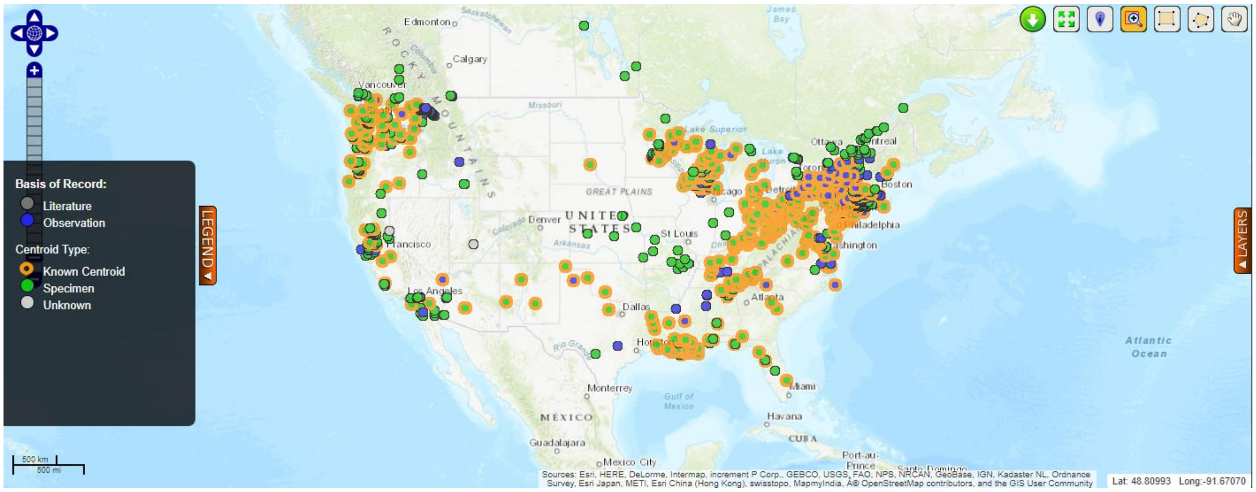

Figure 4. Additional known distribution of *Myriophyllum spicatum* in the contiguous United States. Map from BISON (2018).

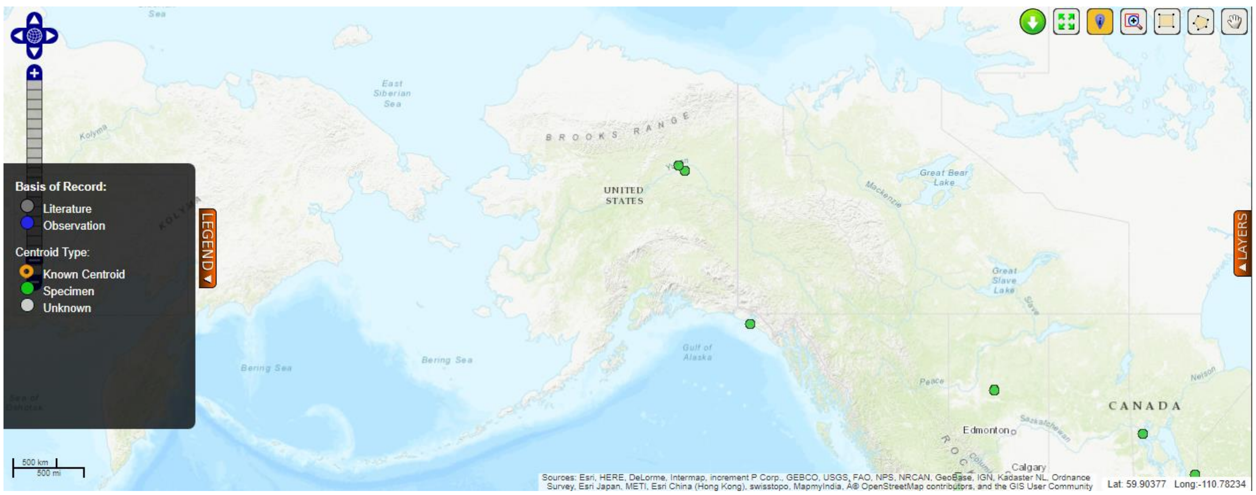

Figure 5. Known distribution of *Myriophyllum spicatum* in Alaska. Map from BISON (2018).

6 Climate Matching

Summary of Climate Matching Analysis

The climate match for *Myriophyllum spicatum* is high across the contiguous United States with no significant areas of low or medium match. There is only one state, Wyoming, in the contiguous United States without currently established populations of *M. spicatum*. The Climate 6 score (Sanders et al. 2014; 16 climate variables; Euclidean distance) for the contiguous United States was 0.999, high. All states in the contiguous United States had high individual climate 6 scores.

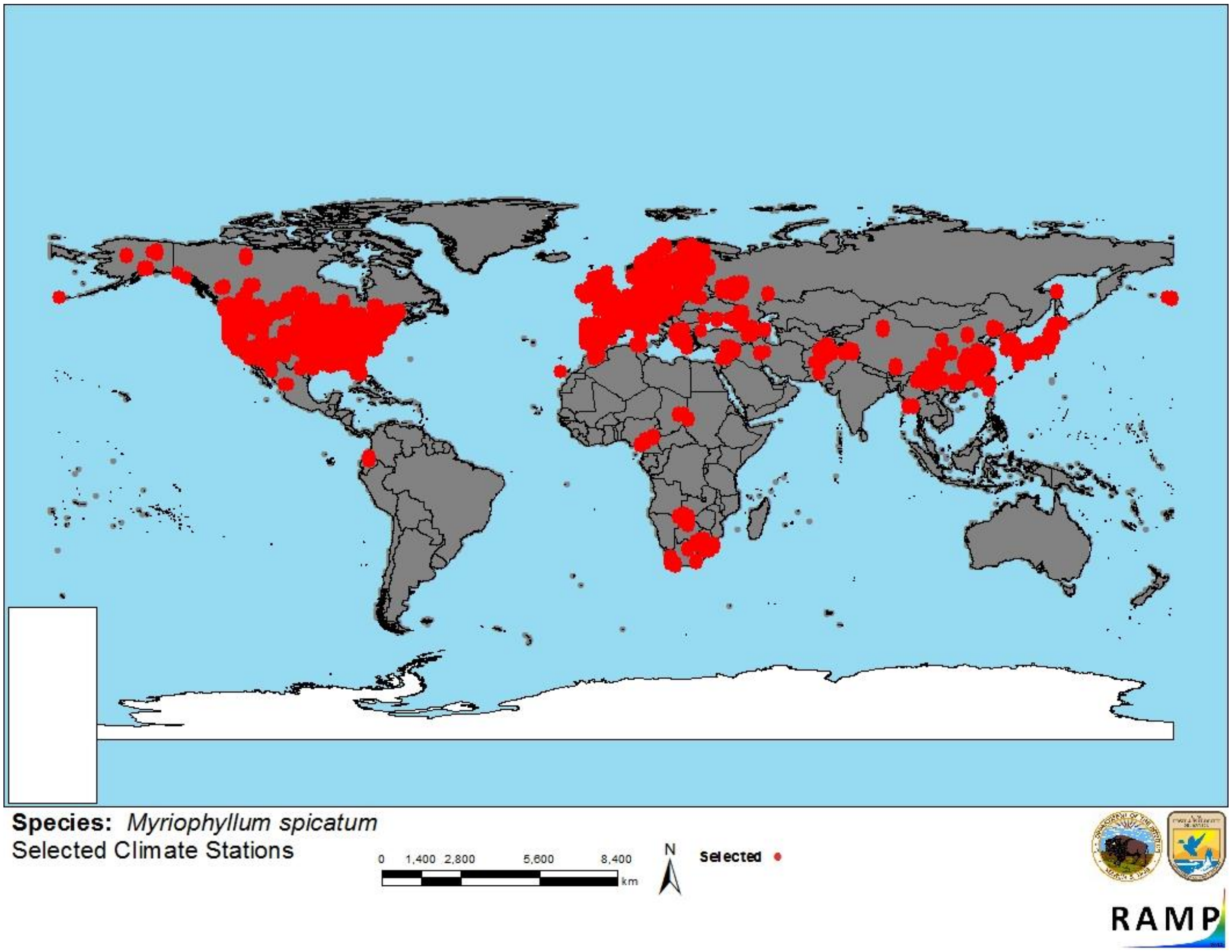

Figure 6. RAMP (Sanders et al. 2014) source map showing weather stations in North and South America, Europe, Asia, and Africa selected as source locations (red) and non-source locations (gray) for *Myriophyllum spicatum* climate matching. Source locations from BISON (2018), EDDMapS (2018), GBIF Secretariat (2018), and Pfingsten et al. (2018a).

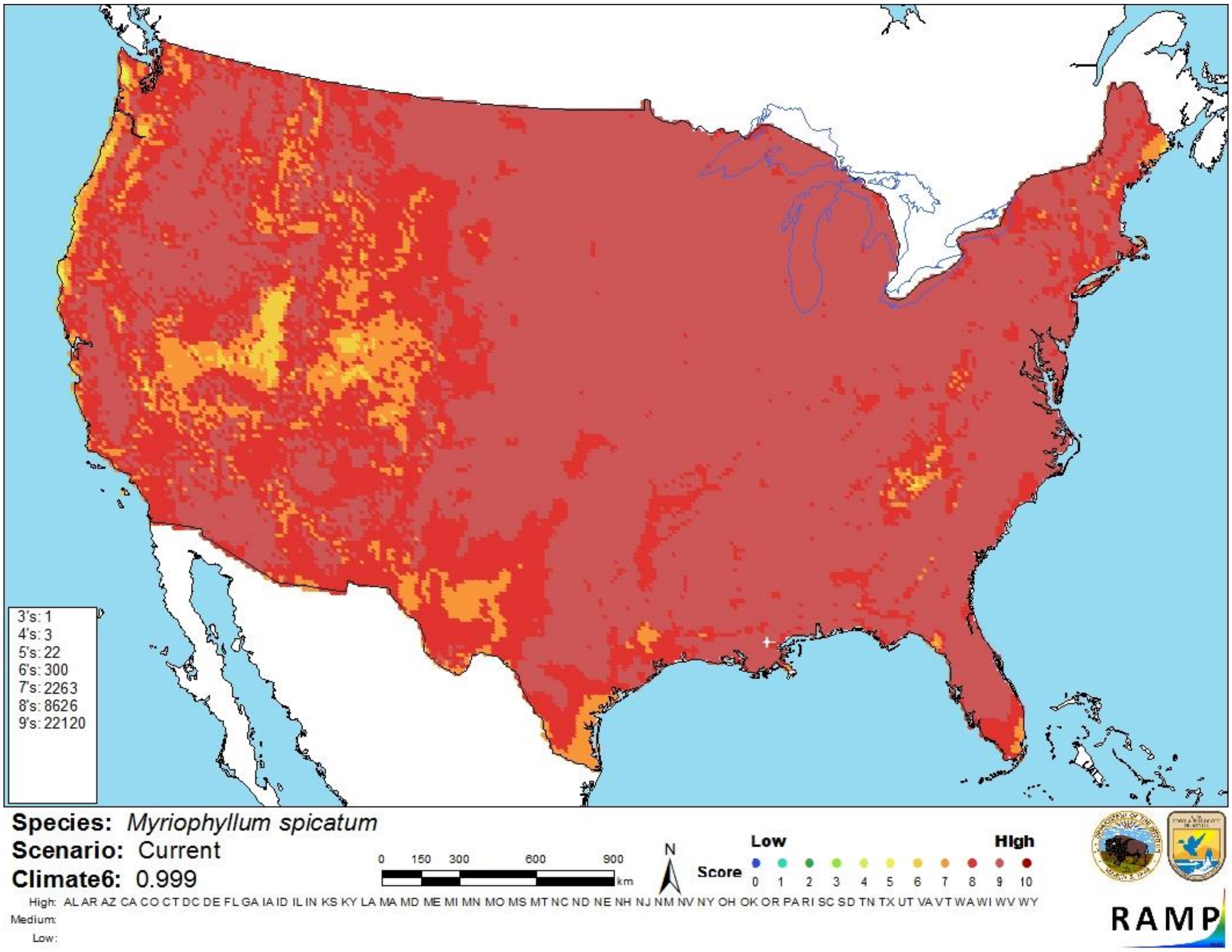

Figure 7. Map of RAMP (Sanders et al. 2014) climate matches for *Myriophyllum spicatum* in the contiguous United States based on source locations reported by BISON (2018), EDDMapS (2018), GBIF Secretariat (2018), and Pfingsten et al. (2018a). 0 = Lowest match, 10 = Highest match.

The High, Medium, and Low Climate match Categories are based on the following table:

Climate 6: Proportion of (Sum of Climate Scores 6-10) / (Sum of total Climate Scores)	Climate Match Category
0.000≤X≤0.005	Low
0.005<X<0.103	Medium
≥0.103	High

7 Certainty of Assessment

Certainty of this assessment is high. Information on the biology, invasion history and impacts of this species is available, including peer-reviewed literature. There is enough information available to describe the risks posed by this species.

8 Risk Assessment

Summary of Risk to the Contiguous United States

Eurasian watermilfoil (*Myriophyllum spicatum)* is an aquatic plant native to Eurasia that can grow in a wide variety of conditions and may hybridize with native species. The history of invasiveness is high. *M. spicatum* has been introduced throughout much of the world. It was introduced in the United States through ship ballast water and/or the aquarium and aquatic nursery trade. *M. spicatum* spreads by attachment to boats and ships. This plant can outcompete and extirpate native plant species creating monocultures that can alter hydrology, change nutrient dynamics and alter food webs. At high densities, abundance and diversity of invertebrates that provide food to fish and foraging space for predator fish are reduced. Heavy infestations limit recreational activities and provide habitat for mosquitoes and parasites that cause swimmer's itch. Substantial financial investments have been made to limit the impact of this species in aquatic environments. Climate matching indicated the contiguous United States has a high climate match for *M. spicatum.* Certainty of this assessment is high. The overall risk assessment category is high.

Assessment Elements

- **History of Invasiveness (Sec. 3): High**
- **Climate Match (Sec. 6): High**
- **Certainty of Assessment (Sec. 7): High**
- **Remarks/Important additional information:** Known populations of *Myriophyllum spicatum* have been documented in all but two states.
- **Overall Risk Assessment Category: High**

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