Curly Leaved Pondweed (*Potamogeton crispus*)

Ecological Risk Screening Summary

U.S. Fish & Wildlife Service, August 2015
Revised, October 2018
Web Version, 2/1/2019

Photo: John Hilty, Illinois Wildflowers. Licensed under Creative Commons BY-NC. Available: http://www.illinoiswildflowers.info/wetland/plants/curly_pondweed.html. (October 2, 2018).

1 Native Range and Status in the United States

Native Range

From CABI (2018):

"*P. crispus* is widespread throughout much of its native range, which is commonly reported to include Europe, Asia, African and Australia (Bolduan et al., 1994), […]"

According to CABI (2018), *Potamogeton crispus* is native to China, India, Iraq, Japan, North Korea, South Korea, Pakistan, Syria, Taiwan, Thailand, Turkey, Turkmenistan, Egypt, Ethiopia, South Africa, Sudan, Austria, Belgium, Bulgaria, Denmark, Estonia, Finland, Germany, Greece, Hungary, Ireland, Italy, Latvia, Liechtenstein, Lithuania, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Spain, Sweden, Switzerland, United Kingdom, Ukraine, and Australia. It is listed as present with no other status information in Georgia, Indonesia, Albania, and Czech Republic.

From Lansdown (2014):

"*P. crispus* is apparently native throughout most of the Old World, from Europe east to Japan and the Korean Peninsula, the Middle East, Indian subcontinent, China and northern southeast Asia with discontinuous populations in Sumatra (Indonesia) and Australia. It also occurs throughout the Mediterranean including North Africa and through the Black Sea region to the Caucasus and occurs throughout most of Africa south of the Sahara."

"NATIVE
Extant (resident)
Afghanistan; Albania; Algeria; Austria; Belgium; Bhutan; Botswana; Bulgaria; China; Czech Republic; Denmark; Egypt; Estonia; Ethiopia; Finland; France; Germany; Hungary; India; Indonesia (Sumatera); Iran, Islamic Republic of; Iraq; Ireland; Israel; Italy; Japan (Shikoku, Kyushu, Honshu, Hokkaido); Jordan; Kazakhstan; Korea, Democratic People's Republic of; Korea, Republic of; Lao People's Democratic Republic; Latvia; Lebanon; Lithuania; Malawi; Mozambique; Myanmar (Myanmar (mainland)); Nepal; Netherlands; Norway; Pakistan; Poland; Portugal; Romania; Russian Federation (Altay, West Siberia, Dagestan, Primoryi); South Africa (Western Cape, Northern Cape Province, North-West Province, Free State, Eastern Cape Province); Spain; Sri Lanka; Sudan; Swaziland; Sweden; Switzerland; Syrian Arab Republic; Tajikistan; Thailand; Turkey; Ukraine; United Kingdom; Uzbekistan; Viet Nam; Zambia; Zimbabwe"

Status in the United States

According to Thayer et al. (2018), *Potamogeton crispus* has been recorded in Alabama from 1943 to 2017, in Arizona from 1957 to 2012, in Arkansas from 1988 to 2015, in California from 1896 to 2016, in Colorado from 1952 to 2009, in Connecticut from 1943 to 2014, in Delaware from 1860 to 1990, in Florida from 1937 to 2002, in Georgia from 1947 to 1980, in Idaho from 1973 to 2018, in Illinois from 1911 to 2013, in Indiana from 1913 to 2016, in Iowa from 1944 to 2012, in Kansas from 1955 to 2015, in Kentucky from 1973 to 2015, in Louisiana from 1949 to 2015, in Maine from 2003 to 2009, in Maryland from 1877 to 2017, in Massachusetts from 1908 to 2015, in Michigan from 1910 to 2018, in Minnesota from 1901 to 2018, in Mississippi from 1979 to 2012, in Missouri from 1903 to 2017, in Montana from 1977 to 2016, in Nebraska from 1965 to 2015, in Nevada from 1973 to 1977, in New Hampshire from 1879 to 2016, in New Jersey from 1866 to 2003, in New Mexico from 1945 to 1981, in New York from 1879 to 2015, in North Carolina from 1950 to 1968, in North Dakota from 1975 to 2009, in Ohio from 1910 to 2018, in Oklahoma from 1936 to 1985, in Oregon from 1947 to 2017, in Pennsylvania from 1861 to 2017, in Rhode Island from 1932 to 2015, in South Carolina in 1997, in South Dakota from 1965 to 2018, in Tennessee from 1946 to 2017, in Texas from 1943 to 1998, in Utah from 1937

to 1988, in Vermont from 1911 to 2010, in Virginia from 1874 to 2002, in Washington from 1947 to 2018, in West Virginia from 1930 to 2015, in Wisconsin from 1905 to 2018, and in Wyoming from 1979 to 2014.

From Thayer et al. (2018):

"Established in all of the continental United States […]."

From CABI (2018)

"*P. crispus* currently remains widespread throughout temperate North America, where local populations continue to expand. It has been estimated that it currently occupies anywhere from 30-90% of its potential range (Tomaino, 2004)."

According to USDA, NRCS (2018), *Potamogeton crispus* is listed as a Class C noxious weed in Alabama and Washington, an invasive, banned plant in Connecticut, an invasive aquatic plant in Maine, a prohibited species in Massachusetts, and a Class B noxious weed in Vermont.

Means of Introductions in the United States

From CABI (2018):

"The first verified report of *P. crispus* in North America came from Philadelphia, PA in 1841-42, and after initial introduction, the plant began to establish quickly (Bolduan et al., 1994). By 1860, its growth in Delaware and Pennsylvania was described as abundant, and it spread rapidly in areas of Massachusetts and New York by the early 1880s (Bolduan et al., 1994). […] Occurrences were subsequently reported just west of the Mississippi River by 1903, and by 1896, the population had spread to the western seaboard (Bolduan et al., 1994). Stuckey (1979) hypothesized accidental introduction during stocking activities as the primary vector for spread in New England, and also noted that the plant was at first intentionally planted due to its suitability as habitat and food source for wildlife."

From Bruckerhoff et al. (2015):

"Single stems of *M. spicatum* and *P. crispus* were viable for up to 18 and 12 h of air exposure, respectively. […] Turions of *P. crispus* successfully sprouted after 28 days of drying. The fact that recreational boaters in the region typically visit multiple lakes within a few days suggests that most lakes are susceptible to introduction of viable plants, and so lake managers should continue to focus attention on boat cleaning."

From Thayer et al. (2018):

"The species has spread across much of the United States, presumably by migrating waterfowl, intentional planting for waterfowl and wildlife habitat, and possibly even as a contaminant in water used to transport fishes and fish eggs to hatcheries (Stuckey 1979). According to Balgie et al. (2010), *P. crispus* can also spread by plant fragments attached to boats and equipment that are not properly cleaned."

Remarks

From Thayer et al. (2018):

"Although examination for *P. crispus* hybridization has been limited, two hybrids exist globally, and one hybrid is known to exist in North America. The hybrid *Potamogeton crispus* x *P. praelongus* (= *P.* x *undulatus* Wolfgang ex Schultes & Schultes f.) has been confirmed from a northeastern Indiana lake (Alix and Scribailo 2006). *Potamogeton* x *cooperi* (Fryer) Fryer, a hybrid between *P. crispus* and *P. perfoliatus*, was found in Europe (Kaplan and Fehrer 2004). Both *P. crispus* and *P. perfoliatus* are found in the Great Lakes, but *P.* x *cooperi* has yet to be discovered in North America."

From Lansdown (2014):

"*P. crispus* has been shown to hybridize with *P. alpinus* (*P.* × *olivaceus* Baagöe ex G. Fisch.), *P. friesii* (*P.* × *lintonii* Fryer), *P. lucens* (*P.* × *cadburyae* Dandy et G. Taylor), *P. perfoliatus* (*P.* × *cooperi* (Fryer) Fryer), *P. praelongus* (*P.* × *undulatus* Wolfg.) and *P. trichoides* (*P.* × *bennettii* Fryer). None of these hybrids is common, […]"

From CABI (2018):

"Formal aquatic plant surveys are generally necessary for the early detection of this 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 Lilianae
Order Alismatales
Family Potamogetonaceae
Genus *Potamogeton*
Species *Potamogeton crispus* L."

Size, Weight, and Age Range

From Thayer et al. (2018):

"Size: up to 5 meters in length (Holm et al. 1997)"

Environment

From CABI (2018):

"*P. crispus* […] generally prefers alkaline, calcareous eutrophic waters (Bolduan et al., 1994). It is disturbance-tolerant and is commonly associated with impacted, disturbed, sometimes highly polluted, sites (O'Hare et al., 2006). It is also able to survive in a wide range of sediments, from gravel or fine sand with low organic content to loamy mud and clay (Bolduan et al., 1994). This is in part due to the ability shared by many aquatic species to acquire nutrients from the surrounding water as well as through roots. It is also important to note that this cold-tolerant species is evergreen and will grow through winter, often under thick ice cover (Stuckey et al., 1978)."

"*P. crispus* is cold-weather and low-light adapted (Tobiessen and Snow, 1984), allowing it to exist in deeper or more turbid waters than many other species (Jian et al., 2003). It has been reported to typically grow in water from 1-3 m deep, although sometimes it can be found in water up to 7 m deep. Photosynthetic rate is highest at 30ºC [water temperature], but vegetative growth has been reported to survive temperatures of 1-4ºC in the field (Bolduan et al., 1994). USDA-NRCS (2002) reports an absolute minimum temperature of -33ºC; active growth stops when temperatures drop below 5ºC. The species is typically associated with eutrophic alkaline sites, and is extremely tolerant of high nutrient systems (7.5 mg P L-1, 75 mg N L-1) (Mulligan et al., 1976). Its main phosphorus source is the sediment, whereas it acquires nitrogen and potassium from the surrounding water (Nichols and Shaw, 1986). A study in Wales shows that *P. crispus* lakes all had conductivity >150mS and Ca+Mg/Na+K hardness ratios >3 (Bolduan et al., 1994)."

From Thayer et al. (2018):

"*P. crispus* survives under the ice throughout the winter, then exhibits rapid growth in the spring when water temperatures rise above 10°C at a growth rate of 8-10 cm/day (Tobiessen and Snow 1983), allows *P. crispus* to exploit the warming waters before other aquatic plants begin to grow."

Climate/Range

From CABI (2018):

"The species therefore appears to be a cold-weather strategist; […]"

Distribution Outside the United States

Native

From CABI (2018):

"*P. crispus* is widespread throughout much of its native range, which is commonly reported to include Europe, Asia, African and Australia (Bolduan et al., 1994), […]"

According to CABI (2018), *Potamogeton crispus* is native to China, India, Iraq, Japan, North Korea, South Korea, Pakistan, Syria, Taiwan, Thailand, Turkey, Turkmenistan, Egypt, Ethiopia, South Africa, Sudan, Austria, Belgium, Bulgaria, Denmark, Estonia, Finland, Germany, Greece, Hungary, Ireland, Italy, Latvia, Liechtenstein, Lithuania, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Spain, Sweden, Switzerland, United Kingdom, Ukraine, and Australia. It is listed as present with no other status information in Georgia, Indonesia, Albania, and Czech Republic.

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"*P. crispus* is apparently native throughout most of the Old World, from Europe east to Japan and the Korean Peninsula, the Middle East, Indian subcontinent, China and northern southeast Asia with discontinuous populations in Sumatra (Indonesia) and Australia. It also occurs throughout the Mediterranean including North Africa and through the Black Sea region to the Caucasus and occurs throughout most of Africa south of the Sahara."

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Introduced

From CABI (2018):

"The first record in New Zealand occurred in 1940, although the first unofficial collection occurred earlier. […] Scant information is available on the population reported in South America."

According to CABI (2018), *Potamogeton crispus* is introduced in Philippines, Canada, Mexico, Fiji, and New Zealand. It is listed as present without other status information in Costa Rica.

From Lansdown (2014):

"It has apparently been introduced to North and South Islands of New Zealand, North America, Mexico and a few locations in Central and South America and Fiji."

From Thayer et al. (2018):

"Established in […] Ontario in Canada."

Means of Introduction Outside the United States

From CABI (2018):

"At least some of the New Zealand introductions can be attributed to accidental or intended plantings (Healy and Edgar, 1980)."

"Fragments of *P. crispus* can spread long distances, especially via the dormant apices that are so prolifically produced during summer. Thus, unintentional introduction via fragments transported on boats and equipment is a significant risk (ISSG, 2006). Maki and Galatowitsch (2004) also found that 10% of aquatic plant mailings in the horticultural trade contained regulated noxious species, including *P. crispus*, indicating a significant risk of introduction through horticultural activities. This species is easily acquired for intentional planting, even in states in which its sale, transportation, and release are regulated (Maki and Galatowitsch, 2004). Additionally, *P. crispus* is spread naturally over long distances via waterfowl, especially in areas along migratory routes (Boylen et al., 2006). Fragments can locally expand populations by passive spread in flowing water or during flood events."

"Tomaino (2004) reports that *P. crispus* has been intentionally planted as waterfowl and wildlife habitat."

Short Description

From Thayer et al. (2018):

"*Potamogeton crispus* grows entirely as a submersed aquatic plant with no floating leaves. Leaves are alternate, 4-10 cm in length and 5-10 mm wide. Leaves are conspicuously toothed along leaf margins, sessile (attached directly to the stem), narrowly oblong, undulate (wavy like lasagna noodles) with a conspicuous mid-vein. Leaf tips are obtuse (rounded or blunt), olive-green to reddish-brown, and somewhat translucent. Stems are flattened, channeled, with few branches. Rhizomes are pale yellow or reddish, rooting at the nodes. Small flowers (3 mm wide), with greenish-brown or greenish-red sepals form on a terminal spike above the waterline producing 3-4 achenes (fruits) per flower."

From CABI (2018):

"Lacunae are conspicuous and occur in rows of 2-5 along the midrib of the leaf. Stipules are not fused to the leaf and persistent, though inconspicuous. Leaves and stem are lax; the plant is either

entirely submersed or nearly entirely submersed with some leaves floating at the surface. Nodal glands in this species are entirely absent. Inflorescences are unbranched and emersed, generally terminal (Flora of North America Editorial Committee, 1993). Flowers are tiny, with four petal-like lobes on spikes 1-3 cm long on stalks up to 7 cm long (Washington State Department of Ecology, 2008). Sessile reddish-brown single-seeded fruits are unkeeled and measure 6 x 2.5 mm. Fruits have a small recurved beak that measures 2-3 mm. Embryo has full spiral. Short, bur-like hardened turions, in which internode length is extremely shortened, measure 1.3-3 by ~2 cm, are common and can be either apical or axillary (Flora of North America Editorial Committee, 1993; USACE, 2002)."

Biology

From Thayer et al. (2018):

"The unique seasonal phenology of *P. crispus* differentiates the species from other submersed aquatic plants found in North American waters. In the colder regions of its range, turions (the primary reproductive propagule) break dormancy in the fall when water temperatures drop (Nichols and Shaw 1986). *P. crispus* survives the winter as whole, intact leafy plants (even under thick ice and snow cover) (Stuckey et al. 1978), then grow rapidly in early spring when water temperatures are still quite cool (10-15°C). In early June plants flower, fruit, and form turions, and then plants senesce by mid-July (Tobiessen and Snow 1983) in most areas of its range. The winter growth form of *P. crispus* is morphologically different from its spring or summer growth form, with leaves that are flattened, narrow, and blue-green in color with few stems and thin rhizomes (Tobiessen and Snow 1983)."

"Germination of seeds is not well understood, but not considered to be the primary means of reproduction (Catling and Dobson 1985; Godfrey and Wooten 1981; Nichols and Shaw 1986)."

From CABI (2018):

"*P. crispus* reproduces mainly vegetatively via rhizomatic spread as well as with vegetative propagules called turions. Turions are formed from buds along the stem at or near peak biomass depending on day length, water temperature, and light intensity (Bolduan et al., 1994). Production is quite prolific: a single turion planted in a 5.9 square metre container yielded 23,250 turions in a single growing season, and densities from 236 – 1648 turions per square metre have been reported in the field (Nichols and Shaw, 1986). High rates of germination have been reported in the lab (100%) and in the field (> 60%) (Bolduan et al., 1994). Turion germination is controlled by light and temperature, and requires a cold (5ºC) or hot (30-35ºC) period to break dormancy (Bolduan et al., 1994). In a South African lake, turion germination was initiated when water temperature fell below 25ºC (Rogers and Breen, 1980) and was inhibited by darkness (Jian et al., 2003). The species does produce seeds, sometimes at very high densities, but field germination rates are extremely low (e.g. 0.001%) (Rogers and Breen, 1980)."

"*P. crispus* has a unique life cycle; it typically acts as a winter annual. After achieving peak biomass (in May in North America) the plant produces turions and dies back completely (Bolduan et al., 1994). The turions remain dormant through the summer months. As the water cools off near the end of summer, the turions germinate, producing the winter growth form. Thus

the plant has two periods of peak biomass, once in the spring and once in the autumn. After autumn germination, the plant spends the winter actively growing; its low light requirement allows it to subsist even under ice (Nichols and Shaw, 1986; Bolduan et al., 1994). The species therefore appears to be a cold-weather strategist; this allows the plant to establish early and either avoid competition with or out-compete other macrophytes (Bolduan et al., 1994)."

Human Uses

From CABI (2018):

"Tomaino (2004) reports that *P. crispus* has been intentionally planted as waterfowl and wildlife habitat."

"*P. crispus* can be used in the treatment of industrial aqueous waste, obviating the need for chemical treatment (Hafez et al., 1998)."

"*P. crispus* has been proven to be a good resource for carotenoids, which are often used in medicine and cosmetics for their anti-oxidation, immunity-regulation and tumour proliferation-slowing properties. Carotenoids like the ones extracted from *P. crispus* plants are also used as colourants and antioxidants in food additives (Ren and Zhang, 2008). The species has been used as an ethnobotanical treatment of cancer (Duke, 2008)."

"Given the species' pollution tolerance, it is a viable candidate for the revegetation and restoration of extremely impacted sites."

From Lansdown (2014):

"The leaves are diuretic and the infusion of dried leaves are taken internally in kidney problems. Its tubers and leaves are edible (Plants for a Future 2010). It is consumed for example in Viet Nam."

Diseases

From Catling and Dobson (1985):

"No invertebrate parasites of curly-leaved pondweed have been reported from North America. In India, larvae of the moth *Nymphula diminutalis* Snellem (Family Pyralidae) feed on leaves and warrant further investigation as a biocontrol agent (Sankaran and Rao 1972)."

"There are several fungal diseases affecting pondweeds but no specific reference is made to any affecting curly-leaved pondweed (U.S. Department of Agriculture 1960)."

Threat to Humans

No threats to humans from *Potamogeton crispus* were found.

3 Impacts of Introductions

From Catling and Dobson (1985):

"Detrimental: In waters where curly-leaved pondweed is well established, the spring and early summer plants may grow in dense stands which cover large areas of the water surface. Such profuse growth impedes water flow in irrigation canals and severely restricts water-based recreation. During periods of rapid growth, *P. crispus* has also been implicated in the depletion of water nutrients making it a nuisance in fisheries (Gupta 1973). It has also been noted that during the rapid spring and early summer growth, curly-leaved pondweed grows above native aquatic species and that the subsequent growth of these native species following the dieback of curly-leaved pondweed is minimal (Nicholson and Best 1974).

In the Rideau and Trent-Severn waterways of Ontario, curly-leaved pondweed is a major problem to water-based recreation (C. Curry, Ministry of Environment, pers. communication). In the Kawartha Lakes of Ontario, it is one of the three major nuisance species and has dominated large areas following the recent decline of *Myriophyllum spicatum* L. Warrington (1980) lists curly-leaved pondweed as "generally a pest in eutrophic conditions" in British Columbia.
In the United States there are many reports of curly-leaved pondweed becoming a serious weed problem in restricting water based recreation (e.g. Falter et al. 1974, Harmen 1974, Simes 1961, Stuckey 1979, Hellquist and Crow 1980) or in fish hatcheries (Simes 1961), or in crowding out other species which are more desirable for wildlife (e.g. *Potamogeton pectinatus* L.). When the spring foliage dies off in midsummer, the oxygen demand created by decomposition may severely deplete the levels of dissolved oxygen in the water and thus have a deleterious effect on fish (Cypert 1967, Gupta 1973)."

"Beneficial: The seeds and vegetative parts of curly-leaved pondweed are eaten by both dabbling and diving ducks and by coots (MacAtee 1939, Cypert 1967). ln marshes adjacent to Lake Erie in southeastern Michigan, curly-leaved pondweed was found to be of major importance as waterfowl food after the water level was lowered below 30 cm to induce fruiting (Hunt and Lutz 1959). One acre produced 4.5-5.5 million seeds (approximately 125 lbs/acre). This is sufficient to support 1000 Mallard-sized ducks for 1 day. In addition, a study of the aquatic invertebrates found on seven species of aquatic plants indicated that curly-leaved pondweed harbored a particularly large assortment of these organisms and thus could be useful in the culture of game fish (Krecker 1939). The production of foliage and fruit earlier in the year than most native submersed aquatics may vastly increase the significance of curly leaved pondweed to various aquatic animals."

From Thayer et al. (2018):

"*Potamogeton crispus* can outcompete native species for light and space early in the growing season; often reducing plant diversity and altering predator/prey relationship (ENSR International 2005; WI DNR 2012). *P. crispus* can provide habitat for aquatic life in the winter and early spring when native plants are not present (IL DNR 2005). Populations provide habitat for macroinvertbrates and fish, including spawning substrate (Catling and Dobson 1985; ENSR International 2005; GLC 2006; Lembi 2003). Aqueous extracts of *P. crispus* demonstrated

antimicrobial activity against 17 different microorganisms including *Escherichia coli* and *Staphylococcus aureus* (Fareed et al. 2008).

Large infestations of *P. crispus* can impede water flow and cause stagnant water conditions (Catling and Dobson 1985; ENSR International 2005; Lui et al. 2010). A large amount of phosphorus is released during decomposition, which can lead to eutrophication and algal blooms (Benson et al. 2004; WI DNR 2012), and oxygen concentration in the water can drop significantly, impacting fish (IPANE 2013; Lui et al. 2010). *P. crispus* has been shown to remove organic contaminants such as dibutyl phthalate and phthalic acid esters (Chi and Cai 2012; Chi and Yang 2012), and inorganics such as cerium, cobalt, cesium, cadmium, and their isotopes (Hafez et al. 1992; Sivaci et al. 2008).

Surface mats of *P. crispus* can inhibit aquatic recreation, such as boating, fishing, and swimming, and reduce the aesthetic value of waterfront property (IL DNR 2009; Jensen 2009; WI DNR 2012). Expensive control programs are often needed to reduce the impacts on recreational activities and to maintain waterfront property values (IL DNR 2005). Waterfront property owners in Michigan spend an estimated $20 million annually to control aquatic invasive plants—primarily Eurasian watermilfoil and curlyleaf pondweed (MSGCP 2007)."

From CABI (2018):

"*P. crispus* can increase algal blooms (Nichols and Shaw, 1986), which can decrease the aesthetic value of a water body. Monotypic stands of this species can be quite a nuisance, presenting significant navigational difficulties to recreational users (Bolduan et al., 1994).These factors have a significant impact on the recreational and real estate value of a water body, and may also have an impact on the tourism industry. Impacts are greatest in the species' introduced range, where it is considered a noxious weed (USDA-NRCS, 2008)."

"Massive stands of *P. crispus* substantially alter a water body's internal loading; it can also reduce the fetch of a lake, sometimes inducing stratification in normally unstratified systems (Bolduan et al., 1994). It has been shown to produce the highest shoot biomass in a comparative study that evaluated four related macrophyte species (Engelhardt, 2006). It can grow in dense monotypic stands and affect habitat structure, which may have impacts on fish species, including those sought both commercially and recreationally (Crowder and Cooper, 1982). *P. crispus* has been reported to decrease the amount of light reaching the sediment surface (Engelhardt, 2006). However, the plant may have positive effects in extremely degraded systems. Feng et al. (2002) report that planting of *P. crispus* in enclosures improved water transparency, decreased electric conductivity and increased pH, and was shown to have an inhibitory effect on green algae."

4 Global Distribution

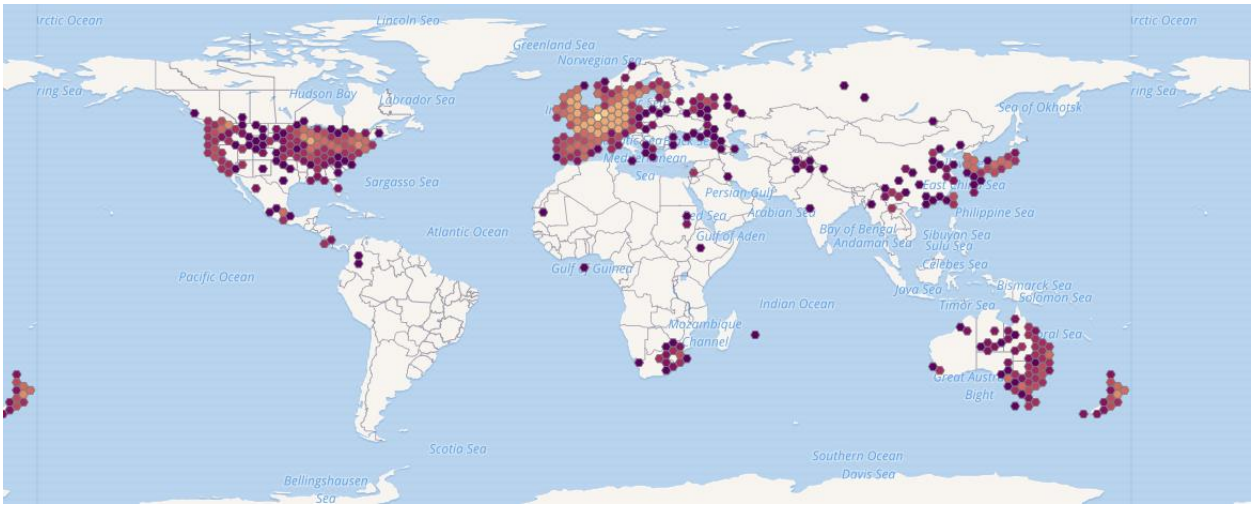

Figure 1. Known global distribution of *Potamogeton crispus*. Locations are in North and South America, Eurasia, Africa, Australia, and New Zealand. Map from GBIF Secretariat (2018).

The location in the ocean west of Africa (Figure 1) were not used as source points for the climate match. The location does not match the recorded specimen collection location in Ohio (GBIF Secretariat 2018).

The location on Mauritius (east of Madagascar, Figure 1) was not used as a source point for the climate match. There is no record of a population here, the recorded species name is a cogener, not *P. crispus*, and the attached specimen image does not look like *P. crispus* (GBIF Secretariat 2018).

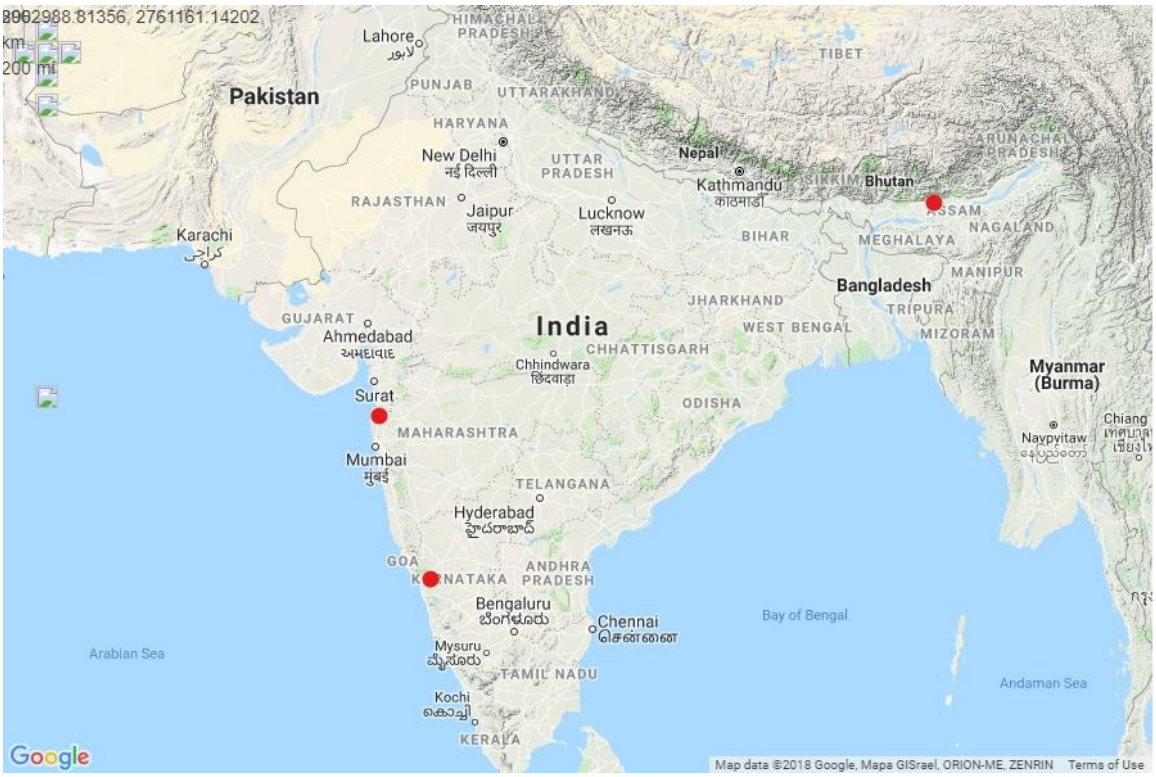

Figure 2. Additional distribution of *Potamogeton crispus* in India. Map from India Biodiversity Portal (no date).

5 Distribution Within the United States

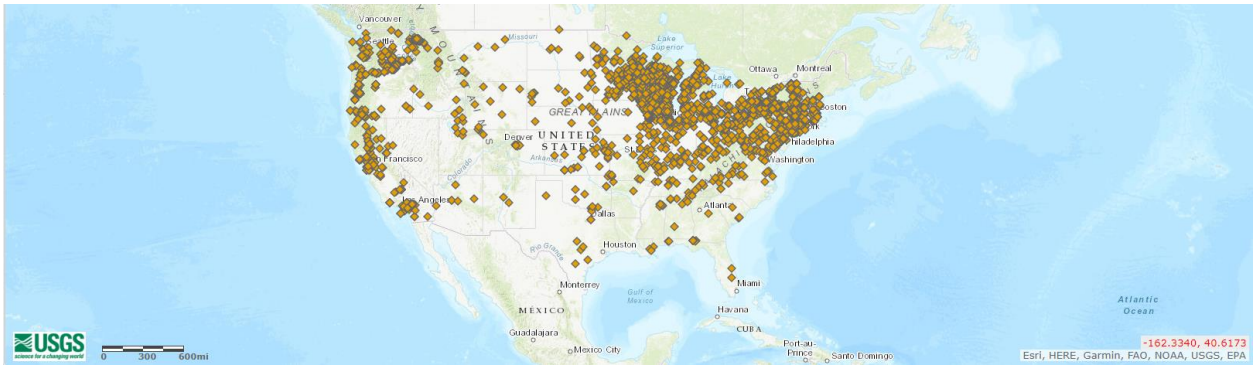

Figure 3. Known distribution of *Potamogeton crispus* in the United States. Map from Thayer et al. (2018).

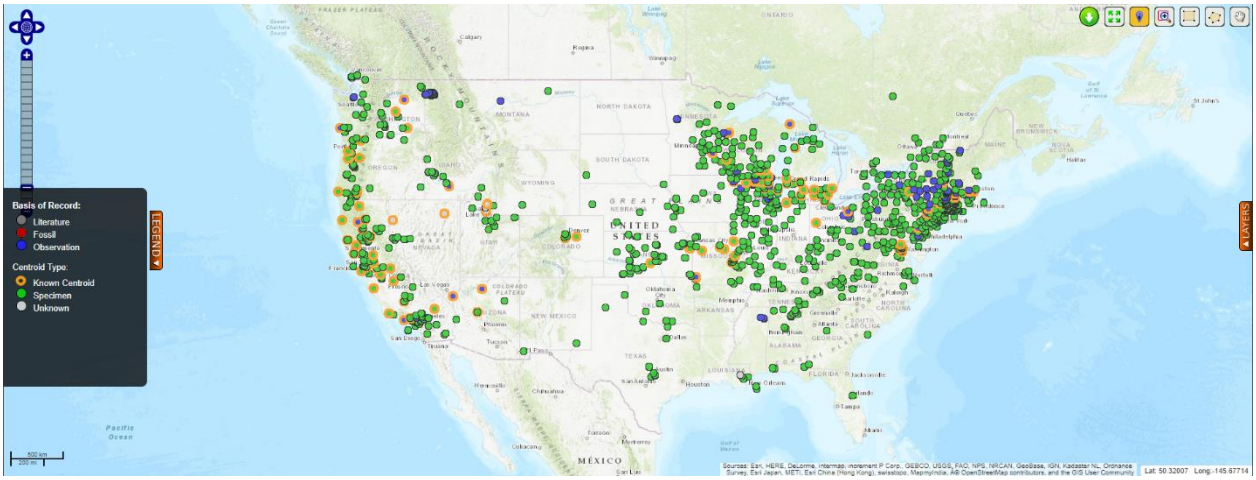

Figure 4. Additional known distribution of *Potamogeton crispus* in the United States. Map from BISON (2018).

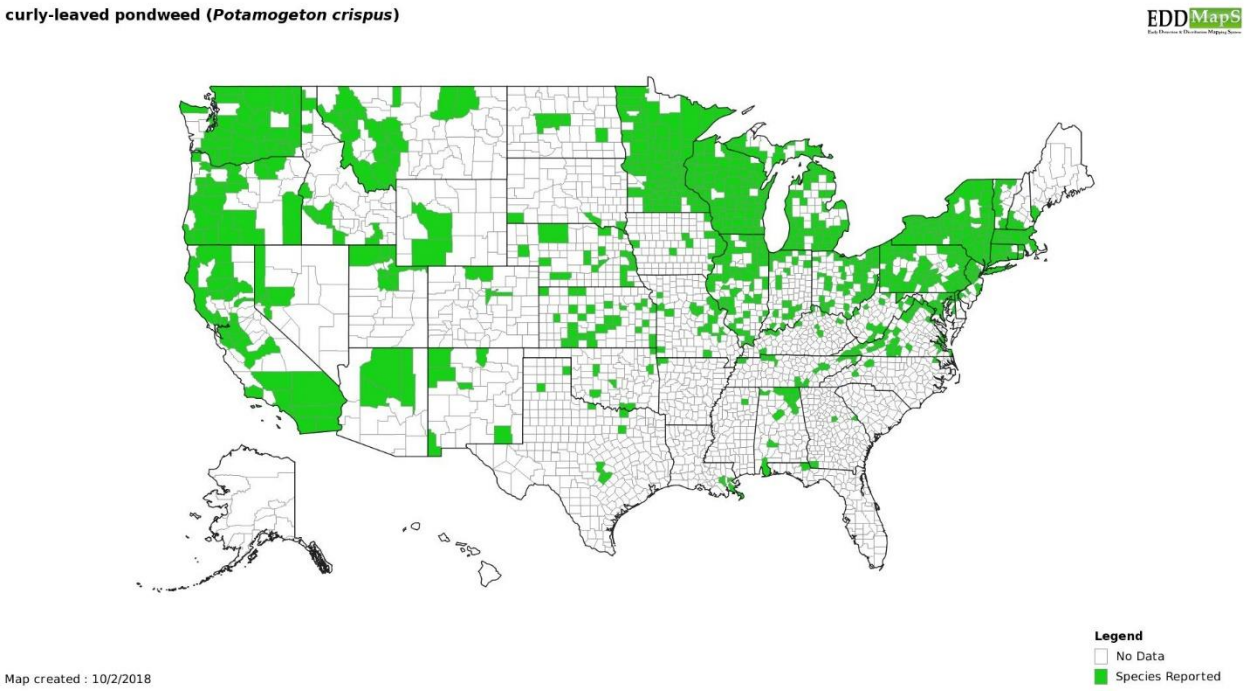

Figure 5. Counties in the United States with known records of *Potamogeton crispus*. Map from EDDMapS (2018).

6 Climate Matching

Summary of Climate Matching Analysis

The climate match for *Potamogeton crispus* was high across the contiguous United States. There were small areas of medium match in eastern Texas, the southern Appalachian Mountains, and the northern Pacific Coast; there were no areas of low match. The Climate 6 score (Sanders et al. 2018; 16 climate variables; Euclidean distance) for contiguous United States was 0.999, high. All States had high individual climate scores.

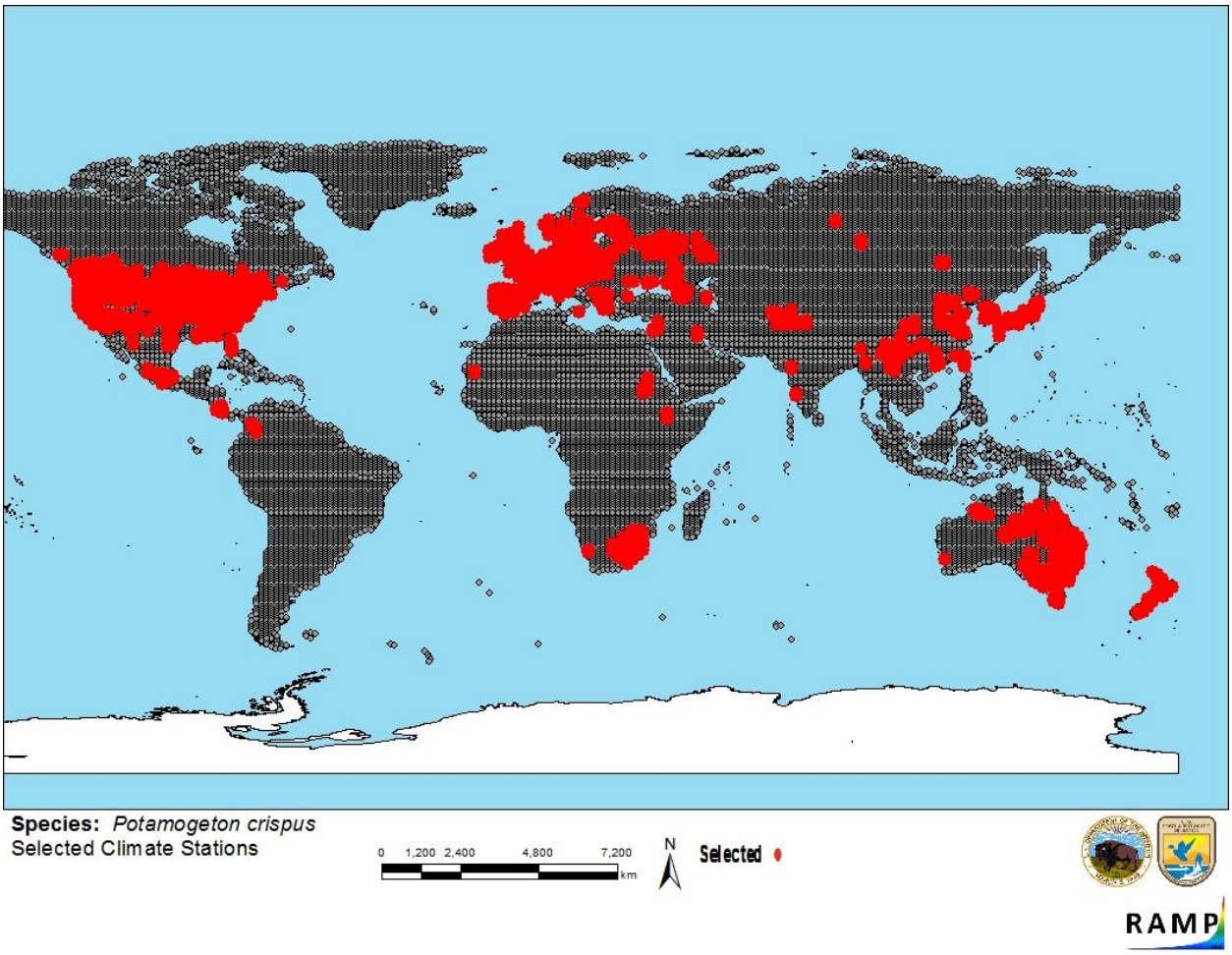

Figure 6. RAMP (Sanders et al. 2018) source map showing weather stations around the world selected as source locations (red) and non-source locations (gray) for *Potamogeton crispus* climate matching. Source locations from BISON (2018), GBIF Secretariat (2018), Thayer et al. (2018), and India Biodiversity Portal (no date).

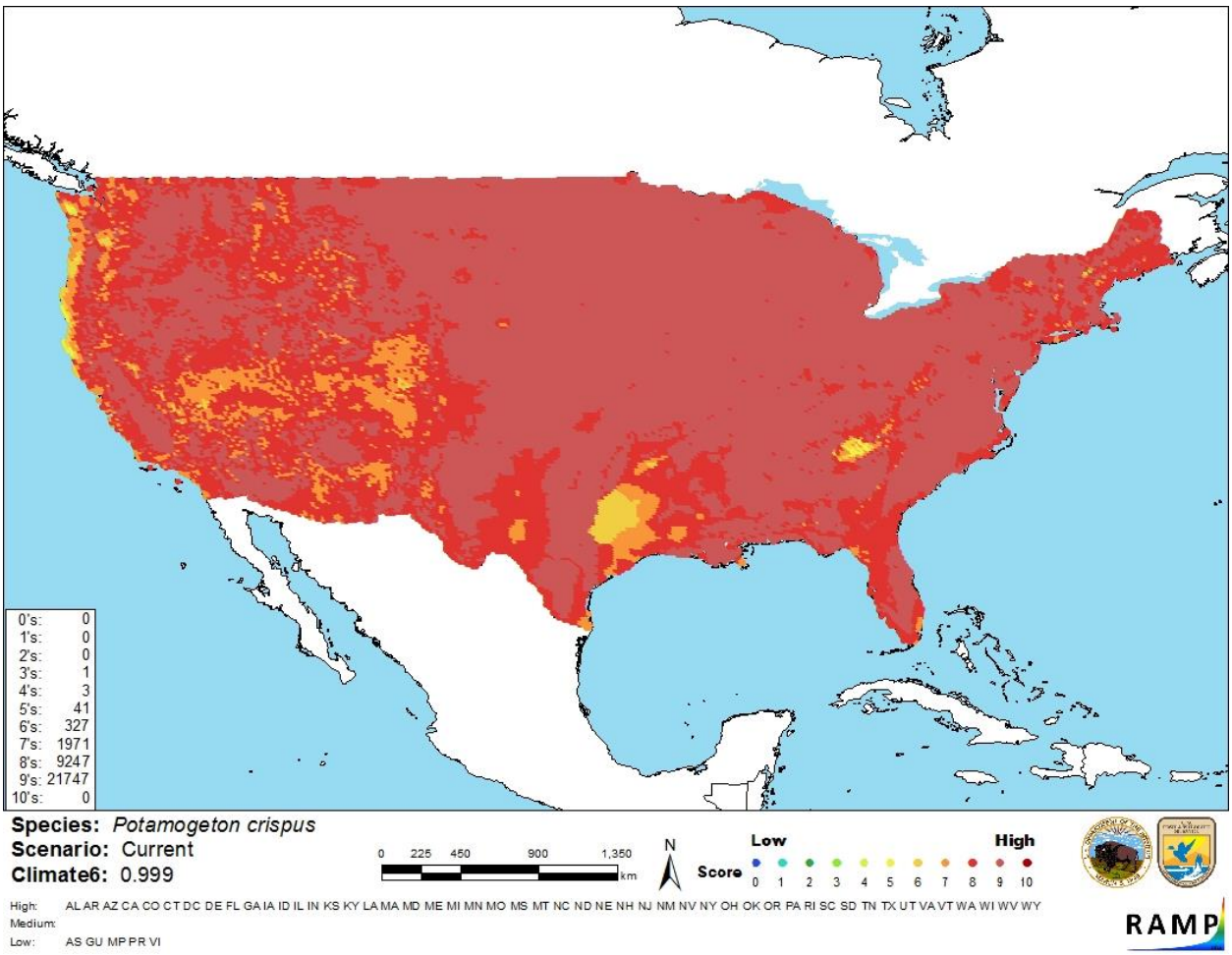

Figure 7. Map of RAMP (Sanders et al. 2018) climate matches for *Potamogeton crispus* in the contiguous United States based on source locations reported by BISON (2018), GBIF Secretariat (2018), Thayer et al. (2018), and India Biodiversity Portal (no date). 0 = Lowest match, 10 = Highest match.

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

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

8 Risk Assessment

Summary of Risk to the Contiguous United States

Curly leaved pondweed (*Potamogeton crispus*) is a plant native to Eurasia, Africa, and Australia. The submerged macrophyte is used in medical treatments, as habitat and food for wildlife, and in restoration projects due to its tolerance of polluted conditions. However, the history of invasiveness is high. Concerns with this plant include competition with native plants, reduced biodiversity, altered water flow in canals, and impacts on water-based recreation. *P. crispus* can alter nutrient cycles and deplete dissolved oxygen levels through the species' interesting spring and fall growth patterns. Climate matching indicated the contiguous United States has a very high climate match. This is unsurprising, given the species is established in all 48 contiguous States. The plant has shown a capability to establish in most eutrophic systems. 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:** *Potamogeton crispus* is established in all 48 contiguous States.
- **Overall Risk Assessment Category: High**

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