Hydrilla (*Hydrilla verticillata*) – dioecious biotype
Ecological Risk Screening Summary

U.S. Fish and Wildlife Service, Web Version – 9/13/2017


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1 Native Range and Status in the United States

Native Range
From Jacono et al. (2011):

"The common dioecious type originates from the Indian subcontinent. Historical reports specify the island of Sri Lanka (Schmitz et al. 1991) while random amplified polymorphic DNA (RAPD) analysis point to India's southern mainland (Madeira et al. 1997)."

From CABI (2015):

"It is thought to be native but is relatively rare in Europe (Preston and Croft, 1997), sufficiently so that it is protected in Lithuania (Balevicius, 1998). It occurs in certain areas in Poland and Belarus, and has been found in solitary lakes in Ireland (Preston and Croft, 1997)."

Status in the United States

From Jacono et al. (2011):

"Southern populations are predominantly dioecious female (plants having only female flowers) that overwinter as perennials."

"The most abundant aquatic plant in Florida public waters (Schardt 1994), seventy percent of Florida's freshwater drainage basins contain waterbodies infested with hydrilla (FLDEP 1988-94 and other data). Less common throughout Alabama, although widespread in the Mobile Delta and northern portion of the Mobile Bay (Zolcynski 1997); common at Coffeeville, Aliceville and Oak Mountain reservoirs of central Alabama (D. Powell, Alabama Power Company, pers. comm. 1996), and well established at Guntersville, and other northern impoundments on the Tennessee River (Bates and Smith 1994). Extending along the Tombigbee River from Aliceville Reservoir, AL into eastern Mississippi (E. Dibble, Mississippi State Universiy [sic], pers. com. 1998). Also, reestablished in the Tennessee-Tombigbee Waterway, at Beckner boat ramp and in the old bendway, (D. Franks, Mississippi Dept. Wildlife, Fisheries and Parks, pers. comm. 2000). Reported in southeastern Tennessee from the middle Tennessee River drainage, where herbicide and natural decline in Lake Chickamauga have precluded recent collection; yet, still found downstream, as scattered stands, in Nickajack Reservoir (Tennessee Valley Authority 1990, D. Webb, Tennessee Valley Authority, pers. com. 1997). Know primarily in the southwestern drainages of Georgia; problematic at Lake Seminole for over a decade (Eubanks 1996). Occurring, otherwise, at a few smaller waterbodes [sic] in Georgia's upper Ocmulgee drainage and at the Strom Thurmond Reservoir on the upper Savannah River (L. Ager, Georgia Department of Natural Resources, pers. com. 1998). Expanding over 32,000 acres in Lakes Marion and Moultrie, South Carolina following the 1989 hurricane, Hugo (Roach et al 1993). Problematic at six additional reservoirs in South Carolina (S. de Kozlowski, South Carolina Department of Natural Resources, pers. comm. 1997), within the Seneca, Saluda, Wateree, Four Hole Swamp, and Cooper drainages. Covering approximately 5,800 acres in North Carolina, primarily at eastern sites, including reservoirs in the upper Neuse River drainage, yet reported from as far west as Buncombe county, in the western mountains (NCDWR 1996). Established in the Potomac, Rappahannock, Anna, Chickahominy, and Appomattox Rivers of Virginia's coastal plain; extending into piedmont Virginia, at several reservoirs (E. Steinkoenig and J. Kauffman, Virginia Game and Inland Fisheries; J. Tate, Virginia Department of Agriculture and Consumer Services; pers. comm. 1998). Although reduced in abundance, continuing to dominate beds of submerged vegetation in the tidal freshwater reaches of the Potomac River on the Virginia/Maryland border (Orth et al. 1996). Established in Maryland at marsh creeks and rivers on the western and northeastern shores of the Chesapeake Bay, including the Pautuxent River, where it has become the most abundant plant species (M. Naylor, Maryland Dept. of Natural Resources, pers. comm. 2000; Orth et al. 1996; Posey et al. 1993). Also common at reservoirs in mid-Maryland, especially those draining the Patuxent River, and in the Ohio drainage of far western Maryland, at Deep Creek Lake (M. Naylor, Maryland Department of Natural Resources, pers. comm. 2000). Discovered recently at three sites in Pennsylvania in scattered stands in the Schuylkill River, downtown Philadelphia (P. Madeira, USDA/ARS, Aquatic Weed Control Research, pers. comm. 1996); at Highland Lake, a 28 acre impoundment on Southwick Creek (Colangelo 1998); and at Lake Nockamixon, where plants are abundant in a drowned portion of Haycock Creek [E. Zacharias and A. Schuyler 8345 (PH), 1998]. Common in Delaware ponds (AREC 1995), especially in southern Sussex Couty [sic] where it has spread to nearly 1200 acres in 14 ponds and portions of the Nanticoke River (C. Martin, Delaware Dept. of Natural Resources, 1999). Present since the late 1980s at two ponds in southeastern Connecticut (Balcom 1997), where plants were originally misidentified due to the absence of midrib teeth (Les 1996). In Massachusetts, found in 2001 in a Cape Cod pond (B. Hellquist pers. comm. 2001) and new to a Pembroke-area pond as of 2008. Found in Maine in 2002 in the Saco drainage at Pickerel Pond, York County, where plants are established and abundant throughout the pond (R. Bouchard, ME DEP, pers comm. 2003). First documented in 2003 for the state of New Jersey in the Lower Delaware drainage at Lake Mallard in the Pinelands National Reserve (Sullivan s.n. DOV, FLAS). This small lake is one of several connected ponds. As of April 2003, hydrilla had not been detected in any of the other linked ponds (G. Sullivan, Allied Biological, Inc., pers. comm. 2003). Found in Indiana's Lake Manitou in 2006, prompting closure to public boating access and chemical treatment (D. Keller, Indiana DNR, pers. comm. 2006). As of June of 2008, the treatments have significantly reduce hydrilla growth and tuber production, prompting a limited re-opening of one boat ramp. Found in a privately-owned artificial pond in Marinette County, Wisconsin in 2007. State and county agencies are working to identify the possible introduction pathway and eradication plan.

Most recently identified (2008) in three lakes in Suffolk and Orange Counties, New York where authorities plan treatments including herbicides and grass carp (S. Kishbaugh, NYSDEC Division of Water, pers. comm. 2008) and in three counties in eastern Kentucky.

West of Mississippi River

Appearing more frequently at lakes and reservoirs in Louisiana, especially along Highway 1 as it stretches diagonally across the state, in canals and bayous of the Atchafalaya Basin, and through the coastal marsh region south of Interstate 10 (C. Biggar, Louisiana Department of Wildlife and Fisheries, pers comm 1998). Also present at Lake Bruin (indicated by the dot in the eastern Tensas drainage) which is disjunct from other infested regions in Louisiana. Known from over 80 Texas reservoirs, residing in drainages that extend from north-central to eastern Texas, and south to the Rio Grande, at the Mexico border (Helton and Hartman 1997; E. Reyes, U.S. Fish and Wildlife Service, pers comm 1998). Eradicated in the mid 1980s from two ponds in Phoenix, Arizona, where no new infestations have been found (E. Hall, Arizona Dept. of Agriculture, pers. comm. 1996). Eradicated from private ponds and several reservoirs in nine California counties; presently occurring at less than 50 sites in Imperial, Tulare, Madera, Mariposa, Calaveras, Yuba, Lake and Shasta Counties (PPDC 1997). Recent infestations in Clear Lake threaten the highly productive Sacramento/San Joaquin River Delta area (Anderson 1996). In 1995, it was discovered in two interconnected Washington lakes, east of Puget Sound, where early biomass measurements reflect high growth potential in the northwestern climate (K. Hamel, Washington State University, pers. comm. 1995). Following successive years of herbicide treatment, only two isolated plants were found in one of these lakes in 2006 and none in 2007. New to the state of Arkansas, established in Lake Ouachita and DeGray Lake, in the Ouachita Headwaters and the Upper Ouachita drainages, respectively. First identified in Lake Ouachita in 1999 during creel surveys. Lake Ouachita is a 42,000 acre lake, with an approximate hydrilla infestation size of 4,000 acres. DeGray Lake is nearly half the size of Lake Ouachita and has 3-4 confirmed acres of hydrilla infested waters. Hydrilla has been verified growing in waters of 7.3 m in depth with expected growth to be in the 9.1 - 10.7 m level in the near future due to light pentration [sic] to 12.2 m in depth and to the sedimentary composition of the lake. Lake Ouachita personnel are working on a project to initiate biological control efforts in the lake (R. Stokes, USACE, Manager, Lake Ouachita, pers. comm. 2003). Hydrilla was found in late 2007, growing with Pistia stratiotes in a geothermal area near Bruneau, Idaho, upstream of the CJ Strike Reservoir and the Snake River. Surveys have found it seven miles downstream from the hot spring area. It was also found in June 2008 in a suburban ditch in West Boise; this ditch remains warm through winter thanks to flow from geothermal wells and drains to the Boise River. Both populations have been determined to be dioecious, hopefully suggesting infestations are limited to geothermally influenced warm-water areas (T. Woolf, Idaho Dept of Agriculture, pers. comm. 2008). Most recently found in a park pond in Kansas, where eradication efforts will begin in 2009 (J. Goeckler, Kansas Department of Wildlife & Parks, pers. comm. 2008)."

From USDA (2017):

Country/State	Common Name	Classification
United States	hydrilla	Noxious weed
Alabama	hydrilla	Class A noxious weed
Arizona	hydrilla, Florida-elodea	Prohibited noxious weed
California	hydrilla	A list (noxious weeds)
	hydrilla	Noxious aquatic weed
	hydrilla	Quarantine
Colorado	hydrilla	A list (noxious weeds)
Connecticut	hydrilla	Invasive, banned
Florida	hydrilla, Florida-elodea	Prohibited aquatic plant, Class 1
Maine	hydrilla	Invasive aquatic plant
Massachusetts	hydrilla	Prohibited
Nevada	hydrilla	Noxious weed
New Mexico	hydrilla	Class A noxious weed
Oregon	hydrilla	“A” designated weed
	hydrilla	Quarantine
South Carolina	hydrilla	Invasive aquatic plant
	hydrilla	Plant pest
Texas	hydrilla	Noxious plant
Vermont	hydrilla	Class A noxious weed
Washington	hydrilla	Class A noxious weed
	hydrilla	Wetland and aquatic weed quarantine

Means of Introductions in the United States

From Jacono et al. (2011):

"The dioecious strain was imported to the United States in the early 1950s for use in aquariums. It entered Florida's inland water system after plants were discarded or planted into canals in Tampa and in Miami (Schmitz et al 1991)."

"Hydrilla is mainly introduced to new waters as castaway fragments on recreational boats, their motors and trailers and in live wells. Stem pieces root in the substrate and develop into new colonies, commonly beginning near boat ramps. Once established, boat traffic continues to shatter and spread hydrilla throughout the waterbody. Both types propagate primarily by stem fragmentation, although axillary buds (turions) and subterranean tubers are also important. Tubers are resistant to most control techniques (Schardt 1994) and may be viable as a source of reinfestation for years (Van and Steward 1990).

Hydrilla may be unknowingly transplanted into private ponds as a contaminant on watergarden plants. It is often found spreading after extensive 2,4-D use in public waters once heavily populated with Eurasian water-milfoil (*Myriophyllum spicatum*) (Bates and Smith 1994)."

Remarks

From CABI (2015):

"*H. verticillata* is a submerged plant that has rapid growth and a highly effective survival strategy that makes it one of the most troublesome aquatic weeds of water bodies in the world. It forms dense masses, outcompeting native plants and interfering with many uses of waterways. It can be spread by water flow, waterfowl and recreational activities and is sold as an aquarium plant. In the USA it has been listed as Federal Noxious Weed since 1976; its import is prohibited in Western Australia and Tasmania, and it is on the EPPO alert list."

2 Biology and Ecology

Taxonomic Hierarchy and Taxonomic Standing

From ITIS (2015):

"Kingdom Plantae
  Subkingdom Viridiplantae
    Infrakingdom Streptophyta
      Superdivision Embryophyta
        Division Tracheophyta
          Subdivision Spermatophytina
            Class Magnoliopsida
              Superorder Lilianae

Order Alismatales
Family Hydrocharitaceae
Genus *Hydrilla*
Species *Hydrilla verticillata* (L. f.)Royle"

"Taxonomic Status: Current Standing: accepted"

Size, Weight, and Age Range

From Jacono et al. (2011):

"Stems grow up to 9 m in length; leaves are 6-20 mm long and 2-4 mm wide."

Environment

From GISD (2011):

"*H. verticillata* is found in freshwater but can tolerate salinities of up to 7% salinity of seawater. It has been found in springs, lakes, marshes, ditches, rivers, and tidal zones. It can grow in relatively low light and CO2 conditions."

From CABI (2015):

"In the tropics, *H. verticillata* is described as tolerant of a wide variety of water conditions, from acidic and oligotrophic to eutrophic or brackish; it thrives on many kinds of pollution and tolerates a great deal of disturbance (Cook and Lüönd, 1982), although increasing salinity appears to limit its dispersal (Rout et al., 1998; Mataraza et al., 1999; Rout and Shaw, 2001). Due to its tolerance of low light conditions (White et al., 1996), it is capable of growing in water up to 7 m deep (Yeo et al., 1984). […] In temperate regions, it grows in alkaline, moderately calcareous, mesotrophic or slightly eutrophic waters (Preston and Croft, 1997), richer in SO4, but generally poorer in Na, K and Cl than those of *Elodea canadensis* (Klosowski and Tomaszewicz, 1997). It also appears to occur more often as scattered stands within more diverse aquatic plant communities (Klosowski and Tomaszewicz, 1997; Balevicius, 1998)."

Climate/Range

From GISD (2011):

"*H. verticillata* prefers temperatures between 20 and 27 degrees Celsius."

From NANSP (2013):

"Optimal growth and survival for the dioecious type is found in warmer climates, while the monoecious form is better suited for more temperate climates with lower temperatures and shorter growing seasons (Ames et al. 1986; Van 1989; Madeira et al. 2000; Netherland 1997; Steward et al. 1987). Dioecious hydrilla typically thrives all year in the warm waters of the southern US, while monoecious hydrilla dies back completely in the winter and acts as a herbaceous perennial (Harlan et al. 1985)."

Distribution Outside the United States

Native

From Jacono et al. (2011):

"The common dioecious type originates from the Indian subcontinent. Historical reports specify the island of Sri Lanka (Schmitz et al. 1991) while random amplified polymorphic DNA (RAPD) analysis point to India's southern mainland (Madeira et al. 1997)."

From CABI (2015):

"It is thought to be native but is relatively rare in Europe (Preston and Croft, 1997), sufficiently so that it is protected in Lithuania (Balevicius, 1998). It occurs in certain areas in Poland and Belarus, and has been found in solitary lakes in Ireland (Preston and Croft, 1997)."

Introduced

From GISD (2011):

"The dioecious and the monoecious plant are now found on every continent except Antarctica."

From Zhuang (2013):

"Introduced:
Austria; Germany; Hungary; Italy; Spain (Canary Is., Spain (mainland)); United States
Present - origin uncertain:
Latvia; Poland"

From CABI (2015):

"On the African continent it occurs around Lake Victoria and Lake Tanganyika in the Rift Valley of East Africa, while it has also been reported from Mozambique and a few isolated places in West Africa and, in 2006, from South Africa."

Means of Introduction Outside the United States

From GISD (2011):

"Floating vegetation/debris: Plant fragments dispersed by river flow.
Ignorant possession: Shipments of water lilies have been found contaminated with Hydrilla.
Pet/aquarium trade: Sold as an aquarium plant."

Short Description

From Jacono et al. (2011):

"Submersed perennial herb. Rooted, with long stems that branch at the surface where growth becomes horizontal and dense mats form. Small, pointed leaves are arranged in whorls of 4 to 8.

Leaves have serrated margins and one or more sharp teeth under the midrib (see Godfrey and Wooten 1979). Development of these features may vary with location, age, and water quality (Kay 1992)."

From CABI (2015):

"*H. verticillata* is a submerged, monoecious or dioecious perennial. Its stems are branched, about 1 mm thick and up to 3 m long; the internodes are 3 to 50 mm long. The sessile leaves are formed in whorls at the nodes; there are 3-8, sometimes up to 12 leaves in a whorl. The leaves are 7-40 mm long, linear to lanceolate, with a conspicuous midrib. They have sharply toothed margins and spines on the vein on the lower side of the leaves; a few teeth may also be formed on this vein. These leaf characteristics are commonly used to distinguish *H. verticillata* from similar submerged plants in the Hydrocharitaceae, like *Egeria* and *Elodea* spp.

The inflorescences are unisexual, arising from spathes situated in the leaf axils, each flower has three sepals and three petals. All six perianth parts are clear or translucent green (the sepals usually slightly reddish).The male spathe is about 1.5 mm long, solitary in the leaf axils, somewhat spiny. The female spathe is about 5 mm long, solitary in the leaf axils. There are three petals, three stamens and three styles. The ovary is cylindrical to narrowly conical and is enclosed in the base of a hypanthium; the style is as long as the hypanthium and there are three stigmas. For further information, see Cook et al. (1974) and Aston (1977).

The fruit is cylindrical, about 7 mm long and 1.5 mm wide. It contains 2-7 oblong-elliptic seeds. For further information, see Cook and Lüönd (1982); Swarbrick et al. (1981); and Yeo et al. (1984)."

Biology

From GISD (2011):

"*H. verticillata* reproduces mostly by asexual vegetative fragmentation (from stem fragments), but it also grows new plants from tubers and underground tubers and reproduces sexually with flowers. One *H. verticillata* tuber can lead to the production of 5,000 new tubers per square m. It spreads faster in flowing water habitats because the fragments are more efficiently dispersed.

Tubers and turions can survive ice cover, drying, ingestion, and regurgitation by waterfowl. Tubers may remain viable in the sediment for several years."

From CABI (2015):

"*H. verticillata* is a submerged plant which is rooted by means of filiform, adventitious roots. The stems, which consist of distinct nodes and internodes, are branched and approach or touch the surface of the water. The internodes tend to elongate in flowing water. The flowers are unisexual, arising from spathes situated in the leaf axils, each flower has three sepals and three petals. All six perianth parts are clear or translucent green (the sepals usually slightly reddish). The ovary is enclosed in the base of a hypanthium, the style is as long as the hypanthium and there are three stigmas. Due to an elongation of the hypanthium, the female flower ascends to the surface of the water. The perianth segments remain closed over the stigmas during this movement and retain a bubble of air above them. The perianth segments open to form a wide funnel which floats with its rim just at the water surface, its walls holding back the water and preventing wetting of the stigmas. The male flower becomes detached from the plant and subsequently rises to the surface of the water where the perianth segments uncurl. The anthers dehisce explosively and spread pollen for some 20 cm around the open flower. Pollination occurs via the air.

H. verticillata spreads horizontally by means of branches which grow over the bottom of a waterbody. Vertical branches and roots are produced at nodes on these runners. Vegetative multiplication is also possible by means of fragmentation, i.e. pieces of branches which have become detached are able to form new, rooted plants, if they come into contact with a favourable substratum. In the USA, hydrilla grows optimally at 20-27°C.

It is capable of surviving conditions unfavourable for growth, by producing two types organ capable of remaining dormant for extended periods. These structures are respectively formed in the axil of a leaf (generally described as axillary turions, turions or green turions) and at the tip of branches which grow into the hydrosoil (generally described as subterranean turions, brown turions or tubers). (Turions can be defined as short, specialized shoots of aquatic plants in which food material is stored and which eventually become detached from the parent plant). The axillary turions are stalked and cylindrical or slightly conical in shape. The subterranean turions are boat-shaped and covered by whorls of tough and fleshy scale leaves. For further information on these turions, see the Description section. As many as 1000 (Pieterse, 1981) to 6000 (USDA, 2011) subterranean turions may be produced per square metre[sic] in one growing season and remain viable for over 4 years (USDA, 2011). In Florida, USA, the average number of subterranean turions varies from 36 to 207 per m^2 and the average number of axillary turions from 5 to 90 per m^2 (Sutton and Portier, 1985). In areas where H. verticillata dies during the winter, the formation of turions occurs mainly in the autumn. Axillary turions are frequently formed on free-floating fragments. The formation of subterranean turions is stimulated by short days (Steward and Van, 1987).

There have been numerous studies into the biology of turion production; the most useful of these is a comprehensive review (Netherland, 1997). Additional studies have dealt with the effects of photperiod on turion development (Steward, 1997; Steward, 2000); factors affecting turion formation (Langeland et al., 1996); the size of turions (Spencer and Ksander, 1995); and the timing of plant development from turions (Spencer and Ksander, 1995; Spencer and Ksander, 1997).

H. verticillata may be either monoecious or dioecious. Its rapid vegetative growth and, as a consequence, the formation of large clones, questions whether strains which produce only male or female flowers are able to reproduce effectively by sexual means. In California and the Gulf States of the USA, and in Europe, there is no seed formation because only female flowers are produced."

From Jacono et al. (2011):

"Freshwater lakes, ponds, rivers, impoundments and canals."

Human Uses

From GISD (2011):

"Pet/aquarium trade: Sold as an aquarium plant."

From Zhuang (2013):

"A dried powder from the plant has be [sic] used as detergent in the treatment of abscesses, burns and wounds. It has been used as an ornamental plant."

Diseases

No OIE reportable diseases were reported.

From CABI (2015):

"Epiphytic cyanobacteria found on hydrilla are thought to be the agents producing a toxin that causes avian vacuolar myelinopathy (AVM) a disease that has killed at least 100 bald eagles (*Haliaeetus leucocephalus*) and thousands of American coots (*Fulica americana*) since 1994 in locations from Texas to North Carolina, USA (Wilde et al., 2005). The incidence of AVM is likely to increase as *H. verticillata* spreads."

Threat to Humans

From CABI (2015):

"It can also result in reduced water flow and stagnant pools which become habitats for mosquito larvae. A case study on the social impact of invasion of a lake in Guatemala by hydrilla has been produced by Binemelis et al. (2007)."

From GISD (2011):

"Apart from interfering with fishing, boat motors can become tangled with them and swimming areas choked. *H. verticillata* often slows or clogs rivers, irrigation ditches, and flood control canals, creating stagnant water that is prime mosquito breeding habitat. Dense stands can even cause flooding, alter water quality by decreasing oxygen levels and increasing pH and water temperature."

3 Impacts of Introductions

From Jacono et al. (2011):

"Once established, hydrilla results in an array of ecosystem disruptions. Changes often begin with its invasion of deep, dark waters where most plants can not grow. Hydrilla grows aggressively and competitively, spreading through shallower areas and forming thick mats in surface waters that block sunlight penetration to native plants below (van Dijk 1985). In the southeast, hydrilla effectively displaces beneficial native vegetation (Bates and Smith 1994) such as wild-celery (*Vallisneria americana*) and coontail (*Ceratophyllum demersum*) (van Dijk 1985; Rizzo et al. 1996).

It has been shown to alter the physical and chemical characteristics of lakes. Colle and Shireman (1980) found sportfish reduced in weight and size when hydrilla occupied the majority of the water column, suggesting that foraging efficiency was reduced as open water space and natural vegetation gradients were lost. Stratification of the water column (Schmitz et al. 1993; Rizzo et al. 1996), decreased oxygen levels (Pesacreta 1988), and fish kills (Rizzo et al. 1996) have been documented. Changes in water chemistry may also be implicated in zooplankton and phytoplankton declines (Schmitz and Osborne 1984; Schmitz et al. 1993).

Hydrilla seriously affects water flow and water use. Infestations in the Mobile Delta are reducing flow in small tidal streams and creating a backwater habitat (J. Zolcynski pers. comm. 1998). Its heavy growth commonly obstructs boating, swimming and fishing in lakes and rivers and blocks the withdrawl of water used for power generation and agricultural irrigation."

From GISD (2011):

"*H. verticillata* competes with native plants by growing to the water surface and forming dense mats that totally exclude sunlight from other plants, which in turn can significantly reduce aquatic plant and animal biodiversity. Large populations of *H. verticillata* may affect fish size and population levels where predatory fish cannot hunt effectively within the thick mats. The dense mats also affect recreational activities. Apart from interfering with fishing, boat motors can become tangled with them and swimming areas choked. *H. verticillata* often slows or clogs rivers, irrigation ditches, and flood control canals, creating stagnant water that is prime mosquito breeding habitat. Dense stands can even cause flooding, alter water quality by decreasing oxygen levels and increasing pH and water temperature."

From CABI (2015):

"*H. verticillata* poses a potential threat to areas outside its native habitats; this has been demonstrated in the USA and the Panama Canal area. As *H. verticillata* is introduced to the New World as an aquarium plant, legislative measures should be taken worldwide to restrain this trade."

"Due to its rapid growth and a highly effective survival strategy, *H. verticillata* is one of the most troublesome aquatic weeds in the world. It rapidly outcompetes other plant species and forms dense masses, which may completely fill the volume of waterbodies. Consequently, the often multifunctional use of canals, rivers and lakes becomes seriously hampered by infestations of the weed.

Harmful effects of *H. verticillata* include: impeding the movement of irrigation and drainage water; hindering navigation and recreational use of the water; physical interference with hydro-electric schemes and fisheries; competition with native plants; impacts on native fauna;

reductions in size and weight of sport fish (Colle and Shireman, 1980 in Jacono et al., 2011); and the creation of favourable habitats for organisms which cause or transmit disease.

Although it is increasingly troublesome in its original habitat in South-East Asia and Australia, particularly in man-made lakes and irrigation canals, its impact is most significant where it is introduced. This applies, in particular, to the USA, where it was introduced in Florida in the early 1950s (Schardt, 1995). The costs of controlling *H. verticillata* in Florida were reported to be $200 per ha per year (Haller, 1995) when an area of more than 12,000 ha were heavily infested in the state. Useful summaries of economic and ecological costs due to *H. verticillata* are provided by the Northeast Aquatic Nuisance Species Panel (for the USA) and by Hofstra and Champion (2006; for New Zealand)."

"Epiphytic cyanobacteria found on hydrilla are thought to be the agents producing a toxin that causes avian vacuolar myelinopathy (AVM) a disease that has killed at least 100 bald eagles (*Haliaeetus leucocephalus*) and thousands of American coots (*Fulica americana*) since 1994 in locations from Texas to North Carolina, USA (Wilde et al., 2005). The incidence of AVM is likely to increase as *H. verticillata* spreads."

4 Global Distribution

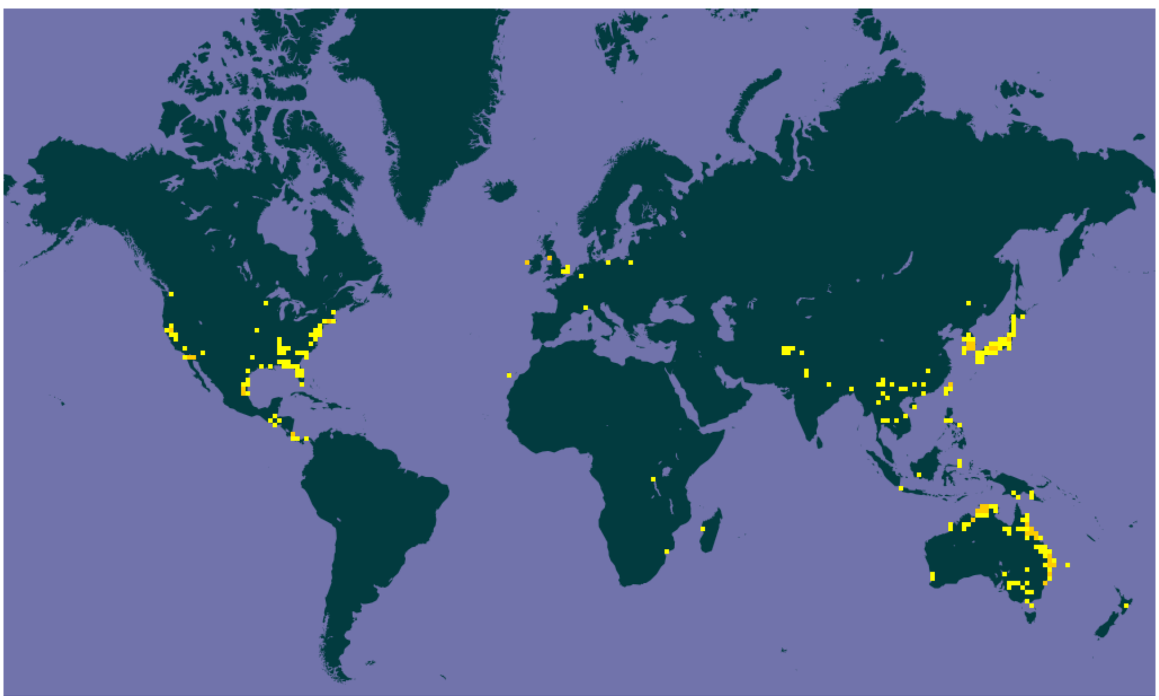

Figure 1. Known global distribution of both biotypes of *Hydrilla verticillata*. Map from GBIF (2013).

5 Distribution Within the United States

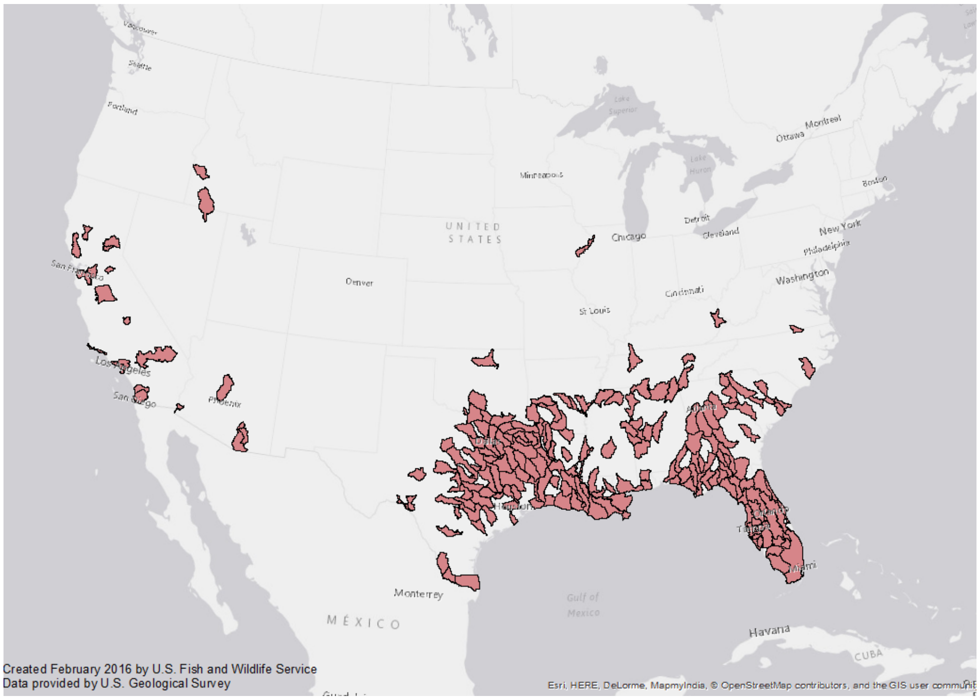

Figure 2. Distribution of dioecious *Hydrilla verticillata* by HUC 8 in the United States. Map developed by U.S. Fish and Wildlife Service with data from U.S. Geological Survey.

6 Climate Matching

Summary of Climate Matching Analysis 1: Both Biotypes

The climate match for *Hydrilla verticillata*, both biotypes, was high for most of the continental United States. The Climate 6 score (Sanders et al. 2014; 16 climate variables; Euclidean distance) for the Continental U.S. was 0.841, high, and all states had individually high climate matches.

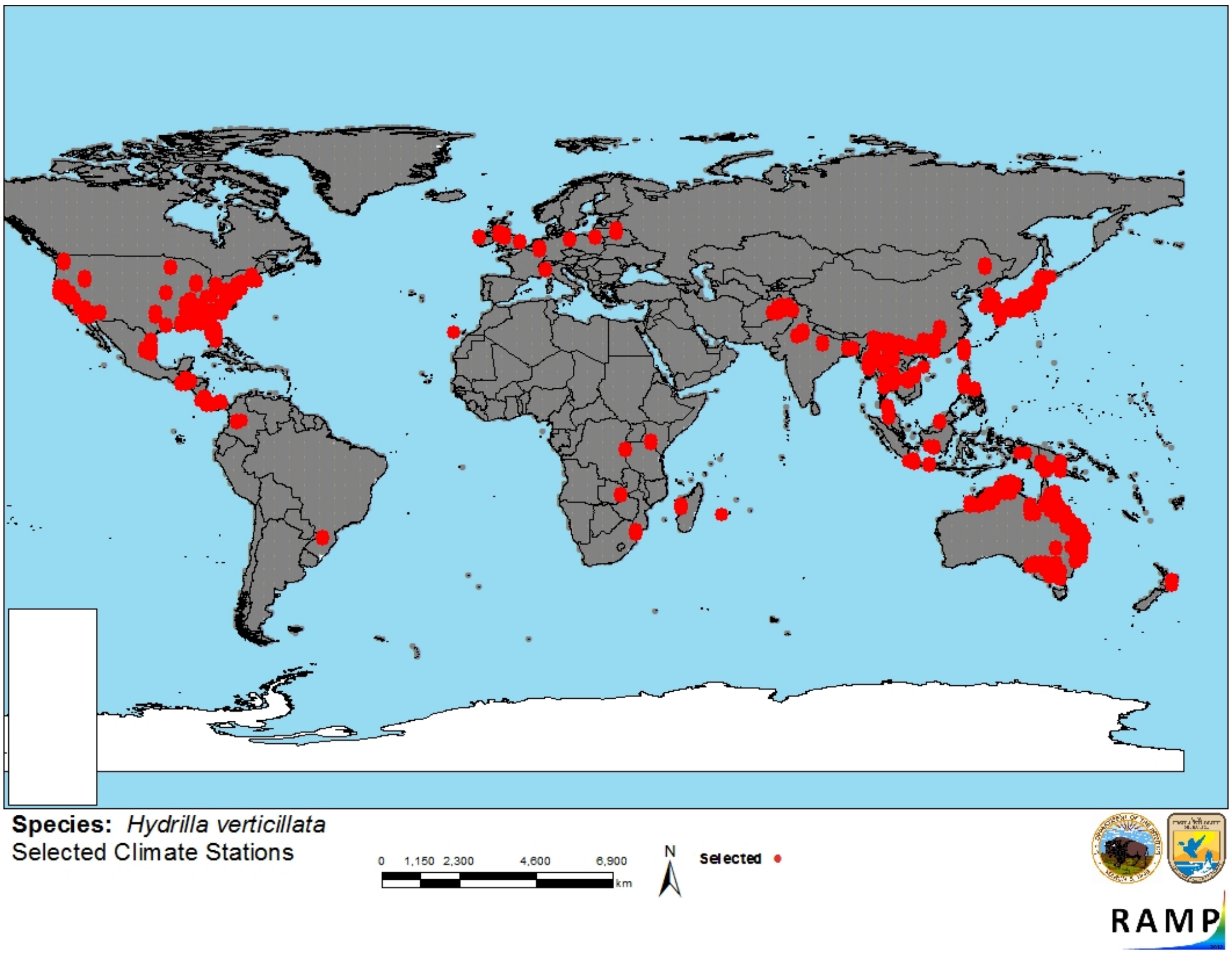

Figure 3. RAMP (Sanders et al. 2014) source map showing weather stations selected as source locations (red) and non-source locations (grey) for *Hydrilla verticillata* climate matching. Source locations represent both biotypes of hydrilla (GBIF 2013).

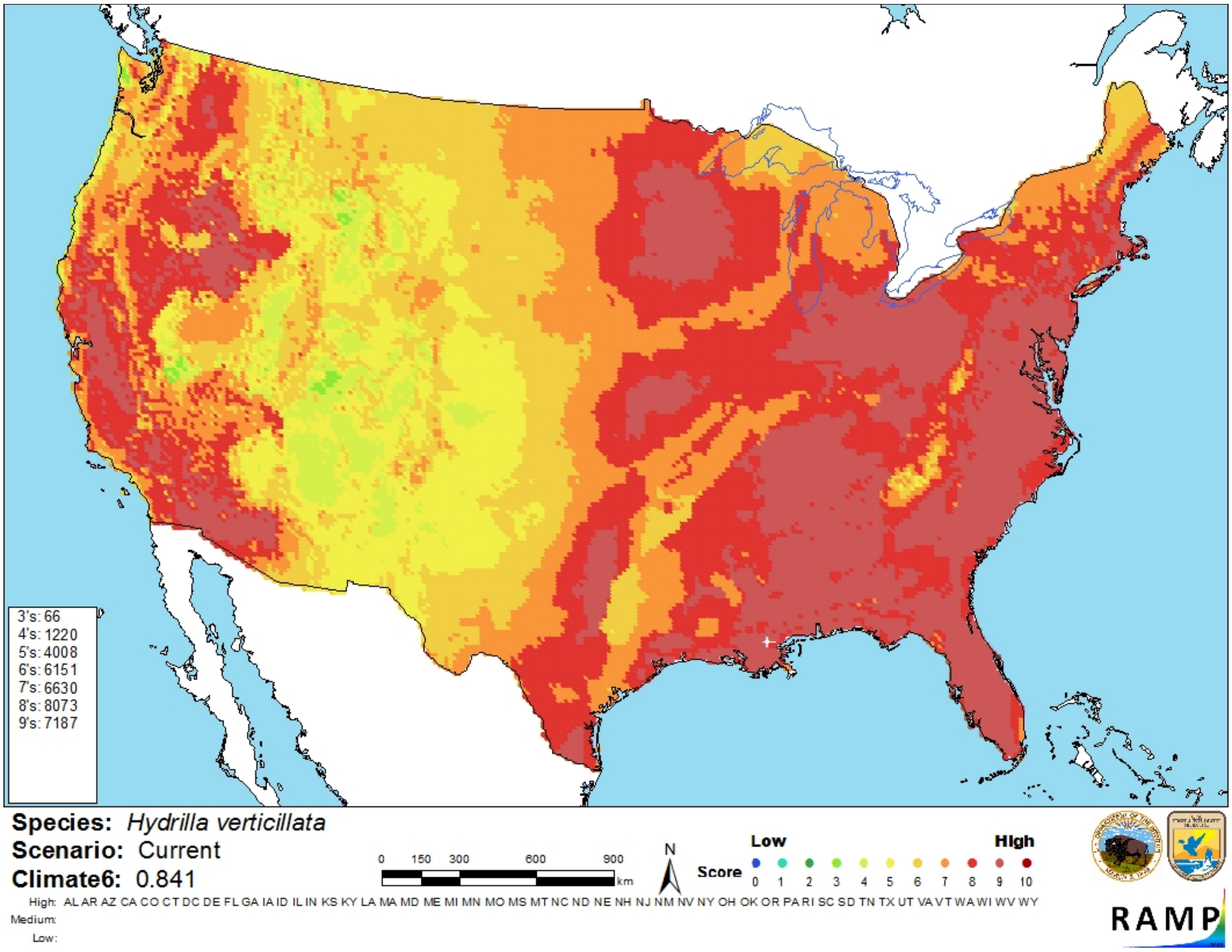

Figure 4. Map from RAMP (Sanders et al. 2014) of a current climate match for *Hydrilla verticillata* in the contiguous United States based on source locations reported by Jacono et al. (2011) and GBIF (2013). 0 = Lowest match, 10 = Highest match.

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

Future Climates for Both Biotypes

Climate matches for *Hydrilla verticillata* using Representative Concentration Pathways (RCPs) for predicting future climates based on human produced greenhouse gases (IPCC 2014). RCP2.6 predicts a scenario where emission of greenhouse gasses is reduced, RCP4.5 predicts continued levels of emission from present, and RCP8.5 predicts a future climate based on rising levels of emissions. Climate matches for each RCP were modeled at two generational time steps, 2050 and 2070.

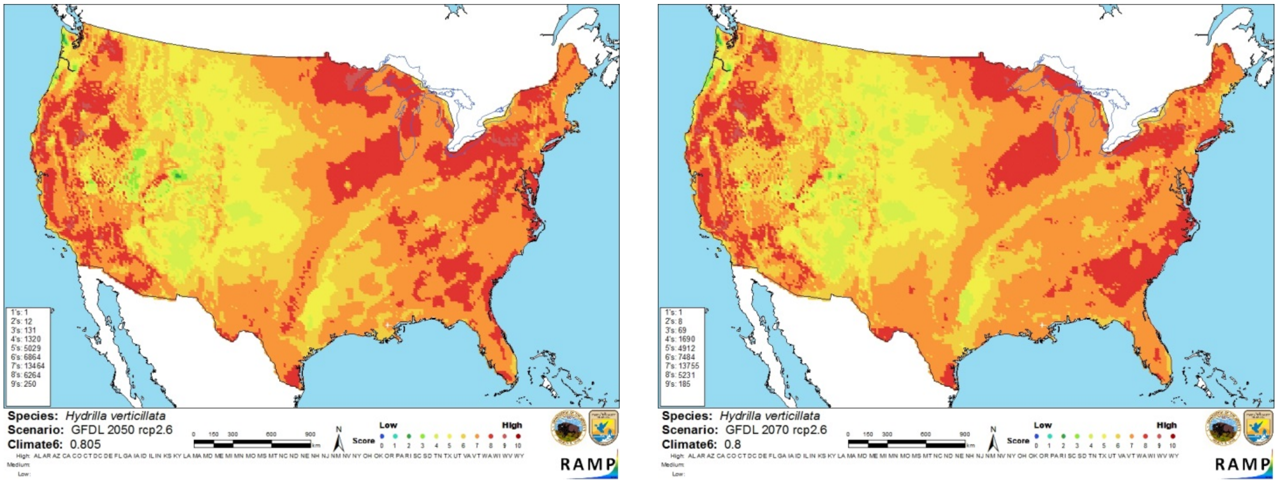

Figure 5. RAMP (Sanders et al. 2014) climate match using RCP2.6 at the 2050 and 2070 time steps.

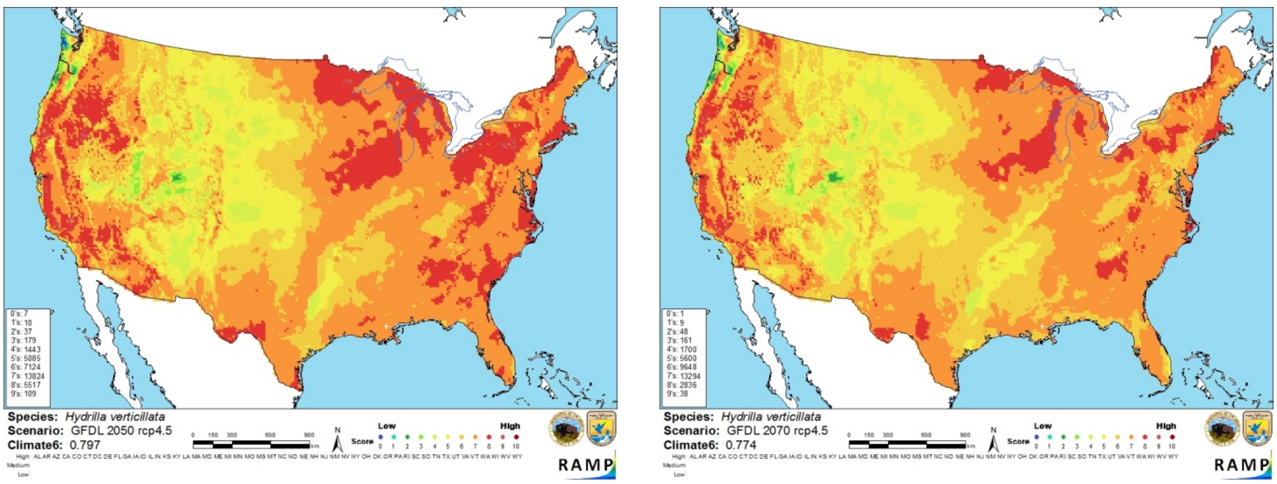

Figure 6. RAMP (Sanders et al. 2014) climate match using RCP4.5 at the 2050 and 2070 time steps.

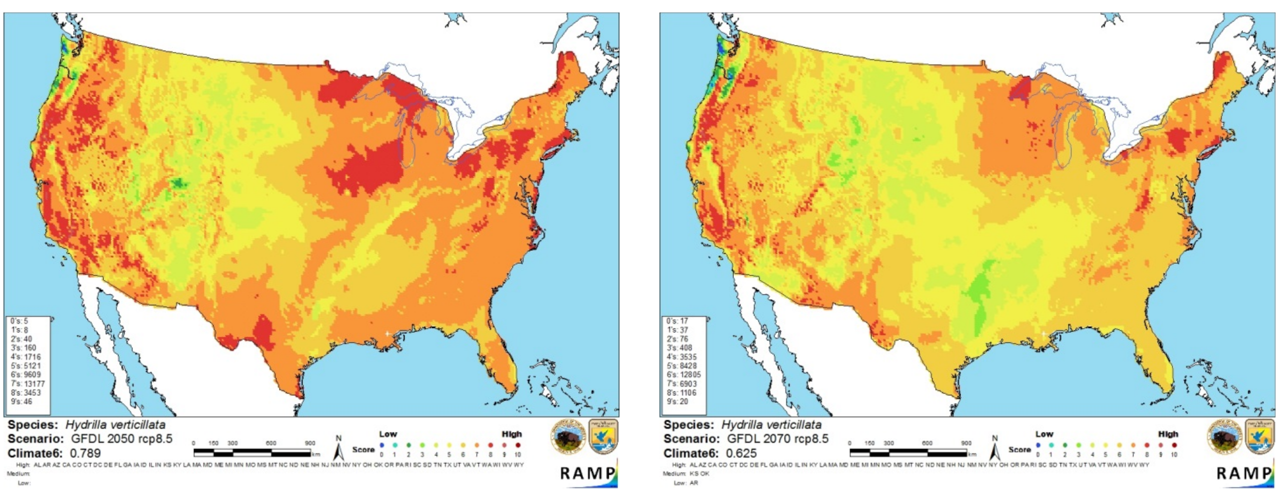

Figure 7. RAMP (Sanders et al. 2014) climate match using RCP8.5 at the 2050 and 2070 time steps.

Summary of Climate Matching Analysis 2: Dioecious Distribution in the United States

The climate match for the dioecious biotype of *Hydrilla verticillata* was high mainly in the eastern United States and select portions of the West Coast. The Climate 6 score (Sanders et al. 2014; 16 climate variables; Euclidean distance) for the Continental U.S. was 0.708, high, and for Alabama, Arizona, Arkansas, California, Connecticut, Delaware, Florida, Georgia, Idaho, Illinois, Indiana, Iowa, Kansas, Kentucky, Louisiana, Maryland, Massachusetts, Michigan, Minnesota, Mississippi, Missouri, Nebraska, Nevada, New Jersey, New Mexico, New York, North Carolina, Ohio, Oklahoma, Oregon, Pennsylvania, Rhode Island, South Carolina, South Dakota, Tennessee, Texas, Utah, Vermont, Virginia, Washington, Washington D.C., West Virginia, and Wisconsin.

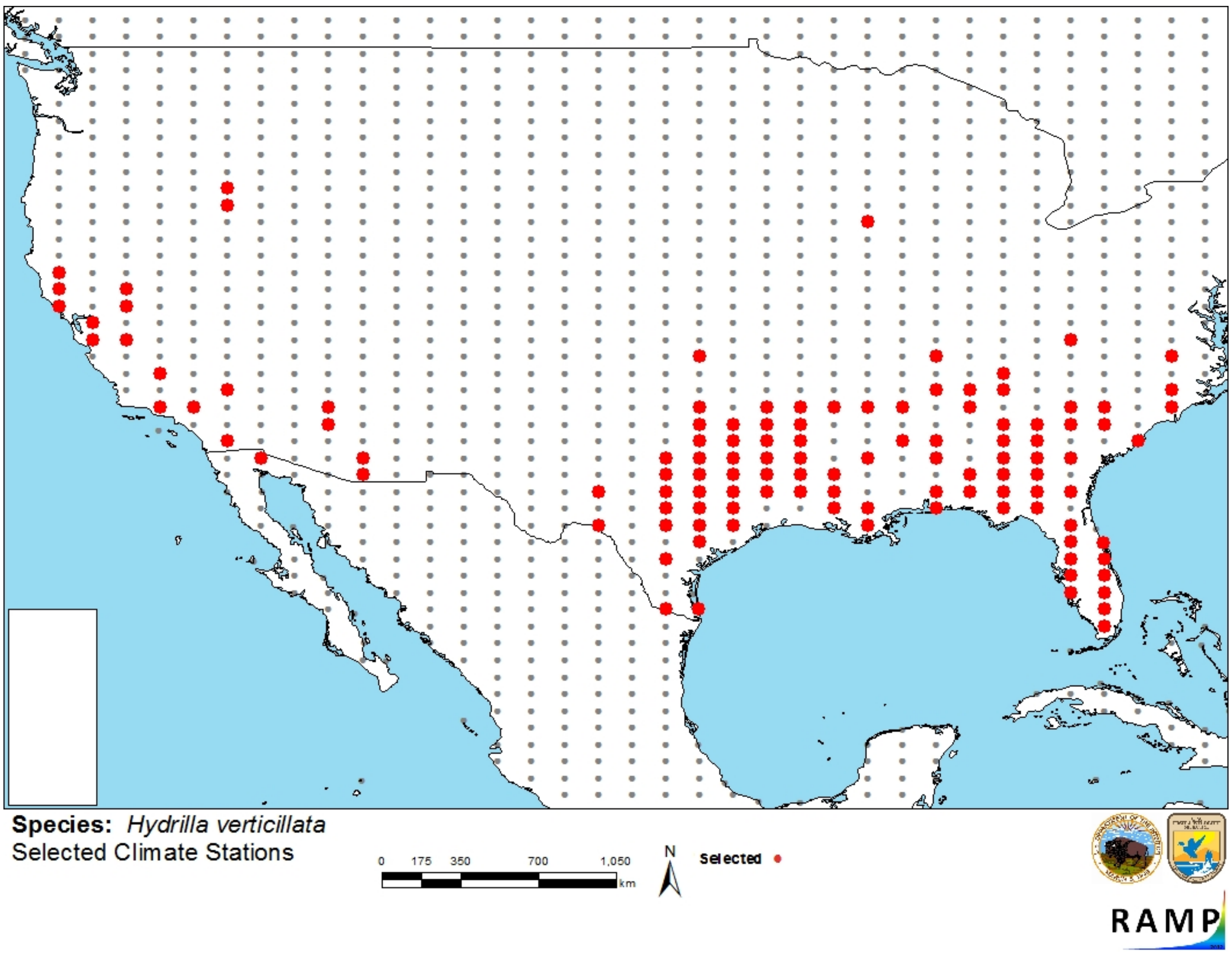

Figure 8. RAMP (Sanders et al. 2014) source map showing weather stations selected as source locations (red) and non-source locations (grey) for dioecious *Hydrilla verticillata* climate matching. Source locations from U.S. Geological Survey.

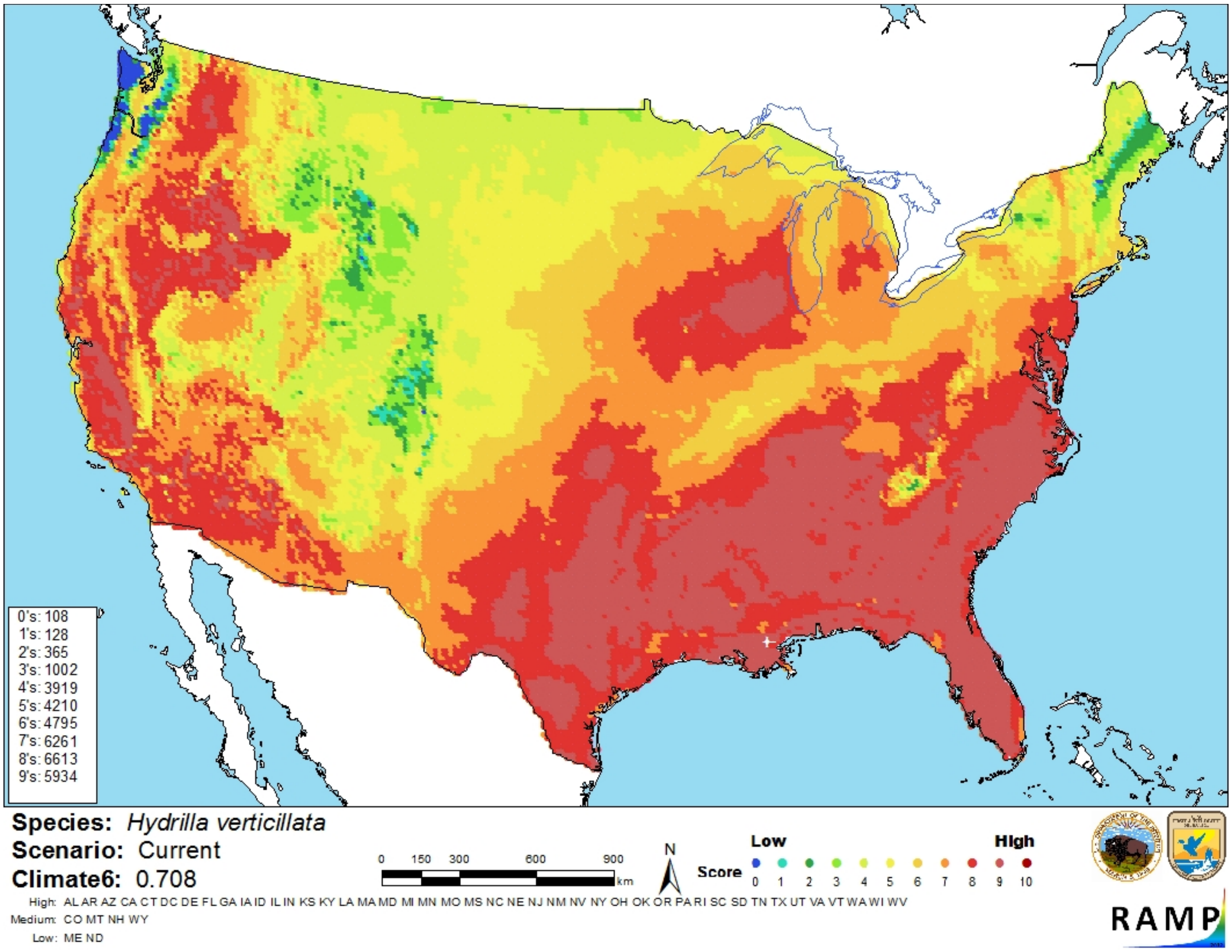

Figure 9. Map from RAMP (Sanders et al. 2014) of a current climate match for dioecious *Hydrilla verticillata* in the continental United States based on source locations from U.S. Geological Survey. 0 = Lowest match, 10 = Highest match.

Future Climates for the Dioecious Biotype

Climate matches for dioecious *Hydrilla verticillata* using Representative Concentration Pathways (RCPs) for predicting future climates based on human produced greenhouse gases (IPCC 2014). RCP2.6 predicts a scenario where emission of greenhouse gasses is reduced, RCP4.5 predicts continued levels of emission from present, and RCP8.5 predicts a future climate based on rising levels of emissions. Climate matches for each RCP were modeled at two generational time steps, 2050 and 2070.

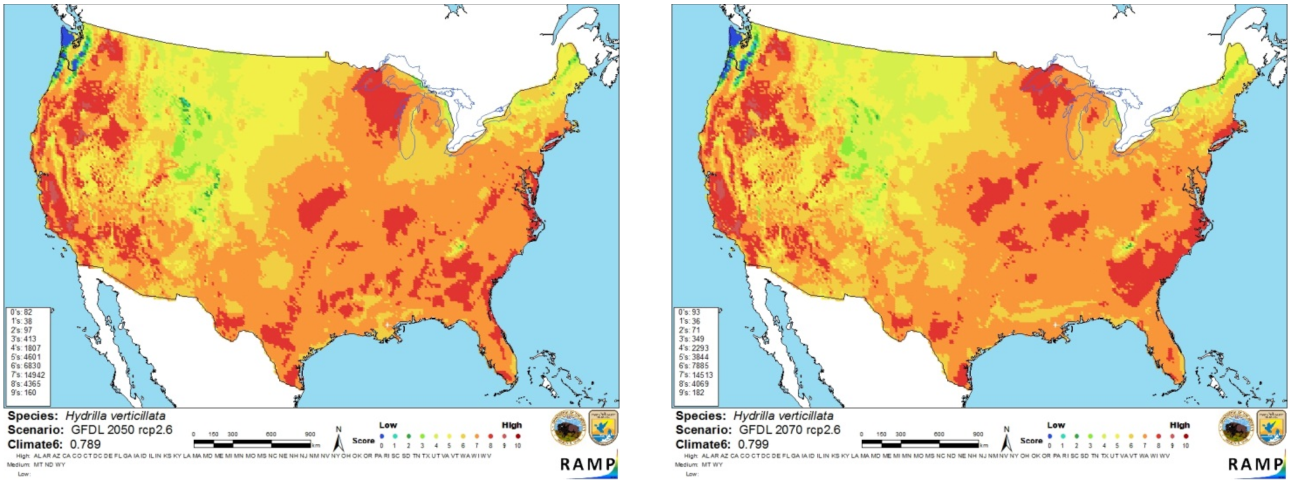

Figure 10. RAMP (Sanders et al. 2014) climate match using RCP2.6 at the 2050 and 2070 time steps. Climate 6 scores remained high.

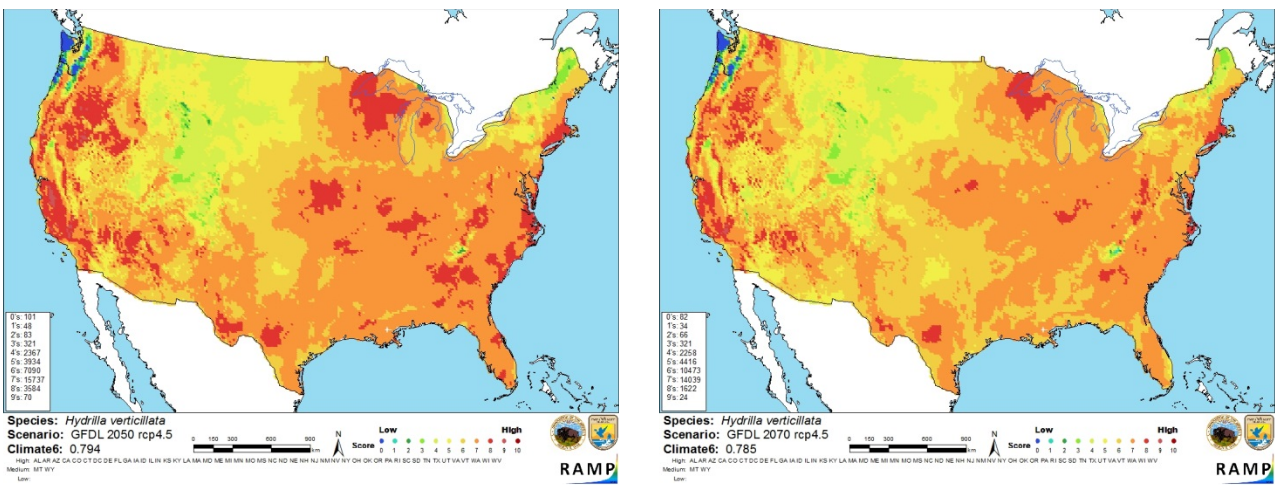

Figure 11. RAMP (Sanders et al. 2014) climate match using RCP4.5 at the 2050 and 2070 time steps. Climate 6 scores remained high.

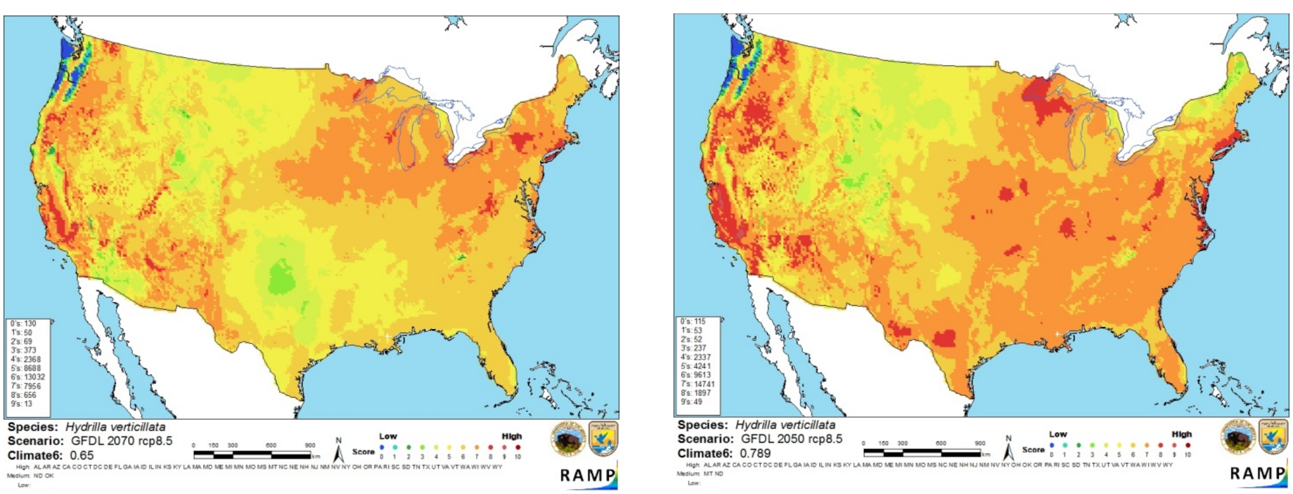

Figure 12. RAMP (Sanders et al. 2014) climate match using RCP8.5 at the 2050 and 2070 time steps. Climate 6 scores remained high.

7 Certainty of Assessment

The certainty of this assessment is high. There is a wealth of information available about *Hydrilla verticillata* and its impacts. There is some information about the distribution of the two different biotypes in the continental U.S.; however distributions of the different biotypes around the world were not available at the time of this assessment. There is a possibility that the climate match would change if a more specific global distribution of the biotypes was known. The information provided above states that the two biotypes have different optimal temperatures. It is the author's opinion that any change in source locations for the climate match would still result in a high climate match for dioecious *Hydrilla verticillata* in the continental United States.

8 Risk Assessment

Summary of Risk to the Contiguous United States

The history of invasiveness is high. *Hydrilla verticillata* is found on virtually every continent with adverse impacts. The climate match is high for the match using the distribution of both biotypes as source locations and the match using just the dioecious biotype distribution as source locations. The climate match for all future scenarios for both sets of source points resulted in a high matches. The certainty of assessment is high. The overall risk assessment 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 No additional remarks.**
- **Overall Risk Assessment Category: High**

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Note: The following references were accessed for this ERSS. References cited within quoted text but not accessed are included below in Section 10.

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Note: The following references are cited within quoted text within this ERSS, but were not accessed for its preparation. They are included here to provide the reader with more information.

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