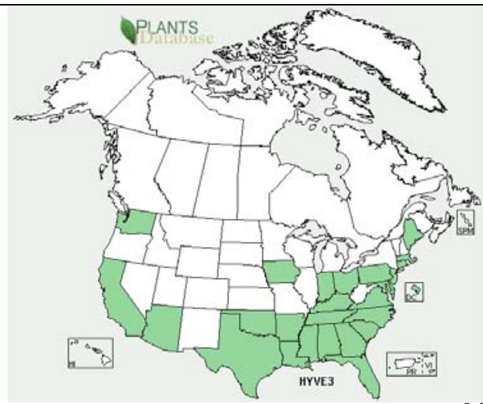
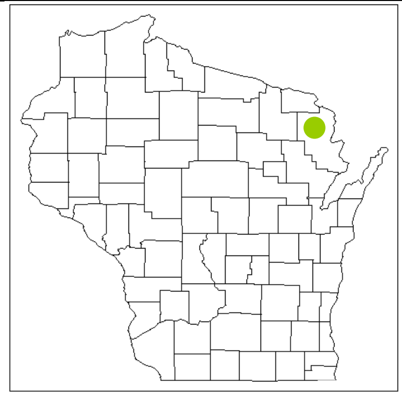
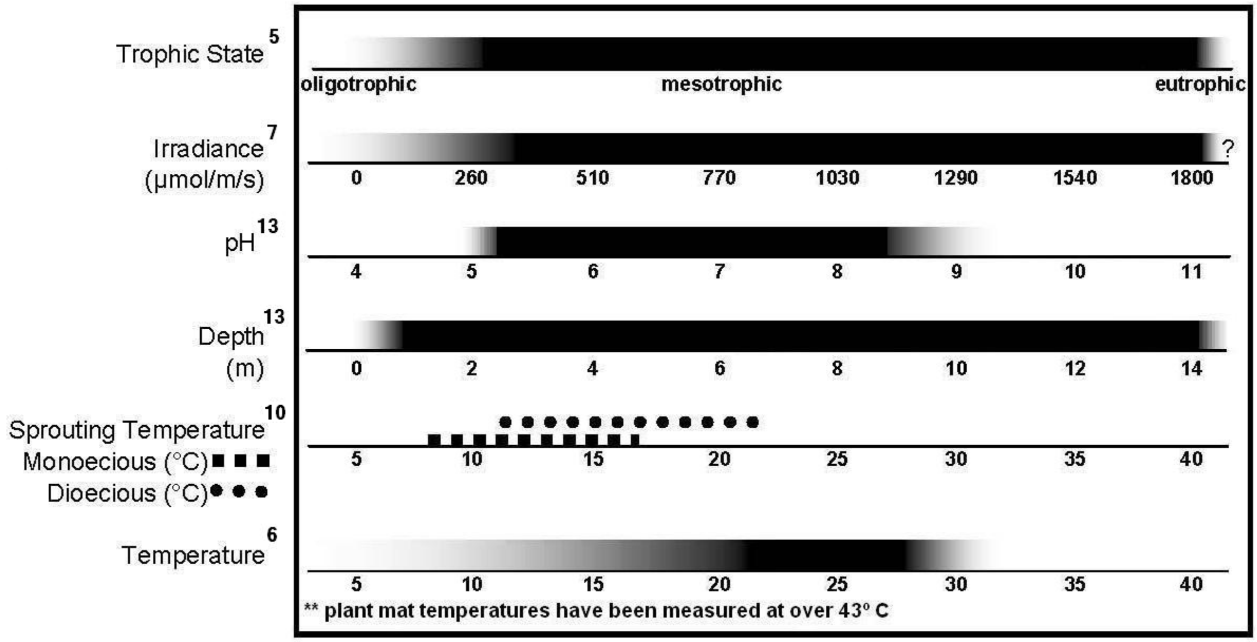
Aquatic Plant		Hydrilla
I. Current Status and Distribution		***Hydrilla verticillata***
a. Range	**Global/Continental**	**Wisconsin**
Native Range Europe, Africa, India, Southeast Asia, Australia[1]	 *Figure 1: U.S and Canada Distribution Map*[2,3,32]	 *Figure 2: WI Distribution Map*
Abundance/Range Widespread: Locally Abundant: Sparse:	 Florida Disturbed, enriched low diversity lakes May be less competitive in diverse lakes[3]	 Not widespread Undocumented Recently discovered and eradicated in a small private pond in Marinette Co., Wisconsin[3]
Range Expansion Date Introduced: Rate of Spread:	 South Florida, 1960[4] Very rapid; relative growth rate of 450 mg/g/week[(5)]	 Likely present since 2005 Widespread in pond
Density Risk of Monoculture: Facilitated By:	 Very high Disturbance, nutrient enrichment[5], low diversity[3]	 High Longer days may be advantageous for tuber production, but short growth window may mean axillary spread is more important[3]
b. Habitat	Almost any freshwater system[6]; brackish waters[1,6]	
Tolerance	Chart of tolerances: Increasingly dark color indicates increasingly optimal range	



Preferences	Enriched, disturbed, low diversity systems; broad environmental tolerances; low CO_2 saturation point[11]; high pH and alkalinity[13]
c. Regulation	
Noxious/Regulated[2]:	Federal Noxious Weed List; AL, AZ, CA, CO, CT, FL, MA, ME, MS, NV, NM, NC, OR, SC, TX, VT, WA
Minnesota Regulations:	*Prohibited*; One may not possess, import, purchase, propagate, or transport
Michigan Regulations:	*Prohibited*; One may not knowingly possess or introduce
Washington Regulations:	*Primary Species of Concern*; Class A Noxious Weed; State Wetland and Aquatic or Noxious Weed Quarantine List
II. Establishment Potential and Life History Traits	
a. Life History	Submersed herbaceous monocotyledonous perennial[6]
Fecundity	Very high; plants can grow several inches in one day[3]; single tuber can produce more than 6,000 new tubers per m^2 [(6)]
Reproduction	Asexual in dioecious strain, sexual and asexual in monoecious strain[3]; monoecious strain north of Carolinas, dioecious form in south[3]
Importance of Seeds:	Seed production can facilitate long term survival[3,12,13]
Vegetative:	Very important and prolific via axillary and subterranean turions[3,6,13]; plant also spreads via fragmentation[13]; tuber longevity approximately 4 years[14]
Hybridization	Undocumented
Overwintering	
Winter Tolerance:	Tolerant[6]
Phenology:	Emerges early relative to native plants (monoecious tubers sprout mid-February, dioecious sprout mid-August)[10]
b. Establishment	
Climate	
Weather:	Prefers environmental disturbance
Wisconsin-Adapted:	Not restricted by climate[3,4]; grows up to 53°N latitude (approximate to Canada/United States border)[4,6]
Climate Change:	Likely to facilitate growth and distribution

Taxonomic Similarity	
Wisconsin Natives:	Medium; family Hydrocharitaceae
Other US Exotics:	Medium; family Hydrocharitaceae
Competition	
Natural Predators:	Several insects[33]
Natural Pathogens:	Undocumented
Competitive Strategy:	Low light compensation and saturation points[6]; prolific vegetative spread by axillary and subterranean tubers[15]; dense canopy[16]; 80% of biomass in upper 2 feet of water[3]; C4-like photosynthesis tolerates harsh conditions imposed by plant itself[11]; photosynthetic rate is affected by pH[13]; in dense beds, 95% of light is shaded within 1 foot of the water surface[3]; requires lower irradiance for half-maximum photosynthetic rate than *Ceratophyllum demersum* and *Myriophyllum spicatum* [9]
Known Interactions:	Reported to dominate communities formerly consisting of *Potamogeton illinoensis*, *Vallisneria americana*, *Najas* spp., *Ceratophyllum demersum*, *Myriophyllum spicatum*, and *Egeria densa*[3,6,13]*;* unknown competitive ability in diverse northern systems[3]
Reproduction	
Rate of Spread:	High
Adaptive Strategies:	Prolific production of long-lived turions[15]; high rate of vertical or lateral expansion[3]
Timeframe	Has rapidly replaced indigenous submerged plants in constructed wetlands[13]

c. Dispersal

Intentional:	Highly valued for fish habitat[3]; aquarium trade[6]
Unintentional:	Wind, water, animals, humans
Propagule Pressure:	High; fragments easily accidentally introduced

Figure 3: Courtesy of Leslie Mehrhof;, Invasive Plant Atlas of New England [17]
Figure 4: Courtesy of David Sutton; University of Florida[18]

III. Damage Potential

a. Ecosystem Impacts

Composition	Displaces native plant species[4]; reduces biodiversity[13]; destroys native fish and wildlife habitat[13]; highly associated with non-native catfish *Hoplosternum littorale*[19]; native seed bank lower in diversity and density under *Hydrilla verticillata* canopies[8]

Structure	Very high tendency to form inhospitable monocultures; changes habitat architecture; fish and invertebrates respond to changes in architecture and conditions; limits sportfish weight and size[20]; prevents re-suspension of sediments[21]
Function	Decreased light penetration[3,5]; changes in diet and food consumption of largemouth bass[8]
Allelopathic Effects	Undocumented
Keystone Species	Undocumented
Ecosystem Engineer	Yes; dense canopy decreases light penetration and alters food web[8]
Sustainability	Undocumented
Biodiversity	Decreases[13]
Biotic Effects	Decrease native species diversity and changes fish community structure
Abiotic Effects	Dissolved inorganic carbon depletion and dissolved oxygen supersaturation in mats[11]
Benefits	Increases clarity, provides some habitat for invertebrates and fish[3,13]
b. Socio-Economic Effects	
Benefits Caveats	Wastewater treatment[22]; lead and fluoride removal[23,24]; aquarium plant; clears water[3,13]; valued by some in the fishing community[3] Risk of release and population expansion; risk of intentional introduction[3]
Impacts of Restriction	Increase in monitoring, education, and research costs
Negatives	Dense stands interfere with drainage, irrigation, navigation, recreation[6,13]; aesthetically devalued; compromises ecosystem
Expectations	More negative impacts can be expected in impacted, light-limited, low diversity systems[3,5]
Cost of Impacts	Decreased recreational and aesthetic value; decline in ecological integrity; increased research expenses
"Eradication" Cost	Very expensive, perhaps impossible without drawdown/sediment removal
IV. Control and Prevention	
a. Detection	
Crypsis: Benefits of Early Response:	High; confused with *Elodea canadensis*[3,6], *Egeria densa*[4,6] Very high; early response is crucial to minimize long-lived turion set[25]
b. Control	
Management Goal 1 Tool: Caveat: Cost: Efficacy, Time Frame:	Eradication/Nuisance relief Chemical herbicide - fluridone, endothall, diquat[25,26] Two- to six- fold higher fluridone-resistant strains documented in 20 Florida lakes[27]; mass vegetation die off and nutrient release[13] Florida spends over $20 million annually; eradication may be impossible[25] Must vary approach[25]; 7-17 years of annual all-out effort just for control in California; can be controlled in 3-6 years with drawdown and sediment replacement[26]
Management Goal 2 Tool: Caveat: Cost: Efficacy, Time Frame:	Nuisance relief Mechanical harvest Harvesting causes fragmentation which increases distribution and density[6]; negative impacts on non-target species $1.5 million/1000 acres/year[28] Must harvest three times per year[28]

Tool:	Biological control: Dipteran *Hydrellia pakistanae*[25], 2 bacterial strains, 42 fungal isolates[29], triploid grass carp[30,31]
Caveat:	Agents are not native; non-target plant species may be negatively impacted
Cost:	Varies
Efficacy, Time Frame:	Undocumented
Tool:	Drawdown
Caveat:	Only feasible in systems where water level can be artificially altered; undocumented effects on other species
Cost:	Undocumented
Efficacy, Time Frame:	May help in exposing plants to die and decompose; sediment should also be removed
Minimum Effort	Minimize plant biomass immediately
Documented Cost	$174 million in Florida and $18 million in California to date[25]
Monitoring	Difficult and expensive because of crypsis

---

[1] US Forest Service, Pacific Island Ecosystems at Risk (PIER). 2010. *Hydrilla verticillata* (L.) Hoyle, Hydrocharitaceae. Retrieved December 22, 2010 from: http://www.hear.org/pier/species/hydrilla_verticillata.htm

[2] United States Department of Agriculture, Natural Resource Conservation Service. 2010. The PLANTS Database. National Plant Data Center, Baton Rouge, LA, USA. Retrieved December 22, 2010 from: http://plants.usda.gov/java/profile?symbol=HYVE3

[3] Netherland, M. 2007. Hydrilla as a competitor in the upper midwest: strengths and weaknesses. Midwest Aquatic Plant Management Society 27th Annual Conference; 2007 March 4; Milwaukee, Wisconsin. Midwest Aquatic Plant Management Society.

[4] Steward, K.K., T.K. Van, V. Carter and A.H. Pieterse. 1984. Hydrilla invades Washington D.C. and the Potomac. American Journal of Botany 71(1):162-163.

[5] Van, T.K., G.S. Wheeler and T.D. Center. 1999. Competition between *Hydrilla verticillata* and *Vallisneria americana* as influenced by soil fertility. Aquatic Botany 62(4):225-233.

[6] Ramey, V. 2001. *Hydrilla verticillata*. Center for Aquatic and Invasive Plants, University of Florida. Retrieved December 22, 2010 from: http://plants.ifas.ufl.edu/node/183

[7] White, A., J.B. Reiskind and G. Bowes. 1996. Dissolved inorganic carbon influences the photosynthetic responses of *Hydrilla* to photoinhibitory conditions. Aquatic Botany 53(1-2):3-13.

[8] Sammons, S.M. and M.J. Maceina. 2006. Changes in diet and food consumption of largemouth bass following large-scale hydrilla reduction in Lake Seminole, Georgia. Hydrobiologia 560(1):109-120.

[9] Van, T.K., W.T. Haller and G. Bowes. 1976. Comparison of the photosynthetic characteristics of three submersed aquatic plants. Plant Physiology 58:761-768.

[10] Spencer, D.F., G.G. Ksander, J.D. Madsen and C.S. Owens. 2000. Emergence of vegetative propagules of *Potamogeton nodosus*, *Potamogeton pectinatus*, *Vallisneria americana*, and *Hydrilla verticillata* based on accumulated degree-days. Aquatic Botany 67(3):237-249.

[11] Spencer, W.E., J. Teeri and R.G. Wetzel. 1994. Acclimation of photosynthetic phenotype to environmental heterogeneity. Ecology 75(2):301-314.

[12] Lal, C. and B. Gopal. 1993. Production and germination of seeds in *Hydrilla verticillata*. Aquatic Botany 45(2-3):257-261.

[13] Gu, B. 2006. Environmental conditions and phosphorus removal in Florida lakes and wetlands inhabited by *Hydrilla verticillata* (Royle): implications for invasive species management. Biological Invasions 8(7):1569-1578.

[14] Van, T.K. and K.K. Steward. 1990. Longevity of monoecious hydrilla propagules. Journal of Aquatic Plant Management 28:74-76.

[15] Spencer, D.F. and G.G. Ksander. 2004. Comparative growth and propagule production by *Hydrilla verticillata* grown from axillary turions or subterranean turions. Hydrobiologia 222(2):153-158.

[16] Best, E.P.H., C.P. Buzzelli, S.M. Bartell, R.L. Wetzel, W.A. Boyd, R.D. Doyle and K.R. Campbell. 2001. Modeling submersed macrophyte growth in relation to underwater light climate: modeling approaches and application potential. Hydrobiologia 444(1-3):43-70.

[17] Mehrhoff, L. 2002. Invasive Plants of New England Database. Retrieved December 22, 2010, from: http://nbii-nin.ciesin.columbia.edu/ipane/icat/browse.do?specieId=22

[18] Sutton, D. 1997. *Hydrilla verticillata* turions. Retrieved December 22, 2010 from: http://keys.lucidcentral.org/keys/aquariumplants2/aquarium_&_pond_plants_of_the_world/key/aquarium_&_pond_plants/media/html/Image_pages/hydrilla_images.html

[19] Nico, L.G. and A.M. Muench. 2004. Nests and nest habitats of the invasive catfish *Hoplosternum littorale* in Lake Tohopekaliga, Florida: a novel association with non-native *Hydrilla verticillata*. Southeastern Naturalist 3(3):451-466.

[20] Colle, D.E. and J.V. Shireman. 1980. Coefficients of condition for largemouth bass, bluegill and redear sunfish in hydrilla-infested lakes. Transactions of the American Fisheries Society 109:521-531.

[21] Brenner, M., L.W. Keenan, S.J. Miller and C.L. Schelske. 1999. Spatial and temporal patterns of sediment and nutrient accumulation in shallow lakes of the Upper St. Johns River Basin, Florida. Wetlands Ecology and Management 6(4):221-240.

[22] Tanaka, N., K.B. Jinadasa, D.R. Werellagama, M.I. Mowjood and W.J. Ng. 2006. Constructed tropical wetlands with integrated submergent-emergent plants for sustainable water quality management. Journal of Environmental Science and Health. Part A-Toxic/Hazardous Substances and Environmental Engineering 41(10):2221-2236.

[23] Gallardo-Williams, M.T., V.A. Whalen, R.F. Benson and D.F. Martin. 2002. Accumulation and retention of lead by cattail (*Typha domingensis*), Hydrilla (*Hydrilla verticillata*), and Duckweed (*Lemna obscura*). Journal of Environmental Science and Health. Part A-Toxic/Hazardous Substances and Environmental Engineering A37(8):1399-1408.

[24] Sinha, S., R. Saxena and S. Singh. 2000. Fluoride removal from water by *Hydrilla verticillata* (l.f.) Royle and its toxic effects. Bulletin of Environmental Contamination and Toxicology 65(5):683-690.

[25] Koschnick, T. 2007. You thought milfoil was tough: options for and challenges associated with Hydrilla control. Midwest Aquatic Plant Management Society 27th Annual Conference; 2007 March 4; Milwaukee, Wisconsin. Midwest Aquatic Plant Management Society.

[26] Akers, P. 2007. California Hydrilla eradication program. In Midwest Aquatic Plant Management Society 27th Annual Conference; 2007 March 4; Milwaukee, Wisconsin. Midwest Aquatic Plant Management Society.

[27] Michel, A., R.S. Arias, B.E. Scheffler, S.O. Duke, M. Netherland and F.E. Dayan. 2004. Somatic mutation-mediated evolution of herbicide resistance in the nonindigenous invasive plant hydrilla (*Hydrilla verticillata*). Molecular Ecology 13(10):3229-3237.

[28] Schardt, J. 2007. Florida Hydrilla management program. Midwest Aquatic Plant Management Society 27th Annual Conference; 2007 March 4; Milwaukee, Wisconsin. Midwest Aquatic Plant Management Society.

[29] Shabana, Y.M., J.P. Cuda and R. Charudattan. 2003. Evaluation of pathogens as potential biocontrol agents of hydrilla. Journal of Phytopathology 151(11-12):607-613.

[30] Yoon, C.K. 2003. Texans call in a monster fish to tame a monster weed. The New York Times. April 8, 2003: Sect. F, Col. 2. Pg. 3.

[31] Sutton, D.L. 1996. Depletion of turions and tubers of *Hydrilla verticillata* in the North New River Canal, Florida. Aquatic Botany 53(1-2):121-130.

[32] Jacono, C.C. and M.M. Richerson. 2003. *Hydrilla verticillata* (L.f.) Royle. Unites States Geological Survey Nonindigenous Aquatic Species Database, Gainesville, FL. Retrieved November 19, 2010 from: http://nas.er.usgs.gov/taxgroup/plants/docs/hy_verti.html

[33] Overholt, W.A., R.S. Copeland, D.W. Williams, F. Wanda, B. Nzigidahera, E. Nkubaye and J. P. Cuda. 2007. Foreign exploration for natural enemies of *Hydrilla verticillata* in East Africa. University of Florida, Biological Control Research & Containment Laboratory. Retrieved December 22, 2010 from: http://bcrcl.ifas.ufl.edu/Invasive_Weeds/Hydrilla/hydrilla%20DEP%20June%202007%20report%20-%20for%20all%20agencies.pdf