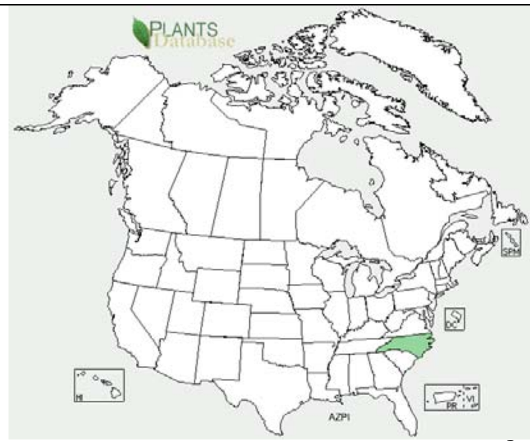
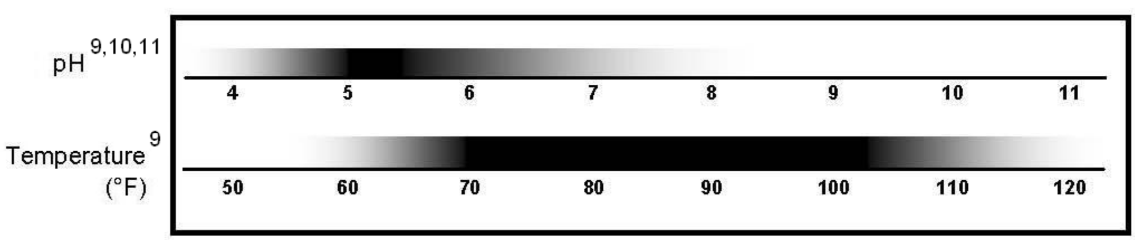
Aquatic Plant		Feathered waterfern; Ferny azolla; Water velvet; Mosquito fern
I. Current Status and Distribution		***Azolla pinnata***
a. Range	**Global/Continental**	**Wisconsin**
Native Range Africa, Madagascar, India, China, Southeast Asia, Japan, Malaysia, Philippines, Vietnam, New Guinea, Australia[1,2]	 *Figure 1: U.S and Canada Distribution Map*[3] *Also reported from Arizona and Florida*[4,5]	Not recorded in Wisconsin[6]
Abundance/Range Widespread: Locally Abundant: Sparse:	Undocumented New Zealand[5] Found on private land in Arizona[4]; found in a drainage canal in Florida[5]; found in North Carolina and Idaho water garden stores[5,7]	Not applicable Not applicable Not applicable
Range Expansion Date Introduced: Rate of Spread:	North Carolina, 1999[(7)] Not known to be spreading in the U.S.; capable of doubling population in 3-5 days[8]	Not applicable Not applicable
Density Risk of Monoculture: Facilitated By:	High; can completely cover the water surface[1,9] High water temperature, acidic water, high nutrient levels[1,9]	Unknown Unknown
b. Habitat	Ponds, backwaters, lakes, reservoirs, wetlands, swamps, rivers, ditches, rice paddy fields, drainage canals, moist soil, and low energy systems[1,7]	
Tolerance	Chart of tolerances: increasingly dark color indicates increasingly optimal range	
 		
Preferences	Acidic conditions, relative humidity greater than 60%, high water temperatures, high phosphorus[9,12]	

c. Regulation	
Noxious/Regulated[3]:	Federal Noxious Weed List; AL, CA, MA, NC, OK[2], OR, SC, VT
Minnesota Regulations:	*Prohibited*; One may not possess, import, purchase, propagate, or transport
Michigan Regulations:	*Not regulated*
Washington Regulations:	*Not regulated*
II. Establishment Potential and Life History Traits	
a. Life History	Free-floating, perennial aquatic fern
Fecundity	High
Reproduction Importance of Spores: Vegetative:	Sexual; Asexual Produces sporocarps[5] Probably most important; fragmentation[5]
Hybridization	Undocumented
Overwintering Winter Tolerance: Phenology:	 Undocumented In Asia, maximum growth from September to January, and decline during April to June[9]; prolific up to March in India[9]
b. Establishment	
Climate Weather: Wisconsin-Adapted: Climate Change:	 Highest laboratory productivity at relative humidity between 85-95%; can survive temperatures between 14-40°C (57-104°F)[9] Uncertain Likely to facilitate growth and distribution
Taxonomic Similarity Wisconsin Natives: Other US Exotics:	 High; *Azolla caroliniana*, *Azolla mexicana*[3,6] Low
Competition Natural Predators: Natural Pathogens: Competitive Strategy: Known Interactions:	 *Elophila africalis* (moth)[13], *Paulinia acuminate* (grasshopper)[14] *Rhizoctonia solani*[15]; *Sclerotium rolfsii*[16] Symbiosis with nitrogen-fixing cyanobacteria[9,17]; rapid reproduction; shades sub-surface vegetation[8,17,18] *Vallisneria americana* decreases due to shading[18]; replaced native *A. rubra* in northern New Zealand[17]; symbiotic association with *Anabaena azollae* (blue green algae)[9]
Reproduction Rate of Spread: Adaptive Strategies:	 High Auto-fragmentation; can survive drawdown and drought[7,17]
Timeframe	Capable of doubling population in 3-5 days[8]
c. Dispersal	
Intentional: Unintentional: Propagule Pressure:	Aquarium trade; agricultural fertilizer[17]; nutrient and heavy metal effluent treatment[19,20,21] 'Hitchhiker' with aquaria plants[5]; wind, water, humans; transport of cattle[17] Low; fragments easily accidentally introduced, but source populations not near Wisconsin

Figures 2 and 3: Courtesy of Sheldon Navie[22]

III. Damage Potential

a. Ecosystem Impacts

Composition	Native plant richness and abundance decreases[18]; macroinvertebrate density (zooplankton) and phytoplankton decreases significantly[23]; fish production decreases[23]
Structure	Monocultures[18]; changes community architecture[18]
Function	Decreases dissolved oxygen concentration and light penetration[18]
Allelopathic Effects	Produces deoxyanthocyanins which act as feeding deterrents to mollusks[24]
Keystone Species	Undocumented
Ecosystem Engineer	Yes; dense surface growth decreases dissolved oxygen concentration and light penetration[18]
Sustainability	Undocumented
Biodiversity	Decreases[25]
Biotic Effects	Reduces submerged plants; decreases fish productivity
Abiotic Effects	Decreases dissolved oxygen concentration and light penetration[5,18]; decreases pH, conductivity, and nutrient concentrations[23]; degrades water quality[7]; symbiotic cyanobacteria fix nitrogen[8]
Benefits	In its native range, provides a food source and habitat for waterfowl, fish, shrimp, insects, worms, snails and crustaceans[26]

b. Socio-Economic Effects

Benefits	Agricultural green fertilizer[1,8,17]; nutrient[9,19,23] and heavy metal effluent treatment[20,21,27,28]; poultry, duck, and aquaculture feed[9,29,30 31,32]; antifungal agent[9]; source of hydrogen gas[9]; mosquito-controlling agent[9]
Caveats	Risk of release and population expansion outweighs benefits of use
Impacts of Restriction	Increase in monitoring, education, and research costs
Negatives	Dense surface growth is unsightly and inhibits recreation[5,7,17]; clogs irrigation pumps and impedes water flow[22]; likely to decrease native diversity and abundance; dense growth of a similar species (*A. filiculoides*) has led to drowning of livestock[33]
Expectations	More negative impacts can be expected in warm, low-energy systems
Cost of Impacts	Decreased recreational and aesthetic value; decline in ecological integrity; increased research expenses
"Eradication" Cost	Undocumented

IV. Control and Prevention	
a. Detection	
Crypsis:	High; confused with other *Azolla* spp.[5,25]
Benefits of Early Response:	High; early response may limit vegetative reproduction and spread between waterbodies
b. Control	
Management Goal 1	Nuisance relief
Tool:	Manual/mechanical harvest
Caveat:	Rapid re-growth means relief is very short-lived; negative impacts on non-target species
Cost:	Estimated $1000/ha/year (on similar species)[32]
Efficacy, Time Frame:	Control must occur several times per year
Tool:	Small-scale chemical (diquat, glyphosate, terbutryn)[25]
Caveat:	Rapid re-growth means relief is very short-lived; negative impacts on non-target species
Cost:	Estimated $136/ha/year (on similar species)[32]
Efficacy, Time Frame:	Control must occur several times per year
Tool:	Biological control (*Stenopelmus rufinasus*, water fern weevil)[34]
Caveat:	Might be suitable, but *A. pinnata* is not a preferred host[35]
Cost:	Initial $7700 investment, plus an estimated $276/ha/year (on similar species)[32]
Efficacy, Time Frame:	Depends on host specificity (not researched thoroughly for *A. pinnata*)

1 Croft, J.R. 1986. The Aquatic Pteridophytes of New Guinea. Retrieved December 17, 2010 from: http://www.anbg.gov.au/fern/aquatic/

2 USDA, ARS, National Genetic Resources Program. Germplasm Resources Information Network - (GRIN) [Online Database]. National Germplasm Resources Laboratory, Beltsville, Maryland. Retrieved December 17, 2010 from: http://www.ars-grin.gov/cgi-bin/npgs/html/taxon.pl?316376

3 United States Department of Agriculture, Natural Resource Conservation Service. 2010. The PLANTS Database. National Plant Data Center, Baton Rouge, LA, USA. Retrieved December 17, 2010, from: http://plants.usda.gov/java/profile?symbol=AZPI

4 EDDMapS. 2011. Early Detection & Distribution Mapping System. The University of Georgia - Center for Invasive Species and Ecosystem Health. Retrieved December 8, 2011 from: http://www.eddmaps.org/

5 Howard, V. 2008. *Azolla pinnata*. USGS Nonindigenous Aquatic Species Database, Gainesville, FL. Retrieved December 8, 2011 from: http://nas.er.usgs.gov/queries/factsheet.aspx?SpeciesID=2745

6 University of Wisconsin – Madison. 2005. Family Azollaceae. Wisconsin Botanical Information System, Wisflora. Retrieved December 17, 2010, from: http://www.botany.wisc.edu/cgi-bin/SearchResults.cgi?Genus=Azolla

7 Stratford, K. and S. Hoyle. 2007. Aquatic Weed Fact Sheet. North Carolina State University. Retrieved December 17, 2010 from: http://www.weedscience.ncsu.edu/aquaticweeds/facts/apfs009-00.pdf

[8] Tung, H.F. and T.C. Shen. 1981. Studies of the *Azolla pinnata-Anabaena azollae* symbiosis: growth and nitrogen fixation. New Phytologist 87(4):743-749.

[9] Gopal, G.V. 2000. *Azolla pinnata* R. Br. Pteridophyte; Salviniales (Azollaceae) in the management of Lake Agro ecosystem. Lake 2000: International Symposium on Restoration of Lakes and Wetlands. Retrieved December 17, 2010 from: http://ces.iisc.ernet.in/energy/water/proceed/proceedings_text/section2/paper3/section2paper3.htm#address

[10] Cary, P.R. and P.G.J. Weerts. 1992. Growth and nutrient composition of *Azolla pinnata* R. Brown and *Azolla filiculoides* Lamarck as affected by water temperature, nitrogen and phosphorus supply, light intensity and pH. Aquatic Botany 43(2):163-180.

[11] Aziz, A. and S. Sharmin. 2000. Growth and nitrogenase activity of *Azolla pinnata* var. *pinnata* R. Brown as affected by some environmental factors. Bangladesh Journal of Botany 29(2):125-131.

[12] Sood, A., A.S. Ahluwalia and S. Dua. 2005. Indicators of phosphorus deficiency in *Azolla pinnata* (Salviniales, Pteridophyta). Acta Botanica Hungarica 47(1-2):197-205.

[13] Fannah, S.J. 1987. *Elophila* sp.? *africalis* Hampson (Lepidoptera: Pyralidae): a new pest of azolla in Sierra Leone. International Rice Research Newsletter 12(3):30.

[14] Sands, D.P.A., R.C. Kassulke. 1986. Assessment of *Paulinia acuminata* (Orthoptera: Acrididae) for the biological control of *Salvinia molesta* in Australia. Entomophaga 31(1):11-17.

[15] Dath, A.P., D.P. Singh. 1998. Effect of rice *Rhizoctonia solani* Kuhn infection on the biomass of different *Azolla* species. Oryza 35(2):186-187.

[16] Shahjahan, A.K.M., S.A. Miah, M.A. Nahar, M.A. Majid. 1980. Fungi attack Azolla in Bangladesh. International Rice Research Newsletter 5(1):17-18.

[17] Global Invasive Species Database. 2010. *Azolla pinnata*. Retrieved December 17, 2010 from: http://www.invasivespecies.net/database/species/ecology.asp?si=204&fr=1&sts=sss

[18] Morris, K., P.C. Bailey, P.I. Boon and L. Hughes. 2003. Alternative stable states in the aquatic vegetation of shallow urban lakes. II. Catastrophic loss of aquatic plants consequent to nutrient enrichment. Marine and Freshwater Research 54(3):201-215.

[19] Tripathi, B.D. and A.R. Upadhyay. 2003. Dairy effluent polishing by aquatic macrophytes. Water Air and Soil Pollution 143(1-4):377-385.

[20] Upadhyay, A.R. and B.D. Tripathi. 2007. Principle and process of biofiltration of Cd, Cr, Co, Ni and Pb from tropical opencast coalmine effluent. Water Air and Soil Pollution 180(1-4):213-223.

[21] Arora, A., S. Saxena and D.K. Sharma. 2006. Tolerance and phytoaccumulation of Chromium by three *Azolla* species. World Journal of Microbiology and Biotechnology 22(2):97-100.

[22] Navie, S. Federal Noxious Weed Disseminules of the U.S. *Azolla pinnata* R. Brown. Retrieved December 17, 2010 from: http://keys.lucidcentral.org/keys/v3/FNWE2/key/FNW_Seeds/Media/Html/fact_sheets/Azolla_pinnata.htm

[23] Abdel-Tawwab, M. 2006. Effect of free-floating macrophyte, *Azolla pinnata,* on water physico-chemistry, primary productivity, and the production of Nile tilapia, *Oreochromis niloticus* L., and common carp, *Cyprinus carpio* L., in fertilized earthen ponds. Journal of Applied Aquaculture 18(1):21-41.

[24] Cohen, M.F., T. Meziane, M. Tsuchiya, H. Yamasaki. 2002. Feeding deterrence of Azolla in relation to deoxyanthocyanin and fatty acid composition. Aquatic Botany 74(2):181-187.

[25] CABI. 2011. *Azolla pinnata* (mosquito fern). Retrieved December 8, 2011 from: http://www.cabi.org/isc/

[26] Gold Coast City Council. 2011. Azolla fact sheet. Retrieved December 8, 2011 from: http://www.goldcoast.qld.gov.au/attachment/azolla_fact_sheet.pdf

[27] Mishra, V.K., B.D. Tripathi, K. Kim. 2009. Removal and accumulation of mercury by aquatic macrophytes from an open cast coal mine effluent. Journal of Hazardous Materials 172:749-754.

[28] Rai, P.K. 2010. Microcosm investigation of phytoremediation of Cr using *Azolla pinnata*. International Journal of Phytoremediation 12:96-104.

[29] Balaji, K., A. Jalaludeen, R. Churchil, P. Peethambaran, S. Senthilkumar. 2009. Effect of dietary inclusion of azolla (*Azolla pinnata*) on production performance of broiler chicken. Indian Journal of Poultry Science 44(2):195-198.

[30] El-Sayed, A. (1992). Effects of substituting fish meal with *Azolla pinnata* in practical diets for fingerling and adult Nile tilapia, *Oreochromis niloticus* (L.). Aquaculture and Fisheries Management 23(2):167-173.

[31] Joseph, A., P. Sherief, T. James. 1994. Effect of different dietary inclusion levels of *Azolla pinnata* on the growth, food conversion and muscle composition of *Etroplus suratensis* (Bloch). Journal of Aquaculture in the Tropics 9(1):87-94.

[32] Datta, S.N. 2011. Culture of *Azolla* and its efficacy in diet of *Labeo rohita*. Aquaculture 310:376-379.

[33] McConnachie, A.J., M.P. de Wit, M.P. Hill and M.J. Byrne. 2003. Economic evaluation of the successful biological control of *Azolla filiculoides* in South Africa. Biological Control 28:25-32.

[34] Pemberton, R.W., J.M. Bodle. 2009. Native North American Azolla weevil, *Stenopelmus rufinasus* (Coleoptera: Curculionidae), uses the invasive old world *Azolla pinnata* as a host plant. The Florida Entomologist 92(1):153-155.

[35] Hill, M.P. 1998. Life history and laboratory host range of *Stenopelmus rufinasus*, a natural enemy for *Azolla filiculoides* in South Africa. BioControl 43(2):215-224.