Risk Assessment for Chinese Water Spinach (*Ipomoea aquatica*) in Oregon

Illustration courtesy of Center for Aquatic and Invasive Plants, University of Florida

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Purpose

The purpose of this risk assessment is to evaluate the potential for *Ipomoea aquatica* to establish in the state of Oregon and become an invasive aquatic weed. It is a federally listed noxious weed, and under Oregon law; federally listed weeds are included on the Oregon noxious weed list by reference.

Methods

A review of available literature on *I. aquatica* and an extensive internet search was conducted for this risk assessment. Peer-reviewed literature was searched using the BIOSIS, Cambridge Scientific Abstracts, Environmental Abstracts, and the APRIS databases. The APRIS database returned over 50 useful articles. Journals that provided information included Aquatics, Economic Botany, the Journal of Inland Fisheries Society of India and the Journal of Aquatic Plant Management. Information was also obtained from the Florida Department of Environmental Protection and the University of Florida's Center for Aquatic and Invasive Plants.

Description and Distribution

I. aquatica is a member of the Morning Glory Family, Convolvulaceae, which contains 500 species. *I. aquatica* and *I. fistula* are the only aquatic species in the genus, which also includes the sweet potato (*Ipomoea batatas* L.).
Cook (1990) provides the following description:

> Perennial or occasionally annual. Stems trailing or erect, emergent or floating, when in water usually thick and spongy and rooting at the nodes. Leaves alternate, petiolate; blades variable, cordate of sagitate to triangular or linear. Inflorescence axillary, 1- to few-flowered, cymose. Sepals 5, free, persisting in fruit. Petals 5, united, large, funnel-shaped, purple to almost white, often with a purple or ink centre. Stamens 5, inserted at the base of and much shorter than the petals. Ovary superior, of 2 united carpels; style 1, simple; fruit a capsule, either 4-valved or splitting irregularly; seeds 4 or less.
>
> Heleophytes, floating or emergent: entomphilous: diaspores relatively large and sometimes hairy seeds, dispersal unknown: *I. aquatica* cultivated for its edible shoots and medicinal properties but sometimes considered to be a serious weed, *I. fistulosa* often planted for hedging or decoration but also a serious

weed in irrigation and drainage channels: Cook, Ipomoea fistulosa: a new problem for India? Aquaphyte 7: 12 (1987).

I. aquatica typically has a lianoid, prostrate growth form, but has been noted to climb vertically, overtopping and twining around other plants (Sharma, 1994). The leaves are alternate, often lanceolate to hastate, with acute tips but leaf shape is highly variable (Sharma, 1994). There are two basic forms of *I. aquatica* that are recognized worldwide: a red form, with red-purple tinged stems, dark green leaves and petioles and pale pink to lilac colored flowers; and a white form, with green stems, green leaves with green/white petioles and white flowers. In Florida, two floating wild biotypes and at least one 'upland' cultivated form have been described. The upland cultivar is sometimes known as *Ipomoea reptans*. The wild forms include the red and white morphs, and are usually found in freshwater marshes and ponds. The upland cultivar also has white flowers and green stems, and roots in non-inundated soils and is grown commercially in raised beds (Van and Madeira, 1998). A study was conducted to examine the genetic relationship between these wild and cultivated biotypes in Florida. DNA fingerprinting can distinguish the Florida upland and cultivated biotypes, however, the they have not diverged significantly from one another and they are all considered *I. aquatica*.

I. aquatica has high growth rates, with a maximum stem elongation rate of 10 cm/day (McCann et al., 1996). Plants branch profusely, with stems growing to over 70 feet long (Florida DEP, 2003). Dense stands form large floating mats of vegetation at the water surface. Patnaik (1976) found that *I. aquatica* grew rapidly in one pond, covering the entire surface, and that the other aquatic plants *Pistia*, *Azolla* and *Utricularia* disappeared – probably due to the shading effect of the over-topping *I. aquatica*.

Reproduction

I. aquatica reproduces by sexual and asexual means. The flowering season lasts from late October to early April in India, and peak flowering season was observed from December to January (Patnaik, 1976). It flowers in the warm months in Florida (Dressler, et al., 1987). Seed formation occurs during this time period and continues into April, reaching its peak during January to March. The seed output varies from 175-245 per plant (Patnaik, 1976). The seeds do not germinate well under water, but can be directly seeded into the ground (Palada and Crossman, 1999). Edie and Ho (1969) and Palada and Crossman (1999) report that the germination and initial growth of *I. aquatica* is poor under water. However, after the monsoon season in India, Patnaik (1976) reported seeing a large number of young plants sprouting along the water margin, which he assumed were from seed germination. The primary means of reproduction is through vegetative fragmentation (Patnaik, 1976; Edie and Ho, 1969; Schartz and Schmitz, 1990). Patnaik (1976) observed that the branches, with roots at each node, grew into independent plants when separated and carried by water, animals and humans, establishing easily in new places.

Habitat and Environmental Factors for Survival

I. aquatica requires a very warm, wet climate to flourish. It grows well as a crop only when the mean temperature is above approximately 25 C, allowing it only to be available during the summer months in Hong Kong (Edie and Ho 1969; Patnaik, 1976). In areas where the weather is not conducive to the growth of *I. aquatica*, it must be grown in greenhouses where the temperature can be kept constant and warm (Lang, 2003).

Patnaik (1976) found it growing in ponds with clay-loam soil (pH 6.8) and in loam soils (pH 7.2-7.8) in India. Water chemistry conditions in India where *I. aquatica* was found to thrive are in Table 1.

Table 1. Water chemistry of ponds in India (From Patnaik, 1976).

Parameter	Range
pH	6.9 – 8.2
Dissolved Oxygen	2.5 - 10.2 ppm
Nitrates	0.04 – 2.3 ppm
Phosphates	Trace – 2.5 ppm

It is unknown if the upland form is capable of growing in aquatic habitats, or if the aquatic form can grow in upland areas, however, Patnaik (1976) observed that when a pond containing the aquatic form of I. *aquatica* dried up, the plants' spreading branches settled on the mud bottom and the roots coming off the nodes were anchored in the soil. Payne (1987) also reported that *I. aquatica* grows well in moist soil or in still to flowing waters.

Distribution

I. aquatica is currently found throughout tropical southeast Asia including, China, Taiwan, India, Malaysia, the West Indies, Africa, Fiji, Virgin Islands, South and Central America (Edie and Ho, 1969; Florida DEP, 2002; Palada and Crossman, 1999). (Palada and Crossman, 1999). The requirement for warm, humid conditions may explain why the plant survives only in Florida, Hawaii and Puerto Rico and why it has become a problem in Florida but not in any other areas of the USA (Figure 1). The plant is cultivated in California (Dechoretz, 2003), Texas (Van and Madeira, 1998), and the US Virgin Islands (Palada and Crossman, 1999).

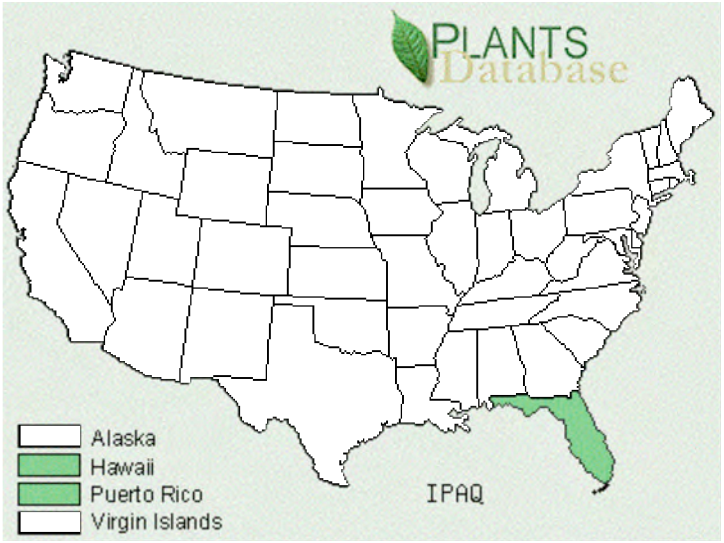

Figure 1. Distribution of *I. aquatica* (Courtesy of USDA Plants Data Base (2003)).

Agricultural, Economic, and Cultural Importance

I. aquatica is an important vegetable crop in Southeast Asia, where it is also known as on choy, water convolvulus, water spinach, swamp cabbage, ung tsoi, weng kai (China and Taiwan), kang kong (S.E. Asia), asagao na, and yu sai (Japan). It was first cultivated around the year 300 in China during the Chin Dynasty (Edie and Ho, 1969). It is one of the few aquatic plants grown as a vegetable (Boyd, 1974; Joyce, 1990). In Southeast Asia it grows wild and is occasionally picked as a green vegetable (Edie and Ho, 1969). It is also cultivated in Fiji, Florida, Hawaii, Texas and California. It is particularly important in the south coastal region of China, including Hong Kong, the main center of its cultivation, but is also a common vegetable in Taiwan and Malaysia and other surrounding southeastern Asian countries (Edie and Ho, 1969; Gopal, 1990).

The young stems and leaves with petioles are picked and used as a green vegetable, usually cooked in frying oil or boiled, especially during the summer months when other leafy crops, such as lettuce, Chinese cabbage and kale do not grow well (Edie and Ho, 1969; National Academy of Sciences, 1976). In India, the young stems and leaves are eaten (Sculthorpe, 1985). Often the young stems and leaves are eaten in salads (Palada and Crossman, 1999). The final product after cooking produces a tender and crisp vegetable, without much flavor and some spicy ingredients or salt are often added to enhance the flavor (Edie and Ho, 1969; Palada and Crossman, 1999). The leaves maintain much of their green color when cooked, but the stems turn yellowish (Palada and Crossman, 1999). Annual production in Hong Kong varies between three to five million kilograms and supplies almost 15 percent of the local vegetable output (Edie and Ho, 1969; National Academy of Sciences, 1976). It is easy to grow, has a high yield, and is considered nutritious (Yamaguchi, 1990). The leaves are a good source of minerals and vitamins A, C and E. The protein content of the fresh plant varies from 1.9 to 4.6 percent, while carbohydrates average 4.3 percent. It has been estimated that a 1 ha pond in a tropical region with a year round growing season, planted with nothing but *I. aquatica* could produce 770 kg of protein and 1,059 kg of carbohydrates annually

(National Academy of Sciences, 1976). Farmers favor *I. aquatica* because it is easy to grow, has relatively low labor requirements and can be harvested irregularly to fit market demand (National Academy of Sciences, 1976).

I. aquatica also has several other important uses. It is used as food for livestock, such as pigs, cattle and fish (Edie and Ho, 1969; National Academy of Sciences, 1976). In addition, preparations of the leaves of *I. aquatica* can be useful in treating gastric and intestinal disorders, and the leaves have been used in traditional medicine as purgatives, diuretics and remedies for biliousness and jaundice and are supposed to purify blood (Sculthorpe, 1985; Patnaik, 1976).

There are two distinct ways of cultivating *I. aquatica*, a dry land (moist soil) and wetland system (Edie and Ho, 1969). In the dry land system, the red stem cultivar is often utilized, (Edie and Ho, 1969) while the white stem cultivar is utilized in wetland cultivation (Yamaguchi, 1990). Plants can be propagated from seed or cuttings (Edie and Ho, 1969; Yamaguchi, 1990; Palada and Crossman, 1999; National Academy of Sciences, 1976). The dry land cultivation is utilized in Hong Kong from March to May, when the fields used for wetland cultivation are still carrying winter crops (Edie and Ho, 1969). Although the red stem variety does not have a high yield and the quality of the plants is poor as the plants are small and tough, there are few other vegetables available between March and May and a ready market is available until the summer crops become available (Edie and Ho, 1969). Heavy applications of fertilizers are made every two to three days once the plants are past the seedling stage. The plants must be watered three to four times daily when they are young and twice daily once the crop is established. Hand weeding is required frequently. Once the plant has matured (45 to 60 days after sowing) (Edie and Ho, 1969; Lang, 2003) the entire plant is pulled up, washed and packed for shipping. A small amount of the white stem variety is grown in dry land cultivation in Hong Kong during the summer. It produces a much larger plant of better quality, having fleshier, more succulent steams and petioles. Several harvests are often taken from one crop by cutting the shoots above the ground, encouraging lateral growth (Edie and Ho, 1969).

In the wetland system, the method of propagation is the same for the dry land system, however, the field is flooded to 3-5 cm deep before the cuttings are planted and the soil trampled to liquid mud. The cuttings are then planted approximately 3-5 cm deep and 40 cm apart. The cuttings root rapidly, and require little further attention. As the crop grows, the water is increased to about 15-20 cm (Edie and Ho, 1969; Yamaguchi, 1990; National Academy of Sciences, 1976). High rates of fertilizers are applied throughout growth, with the water being drained just before application and left dry for 12 hours after fertilizing to conserve fertilizer (Edie and Ho, 1969; Yamaguchi, 1990; National Academy of Sciences, 1976). Weeds are rarely a problem with this type of cultivation system, so labor requirements are lower (Edie and Ho, 1969; National Academy of Sciences, 1976). The growth of the plants is rapid and the first harvest can be made about 30 days after planting (Edie and Ho, 1969; Yamaguchi, 1990; National Academy of Sciences, 1976). The shoots are cut at water level, which stimulates lateral growth. Subsequent harvests are taken every seven to ten days through out the summer, and up to ten such harvests can be taken during the season (Edie and Ho, 1969; Yamaguchi, 1990; National Academy of Sciences, 1976). During September, the plants begin to flower and harvesting stops (Edie and Ho, 1969). The annual yield for this type

of cultivation can be as much as 90,000 kg/ha (Edie and Ho, 1969; National Academy of Sciences, 1976).

In California, *I. aquatica* accounts for more than 75 percent of one farmer's crops, which he exports outside of the state to Oregon, Washington and New York. He states that nearly 90 percent of water spinach supplying the United States is grown in the Gilroy area of California (Lang, 2003)

Environmental Impacts and Invasions

Excessive growth of *I. aquatica* has created problems in fishery management in addition to causing obstructions in navigation and irrigation in India. In addition, it has been shown to create floating mats of intertwined stems over the surface of the water, shading out native submersed plants and competing with native emergents (Langeland and Burks, 2000). In many areas of the tropics, such as the Philippines where it is considered the second greatest problem plant, it has been shown to be a common to serious weed, or present as a weed in many areas (Holm et al, 1979; Gangstadt, 1976; Cook, 1990). Manual removal and chemical methods of control have been found to be effective (Patnaik, 1976). In Florida, attempts to manage *I. aquatica* with aquatic herbicides have been somewhat successful, but with temporary results. Diuron provided acceptable control in dry ditches, but also controlled most other adjacent plants, which would not be acceptable in areas such as the Everglades (Schardt and Schmitz, 1990).

I. aquatica was recognized as a potential threat to natural areas in Florida in 1951 (Osche, 1951 as cited in Langeland and Burks, 2000). It has been introduced into Florida repeatedly since 1979 (Langeland and Burks, 2000). *I. aquatica* is a concern because it creates impenetrable masses of tangled vegetation obstructing water flow in drainage and flood control canals. It also infests lakes, ponds and river shorelines, displacing native plants that are important for fish and wildlife, and creates dense canopies creating stagnant water conditions that are ideal breeding environments for mosquitoes (Florida DEP, 2003). It as been found in two public lakes in Florida, West Lake Tohopekaliga and Lake Maggiorie (Schardt and Schmitz, 1990). The greatest management concern in Florida is invasion of areas of subject to periodic drying and flooding, such as the Everglades (McCann et al., 1996).

Possession of the plant in Florida has been prohibited since 1973 (McCann et al., 1996). Multiple raids have been conducted in Florida in an attempt to curb the spread and growth of the plant. Seeds and plants have been seized and the importation of seeds and cultivation of the plant in certain areas has been halted, and certain infestations in ponds and lakes throughout Florida have been eradicated (Schmitz, 1990). Few other states express the level of concern over *I. aquatica* as Florida does, however, fact sheets and identification guides from other states have described its potential to spread (Oklahoma DWC; Howells, 1999; Lord, 2000). It is listed as a noxious weed in 35 states (USDA, 2003).

Evaluation

I. aquatica has been cultivated for many hundreds of years and has been shipped throughout the world as a vegetable crop. It has spread throughout many of the tropical areas in the world, but there is no evidence that it will grow outside of tropical areas

naturally. California and Washington (Parsons, 2003) consider the plant a low risk for establishment and as a potential nuisance. Temperature is not always an extremely reliable predictor of potential range expansion of aquatic plants; however, due to the requirement for hot, humid conditions for growth and the failure of *I. aquatica* to establish in more temperate areas of Asia, where it has been an important food for several centuries, we conclude that there is a low risk that *I. aquatica* could establish, invade, and create a nuisance condition in Oregon rivers, streams, lakes, and drainage and irrigation canals.

References

Boyd, C.E. 1974. *Utilization of Aquatic Plants*. P.107-115. In: D.S. Mitchell (ed.), Aquatic vegetation and its use and control. Unesco, Paris.

Cook, CDK. 1990. *Aquatic Plant Book*. SPB Academic Publishing, The Hague. 228 pg.

Cook, C.D.K. 1990. Origin, autecology, and spread of some of the world's most troublesome aquatic weeds. p. 31-38. In: A.H. Pieterse and K.J. Murphy (eds.), *Aquatic Weeds: The Ecology and Management of Nuisance Aquatic Vegetation*. Oxford University Press, New York.

Dechoretz, N. 2003. California Department of Food and Agriculture. Personal communication with Dr. Mark Sytsma, on May 8, 2003.

Dressler, R.L., D.W. Hall, K.D. Perkins and N.H. Williams. 1987. *Identification Manual for Wetland Plant Species of Florida.* Gainesville: University of Florida, Institute of Food and Agricultural Sciences (IFAS). 297 pp.

Edie, H.H. and B.W.C. Ho. 1969. *Ipomoea aquatica* as a vegetable crop in Hong Kong. *Economic Botany*. 23: 32-36.

Florida Department of Environmental Protection. 2003. Florida Department of Environmental Protection Weed Alert: Water-spinach (*Ipomoea aquatica*). http://www.dep.state.fl.us/lands/invaspec/2ndlevpgs/pdfs%20for%20pubs/Wtrspnch.pdf Accessed on 5/1/03.

Gangstadt, E.O. 1976. Potential growth of aquatic plants in Republic of the Philippines and projected methods of control. *Journal of the Aquatic Plant Management*. 14: 10-14.

Gopal, B. 1990. Aquatic weed problems and management in Asia. p. 318-340. In: A.H. Pieterse and K.J. Murphy (eds.), *Aquatic Weeds: The Ecology and Management of Nuisance Aquatic Vegetation*. Oxford University Press, New York.

Holm, L., J.V. Pancho, J.P. Herberger, D.L. Plucknett. 1979. *A Geographical Atlas of World Weeds*. John Wiley and Sons, New York. 391 pp.

Howells, R.G. 1999. *Guide to Identification of Harmful and Potentially Harmful Fishes, Shellfish and AquaticPlants in Texas*. Texas Parks and Wildlife, Inland Fisheries Division. 370 pp.

Joyce, J.C. 1990. *Practical Uses of Aquatic Weeds*. p. 274-291. In: A.H. Pieterse and K.J. Murphy (eds.), Aquatic Weeds: The Ecology and Management of Nuisance Aquatic Vegetation. Oxford University Press, New York.

Lang, W. 2003. Letter to Anna McCormack of Warren Allen Kin O'Hara Bennett Jepsen and Diamond, LLP Attorneys at Law. Written March 3, 2003.

Langeland, K.A. and K.C. Burks. 2000. *Identification and Biology of Non-Native Plants in Florida's Natural Areas*. Gainesville: University of Florida, Institute of Food and Agricultural Sciences (IFAS). 166 pp. http://plants.ifas.ufl.edu/identif.html Accessed 5/2/03.

Lord, P.H. 2000. Threats to the Biodiversity of Northeastern North American Lakes: Aquariums and Ponds. In: *Thirty-third Annual Report of the Biological Field Station in Cooperstown, New York*. W.N. Harman (ed.). State University of New York, College at Oneonta. pp.121-133

McCann, J.A., L.N. Arkin and J.D. Williams. 1996. *Nonindigenous Aquatic and Selected Terrestrial Species of Florida: Status, Pathway and Time of Introduction, Present Distribution, and Significant Ecological and Economic Effects*. Gainesville: University of Florida, Institute of Food and Agricultural Sciences (IFAS). http://aquat1.ifas.ufl.edu/mctitle.html Accessed 5/1/03.

National Academy of Sciences. 1976. *Aquatic Plants for Food, Miscellaneus Uses. P. 127-147. In: Making Aquatic Weeds Useful: Some Perspectives for Developing Countries*. National Academy of Sciences, Washington D.C. 175 pp.

Ochse, J.J. 1951. Two vegetables for South Florida. *Proceedings of the Florida State Horticultural Society*. 64: 104.

Oklahoma Department of Wildlife Conservation. No Date. *Don't Free Lily! An Aid for the Responsible Handling of Aquatic Plants*. Langston University, Langston, OK.

Palada, M.C. and S.M.A. Crossman. 1999. Evaluation of tropical leaf vegetables in the Virgin Islands. p. 388–393. In: J. Janick (ed.), *Perspectives on New Crops and New Uses*. ASHS Press, Alexandria, VA.

Parsons, J. 2003. Washington State Department of Ecology. Personal communication with Erin Harwood on May 9, 2003.

Patnaik, S. 1976. Autecology of *Ipomoea aquatica* Forsk. *Journal of the Inland Fisheries Society of India*. 8: 77-82.

Payne, W.J.A. 1956. *Ipomoea reptans* Poir., a useful tropical fodder plant. Tropical Agriculture. 33: 302-305.

Schardt, J. D., and D. C. Schmitz. 1990. 1990 Florida aquatic plant survey report. Unpublished report, Florida Department of Natural Resources, Tallahassee. 89 pp.

Schmitz, D.C. 1990. Memo: The Water Spinach Problem. Permitting Section, Florida Department of Natural Resources, Bureau of Aquatic Plant Management, Tallahassee, 3pp.

Sculthorpe, C.D. 1985. *The Biology of Aquatic Vascular Plants*. Koeltz Scientific Book, Konigstein/West Germany. 610 pp.

Sharma, M. 1994. Taxonomic Notes on North Indian Plants – X. Journal of Economic and Taxonomic Botany. 18(2):387-394.

Van, T.K. and P.T. Madeira. 1998. Random Amplified Polymorphic DNA Analysis of Water Spinach (*Ipomoea aquatica*) in Florida. Journal of Aquatic Plant Management. 36: 107-111.

USDA. PLANTS Database: http://plants.usda.gov/cgi_bin/topics.cgi. Accessed May 12, 2003.

Yamaguchi, M. 1990. Asian vegetables. p. 387-390. In: J. Janick and J.E. Simon (eds.), Advances in new crops. Timber Press, Portland, OR.