Water Hyacinth (*Eichhornia crassipes*)
Ecological Risk Screening Summary

U.S. Fish & Wildlife Service, June 2015
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1 Native Range and Status in the United States

Native Range

From U.S. Forest Service (2015):

"Brazil, French Guian, Guyana, Suriname and Venezuela; […]"

From Coetzee et al. (2009):

"It is indigenous to the New World tropics, and has its center of origin in Amazonia, Brazil (Barrett and Forno 1982)."

From Pallewatta et al. (2003):

"This plant is a native of Amazonia, Brazil."

Status in the United States

From Masterson (2007):

"Within the U.S., *E. crassipes* occurs throughout the southeast north to Virginia and west to Texas, as well as in California and Hawaii. Seasonal escapes from cultivation are reported from New York, Kentucky, Tennessee and Missouri, but populations apparently do not survive through winter. The plant previously occurred in Arizona, Arkansas, and Washington State but is now considered eradicated in these locations (Ramey 2001)."

"The amount of Florida aquatic habitat choked by dense water hyacinth mats is currently much less than during the first 100 years after the arrival of the species. Waterways are kept clear of dense infestations only through extraordinary management efforts involving field crews engaged in full time mechanical removal and biocidal control of *E. crassipes*. Complete eradication from Florida is impossible."

From U.S. Forest Service (2015):

"Planting of this species in the State of Florida (U.S.) is prohibited by Florida Department of Environmental Protection (Hunsberger, 2001)."

The U.S. Forest Service (2015) lists *Eichhornia crassipes* as introduced and invasive in American Samoa (Tutuila Island), California, Florida, Guam, and Hawai'i (Hawai'i, Kaua'i, Maui, and O'ahu islands); as introduced in the Northern Mariana Islands (Rota and Saipan islands) and Wake Island.

USDA, NRCS (2017) lists *Eichhornia crassipes* as a Class C noxious weed in Alabama, a Prohibited noxious weed, Regulated noxious weed, and Restricted noxious weed in Arizona, a C list (noxious weeds) in California, a Prohibited aquatic plant, Class 1 in Florida, an invasive aquatic plant, plant pest in South Carolina, and a noxious plant in Texas.

From Pfingsten et al. (2017):

"Nonindigenous Occurrences: The first U.S. occurrence was documented from the Southern States Cotton Expo in New Orleans, Louisiana in 1884 (Klorer 1909; Penfound and Earle 1948). Waterhyacinth has since spread throughout the southeastern U.S., much of California, the northeastern coastal region, and up the Mississippi River into the Great Lakes region. It further spread to the islands of Puerto Rico, Hawaii, and Guam.

Alabama – All drainages except Middle Tennessee-Hiwassee (Alabama Plant Atlas Editorial Committee 2015; Bartodziej and Ludlow 1997; Bayne 1979; Center for Environmental Studies 2015; Crouch and Golden 1997; GBIF 2013; iDigBio 2015; Kight 1988; Madsen 2010; Zolczynski and Shearer 1997).
Arizona – Lower Colorado (Calflora 2015; Thomas and Guertin 2007), Lower Gila-Agua Fria, Middle Gila, Salt, Santa Cruz, and Verde (Center for Environmental Studies 2015; iDigBio 2015; Thomas and Guertin 2007) drainages.
Arkansas – Lower Arkansas-Maumelle (Marks 2006), Robert S. Kerr Reservoir (Sabrina Hardcastle, Ebbing Air National Guard Base, pers. comm.), and Upper Ouachita (Madsen 2010) drainages, and Chicot, Clark, Jefferson, Pope (Marks 2006), and Washington (Smith 1988) Counties.
California – All drainages except Carson, Klamath, Mono-Owens Lakes, North Lahontan, Truckee, Upper Sacramento, and Walker (Barrett 1980; Calflora 2015; California Department of Fish and Game 2009; Center for Environmental Studies 2015; Cohen and Carlton 1995; GBIF 2013; iDigBio 2015; Johnson 1920; Regents of the University of California 2015; Toft et al. 2002)
Colorado – San Luis (Colorado Weed Management Association 2008), and Upper Arkansas (iDigBio 2015) drainages, and El Paso (Hartman and Nelson 2001) County
Connecticut – All drainages (Connecticut Agricultural Experiment Station 2008; EDDMapS 2015; GBIF 2013; Gibbons 2011; iDigBio 2015)
Delaware – All drainages (Aquatic Resources Education Center 1995; Martin 1999)
Florida – All drainages (Barrett 1980; Beaton and Murphy-Hoffman 2015; Bogart 1949; Center for Environmental Studies 2015; EDDMapS 2015; Fox and Wigginton 1996; iDigBio 2015; Lynch et al. 1950; Madsen 2010; Moody 1973; Muenscher 1944; Myers and Ewel 1990; O'Keefe 1976; Perfetti 1983; Perkins 1974; Poppleton et al. 1977; Schardt 1995; Webber 1897; Wunderlin et al. 1995)
Georgia – All drainages except Middle Tennessee-Hiwassee (Aurand 1982; Center for Environmental Studies 2015; EDDMapS 2015; Newman and Thomaston 1979; Thomaston 1984; University of Florida Herbarium 2016).
Guam – Heavily developed area of the Agaga River (Steve Walsh, USGS, pers. comm.)
Hawaii – Hawaii, Kauai, Maui, and Oahu (GBIF 2013; iDigBio 2015; Mehrhoff 1996; Smith 1978) drainages
Idaho – Along the Snake River in the Upper Snake-Rock drainage (EDDMapS 2015; Tom Woolf, ID Department of Agriculture, pers. comm.)
Illinois – Lower Illinois (EDDMapS 2015), Lower Ohio (EDDMapS 2015; Loyola University Chicago 2013), Upper Illinois (Adam et al. 2001; Adam et al. 2004; Center for Environmental Studies 2015; EDDMapS 2015; Loyola University Chicago 2013), Upper Mississippi-Meramec (EDDMapS 2015), and Wabash (Center for Environmental Studies 2015; GBIF 2013; iDigBio 2015; Loyola University Chicago 2013) drainages
Indiana – Along the Ohio River in the Highland-Pigeon (Eric Fischer, IN DNR, pers. comm.; EDDMapS 2015) drainage, and in an undisclosed pond in southern Indiana (Alix and Scribailo 2010; Seng and White 2003)
Kansas – Lower Cottonwood (Freeman 2000; GBIF 2013; iDigBio 2015), Lower Kansas, Kansas (Center for Environmental Studies 2015; Freeman 2000; GBIF 2013; iDigBio 2015), and Middle Neosho (Jessica Howell, KS DWPT, pers. comm.) drainages

Kentucky – Lower Tennessee (Benji Kenman, KY Fish and Wildlife Service pers. comm.) drainage, and Jefferson (Beal and Thieret 1986; Brown and Athey 1992), Trigg (Chester et al. 1993), and Todd Counties (Chester et al. 1993).
Louisiana – All drainages except Lower Mississippi-Baton Rouge, Lower Mississippi-Greenville, and Lower Mississippi-Natchez (Barrett 1980; Batte 2015; Center for Environmental Studies 2015; Conner et al. 1986; GBIF 2013; Gettys 2015; Hess et al. 1989; iDigBio 2015; Klorer 1909; Lynch et al. 1950; Madsen 2010; Maurin 2016; Myers and Ewel 1990; Penfound and Earle 1948; Perfetti 1983; Thomas and Allen 1993; Valentine 1976)
Maryland – Fresh Pond (Angel's Bog) near Lake Shore in the Severn drainage (Bill Sipple, US EPA, pers. comm.)
Massachusetts – Cape Cod drainage (EDDMapS 2015; Harvard University Herbaria 2007).
Michigan – Saginaw, Southeastern Lake Michigan, and St. Clair-Detroit drainages (Michigan State University 2015)
Minnesota – Charles Perry Park wetlands in the Twin Cities drainage (EDDMapS 2015)
Mississippi – All drainages except Hatchie-Obion, Lower Mississippi-Baton Rouge, Lower Mississippi-Greenville, Lower Mississippi-Natchez, and Middle Tennessee-Elk (Aurand 1982; Bryson and Skojac 2011; Center for Environmental Studies 2015; EDDMapS 2015; GBIF 2013; iDigBio 2015; Jones 1974; Lowe 1921; Madsen 2010; Robles et al. 2015; Skojac et al. 2007)
Missouri – Gasconade (GBIF 2013; Padgett 2001), St. Francis (Yatskievych 1999), Upper Mississippi-Meramec (GBIF 2013), and Upper White (GBIF 2013) drainages
New Hampshire - [Old] Durham Reservoir in the Piscataqua-Salmon Falls drainage (CNH 2015).
New Jersey – Cohansey-Maurice, Lower Delaware (David Snyder, NJ Natural Heritage Program, pers. comm.), and Raritan (EDDMapS 2015) drainages
New York – Lake Ontario (iMapInvasives 2015), Lower Hudson (Mike Goehle, USFWS, pers. comm.), Middle Hudson (iMapInvasives 2015), Niagara (iMapInvasives 2015; Scott Kishbaugh, NY DEC, pers. comm.), and Southern Long Island (New York Botanical Garden 2015) drainages
North Carolina – Cape Fear (EDDMapS 2015; University of Florida Herbarium 2015), Lower Pee Dee, Neuse, Onslow Bay, and Pamlico drainages (Stratford Kay, North Carolina State University, pers. comm.), and Anson and Bladen Counties (Beal 1977)
Oregon – Lower Deschutes (GBIF 2013), Lower Rogue (Linda Hardison, Oregon Flora Project; pers. comm.), Lower Willamette (iMapInvasives 2012), and South Umpqua (Carri Pirosko, ODA, pers. comm.) drainages.
Puerto Rico – Cibuco-Guajataca (Missouri Botanical Garden 2015), Culebrinas-Guanajibo (Smithsonian National Museum of Natural History 2015), Eastern Puerto Rico (Missouri Botanical Garden 2015; Smithsonian National Museum of Natural History 2015), and Southern Puerto Rico (EDDMapS 2015; GBIF 2013; iDigBio 2015; Missouri Botanical Garden 2015) drainages (Acevedo-Rodríguez and Strong 2005; GAEI 2015; Felix Grana, PR DNER, pers. comm. 2007).
South Carolina – All drainages (Allen and Thomasan 2012; Aurand 1982; Center for Environmental Studies 2015; GBIF 2013; Radford et al. 1968; Radford et al. 1997; South Carolina Department of Natural Resources 2007)
Tennessee – Lower Mississippi-Memphis (Chester et al. 1993), Red (Madsen 2010), and Stones (EDDMapS 2015) drainages

Texas – Big Cypress-Sulphur (Helton and Hartmann 1996; Johnson et al. 1991; Johnson 2008; Texas Invasive Plant and Pest Council 2015), Central Texas Coastal (Madsen 2010; Texas Invasive Plant and Pest Council 2015), Galveston Bay-Sabine Lake (Center for Environmental Studies 2015; Helton and Hartmann 1996; Sanderson 1996; Texas Invasive Plant and Pest Council 2015), Guadalupe (Center for Environmental Studies 2015; Helton and Hartmann 1996; Johnson et al. 1991; Lemke 1989; Texas Invasive Plant and Pest Council 2015), Lavaca (Helton and Hartmann 1997; Johnson et al. 1991; Madsen 2010; Texas Invasive Plant and Pest Council 2015), Little (Texas Invasive Plant and Pest Council 2015), Lower Brazos (Hannick et al. 2013; Helton and Hartmann 1996; Texas Invasive Plant and Pest Council 2015), Lower Colorado (Helton and Hartmann 1996; Texas Invasive Plant and Pest Council 2015), Lower Rio Grande (Helton and Hartmann 1996; iDigBio 2015), Lower Trinity (Barrett 1980; Brown et al. 2009; Helton and Hartmann 1996; Johnson et al. 1991; Madsen 2010; Texas Invasive Plant and Pest Council 2015), Middle Colorado-Llano (Center for Environmental Studies 2015; GBIF 2013; Helton and Hartmann 1996; iDigBio 2015; Texas Invasive Plant and Pest Council 2015), Neches (Beck and Ott 2006; Helton and Hartmann 1996; Johnson et al. 1991; Texas Invasive Plant and Pest Council 2015), Nueces (Johnson et al. 1991; Texas Invasive Plant and Pest Council 2015), Sabine (Helton and Hartmann 1996; Texas Invasive Plant and Pest Council 2015), San Antonio (Center for Environmental Studies 2015; Helton and Hartmann 1996), San Bernard Coastal (Rhandy Helton, TPWD, pers. comm.), San Jacinto (Barrett 1980; Helton and Hartmann 1996; Johnson et al. 1991; Texas Invasive Plant and Pest Council 2015), Southwestern Texas Coastal (Center for Environmental Studies 2015; GBIF 2013; Helton and Hartmann 1996; iDigBio 2015; Texas Invasive Plant and Pest Council 2015), and Upper Trinity (Center for Environmental Studies 2015; Texas Invasive Plant and Pest Council 2015) drainages
Utah – Private garden pond in Cache County, of the Little Bear-Logan drainage (Center for Environmental Studies 2015; iDigBio 2015)
Virgin Islands – Catherine's Rest (Hope) in St. Croix drainage (Acevedo-Rodríguez and Strong 2005; Missouri Botanical Garden 2015)
Virginia – Albemarle (EDDMapS 2015), Eastern Lower Delmarva (Harvill et al. 1977), Hampton Roads (Lynn Swanson, City of Chesapeake Ag. Dept., pers. comm.), and Lynnhaven-Poquoson (Radford et al. 1968) drainages, and Spotsylvania (Fassett 1957) County
Washington – Lake Washington (EDDMapS 2015), Lower Columbia-Clatskanie (GBIF 2013), and Snohomish (Parsons 2005) drainages
West Virginia – McDonough Park in Parkersburg of the Upper Ohio-Shade drainage (Center for Environmental Studies 2015)
Wisconsin – Buffalo-Whitewater (EDDMapS 2015), La Crosse-Pine (Roe 2015), and Upper Rock (Susan Graham, WI DNR, pers. comm.) drainages"

"Populations in the southeastern (North Carolina to Texas) and southwestern (California and Arizona) US remain established (including Guam, Hawaii, Puerto Rico, and the Virgin Islands), while those in northern states (Washington to Colorado to New York) likely do not overwinter."

From Jacono et al (2017):

"*Eichhornia crassipes* is sold at aquarium stores and is sold in the Great Lakes. This species is a popular aquarium plant and is available for purchase in the Great Lakes region. […] In a survey of aquarium stores near Lakes Erie and Ontario, *E. crassipes* was available for purchase in 30%

of the stores (Rixon et al. 2005). Title 18 U.S. Code 46 states that it is a violation of the law to knowingly transport *E. crassipes* in interstate commerce, and to sell or purchase the plant (18 U.S.C. § 46). The sale of this species is prohibited in Chicago and Illinois State, but not in Indiana, Michigan, Minnesota, New York, Ohio, Ontario, Pennsylvania, Quebec, or Wisconsin (Great Lakes Panel on Aquatic Nuisance Species 2012)."

Means of Introductions in the United States

From Masterson (2007):

"The U.S. invasion history of water hyacinth is well documented. The Brazil native was first introduced to the U.S. as an ornamental aquatic plant at a New Orleans, LA exposition in 1884. *Eichhornia crassipes* escaped from cultivation to arrive in Florida by 1890, and over the ensuing 60 years, dense mats of this highly invasive plant had taken over more than 50,000 ha of Florida freshwater habitat (Gopal and Sharma 1981, Schmitz et al. 1993)."

From Pfingsten et al. (2017):

"Sold as an ornamental for fish ponds; sometimes escapes or is intentionally introduced into larger water bodies such as lakes and reservoirs."

Remarks

From CABI (2017):

"Harley et al. (1996) comment that people in Papua New Guinea have died through a combination of reduced nutrition, degraded water, increased disease vectors and generally reduced health, directly related to the degrading effect of water hyacinth on the environment."

2 Biology and Ecology

Taxonomic Hierarchy and Taxonomic Standing

From ITIS (2015):

"Taxonomic Status:
Current Standing: accepted"

"Kingdom Plantae
  Subkingdom Viridaeplantae
    Infrakingdom Streptophyta
      Division Embryophyta
        Subdivision Tracheophyta
          Infradivision Spermatophytina
            Class Magnolipsida
              Superorder Lilianae
                Order Commelinales

Family Pontederiaceae
Genus *Einhornia* Kunth
Species *Eichhornia crassipes* (Mart.) Solms"

From Pfingsten et al. (2017):

"**Synonyms and Other Names:** water hyacinth, water-hyacinth, common waterhyacinth, *Eichhornia speciosa* Kunth, *Piarpus crassipes* (Mart.) Britton, *Heteranthera formosa*, *Pontederia crassipes* (Mart. and Zucc.), *Eichornia crassipes* (Mart. and Zucc.)"

Size, Weight, and Age Range

From U.S. Forest Service (2015):

"[…] [petioles] up to 30 cm long when older […]"

"[…] [lamina] 4 to 15 cm long and wide […]"

"[…] flower-bearing part of the rachis up to 15 cm or less long; entire scape may be 30 cm; […]"

From Masterson (2007):

"Aerial portions of *Eichhornia crassipes* generally grow to 0.5 m in height, although individuals in some Asian populations may reach nearly 1 m (Gopal 1987)."

Environment

From U.S. Forest Service (2015):

"It is an aquatic floating weed. It does not tolerate brackish water (Holm *et al*. 1977, p. 72-77) and salinity can limit or modify its distribution."

From GISD (2017):

"*Eichhornia crassipes* has been found to tolerate salinity levels up to 0.24% in Indonesia (Kikuchi et al. 1997 in ESA 2000)."

From Téllez et al. (2008):

"Also, growth stops if the water temperature falls below 10°C or rises above 40°C (François 1970)."

"Another determining factor for the growth of *E. crassipes* is pH. This has to be between 6 and 8. When the values move outside this interval, the plant can regulate pH of the medium within this range with its growth frequently resulting in the alkalinization of the water. Maximum growth (number of plants and dry weight) is at pH 7, with pH 3.2–4.2 being very toxic for the plant, 4.2–4.3 inhibitory, and 4.3–4.5 possibly inhibitory (Berg 1961)."

"Maximum growth of *E. crassipes* has been observed at N:21 mg/L, P:62 mg/L, and Fe:0.6 mg/L. Deficiency of N or P has less adverse effect than that of Ca. A lack of Ca prevents the plant's vegetative reproduction (Desougi 1984), the minimum concentration necessary being Ca:5 mg/L (Oki et al. 1978), with this element being essential for seed formation (Talatala 1974). Nitrates are the main nutrient responsible for the growth of this invading plant. Their concentration in the River Guadiana in 2005 varied between 19.63 to 23.52 mg/L in the zones of greatest infestation. Phosphate concentrations were between 0.02 to 3.31 mg/L."

Climate/Range

From Villamagna and Murphy (2009):

"Water hyacinth has invaded freshwater systems in over 50 countries on five continents and, according to recent climate change models, its distribution may expand into higher latitudes as temperatures rise (Rodrıguez-Gallego *et al*. 2004, Hellmann *et al*. 2008, Rahel and Olden 2008). […] It is prevalent in tropical and sub-tropical waterbodies […]."

From Coetzee et al. (2009):

"Its distribution is now mainly pantropical, but it also occurs in warm temperate regions of the world, limited to latitudes of 40^{o} N and S (Gopal 1987)."

From GISD (2017):

"Despite the fact that they can sometimes can [sic] form large floating mats during hot summers (even under Moscow climatic conditions), the first frosts in October kill them completely."

From Masterson (2007):

"Although *Eichhornia crassipes* is excluded from cold climates due to temperature limitations, it does exhibit a degree of freeze tolerance. Aerial portions of the plant killed back by moderate freeze events can quickly regrow from submerged stem tips protected from freezing by water (Langeland and Burks 1998)."

From Téllez et al. (2008):

"The northernmost limit of the area of distribution of *E. crassipes* is where the mean January temperature is 1°C, the mean annual temperature is 13°C, and the average lowest temperature in the year is -3°C (Ueki et al. 1976). The optimal mean temperature for plant growth is between 25°C and 27°C (François 1970)."

From U.S. Forest Service (2015):

"[…], occurring near sea level (but elsewhere up to an elevation of 1,600 m or higher)" (Smith, 1979; pp. 175-176)."

Distribution Outside the United States

Native

From U.S. Forest Service (2015):

"Brazil, French Guian, Guyana, Suriname and Venezuela; […]"

From Coetzee et al. (2009):

"It is indigenous to the New World tropics, and has its center of origin in Amazonia, Brazil (Barrett and Forno 1982)."

Introduced

From Coetzee et al. (2009):

"Even though the first introduction of *E. crassipes* to the African continent was made in Egypt between 1879 and 1892 (Edwards and Musil 1975), many invasions in Africa were first noticed only in the 1980s and it continues to invade many waterways of Africa, even though regional bans have been placed on its transport, and numerous control efforts have been implemented (Navarro and Phiri 2000)."

From GISD (2017):

"Water hyacinth currently occurs along the east coast of Australia from Kiama in NSW to southern Cape York Peninsula in Queensland. In the early 1900s dominant infestations in northern coastal rivers of NSW were a major hindrance to river navigation. In inland NSW, water hyacinth was identified on the Gingham Watercourse near Moree in 1955. By 1976 it had become a major infestation covering 7000 hectares, threatening the Murray-Darling system. These infestations are now under control but require annual monitoring and maintenance. Populations are also known to occur in Darwin, Perth, and the Mitchell River on western Cape York Peninsula, Mt Isa and Georgetown in Queensland. Infestations in Victoria and South Australia have been eradicated. It has never been found in the wild in Tasmania."

"Water hyacinth, *Eichhornia crassipes* is found in freshwater habitats, it is reported upland coastal habitats [in Bermuda] (Bermuda Natural History Museum, undated in Varnham, 2006)."

"*Eichhornia crassipes* has been introduced to other parts of Brazil beyond its native distribution in the Amazon Basin."

"Water hyacinth, *Eichhornia crassipes* probably introduced as an ornamental and possibly naturalised does not appear to thrive in the wild in the Cayman Islands (Burton, 2003 in Varnham, 2006)."

"Water hyacinth was introduced into China in the early 1900s. As an ornamental plant, it was first introduced into Taiwan in 1903 from Southeast Asia. In the 1930s it was introduced to the mainland (Diao 1989, in Jianqing et al. 2001). But the first scientific record appeared for the mainland in 1954 in the book, 'Taxonomy Catalogue for China's Plants: Families and Genera'

(Anon. 1954, in Jianqing et al. 2001). In the 1950s and 1960s, water hyacinth was distributed widely into almost all provinces for animal food."

"Water hyacinth is now distributed naturally in 17 provinces or cities in China. In several other provinces water hyacinth is still utilised but cannot overwinter."

"Proliferation of *Echhornia crassipes* have been reported in Lakes Victoria and Naivasha (Gang P. Society for Protection of Environment in Kenya, pers. comm., July 2003)."

"There is an enormous presence of water hyacinth in some of these lakes and rivers of one the most important National Parks in the West of Madagascar, Ankarafantsika (Gerardo García, Durrell Wildlife Conservation Trust (DWCT) pers. comm., April 2003."

"*E. crassipes* has mostly been found in Northland and Auckland, with some sites as far south as Wellington. Many of the known sites of water hyacinth are now considered historical, having been clear of the plant for at least 20 years. The seed of water hyacinth may remain viable for up to twenty years and in New Zealand plants have been found at a site previously clear for seven years."

"Classed as one of the worst and most aggressive invasive plant species present in Portugal *E. crassipes* was introduced as an ornamental and now invades water courses and lagoons in the country."

"Different stretches of freshwater in coastal zones [of Reunion] are overgrown to a greater or lesser degree by water hyacinth and water lettuce (Pistia stratiotes). In February 2006, an analysis done on l Etang du Gol (16ha) showed it to be 100% overgrown, 40% of it due to water hyacinth. Even though major climatic events (hurricanes or tropical storms) result in evacuation of floating aquatic plants to the sea, recolonization of the surface of the pond is ensured from remaining seeds and fragments (Le Bourgeois, 2006)."

"Tropical water weeds *E. crassipes* and *Pistia stratiodes* have lately been found in many ponds and rivers of Moscow and its neighborhood. Both of the species are grown as ornamental and escape summertime cultivation, the first is suggested for use in wastewater treatment, too. These plants are regarded as invasive weeds in many tropical and subtropical countries."

"Despite the fact that they can sometimes can form large floating mats during hot summers (even under Moscow climatic conditions), the first frosts in October kill them completely. *E. crassipes* and *Pistia stratiodes* can hardly become established in natural systems of the middle European Russia, although they may be potentially hazardous for southern regions of the country."

"Water hyacinth entered Sri Lanka in 1904 and spread rapidly to cause major environmental problems. Water hyacinth was introduced into the Botanical Gardens in Colombo in 1904 and by 1909 it was seen as such a significant pest that the Water Hyacinth Ordinance was proclaimed (Jepson 1933, Kotalawala 1976, in Room and Fernando 1992). Despite several expensive eradication campaigns, the weed was found throughout the lowlands by 1922 and 338 infestations were reported in 1933 (Jepson 1933, in Room and Fernando 1992). Infestations remained widespread, numerous and flourishing throughout the 1980s."

GISD (2017) lists *Eichhornia crassipes* as alien and established in Australia (New South Wales, Northern Territory, Queensland, Western Australia, and Norfolk Island), Bahamas, Bangladesh, Benin, Bermuda, Brunei, Burkina Faso, Burundi, Cambodia, Cameroon, Cayman Islands, Chile, China (Dianchi Lake, Fujian, Guangdong, Wenzhou, Yunnan, and Zhejiang), Christmas Island, Colombia, Republic of the Congo, The Democratic Republic of the Congo (Zaire), Cook Islands (Mangaia and Rarotonga islands), Costa Rica, Cote d'Ivoire, Cuba, Dominican Republic, Ecuador, Egypt, Equatorial Guinea, Ethiopia, Fiji (Viti Levu Island), French Polynesia (Raiatea, Tahiti, and Ua Pou islands), Gabon, Ghana, Guadeloupe, Guatemala, Guinea, Guinea-Bissau, Haiti, Honduras, Hong Kong, India, Indonesia (Papua (Irian Jaya)), Jamaica, Japan, Kenya (Lake Victoria), Lao People's Democratic Republic, Liberia, Madagascar, Malawi, Malaysia, Maldives, Marshall Islands (Kwajalein and Majuro islands), Martinique, Mauritius, Mexico, Micronesia (Chuuk, Kosrae, Pohnpei, and Yap islands), Mozambique, Myanmar (Burma), Nauru, New Caledonia, New Zealand, Nicaragua, Nigeria, Palau (Babeldaob, Koror, and Ngerekebesang islands), Panama, Papua New Guinea, Peru, Philippines, Portugal, Reunion, Nile River, Rwanda, Saint Lucia, Samoa (Upolu Island), Senegal, Sierra Leone, Singapore, Solomon Islands, South Africa, Sri Lanka, Sudan, Swaziland, Taiwan, Tanzania, Thailand, Togo, Uganda, Vanuatu, Venezuela, Vietnam, British Virgin Islands (Beef Island), Zambia, and Zimbabwe (Lake Chivero). It is listed as invasive but eradicated in parts of Australia (South Australia and Victoria). It is listed as alien and status uncertain in Israel, Jordan, Lebanon, Occupied Palestinian Territory, Russia (Moscow), and the Syrian Arab Republic.

The U.S. Forest Service (2015) lists *Eichhornia crassipes* as introduced and invasive in Australia (Norfolk and Christmas islands, Northern Territory, Queensland), Brunei, Cambodia, China, Colombia, Cook Islands (Rarotonga Island), Fiji (Viti Levu Island), French Polynesia (Raiatea, Tahiti, Tubuai, and Ua Pou islands), Hong Kong, Indonesia, Japan, Malaysia, Maldives, Mauritius, Mexico, Micronesia (Pohnpei Island), Nauru, New Caledonia (New Caledonia islands and Île Granda Terre), New Zealand, Nicaragua, Philippines, Réunion Island, Samoa (Upolu Island), Singapore, Solomon Islands, South Africa, Taiwan, Thailand, Vanuatu, and Vietnam; as introduced in French Polynesia (Tetiaroa Atoll), Marshall Islands (Arno and Majuro atolls), Micronesia (Chuuk, Kosrae, and Yap islands), Palau (Babeladaod, Koror, and Ngerkebesang islands), Papua New Guinea, and Seychelles.

Eichhornia crassipes was discovered in Spain in 2004 where is has become established (Téllez et al. 2008).

In addition to the countries already listed above, CABI (2017) lists *Eichhornia crassipes* as introduced with a restricted distribution in Angola, Bhutan, Czech Republic (not considered invasive), France (not considered invasive), Mali, Niger, and Pakistan; invasive and present in few locations in Israel; present in Antigua and Barbuda, Aruba, Barbados, Belize, Botswana, Canada, Dominica, El Salvador, Italy, Jordan, Korea, Lebanon, Morocco, Rodriguez Island, Romania, Saint Vincent and the Grenadines, Trinidad and Tobago, and Turkey; introduced but not established in Belgium, and Hungary

Eichhornia crasspies was introduced to the Netherlands in 1917, it did not become established in the wild (NOBANIS 2017).

From Landsdown (2017):

"*Eichhornia crassipes*, water hyacinth, is [sic] tropical aquatic plant that has been recorded from around 25 sites in GB [Great Britain] but has rarely persisted due to frost."

According to DAISIE (2017) *Eichhornia crassipes* was introduced to but did not establish in Belgium, Czech Republic, Hungary, and Sicilia. It was introduced and did establish in the Azores, Corsica, France, Italy, Portugal, and Spain. It was introduced to Romania but no information on status of establishment was given.

According to Pallewatta et al. (2003) *Eichhornia crassipes* is present in wetlands in Tarai, Siwalik, and mid-hills in Nepal.

Means of Introduction Outside the United States

From Villamagna and Murphy (2009):

"There is not a clear record of how, why and when water hyacinth was introduced to waterbodies outside of its native range, but many populations are well established and persistent despite control efforts. Introductions to non-native waterbodies have been accidental and intentional; intentional introductions to ponds are common as water hyacinth is an ornamental plant that reduces nutrient concentrations and algae blooms."

From GISD (2017):

"In the 1950s and 1960s, water hyacinth was distributed widely into almost all provinces in China for animal food. After artificial transplanting and mass rearing and breeding, water hyacinth was distributed to further areas in the 1970s (Jianqing et al. 2001).Water hyacinth has an attractive purple flower which has made it a favourite amongst ornamental pond and botanical garden enthusiasts. As a result humans have spread it widely and due to its fast growth rate it now flourishes in all continents but Europe. Most spread can be attributed to deliberate planting of water hyacinth in ponds or dams as an ornamental, or use in aquariums. Unwanted plant material is discarded into creeks, rivers and dams is a major mode of dispersal (Burton 2005).Water hyacinth has an attractive purple flower which has made it a favourite amongst ornamental pond and botanical garden enthusiasts. As a result humans have spread it widely and due to its fast growth rate it now flourishes in all continents but Europe (Lindsey and Hirt 1999, in Williams Undated). Seeds are translocated by machinery (Burton 2005)."

Short Description

From U.S. Forest Service (2013):

"A perennial aquatic **herb**; stems short, floating or rooting in mud, rhizomatous or stoloniferous, rooting from the nodes; **roots** long, sometimes dark because of their purple anthocyanin, pendant; **leaves** in a rosette; petioles spongy, in young specimens short and with a one-sided swelling or inflation but up to 30 cm long when older, tapering and narrowing from the bulbous base to the point of attachment with the lamina; **lamina** circular to kidney-shaped, glossy smooth, 4 to 15 cm long and wide, acting as a sail in the wind; **inflorescence** in spikes with about eight flowers, long peduncled, bibracteate, the lower bract with long sheath and small lamina, the upper almost entirely included within the sheath of the lower one, tubular with a small pointed tip (apiculate); flower-bearing part of the rachis up to 15 cm or less long; entire scape may be 30 cm; perianth six-lobed, united below into a narrow tube, lilac, bluish purple or white, the upper lobe bearing a violet blotch with yellow center; stamens six, three long, three shorter, attached to the tube; **capsule** membranous, three-locular, dehiscent, many-seeded, as many as 50 or so per capsule; **seed** ovoid, ribbed, 0.5 to 1 mm. The species is distinguished by the almost one-sided swelling or inflation of the petiole, its long peduncled bibracteate spike, and its upper perianth blotched with yellow at the center" (Holm *et al*. 1977, p. 72)."

"Rooted only at flowering time by long slender roots; otherwise floating, with thick, fleshy, more or less horizontal **roots**; **leaves** clustered, on bulbously inflated petioles, blades rounded or oblong, up to 3-4 inches wide; **flowers** showy, pale violet with a spot of bright yellow on the large upper lobe, some forms with pink and yellow flowers, all parts edible" (Stone 1970, p. 116)."

From GISD (2017):

"As much as 50% of a single water hyacinth's biomass can be roots. Roots are adventitious and fibrous, 10-300cm in length. As many as 70 lateral roots percm give the roots a feathery appearance. They are dark violet to bluish or pinkish violet (though whitish if grown in total darkness) and contain soluble pigments, including anthocyanins that may protect the root from herbivory (Gopal 1987, in Batcher Undated)."

"Flowers are borne terminally on a lavender spike on an elongated peduncle and are subtended by two bracts. The lower bract has a distinct blade. Each spike has 4-25 flowers (maximum 35) with 8-15 being the most common. The perianth tube is 1.5-1.75cm long with a green base and pale top. Tepals are ovate to oblong, thin, lilac and up to 4cm long. The posterior tepal (labellum) has a central bright yellow diamond-shaped region surrounded by a deep blue border with bright red radiating lines. When young, this labellum has a green spot. There are six stamens (sometimes 5 or 7) having curved filaments with glandular hairs. Three are small and close to the perianth tube. Anthers are violet and measure 1.4-2.2mm long (Gopal 1987, in Batcher Undated)."

"The fruit is a thin-walled capsule enclosed in a relatively thick-walled hypanthium developed from the perianth tube. Mature seeds can number 450 per capsule, are 4 x 1mm, with an oval base and tapering apex. The coat has 12-15 longitudinal ridges (Gopal 1987, in Batcher Undated)."

Biology

From Masterson (2007):

"Water hyacinth mats are capable of attaining incredibly high plant density and biomass. A single hectare of dense *E. crassipes* mat can contain more than 360 metric tons of plant biomass."

"Water hyacinth is capable of sexual and asexual reproduction and both modes are important to the species' success as a pernicious aquatic invader. In mild climates, plants can flower year-round, and from early spring to late fall elsewhere. They can produce an abundance of seeds (Flora of North America 2003, Langeland and Burks 1998). A study by Barrett (1980b) confirmed that tropical *E. crassipes* populations produced twice as many seeds as did temperate populations and attributed the difference to higher rates of pollinating insect visitation in the tropics. Seed germination tends to occur when water levels are down and the seedlings can grow in saturated soils.

Vegetative reproduction occurs via the breaking off of rosettes of clonal individuals. The stolons (horizontal shoots capable of forming new shoots and adventitious roots from nodes) are easily broken by wind or wave action and floating clonal plants and mats are readily transported via wind or water movement (Barrett 1980a, Langeland and Burks 1998)."

From U.S. Forest Service (2015):

"Freshwater lakes, ponds, marshes, ditches, canals, slow-moving streams."

From GISD (2017):

"Maximum fruiting occurs in 90% humidity and at 22.5°C to 35°C (Gopal 1987, in Batcher Undated). Several species of bee pollinate the flowers and several researchers report a highlvel [sic] of self-compatibility (Batcher Undated). High light intensity and altering high and low temperatures (5°C to 40°C) favour germination (Batcher Undated).\r\n"

From Pfingsten et al. (2017):

"In the absence of sustained freeze, the plant grows as a perennial. In its northern range, the plant grows as an annual, where it is either re-introduced or germinates from seed. Long-term exposures (2-4 weeks) to temperatures at or near freezing are required to significantly reduce *E. crassipes* populations (Owens and Madsen 1995; Russell 1942)."

Human Uses

From Villamagna and Murphy (2009):

"[…] water hyacinth is an ornamental plant that reduces nutrient concentrations and algae blooms."

"In California (U.S.A.), water hyacinth leaf tissue was found to have the same mercury concentration as the sediment beneath, suggesting that plant harvesting could help mediate mercury contamination if disposed of properly (Greenfield et al., 2007). On a similar note, water hyacinth's capacity to absorb nutrients makes it a potential biological alternative to secondary and tertiary treatment for wastewater (Ho & Wong, 1994; Cossu et al., 2001)."

From GISD (2017):

"There has been some use of *E. crassipes* for the removal of nutrients and heavy metals from sewage and sludge ponds (bioremediation) (Vietmeyer 1975, in Batcher Undated). In Kenya the experimental use of water hyacinth as an organic fertiliser and animal feed has been undertaken in places such as flower farms (The Nation Nairobi 2004). However there is some controversy as to the effect of the fertiliser on the soil due to its highly alkaline PH value (>9)."

"In China the weed was widely used as animal food from the 1950s to the 1970s. As at that time, the economy in rural areas was very depressed and there was great shortage of food for animals. It was also used for fertiliser in a few areas. Since the end of 1980s the use of water hyacinth has fallen greatly and its sole use now is for feeding ducks and as a test plant for the purification of polluted water (Jianqing et al. 2001)."

"A chemist, in Kenya has invented ways in which the water hyacinth can be used as the main raw material for making organic fertilisers and animal feeds. Presently, his liquid fertiliser is being used in flower farms (The Nation (Nairobi) March 25, 2004)."

"Early in 1974, a first law (decreto-lei 165/74 de 22 Abril) [in Portugal] recognized water-hyacinth (*Eichhornia crassipes*) as an invasive species, forbidding its importation, culture, selling, transport or possession."

From U.S. Forest Service (2015):

"A declared noxious weed in Western Australia, the Northern Territory and Queensland (Smith, 2002; p. 82). A Class A (eradicate) noxious weed in New Zealand. Can be used for pig feed, but this may aid in its spread."

From CABI (2017):

"It can be used as a mulch, for making compost, fuel bricks, paper or board, for generating methane biogas, and for removing nutrients and toxic chemicals from water. Recent work on composting includes Montoya et al. (2013) who found that a large-scale composting system using water hyacinth as a primary feedstock reached high enough temperatures to inactivate seeds and other propagules, and thus that the plant can be composted without the potential danger of spread."

"Work on utilization includes use as an organic manure in Bangladesh (Nasima et al., 1997); as a compost to suppress nematodes in India (Verma et al., 1997); for water purification (Ayade, 1998); for biogas production (Rodriguez et al., 1997; Sarkar and Banergee, 2013)); for feeding buffaloes in India (Mitra et al., 1997); and as a mulch to suppress weeds in Indonesia (Lamid and Wahab, 1996). Masto et al. (2013) explored the conversion of *E. crassipes* to biochar for improvement of soil quality. There are many recent studies on utilizing *E. crassipes* for bioenergy. Hussain et al. (2013) converted *E. crassipes* biomass into liquid hydrocarbon fuel using catalytic pyrolysis. Bergier et al. (2012) suggest that biomass from water hyacinth in the Panatanal of South America could be managed for production of biofuels. Sudhakar et al. (2013) assess bioelectricity production using water hyacinth biomass. Anaerobic co-digestion with poultry litter for biogas production is considered by Patil et al. (2013), while Zhang et al. (2013) report on hydrothermal liquefaction. Biogas production from water hyacinth polluting water bodies in Nigeria is studied by Adeleye et al. (2013)."

From Jacono et al (2017):

"*Eichhornia crassipes* is sold at aquarium stores and is sold in the Great Lakes. This species is a popular aquarium plant and is available for purchase in the Great Lakes region. […] In a survey of aquarium stores near Lakes Erie and Ontario, *E. crassipes* was available for purchase in 30% of the stores (Rixon et al. 2005). Title 18 U.S. Code 46 states that it is a violation of the law to knowingly transport *E. crassipes* in interstate commerce, and to sell or purchase the plant (18 U.S.C. § 46). The sale of this species is prohibited in Chicago and Illinois State, but not in Indiana, Michigan, Minnesota, New York, Ohio, Ontario, Pennsylvania, Quebec, or Wisconsin (Great Lakes Panel on Aquatic Nuisance Species 2012)."

Diseases

From CABI (2017):

"Almost 100 different insect species and a comparable number of pathogens have been recorded as attacking *E. crassipes* (refer to Gopal, 1987). Most of these are restricted to the areas of the New World from which the weed originates. In Africa and Asia, the weed is normally quite healthy, though sporadically attacked and sometimes moderately damaged by sundry local organisms. A few species of insects and fungi have been developed for use as biological control agents, with varying success (see Control [in source material])."

CABI (2017) lists *Acremonium zonatum, Alternaria alternata, Alternaria eichhorniae, Cercospera rodmanii, Cercospora piaropi, Cercospora rodmanii, Cochliobolus lunatus, Cochliobolus sativus, Cochliobolus spicifer, Fusarium chlamydosporum, Gibberella intricans, Gibberella zeae, Haematonectria haematococca, Myrothrcium roridum, Penicillium oxalicum, Phoma sorghina, Thanatephorus cucumeris,* and *Uredo eichhorniae* as pathogens of *Eichhornia crassipes*.

Poelen et al. (2014) list *Kalopolynema poema, Aprostocetus yerbamatei, Anagrus empanadus,* and *Aprostocetus taosae* as parasites of *Eichhornia crassipes.*

Threat to Humans

From CABI (2017):

"The same authors refer to the recent increase in water hyacinth infestations in West Africa which are resulting in serious disruption of the socio-economic structure, food supply and health of several million people."

"*E. crassipes* may reduce water quality in various ways and encourage mosquitoes, snails and other organisms associated with human illnesses, including malaria, schistosomiasis, encephalitis, filariasis and cholera (Gopal, 1987). Harley et al. (1996) comment that people in Papua New Guinea have died through a combination of reduced nutrition, degraded water, increased disease vectors and generally reduced health, directly related to the degrading effect of water hyacinth on the environment. Dense mats greatly hinder boating by fishermen and may prevent fishing altogether, thus denying the locals their main source of protein and sometimes forcing people to relocate. In extreme cases of competition between *E. crassipes* and rice crops, fields have been abandoned. In the Lake Victoria Basin, the main negative social impact were identified by interviewees as an increase in certain diseases, difficulties associated with clean water availability and migration of communities (Mailu, 2001)."

3 Impacts of Introductions

From Coetzee et al. (2009):

"*Eichhornia crassipes* is recognized as the world's worst aquatic weed, because of the significant ecological impacts it has on the environment, and the associated cascading socioeconomic effects. Dense impenetrable mats restrict access to water, negatively impacting fisheries and related commercial activities, the effectiveness of irrigation canals, navigation and transport, hydroelectric programs, and tourism (Navarro and Phiri 2000). Other problems include property damage during floods as a result of *E. crassipes* building up against bridges, fences, walls, obstructing water flow, and increasing flood levels. Arguably, the most affected are poverty-stricken communities in rural Africa, where the extent of these effects are yet to be fully measured. *Eichhornia crassipes* alters the livelihoods of any community with high dependence on freshwater waterways for food (subsistence or commercial), transport, and clean water. Ecologically, benthic and littoral diversity is reduced (Masifwa et al. 2001; Toft et al. 2003; Midgley et al. 2006). For example, Midgley et al. (2006) found that the benthic invertebrate community beneath *E. crassipes* mats was significantly less diverse than the community in open water on New Years Dam, South Africa, and similarly Masifwa et al. (2001) found a decrease in littoral macroinvertebrate diversity beneath dense *E. crassipes* mats on Lake Victoria in Uganda. Increases in the populations of vectors of human and animal diseases, such as *Eichhornia crassipes* 187 bilharzia, malaria, and cholera, are also associated with *E. crassipes* infestation because these plants interfere with pesticide application (Harley et al. 1996). Because of its rapid growth rate whereby it can double in number in suitable habitat every 11 to 18 days (Edwards and Musil 1975), *E. crassipes* is able to outcompete native aquatic plants by utilizing the available nutrients in the water, and by successfully competing for space and sunlight (Cilliers 1991)."

From GISD (2017):

"Ethnobotanic investigations estimate the losses for fishing, arboriculture and vegetable gardening at more than 20 million francs CFA per annum, that is approximately $US 35,000 to 40,000. Currently the water hyacinth invasion threatens the three largest sources of water in Burkina Faso, the Kompienga (20,000 ha) located in the basin of Niger, the Bagré (25,000 ha) and the Bougouriba which belongs to the basin of Volta (Lompo-Ouedraogo, Z., pers.comm., 2005)."

"Boat traffic on several rivers [in Florida] was halted; hundreds of lakes and ponds were covered from shore to shore with up to 200 tons of water hyacinths per acre."

"The total infested area is estimated to be 487 km2 covering most of the drainage and irrigation canals in different governorates of Egypt, and about 151 km2 covering lakes (Fayad et al. 2001). The water hyacinth problem is particularly severe in the Nile Delta and the irrigation systems (Shabana et al. 2001)."

From U.S. Forest Service (2015):

""High growth rates mean populations can quickly form thick mats on the water surface. This makes passage by boats difficult, chokes irrigation channels, pollutes water and provides breeding grounds for disease-carrying insects. The natural beauty of areas is also degraded as native plants, birds and fish are displaced." (Smith, 2002; p. 82)."

From Masterson (2007):

"The documented negative economic impacts of water hyacinth invasion worldwide have included the clogging of irrigation channels, choking off of navigational routes, smothering of rice paddies, loss of fishing areas, increase in breeding habitat available to disease-transmitting mosquitoes, and others (Room and Fernando 1992, ISSG)."

From Villamagna and Murphy (2009):

"The most commonly documented effects are lower phytoplankton productivity and dissolved oxygen concentrations beneath these mats (Rommens et al., 2003; Mangas-Ramirez & Elias-Gutierrez, 2004; Perna & Burrows, 2005). Other water quality effects include higher sedimentation rates within the plant's complex root structure and higher evapotranspiration rates from water hyacinth leaves when compared to evaporation rates from open water (Gopal, 1987). Water hyacinth also has been found to stabilise pH levels and temperature within lotic systems, increasing mixing within the water column and potentially preventing stratification (Giraldo & Garzon, 2002).Water hyacinth mats decrease dissolved oxygen concentrations beneath mats by preventing the transfer of oxygen from the air to the water's surface (Hunt & Christiansen, 2000) and by blocking light used for photosynthesis by phytoplankton and submersed vegetation."

"Water hyacinth was found to selectively inhibit planktonic green algae in a shallow Portuguese lake (Almeida et al., 2006), yet phytoplankton density in littoral sites with water hyacinth in

Lake Chivero (Uganda) was 10–30 times higher than littoral sites without water hyacinth (Brendonck et al., 2003). Water hyacinth can trap phytoplankton and detritus, thereby increasing, at least temporarily, phytoplankton densities beneath mats (Brendonck et al., 2003)."

"The effects of water hyacinth on zooplankton reported in the literature are inconsistent (Table 2), suggesting that factors such as algal concentrations and physiochemical conditions at the time of sampling, the time of day at which zooplankton was sampled, the presence of predators, the effects of water hyacinth on potential predators and the spatial configuration of water hyacinth may be influencing zooplankton response."

"Researchers in Florida took an experimental approach to determine the effects of water hyacinth mats on the macroinvertebrate and fish communities associated with native submersed vegetation *Sagittaria kurziana* Glück. Epiphytic macroinvertebrate abundance within the submersed vegetation initially decreased with the addition of a water hyacinth canopy, but total macroinvertebrate abundance did not differ. Total macroinvertebrate abundance within sites with water hyacinth and *S. kurziana* was significantly greater than sites without water hyacinth during the autumn and winter, starting approximately 80 days after the introduction of water hyacinth. Taxa richness was consistently greater at sites with water hyacinth and *S. kurziana* and community composition differed between the plants as well (Bartodziej & Leslie, 1998). Together these studies support the conclusion that water hyacinth can enhance macroinvertebrate abundance and richness through the provision of additional, and in some cases novel, habitat."

"Brendonck et al. (2003) found that fish diversity in Lake Chivero (Zimbabwe) was higher at littoral sites with water hyacinth than without, although confidence in this result was dampened by variability associated with sampling techniques. On the St Marks River in Florida (U.S.A.), total fish abundance and biomass were similar within submersed vegetation in areas with and without a water hyacinth canopy, but species richness was significantly higher in areas with the water hyacinth canopy. Community composition differed between sites with and without water hyacinth; notable differences included the presence of two insectivorous fish species only found at sites with water hyacinth (Bartodziej & Leslie, 1998). After mechanical control of water hyacinth in a Mexican reservoir three common species (*Cyprinus carpio* L., *Poecilia sphenops* Valenciennes, and *Heterandria jonesii* Günther) disappeared."

From Pfingsten et al. (2017):

"Since its introduction, *E. crassipes* has notoriously interfered with navigation, triggering the 55th Congress, through the Rivers and Harbors Act of 1899, to authorize the U.S. Army Corps of Engineers to address the problem (Schardt 1997) after commercial commerce was impeded *by E. crassipes* on the St. Johns River (Webber 1897). In one instance, 65 feet of a railroad trussel across Rice Creek near Palatka, FL was destroyed in 1894 by build-up of waterhyacinth."

From CABI (2017):

"Annual costs of control or removal have, in the past, amounted to millions of dollars on the Panama Canal, on the Nile in Sudan, on the Congo and have been as much as $35 million in southern USA. Costs of controlling water hyacinth in Malaysia have been estimated at M$ 10 million per year (Mahomed [Mohamed] et al., 1992), while Harley et al. (1996) quoting this figure, state that present actual costs are believed to be much higher. In recent years, the operation of Port Bell, Uganda, on Lake Victoria has been seriously threatened and costs have involved $1 million for a mechanical harvester, as well as the loss of trade at times when the port was completely blocked (Hill, 1999). Infestations are also increasing in Ethiopia, creating a range of problems including restricted access (Aweke, 1994). Harley et al. (1996) refer to 'devastating effects' on socio-economic structure and on the environment in the lower flood plain of the Sepik river in Papua New Guinea resulting from problems of access to subsistence gardens, hunting and fishing areas, and markets. The same authors refer to the recent increase in water hyacinth infestations in West Africa which are resulting in serious disruption of the socio-economic structure, food supply and health of several million people. In Nigeria, Alimi and Akinyemiju (1991) showed that costs of fuel and repairs to boats on infested waterways was approximately three times that on uninfested waterways. The problem has also been increasing recently in Mali (Dembele et al., 2000). Economic losses also result from interference with recreational uses of water bodies (for example, Gopal, 1987; Aweke, 1994; Cilliers et al., 1996)."

"Interference with fishing. This effect is most acute for small-scale fishing communities. Apart from the problems of access to fishing grounds and interference with the spreading or retrieval of nets or with landing their catch, there can be serious effects on fish stocks and fish breeding. Although a sparse cover of water hyacinth may not reduce fish and may even be used to advantage in some fishing techniques (Gopal, 1987), a dense infestation can lead to de-oxygenation and kill-off fish or reduce fish stocks. Gopal (1987) refers to heavy losses of fish production in the Congo, Nile and other rivers and in Pakistan and to losses amounting to 45 million kg in West Bengal, India in the 1950s and reductions of 70% in fish production in the USA as a result of a cover of only 25%, presumably due to reduction of phosphorus levels and phytoplankton. The shallow water of lake edges can be especially important spawning areas for fish and a dense cover of water hyacinth can interfere severely with fish breeding. Hill (1999) refers to this phenomenon on Lake Victoria where the estimated 10,000 ha of the weed includes an almost continuous fringe along the shoreline extending to at least 10 m. Labrada (1996) quotes fuel costs increased by a factor of 2-3 and fish catches down 50-75% on parts of Lake Victoria. Fishermen affected by another relatively new infestation, in the Shire river in Malawi, report reduced catches which are not confirmed by the locally available statistics but there is no doubt fishermen are being troubled by a reduced range of fish species, loss of nets and impeded access (Terry, 1996)."

"Risks of mechanical damage to hydro-electric installations and other structures such as bridges. Expensive barriers or mechanical harvesters may be needed to minimize these risks, for example, to the Owen Falls Dam on Lake Victoria (Hill, 1999). Elsewhere, there are similar concerns in South Africa (Harley et al., 1996), Brazil (Pitelli, 2000), New Zealand (Clayton, 2000) and Ethiopia (Aweke, 1994)."

"Reduced irrigation flow can indirectly cause crop loss but there can also be direct interference and competition from water hyacinth where it occurs in flooded rice. Such losses have been estimated at many million dollars in West Bengal, India and as significant in many other countries including Sri Lanka, Bangladesh, Burma, Malaysia, Indonesia, Thailand, Philippines, Japan and Portugal (Gopal, 1987)."

"Restricting water flow in rivers, irrigation and drainage channels, thus reducing irrigation water and/or leading to greater risk of flooding. Gopal (1987) refers to water flow being reduced by 40-95% in irrigation channels, sometimes leading to flooding in Malaysia and Guyana."

From Pallewatta et al. (2003):

"Now almost all the wetlands of Bangladesh are covered by this water hyacinth (Ameen, 1990), and it is a very serious invasive, replacing indigenous aquatic species such as *Enhydra flactuans*, *Ipomoea aquatica* and *Dodonaea viscosa*."

4 Global Distribution

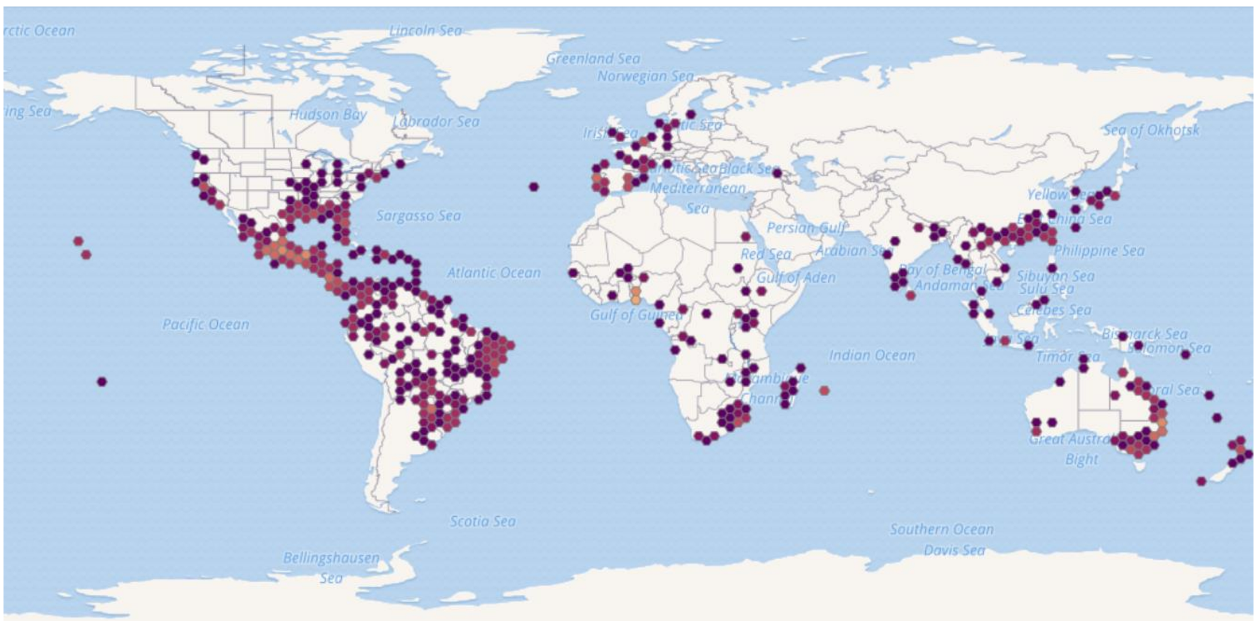

Figure 1. Known global distribution of *Eichhornia crassipes*. Map from GBIF Secretariat (2017).

The location in the country of Georgia is from a specimen in a botanical garden and does not represent an established population in the wild (GBIF Secretariat 2017). It was not used as a source point in the climate match.

The locations in the United Kingdom were not used as source points. There is no indication that they are representative of established populations (Landsdown 2017).

Locations in Belgium, the Czech Republic, Hungary, and Sicilia were not used as source points for the climate match. *Eichhornia crassipes* was not established in those countries (DAISIE 2017).

5 Distribution Within the United States

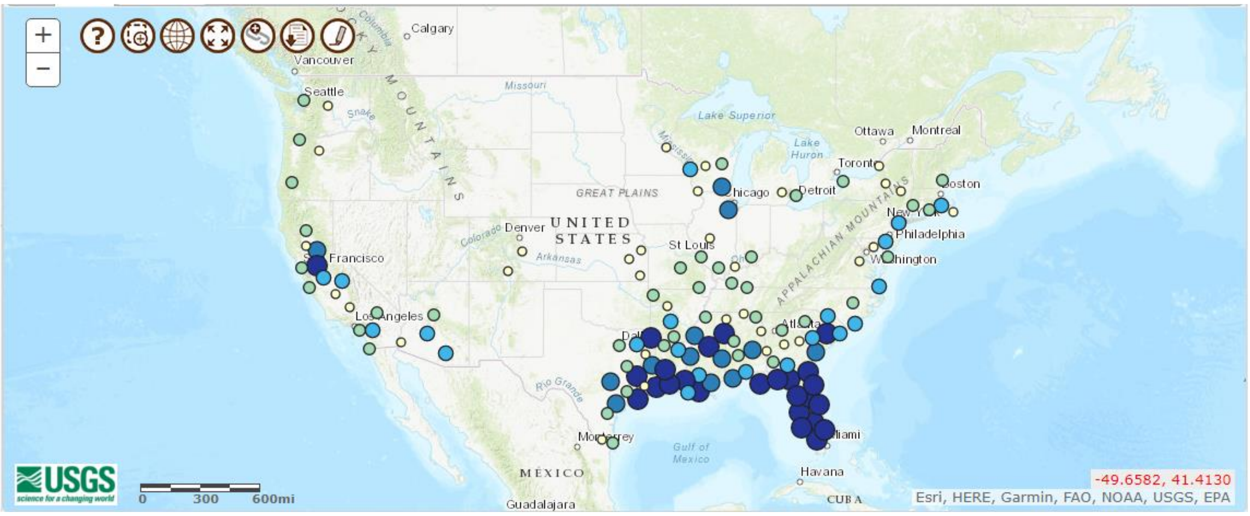

Figure 2. Known distribution of *Eichhornia crassipes* in the contiguous United States. Map from Pfingsten et al. (2017).

The locations in Washington, Colorado, and New York were not used as source points because the plant most likely does not sustain a population overwinter (Pfingsten et al. 2017).

Figure 3. Known distribution of *Eichhornia crassipes* in the state of Hawai'i. Map from Pfingsten et al. (2017).

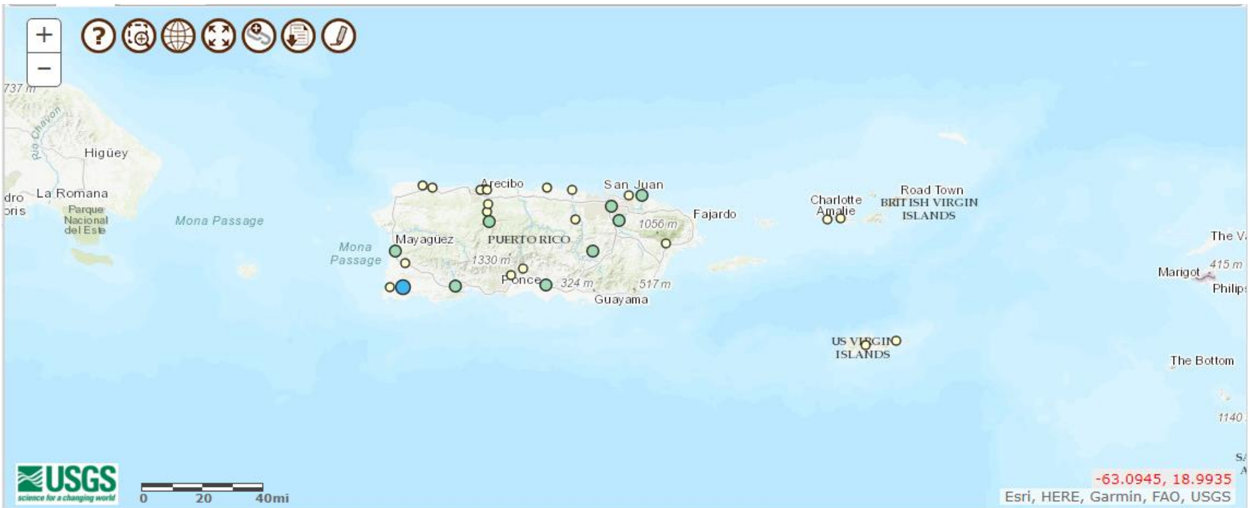

Figure 4. Known distribution of *Eichhornia crassipes* in Puerto Rico and the U.S. Virgin Islands. Map from Pfingsten et al. (2017).

6 Climate Matching

Summary of Climate Matching Analysis

The climate match for *Eichhornia crassipes* was low to medium along the Canadian border in the Midwest and in small pockets in the Pacific Northwest. The climate match was medium to high everywhere else with the highest matches in the southeastern third of the contiguous United States and California. There are many established populations in the southern United States; those areas were used as both source and match points for the climate match. The Climate 6 score (Sanders et al. 2014; 16 climate variables; Euclidean distance) for the contiguous United States was 0.662, high, and all states except for Colorado, Idaho, Minnesota, Montana, North Dakota, South Dakota, Utah, and Wyoming had individually high climate matches.

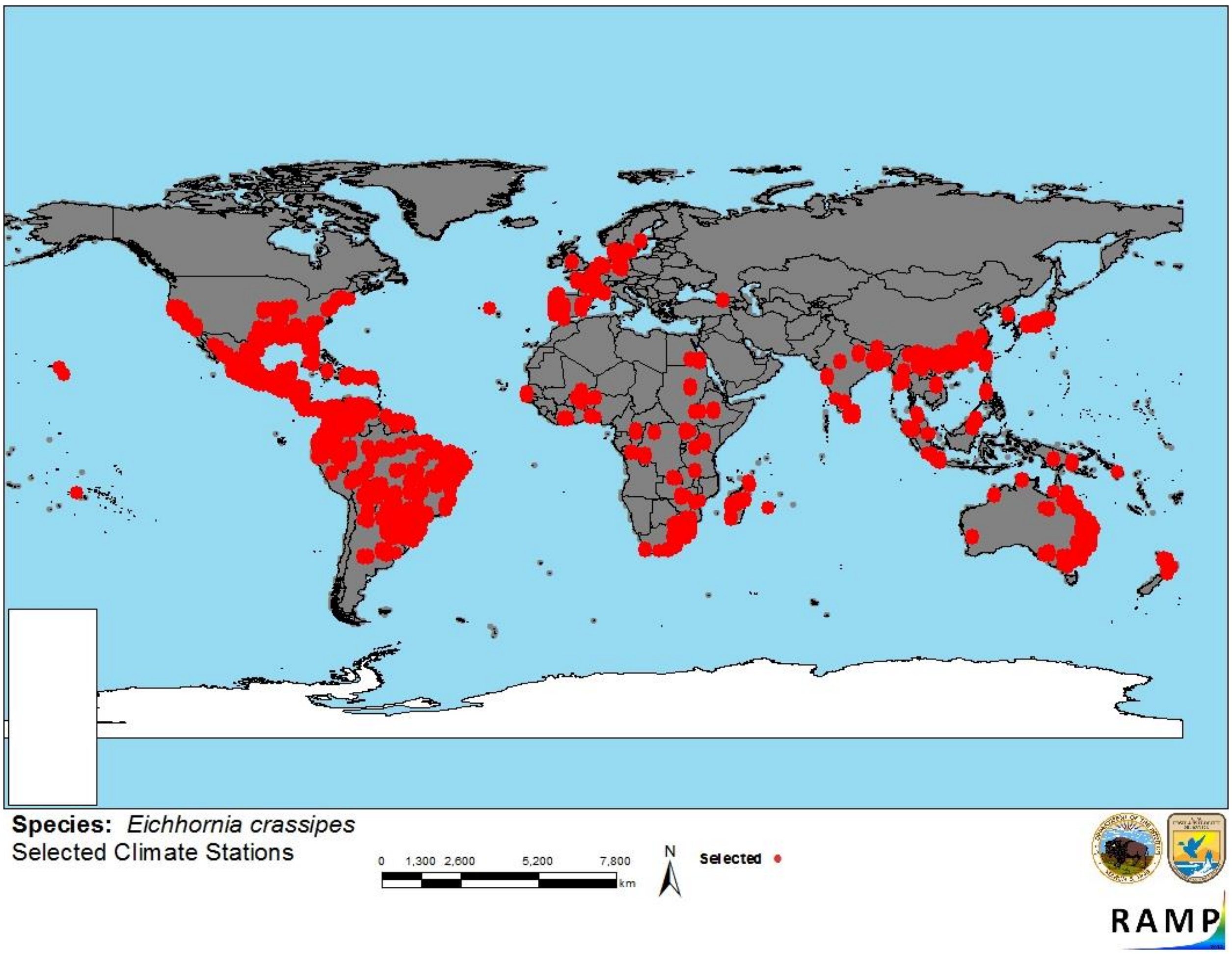

Figure 5. RAMP (Sanders et al. 2014) source map showing weather stations selected as source locations (red) and non-source locations (gray) for *Eichhornia crassipes* climate matching. Source locations from DAISIE (2017), GBIF Secretariat (2017), Landsdown (2017), and Pfingsten et al. (2017).

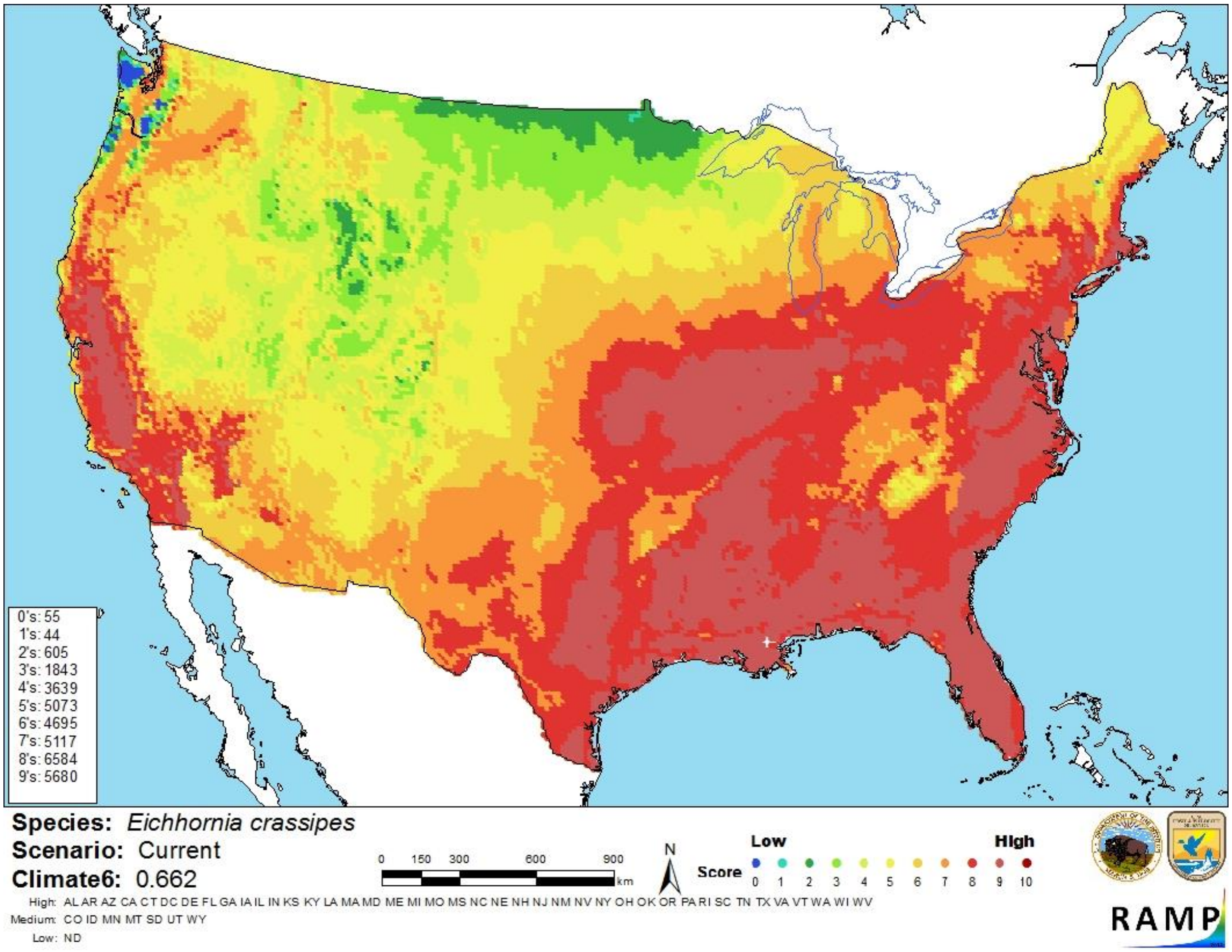

Figure 6. Map of RAMP (Sanders et al. 2014) climate matches for *Eichhornia crassipes* in the contiguous United States based on source locations reported by DAISIE (2017), GBIF Secretariat (2017), Landsdown (2017), and Pfingsten et al. (2017). 0 = Lowest match, 10 = Highest match. Counts of climate match scores are tabulated on the left.

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

Certainty of assessment for *Eichhornia crassipes* is high. High quality information on the biology, invasion history and impacts of this species was available. This species is one of the most well studied invasive species, there was a plethora of information regarding documented harmful impacts.

8 Risk Assessment

Summary of Risk to the Contiguous United States

The history of invasiveness for *Eichhronia crassipes* is high. *E. crassipes* is native to the Amazon basin. The species has likely spread worldwide either incidentally or as an ornamental plant. Substantial peer reviewed literature is available documenting adverse impacts caused by this species. Climate matching indicated the contiguous United States has a high climate match with locations that have established *E. crassipes* populations. This indicates that there is suitable climate that could support further establishment of this species in the contiguous United States. The certainty of 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** *Eichhornia crassipes* already has a wide distribution within the United States. Human deaths in Papua New Guinea have been attributed to the negative impacts of *E. crassipes* introductions.
- **Overall Risk Assessment Category: High**

9 References

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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