African Elodea (*Lagarosiphon major*)

A Technical Review of Distribution, Ecology, Impacts, and Management

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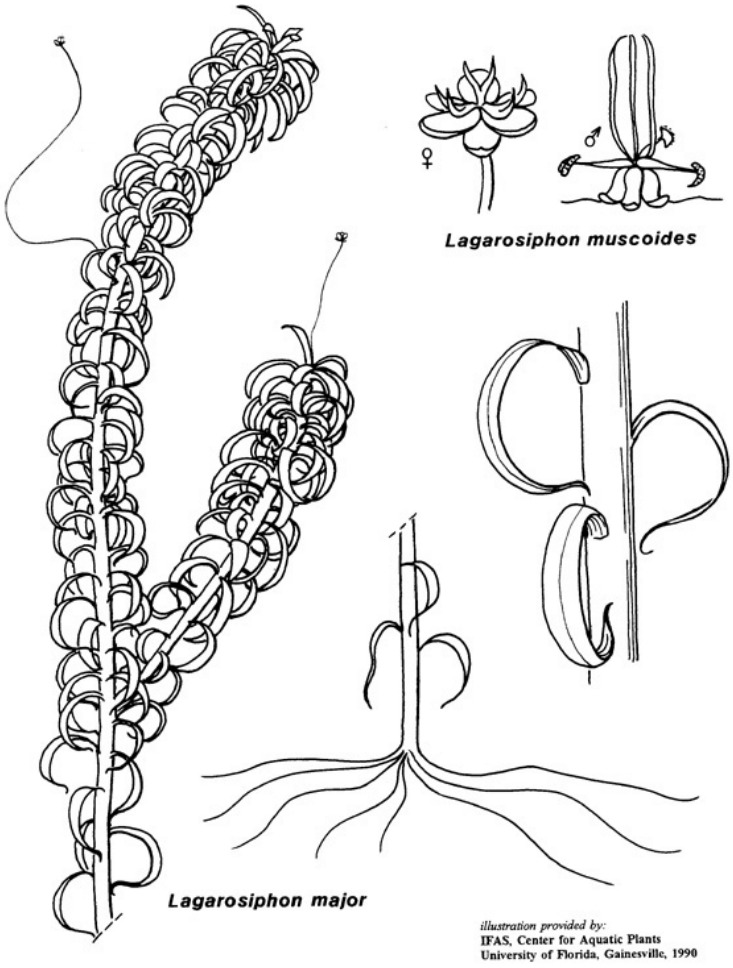

Lagarosiphon major

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African elodea, (*Lagarosiphon major*):

A Technical Review of Distribution, Ecology, Impacts, and Management

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This literature review was commissioned by the nonprofit Centre for Agricultural Bioscience International (CAB International; http://www.cabi.org/index.asp) as part of a larger invasive species compendium. We completed eight literature reviews for the project, and due to the large number of requests for this information, we have decided to make the reviews available as DNR miscellaneous publications. Species reviewed include:

- Carolina fanwort (*Cabomba caroliniana*) – [PUB-SS-1047 2009]
- European frog-bit (*Hydrocharis morsus-ranae*) – [PUB-SS-1048 2009]
- Indian swampweed (*Hygrophila polysperma*) – [PUB-SS-1049 2009]
- African elodea (*Lagarosiphon major*) – [PUB-SS-1050 2009]
- Yellow floating heart (*Nymphoides peltata*) – [PUB-SS-1051 2009]
- Curly leaf pondweed (*Potamogeton crispus*) – [PUB-SS-1052 2009]
- Water spangles (*Salvinia minima*) – [PUB-SS-1053 2009]
- Water chestnut (*Trapa natans*) – [PUB-SS-1054 2009]

In completing the literature reviews, we preferentially consulted the peer-reviewed primary literature and supplemented the reviews with secondary sources where necessary. The outline for the reviews is identical for each species and was provided as part of the CAB International commissioning. This effort compliments work conducted during the development of the WDNR's proposed invasive species identification, classification and control rule; a more exhaustive list of species and accompanying literature review summaries can be found on the DNR website at: http://dnr.wi.gov/invasives/

Identity

Taxonomy and Nomenclature

The genus *Lagarosiphon* (family Hydrocharitaceae) is generally accepted as containing approximately 15-18 species, which occur primarily in Africa, Madagascar, and India (IPNI-GBIF, 2004; UFL-IFAS, 2001). The genus name comes from the Greek *lagaros* meaning 'narrow, thin' and *siphon* meaning 'tube', likely referring to the long thin tubes that allow the female flowers to reach the water's surface (UFL-IFAS, 2001). *Lagarosiphon major* was first named *Lagarosiphon muscoides* Harvey in 1841, was revised to *L. muscoides* var. *major* by Ridley in 1886, and further revised to its current accepted scientific name, *Lagarosiphon major* (Ridl.) Moss in 1928. *Lagarosiphon major* is synonymous with "*Elodea crispa",* a name that is often used by those using the plant in aquaria (Mason, 1960). The English common name 'oxygen weed' refers to the species ability to "oxygenate" the water, however, the dense mats of vegetation that are characteristic of this species when introduced outside of its native range actually

decrease the oxygen levels by limiting water circulation and increasing decomposition. It is also referred to by the common name 'curly waterweed'.

Summary of Invasiveness

L. major is an aquatic, submerged plant that can grow in dense mats up to 2-3m thick and cause many negative environmental and economic impacts. Some of these impacts include displacing native plant species, decreasing water quality, reducing biodiversity, blocking hydroelectric intakes, impeding recreational activities, and diminishing aesthetic value. *L. major* is very difficult to control, and its ability to form new plants vegetatively facilitates its spread to new locations. The trade and potential escape of *L. major* through the aquarium and water garden industry plays a large role in its spread to new locations (Natural Heritage Trust, 2003), as does the transportation of this plant on recreational equipment moving between water bodies (Cronk and Fuller, 1995). *L. major* is declared a noxious weed in New Zealand (Winterton and Scher, 2007), the United States (USDA-PPQ, 2006), and is on the *Alert List for Environmental Weeds* in Australia (Natural Heritage Trust, 2003). *L. major* is already well established in New Zealand and parts of Europe. Other species of the family Hydrocharitaceae also have the potential to become invasive, and *Elodea canadensis, Egeria densa,* and *Hydrilla verticillata,* have been recorded as problematic outside of their native range.

Distribution, Introduction, and Spread

Distribution

L. major is native to Southern Africa and South Tropical Africa, and has been found in the regions of Zambia, Zimbabwe, Botswana, Lesotho, and South Africa (USDA-ARS, 1997). In these regions, *L. major* is naturally found in high mountain freshwater streams and ponds (Cronk and Fuller, 1995). However, there is some disagreement on the status of *L. major* in Southern Africa, and some report it as a nuisance weed species (CAPM-CEH, 2004, Caffrey and Acevedo, 2007), while there are other reports of *L. major* as a restricted species in those regions (Cronk and Fuller, 1995).

L. major has been introduced to several other parts of the world, though only the female plant is known outside of its native range. Thus, all reproduction of *L. major* in its adventive range is done vegetatively, while seed production and male flowers are restricted to its native range of Africa. *L. major* was introduced to New Zealand in the 1950s, and has naturalized in many freshwater lakes in the country (NZPCN 2005). *L. major* was first recorded in Britain in 1944, and was first reported in Germany and Ireland in 1966. In southern Australia, *L. major* has been found and eradicated from a few small dams, and it is currently not known to be naturalized (Natural Heritage Trust, 2003).

History of Introduction and Spread

L. major was first reported as being naturalized in New Zealand in 1950, and by 1957 the population had grown to nuisance levels in Lake Rotorua. It is believed that *L. major* was intentionally introduced to Lake Rotorua with the intention of improving the oxygen levels (Cronk and Fuller, 1995), although the dense mats of vegetation that occurred actually decreased the lake oxygen levels. *L. major* spread to Lake Taupo around 1966, and was probably introduced to the lake by recreational boat traffic (Cronk and Fuller, 1995). *L. major* continues to spread to many other freshwater lakes in New Zealand, and is a major concern in the region.

L. major was first recorded in a chalk pit in Britain in 1944, and has since spread to several other locations throughout Europe. *L. major* was first recorded both in Germany and Ireland in 1966, and its introductions were intentional horticultural and ornamental releases (NOBANIS, 2005; BioChange, 2007). In Ireland, the occurrence of *L. major* between 1987 -1999 was recorded as being present in 7 hectads (1 hectad = 10km X 10km), (BioChange, 2007), though many additional *L. major* occurrences have been reported recently during the last five years (NBGI, 2007).

There are currently no naturalized populations of *L. major* in Australia, but there have been small invasions near Melbourne in Victoria, and Newcastle in New South Wales that were eradicated in the 1970s. These introductions were believed to have been plants that had originated in aquariums or ponds. In addition, there is a record of a cultivated specimen near Queensland in 1990 (Natural Heritage Trust, 2003).

Risk of Introduction

L. major is a popular aquarium and water garden plant, and the ability to order this plant over the internet and through mail order gives it the ability to travel to all parts of the world (Natural Heritage Trust, 2003). It has escaped confinement and has been intentionally introduced on several occasions outside of its native range. In the locales to which it has been introduced, it has often become the dominant plant species, outcompeting both native and previously established exotic species, in addition to displacing other species which depend on the ecosystem. *L. major* has the potential to colonize large areas within a growing season by means of vegetative propagation, and is listed as a noxious weed in many parts of the world.

Biology and Ecology

Description

L. major is a dioecious, perennial submerged aquatic plant with adventitious roots and rhizomes that attach the plant to the substrate. The brittle, sparsely branched stem can grow up to 20 feet long, is 3-5mm in diameter and curves like a 'J' towards the base. The dark green leaves are alternately spiraled around the stem, though often crowded towards the stem tip. The leaves are minutely toothed, 5-20mm long, 2-3mm wide and generally have tapered tips that curve down towards the stem, though in low alkalinity waters the leaves can appear straight (Natural Heritage Trust, 2003). The female flower is very small, with 3 transparently white/pink petals that are attached to a filament-like stalk above the water's surface. Only the female plant is known outside of its native range. The fruit is a beaked capsule, containing approximately nine seeds, each seed being approximately 1/8 inch long (UFL-IFAS, 2001).

Similarities to Other Species

Several other species in the family Hydrocharitaceae look very similar to *L. major*, including *Egeria densa*, *Elodea canadensis*, and *Hydrilla verticillata*. However, unlike the leaves of the other species, which grow in groups or whorls circularly around the stem, the leaves of *L. major* are distinguishably alternately spiraled (Natural Heritage Trust, 2003). The presence of recurved leaves and a downward curving stem towards the apex also help to distinguish *L. major* from these similar species (Scher and Walters, 2010). *L. major* is often also mislabeled as "*Elodea crispa*", usually by those dealing with the plant in the aquarium trade.

Habitat
L. major prefers lakes, reservoirs, and slow moving rivers with silty or sandy bottoms. *L. major* is also known to occur in wetlands, water courses, riparian zones (ISSG, 2006), canals and drainage ditches (CAPM-CEH, 2004). It prefers the cool waters of the temperate zone, and grows best under high light intensity. *L. major* can grow to depths of 6.6 m (Coffey and Wah, 1988), but may grow out only to 1 m in murky water (Natural Heritage Trust, 2003). *L. major* grows best in areas sheltered from wind, waves, and current.

Genetics
L. major has a chromosome number of 2n=22 (Uchiyama, 1989) or 2n=24 (Kiehn et al., 2000). *L. major* has 2 complete sets of chromosomes in each cell, and its nuclear DNA expressed on a diploid basis is equal to 3.6, 6.5 pg/2C (BioChange, 2007).

Reproductive Biology
L. major is a dioecious plant, which refers to a species in which the male and female reproductive organs occur on different individuals. *L. major* has the ability to reproduce by both vegetative and sexual means, though only vegetative reproduction has been observed outside of its native range. All populations of *L. major* outside of its native range are female, while seed production and male flowers are restricted to its native range of Africa. The fruit is a capsule with approximately 9 seeds (Scher and Walters, 2010).

Physiology and Phenology
In the Northern hemisphere, *L. major* becomes dormant in the winter and emerges in the spring from rhizomes and shoots. *L. major* is capable of producing two types of flowers; the male flowers break free from the plant and float along the water's surface, while the female flowers remain attached to the plant by long, filament-like stalks. All populations of *L. major* outside of its native range have consisted of plants with only female flowers, and male flowers, fruits, and seeds have not been recorded outside of Africa. Female flowers appear from summer to early fall, and the overall growth of *L. major* decreases as day length and light intensity decreases (Natural Heritage Trust, 2003).

Associations
None known.

Environmental Requirements
L. major can live in a range of nutrient levels, however, in lakes with accelerated eutrophication and severely decreased water clarity, *L. major* abundances decline. *L. major* prefers high light intensity, and its best growth is recorded at 600 micro-einsteins/m^2/h (Schwarz and Howard-Williams, 1993). *L. major* is able to withstand a relatively high pH, and its own photosynthetic activity has been recorded as raising pH levels to 10-10.4 in the surrounding water (CAPM-CEH, 2004). In conjunction with pH, *L. major* can survive in high alkalinity conditions as well. The optimum temperature of *L. major* is 20-23°C, with a maximum temperature of approximately 25°C. *L. major* is thought to be absent below temperatures of 10°C (Natural Heritage Trust, 2003).

Movement and Dispersal

Natural Dispersal
Hydrochory, the dispersal of disseminules by water currents, seems to be the main dispersal mode of vegetative fragments within a water body (ISSG, 2006).

Vector Transmission
There is no evidence that this plant might be carried between sites by birds because it is a relatively large plant (CAPM-CEH, 2004).

Accidental Introduction
L. major can be spread accidentally to new locations by the movement of boats, trailers, nets, sea planes, and other recreational equipment between water bodies (Natural Heritage Trust, 2003; McGregor and Gourlay, 2002). It is also possible for *L. major* to be a 'hitchhiker' plant with other species ordered through water garden catalogs. *L. major* can also be accidentally introduced by flooding of ornamental ponds into surrounding natural waterways. *L. major* has also been introduced through hobbyists emptying unwanted aquarium species directly into surrounding waterways.

Intentional Introduction
L. major has been intentionally planted as an 'oyxgentator' or ornamental in different water bodies throughout its current distribution. The trade of this plant as an ornamental through the internet and mail order has greatly increased its availability and ease of spread into new environments (Natural Heritage Trust, 2003).

Natural Enemies
McGregor and Gourlay (2002) report the nematode *Aphelenchoides fragariae* attacking the apical tips of *L. major. Nymphula nitens* has also been reported as feeding on several aquatic weeds, though it is not selective to *L. major*.

Impacts

Economic Impact
L. major has blocked intakes of hydroelectric systems and has the potential to limit flow in irrigation channels. In addition, the loss of recreational and aesthetic value associated with *L. major* can also cause a decline in lakefront property values, as well as possible declines in tourism related revenue for the community.

Social Impact
L. major can form dense mats that impede recreational activities such as boating, fishing, swimming, water skiing, canoeing, and kayaking. In addition, unsightly mats of vegetation decrease aesthetic values. These declines in recreational and aesthetic values can decrease tourism, which can be a major source of livelihood within the community.

Impact on Habitat
L. major alters the chemical composition of the water body by creating stressful conditions of high pH and low CO_2 (James et al., 1999). The photosynthesis of *L. major* has been recorded as raising surrounding pH to levels over 10, and has the ability to raise levels to 10.4, (the limit of bicarbonate uptake) in small water bodies (CAPM-CEH,

2004). These high pH levels inhibit other native species from effectively photosynthesizing, giving *L. major* a competitive advantage.

L .major can also be an excellent competitor for light, and has been known to outcompete native aquatic vegetation and associated invertebrate populations (ISSG, 2006). Despite this species' common name of "oxygen weed", the dense mats of vegetation that are characteristic of this species when introduced outside of its native range actually decrease the oxygen levels by limiting water circulation and increased decomposition of dead plants. Dense mats of *L. major* also have the ability to change water hydrology and quality, negatively affecting the ecosystem in which it occurs.

Impact on Biodiversity
L. major reduces biodiversity by competing with and displacing native vegetation, and is capable of changing the fauna and flora of an ecosystem. *L. major* has outcompeted native species wherever it has colonized, due in part to its ability to outcompete submerged vegetation for light and photosynthesize in the inhospitable, stress-inducing water conditions that it creates. In particular, *L. major* has out competed *Myriophyllum* spp., *Potamogeton* spp., (Rattray et al., 1994), and *Elodea* spp. (James et al., 1999). Decomposing mats of *L. major* also have the ability to cause fish kills by creating low oxygen levels in the water.

Management

Economic value
Ornamental plants of *L. major,* often sold under the name *"Elodea crispa",* are sold for aquariums and water ponds, though the specific economic value of this particular species in the ornamental plant trade is unknown. *L. major* was also once sold as capable of "water purification", though the continuance of this practice is unknown (NBGI, 2007).

The utilization of *L. major* as fodder for stock food was explored as a possible usage of harvested biomass, though the high levels of arsenic accumulated by the plants proved unsuitable (ISSG, 2006).

Social Benefit
L. major is enjoyed by many aquarium hobbyists due to the plant's minimal maintenance required and ease of growth.

Environmental Services
In severely disturbed ecosystems where exotics are the only plants capable of surviving, removal of plants such as *L. major* can further degrade the habitat. *L. major* can provide some habitat for aquatic fauna, its leaf surface supports periphyton, and plant stands can increase sedimentation, which could be beneficial in some areas (McGregor and Gourlay, 2002).

Invasive Species Management

Prevention
As with all weed management, prevention is better and more cost-effective than control.

Detection and inspection methods
Infestations are often first reported at boat launches, and these areas should be monitored frequently in order to eradicate or control new invasions at an early stage (Natural Heritage Trust, 2003). All recreational equipment should be inspected before leaving any water body, and any visible plants, animals, or sediment should be removed. In addition, rinsing gear with hot water or steam may help in removing non-visible organisms.

Rapid Response
Early detection and eradication are essential in the prevention of future invasions and spread of *L. major*. Smaller, localized populations have better success at being controlled than those which have the opportunity to spread and become well-established (Natural Heritage Trust, 2003).

Public awareness
Several publications have been produced in areas with *L. major* populations regarding the impacts of invasive species such as *L. major*, and the steps that lake recreationists need to take in order to prevent introducing and spreading aquatic invasives.

Eradication
In southern Australia, *L. major* has been found and eradicated from a few small dams (Natural Heritage Trust, 2003).

Cultural Control and Sanitary Measures
Several regions where aquatic invasives have established have started requiring that recreationists drain all water and clean off all gear (boats, trailers, fishing equipment, etc.) used on water bodies in order to minimize the chance of spreading aquatic invasive species, such as *L. major*, to other areas.

Physical and Mechanical Control
Attempts to control *L. major* have had limited efficacy due to its ability to propagate vegetatively through fragments and underwater roots and rhizomes. Attempts to mechanically harvest only serve as means of creating and introducing more plant fragments, and potentially aiding in dispersal to new locations. There has been some success with mechanical harvesting that is conducted at or near root level (Caffrey and Acevedo, 2007). Suction dredging has also been used, but it is nearly impossible to remove all vegetation and regeneration is highly likely (Natural Heritage Trust, 2003).

Weed mats have been used in small localized areas (ENVBOP, 2003; Caffrey and Acevedo, 2007), but are difficult to maintain. It may also be possible to alter water depth and flow speeds in channels, thereby rendering them inhabitable, though there are limited practical situations where these control methods can be applied (CAPM-CEH, 2004).

Movement Control
Several countries have banned the importation or sale of exotic plants, such as *L. major*, in attempts to minimize the chance of introduction to non-native regions.

Biological Control
McGregor and Gourlay (2002) report that the nematode *Aphelenchoides fragariae* has been recorded attacking the apical tips of *L. major,* resulting in shoot dwarfing. In

addition, *Nymphula nitens* also feeds on many aquatic weeds and might be a potential biocontrol agent, but it is not selective against also consuming native vegetation. Neither species has yet been studied for its potential as a biological control agent.

Grass carp have been suggested as a potential biological control method, though studies have shown that *L. major* is not one of their preferred food sources, and their introduction would negatively impact the remaining native submerged vegetation (CAPM-CEH, 2004).

Chemical Control

L. major has been found to be susceptible to herbicides containing terbutryn or dichlobenil. The preferred method of control is an early spring (March or early April in the Northern hemisphere) application of dichlobenil. Terbutryn (Clarosan) should only be used when *L. major* is the overwhelmingly dominant species, because this herbicide will kill most species of submerged aquatic plants, and has the ability to cause fish kills due to a sudden decline in photosynthesis (CAPM-CEH, 2004). Diquat has also been moderately successful against *L. major*, though its effectiveness differs greatly among scenarios, and it is not effective in turbid waters (UFL-IFAS, 2001).

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Lagarosiphon major
Plant, alternately spiraled leaves

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