Department of **Agriculture and Fisheries**
Biosecurity Queensland

Invasive plant risk assessment

Bog moss

Mayaca fluviatilis Aubl.

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Summary

Mayaca fluviatilis Aubl. (bog moss) is a tropical/subtropical aquatic plant native to Central and South America, the Caribbean and the United States. Under favourable conditions it can form dense mats that block freshwater ponds, streams and drainage ditches.

The first naturalised population of *M. fluviatilis* in Queensland was formally identified near Innisfail in 2008. Prior to this, the plant had been sold as an aquarium plant for many years.

M. fluviatilis is a pest within parts of its native range, particularly in Puerto Rico, Florida and North Carolina.

Dispersal is via broken stem fragments. Seed production has been recorded overseas. However, specimens grown in aquaria in Queensland are believed to be sterile.

While the species' potential impact is difficult to predict, it might smother and replace native aquatic plant species, block drainage/irrigation ditches on sugarcane farms, and impede recreational activities such as boating and fishing.

This assessment concludes that *M. fluviatilis* poses a high weed risk, based on the following evidence:

(1) it has a history as a pest within its native range,

(2) it is well adapted to subtropical and tropical climates of Queensland, and

(3) experience in North Queensland confirms it can block drainage infrastructure on sugarcane farms.

Important note:
Please send any additional information, or advice on errors, to the authors.

Identity and taxonomy

Species: *Mayaca fluviatilis* Aubl.

Synonyms:

Mayaca aubletii Michx.
M. longipes Gand.
M. michauxii Schott & Endl.
M. caroliniana Gand.
M. longipes Gand.
M. vandellii Schott & Endl.
M. wrightii Griseb.
Syena fluviatilis Willd.
S. mayaca J.F. Gmel.
S. aubletii Michx in Schott & Endl.
S. nuttaliana Schult.

Common names:

Bog moss (US), stream bog moss (US), pine tree (New Zealand).

Aquarium/pond trade names:

Green mayaca (and mayaca green), green pine, silver foxtail.

Family: Mayacaceae

The family Mayacaceae comprises a single genus—*Mayaca*. The number of species in the genus is uncertain; some publications state that there are four species (Mabberley 2000; Lourteig 1952), others state there are 10 (Heywood 1998; Thieret 1975) and the Missouri Botanical Garden's Tropicos database (Tropicos 2010) lists 12 species. The Mayacaceae are found mainly in the Americas, with one species, *Mayaca baumii* Gürke, in sub-Saharan Africa (Angola).

Subordinate taxa:

Mayaca fluviatilis forma *fluviatilis*
M. fluviatilis forma kunthii (Seub.) Lourteig
M. fluviatilis var. wrightii (Griseb.) M. Gómez

Related species:

Mayaca aubletii Michx.
M. baumii Gürke
M. brasillii Hoehne
M. boliviana Rusby
M. curtipes Poulsen, V.A.
M. endlicheri Poepp. Ex Seub.
M. lagoensis Warm.
M. longipedicellata
M. longipes Mart. Ex Seub.
M. madida Vell. (Stellfeld)
M. sellowiana Kunth

Taxonomic uncertainty:

There is considerable uncertainty regarding the taxonomic relationship between species of *Mayaca* and between various forms of *M. fluviatilis*. Semi-aquatic plants often have the ability to produce different types of leaves above and below water (a feature known as heterophylly) (Wells and Pigliucci 2000). Such morphological plasticity is thought to be an adaptation to a dynamic environment (Wells & Pigliucci 2000; eFloras 2010). For example, *M. fluviatilis* and *M. aubletii* display subtle differences in morphology, with shorter leaves, longer pedicels and ovoid to nearly globose capsules evident in *M. aubletii* and longer leaves, shorter pedicels and oblong-ellipsoid capsules in *M. fluviatilis* (eFloras 2010). Such plasticity has confounded attempts to classify the species and makes identification difficult.

Description

M. fluviatilis is a perennial monocotyledonous plant that can grow either fully submerged, in the form of semi-floating mats, or as a semi-terrestrial plant on the margins of wetlands. It can form very dense mats of branching prostrate or erect stems, generally 40–60 cm long (eFloras 2010), but sometimes well over 1 m (CAIP 2009). Its morphology varies depending on prevailing conditions (Thieret 1975; eFloras 2010). Submerged specimens tend to have long trailing stems with spirally arranged leaves that are long-tapering and translucent (Figure 1); also see online video link (http://plants.ifas.ufl.edu/node/263). They also have a thicker endodermis and more aerenchyma than emersed forms. Emersed plants tend to have shorter stems with shorter, thicker closely imbricate leaves (Thieret, 1975); see Figures 2, 3 and 4.

Figure 1. Submerged stems of *Mayaca fluviatilis* showing spirally arranged, long tapering leaves and white stems. Note: Stem tips are pink in colour compared with pinkish-red for *Rotala wallichii*. The latter has pinkish-purple flowers arranged in a raceme (photo: Audrey Reilly and Kylie Goodall, DERM).

Figure 2. Leaves of floating *M. fluviatilis* (photo: Vic Ramey, University of Florida/IFAS Center for Aquatic and Invasive Plants).

The leaves are sessile, without a sheath (Mabberley 2000), soft, moss-like and thread-like, arranged densely in a spiral around the stem. Leaves are not divided like those of *Egeria densa* (CAIP 2009) or *Myriophyllum aquaticum*. Leaf blades are narrowly lanceolate to linear, 2–30 mm × 0.5 mm, and the apex entire or notched (Heywood 1998; eFloras 2010).

Flowers are up to 10 mm wide, bisexual, borne singly on pedicels 2–12 mm long and subtended by membranous bracts, which usually become reflexed after flowering (Heywood 1998; eFloras 2010). Flowers are terminal, but appear to be axillary due to the sympodial structure of the stem (Mabberley 2000; Philipps 2010).

Figure 3. *Mayaca fluviatilis* in flower (photo: Tom Philipps, USDA Forest Service).

Figure 4. Flower of *Mayaca fluviatilis*—Taree, New South Wales (photo: Peter Harper).

The perianth is arranged in two whorls: the outer sepal-like with three elongate segments that persist in fruit, the inner petal-like with three whitish pink to violet or even maroon segments (Heywood 1998). The sepals are ovate to lanceolate-elliptic, 2–4.5 mm x 0.7–1.5 mm; petals, sometimes whitish basally, are also broadly ovate, 3.5–5 mm × 3–4.5 mm (eFloras 2010).

The three stamens (1.5–3 mm in length) are alternate with petal-like segments; filaments are 1–2 mm; anthers are 0.5–1 mm, dehiscing by means of apical, pore-like slits (Heywood 1998; eFloras 2010). The ovary is superior and composed of three fused carpels, forming a single locule containing numerous orthotropous ovules attached in two rows to three pariental placentas (Heywood 1998). The fruit is a three-valved capsule that is nearly globose to ellipsoid, often irregular because of abortion, to 4 mm × 3.4 mm (Heywood 1998; eFloras 2010). There are 2–25 seeds per capsule. Seeds are nearly globose, 1.3 mm × 0.9 mm. The seed coat is ridged and pitted (eFloras 2010).

Figure 5. *Solitary Mayaca fluviatilis* flowers showing long pedicels
(photo: Audrey Reilly and Kylie Goodall, DERM).

The seeds of *Mayaca* species are characterised by the presence of an embryostegium or 'stopper' at the micropylar end, which seems to develop from the inner integument. The disintegration of this 'stopper' is thought to provide a canal for the emergence of the seedling (Thieret 1975).

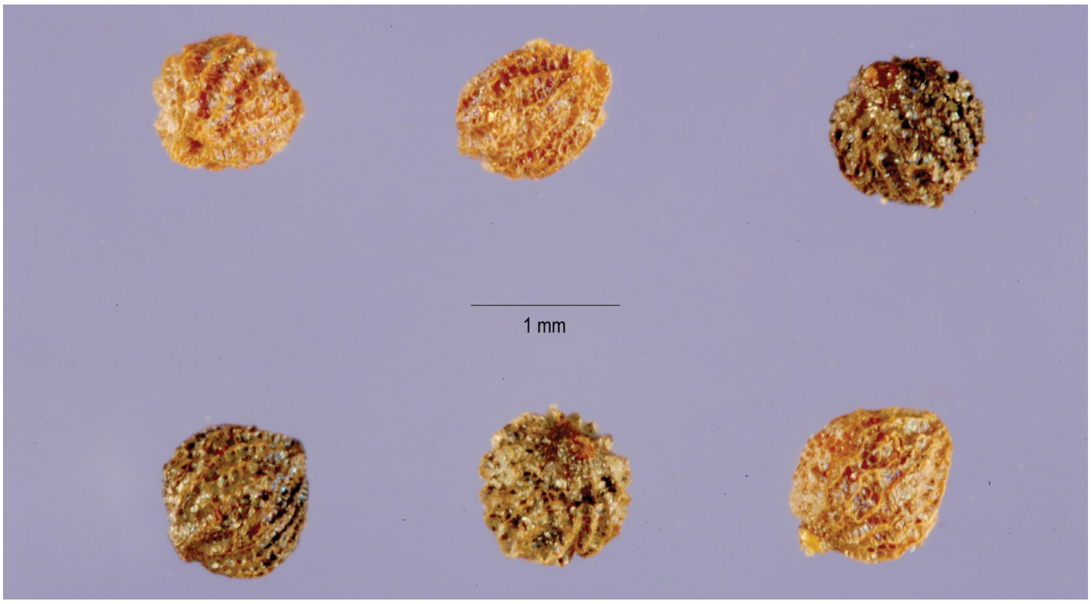

Figure 6. Seeds of *Mayaca fluviatilis* (photo: Jose Hernandez @ USDA–NRCS PLANTS Database).

M. fluviatilis can initially grow as a fully submerged plant, rapidly forming numerous stems. Once these stems reach the water surface, they spread out, forming a dense mat of shorter branches (Figure 7).

Figure 7. Mats of *Mayaca fluviatilis* in a drainage channel near Innisfail
(photo: Audrey Reilly and Kylie Goodall, DERM).

A helpful video on the identification of *M. fluviatilis*, prepared by the Center for Aquatic and Invasive Plants, University of Florida, IFAS, is available at http://plants.ifas.ufl.edu/node/263

Reproduction and dispersal

In the southern United States, where *M. fluviatilis* is native, flowering occurs from March to November, but typically May to October (Philipps 2010).

Seeds are probably dispersed by water (Thieret 1975). Ludwig (1886) found that seeds dried for six weeks germinated in water more rapidly than those that had been continuously submerged for the same period. This second group did not germinate even after 12 weeks submerged.

Plants sold in the commercial aquarium plant trade are thought to be sterile due to selection of clonal stock over long periods of time (E Frazer, Pisces Aquarium Plants, pers. comm., March 2010).

Yakandawala (2009) found that stem fragments as small as 2 cm long could produce new roots and shoots. Hence, mechanical removal or other physical disturbance has the potential to dramatically increase rate of spread.

Native range and worldwide distribution

M. fluviatilis is native to Central and South America, the Caribbean and the US.

Tropicos (2010), USDA (2010) and GRIN (2010) list herbarium collections from the following countries:

- Central and South America—Argentina, Belize, Bolivia, Brazil, Colombia, Costa Rica, Ecuador, French Guiana, Guatemala, Guyana, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, Suriname, Uruguay and Venezuela
- Caribbean—Cuba, Dominican Republic, Haiti, Jamaica, Puerto Rico, Trinidad and Tobago
- US—Alabama, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, Texas and Virginia.

M. fluviatilis has naturalised in Sri Lanka (Yakandawala 2009) and Singapore (Aquatic Quotient 2005).

History of introduction and spread in Queensland

Naturalised *M. fluviatilis* was first recorded in Queensland in shallow flowing water within a table drain at Silkwood, near Innisfail in 2008 (Figure 8) (A. Reilly, Qld DERM, pers. comm., March 2010). The source of the infestation was an overflow drain from nearby aquaculture ponds. *M. fluviatilis* was being sold as an aquarium plant. It has been speculated that the plant may have originally entered the watercourse some time in 2006.

Figure 8. *M. fluviatilis* growing immediately downstream of its suspected origin, near Innisfail (photo: Audrey Reilly and Kylie Goodall, DERM).

In April 2010, plant material tentatively identified as *M. fluviatilis* was detected near Mareeba and near Mossman. Specimens were sent to the Queensland herbarium for identification but may be *Myriophyllum* spp. (K. Stephens, Qld herbarium, pers. comm., March 2010).

Distribution in Australia

Outside Queensland, naturalised *M. fluviatilis* has only been detected at a single site near Taree (New South Wales) in 2008 (North Coast Weed Read 2008; Asia Pacific Weed Service Newsletter 2008); see Figure 9.

Figure 9. *Mayaca fluviatilis* in a pond near Taree, northern New South Wales (photo: Peter Harper).

Ecology and preferred habitat

Climatically, *M. fluviatilis* is well suited to tropical and subtropical areas. Within these climate zones it is best adapted to freshwater aquatic habitats, namely shallow wetlands, seepage areas and the margins of lakes, ponds and rivers (CAIP 2009; Heywood 1998; Philipps 2010). These sites experience fluctuations in water level, with periodic inundation during floods and short-term desiccation during the dry season (USDA 2010; FLUCCS n.d.).

M. fluviatilis can tolerate water 1–2 m deep (North Carolina Department of Environment and Natural Resources, 2006). Some authors describe the plant as 'amphibious', since it can grow below and above water (Champion & Clayton 2000; de Carvalho et al. 2009), whereas others state that it is an obligate submerged plant (Champion & Clayton 2001; FLUCCS n.d.).

This study was unable to find detailed information on environmental variables that define this species' preferred habitats. In Florida, *M. fluviatilis* is typically found in lakes with a low pH and low levels of phosphorous and nitrogen. Philipps (2010) categorised its preferred habitat as waterways with high acidity and high levels of organic matter. Venero Camaripano and Castillo (2003) found *M. fluviatilis* in flooded forest at altitudes of 0–1200 m in Sipapo, Venezuela. Visual observation of the species in Queensland and New South Wales suggests it prefers open waterbodies (full sun) and perhaps disturbed sites.

Experienced growers of aquarium plants comment that *M. fluviatilis* is 'self-smothering' in aquaria, becoming brittle and dying off after rapidly depleting soluble carbon dioxide, reducing water circulation and lowering pH (resulting in iron deficiency). Like many aquatic plants, *M. fluviatilis* grows in phases or 'flushes', depending on the suitability of prevailing environmental conditions (E Frazer, pers. comm., March 2010). There is little information on its growth requirements in *situ*; however, temperature requirements *ex situ* in an aquarium environment are reported in the range of 20–30 °C.

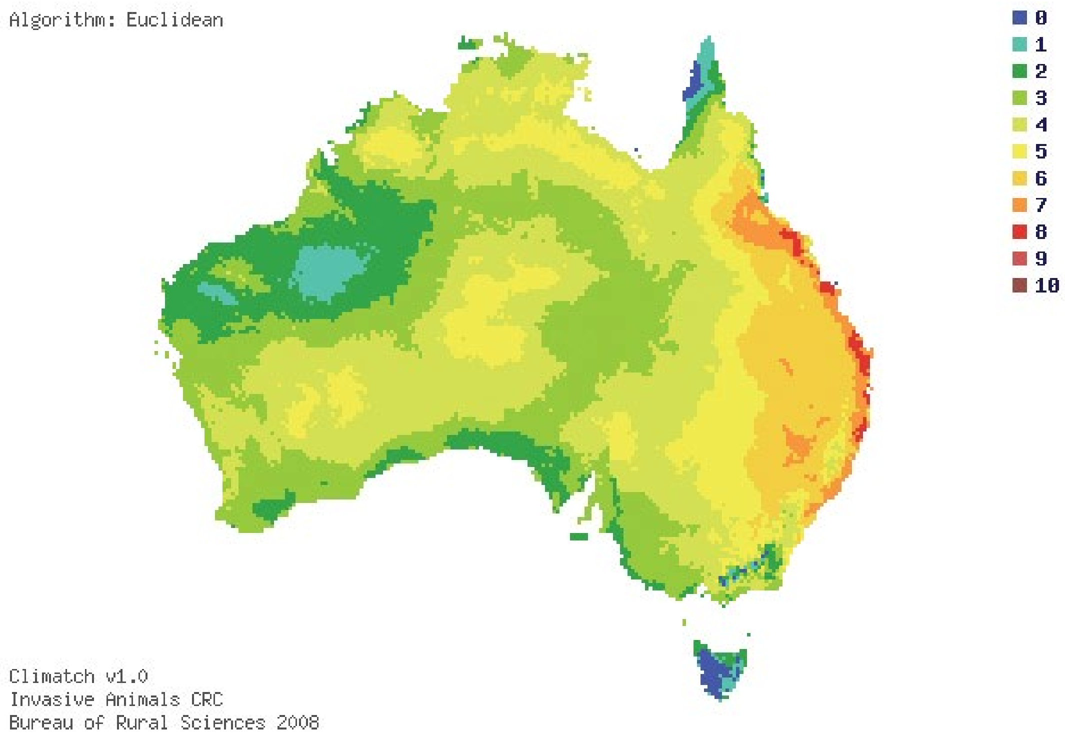

Figure 10. Areas of Australia where climate appears suitable for survival of *Mayaca fluviatilis*. This model was generated using 'Climatch' climate-matching computer program and was based on global distribution data for the species. Blue and green indicate areas where climate is considered unsuitable for this species, yellow and orange indicate areas where climate is marginally suitable and red indicates areas where climate is highly suitable (map by Martin Hannan-Jones).

History as a weed overseas

M. fluviatilis is listed as a noxious weed in Puerto Rico and is subject to control activity in Florida and North Carolina. These locations are all within the species' native range. In Florida, it blocks freshwater lakes and is subject to periodic control action to allow recreational activities (fishing and boating) (GCW 2007; GRIN 2010; Hanlon et al. 2000; North Carolina Department of Environment and Natural Resources 2006).

Yakandawala (2009) expressed concern at the invasive potential of *M. fluviatilis* in Sri Lanka, where it has naturalised in two waterbodies. An online forum for aquarium enthusiasts states that *M. fluviatilis* has naturalised in Singapore (MacRitchie Reservoir) in 2005 (Aquatic Quotient 2005).

This study was unable to find data on the species' economic impacts elsewhere.

Current impact in Queensland

Currently, the impact of *M. fluviatilis* is negligible in Queensland, since it is restricted to a small infestation near Innisfail. At one point in time, this infestation had blocked 1.5 km of table drain (Figure 11). Subsequent damage to a culvert and section of road during heavy rain was blamed on blockage by *M. fluviatilis*. The infestation was mechanically removed by a local drainage board (A Reilly pers. comm., March 2010). However, by December 2008 it had grown back to infest 2.5 km of the same drain. Soon after, flooding washed large amounts of plant material downstream, possibly including the river catchments for Maria Creek National Park. There is concern that it may have spread into Liverpool Creek and the Kurrimine Beach Wetland Aggregation and National Park (Weed Spotters Queensland Network 2009).

Figure 11. Table drain blocked by *Mayaca fluviatilis* alongside sugarcane near Innisfail
(photo: Audrey Reilly and Kylie Goodall, DERM).

Potential impact in Queensland

Prolific growth of *M. fluviatilis* could block drains, irrigation infrastructure, freshwater lakes, ponds and streams, in much the same way as a range of other widespread aquatic weed species. Blocked drains increase waterlogging problems in adjacent crops and can cause greatly reduced yields. Large mats that break free during floods could cause significant damage to bridges and moored boats. Experience from New South Wales suggests that dense growth of *M. fluviatilis* can pose a threat to human safety since swimmers are unable to break through the mats from underneath and could become entangled (P Harper pers. comm., March 2010); see Figures 12 and 13. As has occurred in the US, dense mats can impede recreational activities such as fishing and boating. Such growth needs to be removed on a regular basis, thereby generating ongoing costs for government and other water management agencies. Uncontrolled growth might have localised impacts on tourism, if recreation is hindered.

Figure 12. Dense growth of *M. fluviatilis* can block waterways and impede recreational activity such as boating and fishing—photo taken near Taree, New South Wales (photo: Peter Harper).

Figure 13. Dry mat of *Mayaca fluviatilis* (photo: Audrey Reilly and Kylie Goodall, DERM).

The impact of *M. fluviatilis* on native aquatic ecosystems is difficult to predict. However, it might compete with certain native aquatic plants, especially in disturbed sites. It seems reasonable to be concerned that, under favourable conditions, *M. fluviatilis* could form dense mats that exclude most other plant life.

M. fluviatilis could potentially occupy the same niche as several species of native *Myriophyllum*. Two species of *Myriophyllum* are listed as threatened in Queensland: *M. artesium* (endangered) and *M. coronatum* (vulnerable), as defined by Queensland's Nature Conservation (Wildlife) Regulation 2006. *M. artesium* exists in spring wetlands in Barcaldine and Eulo and *M. coronatum* exists only in Lake Bronto, Cape York.

Uses

M. fluviatilis has been sold as an aquarium plant possibly since the early 1900s. It is valued for its attractive foliage and stems but can be difficult to maintain, requiring high light levels, additional carbon dioxide and fertiliser ('The stemmed plants' 2006). Current sales in Queensland are estimated to be less than 1% of the total market for aquarium plants (E Frazer, pers. comm., March 2010). Although, quite popular in Australia some years ago, its popularity has declined over the last few years.

Control

Mechanical control is often used to clear aquatic plant infestations. However, there is a high risk of spread associated with any method that causes fragmentation of stems (Gettys et al. 2009).

In Florida, sterile triploid grass carp have been used to control various aquatic macrophytes, including *M. fluviatilis*. Hanlon et al. (2000) reported successful control of aquatic macrophytes after stocking lakes with more than 25–30 grass carp per hectare of vegetation. Notably, control was ineffective if lakes were stocked with fewer fish. In a 55 ha lake, of which 40% was covered by with *M. fluviatilis*, weed cover was reduced to zero after four years of stocking with grass carp at a rate of 18 carp per hectare of vegetation (Hanlon et al. 2000).

Herbicide control experiments have been undertaken on *M. fluviatilis* in New South Wales, but effective treatments have proved elusive.

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