WRITTEN FINDINGS OF THE
WASHINGTON STATE NOXIOUS WEED CONTROL BOARD
Updated in 2014

Scientific name: *Egeria densa* Planch

Synonyms: *Elodea densa* (Planch.) Casp., *Anacharis densa* (Planch.) Vict., *Philotria densa* (Planch.) Small

Common name: Brazilian elodea, giant elodea, anacharis, common waterweed, South American waterweed, egeria

Family: Hydrocharitaceae

Legal Status: Class B noxious weed (1993), Quarantine list, WAC 16-752

Image: left, underwater growth, image by USGS Archive, U.S. Geological Survey, Bugwood.org; center, stem tip, image by Robert Vidéki, Doronicum Kft., Bugwood.org; right, underwater growth with white flowers emerging from the water, image by Jenifer Parsons, WA Dept. of Ecology.

<u>Description:</u> (from Cook and Urmi-Konig 1984 unless noted otherwise)

Egeria densa is a submersed, freshwater perennial plant that looks very much like a larger, more robust version of its commonly-found native relative, *Elodea canadensis* (waterweed). *Egeria densa*'s leaves are 1 to 4 cm long, 1.5 to 4.5 mm broad, and occur in whorls. The leaves are minutely serrated, linear, and spreading to somewhat recurved. The lowest leaves are opposite or in whorls of 3, while the middle and upper leaves are in whorls of 4 to 9. Internodes are 2.5 to 24 mm long, with short internodes toward the top, giving the plant its leafy, robust appearance. Stems are 1 to 3 mm diameter, erect, cylindric, simple or branched and grow until they reach the surface of the water, where they form dense mats. Branches, roots and flowers form at nodes that are actually two nodes growing very closely together, forming 'double nodes'. These have 5 to 9 leaves, whereas sterile nodes generally have 4 leaves. At the base of each branch there are opposite scale-like leaves.

Egeria densa male flower with three white sepals. Image by Leslie J. Mehrhoff, U. of Connecticut, Bugwood.org.

Flowers are dioecious, with only male plants known outside the native range except in a couple of locations in Chile (Yarrow et al. 2009). Male flowers arise from double nodes on thin pedicels up to 80 mm long. There are 3 sepals to 4.4 mm long and 3 white petals to

10.5 mm long. The 9 stamens have club-shaped filaments with a constriction below the anther, and yellow to orange anthers. The whole flower is 18-25 mm across and floats on or rises slightly above the water's surface.

Roots are white or pale, slender and unbranched. Adventitious roots are freely produced from double nodes on the stem.

Similar species:
The genus *Egeria* contains three species, all native to South America. *Egeria najas* has occasionally been sold in the aquarium trade and is weedy in its native Brazil. *Egeria heterostemon* is a more recently described species (Koehler and Bove 2001). The three are distinguished by details of the male flowers: *E. heterostemon* has unequal stamens, whereas *E. densa* and *E. najas* have stamens that are all alike. *Egeria najas* generally has 5 leaves per whorl at sterile nodes, and lacks a constriction of the filament below the anthers (Koehler and Bove 2001).

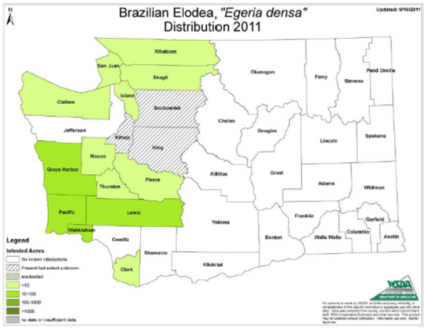
Elodea canadensis, common waterweed, is a native plant in Washington that looks similar to *Egeria densa* but has shorter leaves (commonly less than 1 cm) that typically occur in whorls of 3 (sometimes 4) (Hamel et al. 2001).

<u>Economic Importance:</u> *Egeria densa* was once sold in Washington as a popular aquarium plant; touted as a good oxygenator. It is still sold in many other states, and it has also been widely used in biology classrooms to demonstrate cytoplasmic streaming. As a consequence, it has become an aquatic weed throughout the world where it has been introduced as people discard their aquariums or unused classroom material into a local lake or river (Cohen et al. 2007).

The characteristics that make *Egeria densa* a good aquarium plant also contribute to its invasiveness. Yarrow et al. (2009) summarized these characteristics as a relatively fast growth rate, acclimatization to different light regimes, flexible nutrient uptake from the water column and sediments, high productivity in low to medium nutrient environments, high phenotypic plasticity, high dispersal via vegetative fragments and high potential to colonize disturbed areas.

These adaptations allow *Egeria densa* to form dense monospecific stands that restrict water movement, trap sediment, and cause fluctuations in water quality. Dense beds interfere with recreational uses of a waterbody by interfering with navigation, fishing, swimming, and water skiing (Yarrow et al. 2009). An estimated 1500 acre feet of storage capacity were lost annually in Lake Marion, South Carolina due to sedimentation caused by *E. densa* growth (Getsinger 1982). In Washington State, local and state governments and lake residents spend thousands of dollars every year to manage *E. densa* infestations. The cost of one control project was over $1,000,000 (K. Hamel personal communication).

Geographic Distribution: *Egeria densa* is native from the central Minas Gerais region of Brazil to the coastal areas of Argentina and Uruguay and inland nearly to Paraguay (Cook and Urmi-Konig 1984). Due to its popularity as an aquarium plant, *E. densa* has spread to at least 27 countries including New Zealand, Australia, much of Europe, Japan, Canada, Mexico, Columbia, Chile and outside its native range in Brazil and Argentina (Yarrow et al. 2009). In the United States, this plant has established in fresh waters from Washington and Oregon intermittently across the northern states to Massachusetts, and in all southern states from California, to Florida and Hawaii (PLANTS database 2014).



WSDA *Egeria densa* distribution map in Washington State, 2011.

In Washington State, *Egeria densa* was first reported in Long Lake, Kitsap County in the early 1970s. Currently, *E. densa* infests many western Washington lakes scattered over a wide geographic area. *Egeria densa* has not yet been reported growing in eastern Washington lakes, though it has been found in Idaho (T. Woolf, personal communication). *Egeria densa* causes many problems in Oregon's coastal lakes (M. Sytsma, personal communication), and the Sacramento delta area in California (California Department of Boating and Waterways 2006).

Habitat:
Egeria densa has a wide range of tolerance for a variety of aquatic habitats. It typically grows in lakes, but in Washington it has also been a problem in the Chehalis River where it grows in flowing water and rocky substrate (R. Johnson, personal communication 2014). It has been found at depths up to 7 m (23 ft) (Carrillo et al. 2006) and reaching the surface from 5 m deep in clear water (Wells and Clayton 1991). It can survive under ice cover in water 1° C (Catling and Wojtas 1986). It does best in waters with good to moderate water clarity (Yarrow et al. 2009). It tolerates salinity up to 5 g/l (ppt) (Hauenstein and Ramirez 1996). Under the right conditions, it can form expansive dense monospecific stands, and can be considered an ecosystem engineer under those conditions (Yarrow et al. 2009).

History:
The earliest report of *Egeria densa* in the United States was from Millneck, Long Island where the plant was collected in 1893. It was offered for sale in the United States in 1915, where it was recommended as a good "oxygenator" plant. The first European record of this species outside of cultivation was in a canal in Leipzig, Germany in 1910 (Yarrow et al. 2009).

Growth, Development and Physiology:
In temperate climates Egeria densa overwinters on the lake bottom. In Long Lake, Kitsap County, about 25 percent of the biomass overwinters along the bottom in a dormant-like, evergreen condition (Welch et al. 1994). Haramoto et al. (1988) found that in Japan it spends the winter as dense short stemmed mats on the lake-bottom. When the water temperature rose above 15° C, branches and roots formed and stems elongated, with maximum growth reached at 21° C. In warm climates it will senesce during periods of high water temperature (over about 32° C), thus will have growth periods in both spring/early summer and fall (Yarrow et al. 2009, Getsinger 1982). Pennington and Sytsma (2009) found that in a coastal Oregon lake Egeria densa persisted as an evergreen perennial, as the climate was neither warm nor cold enough to trigger senescence.

Flowering occurs when branches reach the water surface, and has been observed in Washington populations anytime between mid-June and early October (Jenifer Parsons pers. comm.). The intensity of flowering varies from year to year.

Other characteristics that contribute to *Egeria densa*'s success:

Egeria densa has a C4-like pathway which gives it an advantage over other plants during times of low CO_2, high oxygen and high temperatures (Yarrow et al. 2009). CO_2 is slow to diffuse through water, so plants with improved abilities to conserve and obtain it can continue to grow when levels are reduced.

Various studies show *E. densa* absorbs much of its nutrient requirements from the water (Yarrow et al. 2009), thus it can get nutrients from the sediment with roots, and the water column.

Egeria densa acclimates to different light regimes, with low light causing elongation of shoots and upper branches (Yarrow et al. 2009). In one study, it grew just as fast at 25% ambient light as at 50%, allowing it to grow into deeper water than other invasive aquatic weeds in New Zealand (Dollerup et al. 2013).

Pennington and Sytsma's (2009) study found low points in carbohydrate storage and stem nitrogen were variable, and suggested that targeting control to those low points may not be as valuable to *E. densa* control in the coastal West as in other parts of the country with more extreme seasonal water temperatures.

Reproduction: Female flowers and seeds have never been reported from *Egeria densa* populations established in the United States. The absence of sexual reproduction in introduced populations emphasizes the importance of vegetative reproduction. Double nodes produce lateral buds, branches, and adventitious roots. The plant fragments readily and each fragment containing a double node has the potential to develop into a new plant. Plant root crowns also develop from double nodes along old shoots. When a shoot sinks to the bottom during fall and winter senescence, a new root crown may develop at one or several double nodes along the shoot (Haramoto et al. 1988). *Egeria densa* lacks specialized storage organs such as rhizomes or tubers and stores carbohydrates in stem tissues, with highest concentrations in the lower stem and root crowns (Pennington and Sytsma 2009). Haramoto et al (1988) found starch content was highest in the stems in early winter, and lowest in late winter/early spring in temperate Japan. However, Pennington and Sytsma (2009) found the low points in carbohydrate storage and stem nitrogen were variable in coastal Oregon, and suggested that targeting control to those low points may not be as valuable to control in the coastal West as in other parts of the country with more extreme seasonal water temperatures.

Control Methods:

<u>Mechanical methods:</u>
Because *Egeria densa* spreads readily through fragmentation, mechanical controls such as cutting, harvesting, and rotovation (underwater rototilling) should be used only when the extent of the infestation is such that all available niches have been filled. Using mechanical controls while the plant is still invading will tend to enhance its rate of spread. If the lake is already full of *E. densa*, harvesting temporarily removes surfacing mats and creates open areas of water. In Louisiana, *E. densa* that was harvested in May had regrown to the surface by August (Johnson and Bagwell 1979). Harvesting was used extensively on Long Lake, in Kitsap County, and reduced *E. densa* biomass by up to 69% (Welch et al. 1994).

<u>Cultural Methods:</u>
Localized control (in swimming areas and around docks) can be achieved by covering the sediment with an opaque fabric which blocks light from the plants. In one experiment using natural burlap and coconut fiber products, Hofstra and Clayton (2012) found that *E. densa* emergence and biomass was reduced more than some thinner-stemmed plants (like *Elodea canadensis*) that successfully grew through small openings in the weave.

Managers of reservoirs and some lake systems may have the ability to lower the water level as a method of managing aquatic plants. Goldsby and Sanders (1977) reported that consecutive drawdowns in Black Lake, Louisiana eradicated *E. densa*. They noted that consecutive drawdowns may be more effective than an individual drawdown. *Egeria densa* is susceptible to desiccation and freezing (Yarrow et al. 2009) however, the success of a drawdown is dependent on several factors such as degree of desiccation (drawdowns in rainy western Washington are often ineffective), the composition of substrate (sand vs. clay), air temperature (the exposed sediments need to freeze down to 8-12 inches), and presence of snow.

Chemical Control:

Herbicide use on submersed plants is complicated by the fact that the herbicide is suspended in the water, and may be moved away from target plants by that water before the plant has absorbed enough herbicide to cause damage. Due to this, specific concentration and exposure time (CET) recommendations have been developed for many herbicides and target weeds (Getsinger et al. 2011). This means that knowledge about local water circulation patterns is important when trying to achieve the desired CET.

Langeland et al. (2009) reports excellent control of *Egeria densa* with diquat and copper (copper is not allowed in Washington except under certain conditions in irrigation canals), and good control with fluridone and penoxslam in Florida. Herbicides that are not recommended by them for *E. densa* control are endothall, 2,4-D, glyphosate, imazapyr, triclopyr, carfentrazone-ethyl, and imazamox.

The California Department of Boating and Waterways has been actively controlling *Egeria densa* in the Sacramento Delta since 2001. They mainly depend on herbicides. Until recently, they used fluridone in three formulations (liquid, pellets and granular) and diquat. They added imazamox and penoxsulam to their strategy in 2012 to reduce dependence on fluridone and because of the lower toxicological risk of those new products. Their website has links to many reports and studies on their control program http://dbw.parks.ca.gov/Reports/Default.aspx#AIS.

Additional information on specific herbicides with literature on *Egeria densa* control:
Diquat: Diquat is effective against *E. densa*. It was shown to reduce biomass by greater than 90% at the full label concentration (0.37 mg/l ai) with a 2.5 hour half-life and 0.185 mg/l ai for a 4.5 hour half-life (Skogerboe et al. 2006). Diquat will bind quickly to suspended organic matter and minerals, so use in turbid water will give poor results or completely fail to control egeria (Poovey and Getsinger 2002). The Washington State Department of Ecology supported a study of diquat on *E. densa* in Battleground Lake, and excellent control was achieved, though the *E. densa* was not eradicated using herbicides alone (Parsons et al. 2007).

Flumioxazin: Flumioxazin is not recommended for *E. densa* control. It is a contact herbicide that is rapidly degraded by hydrolysis. The degradation rate is greatly impacted by water pH, with a half-life of about 4 days at pH 5, about 16 hours at pH 7 and about 18 minutes at pH 9. *Egeria densa* is relatively tolerant to flumioxazin, with an application rate of 3285 ug/l (active ingredient) required to achieve 50% biomass reduction at pH 7 (note, the label rate is 400 ug/l) Mudge and Haller (2010).

Fluridone: is a slow acting systemic herbicide extensively used for *E. densa* control in the Sacramento Delta. A study in Washington State followed a fluridone treatment of *E. densa* and Eurasian watermilfoil in Loomis Lake. Good control was achieved, however the *E. densa* returned to dominate the lake due to lack of follow up control of the plants not killed by the initial treatment (Parsons et al. 2009).

Imazamox: according to the label for Clearcast®, *E. densa* is less susceptible to imazamox than other submersed weeds such as curlyleaf pondweed and Eurasian watermilfoil, requiring higher application rates to achieve control. It is one of four herbicides currently being used in the Sacramento delta for *E. densa* control (USDA 2013).

Note: Use of pesticides in water is regulated in Washington. All applicators must have an aquatic endorsement on their pesticide applicators license, which is issued by the Washington Department of Agriculture. In addition, coverage under a permit issued by the Department of Ecology is required. See http://www.ecy.wa.gov/programs/wq/pesticides/index.html for details.

Biological Control:
To date, no classical biocontrol agents have been developed for *E. densa*, although a few are under investigation. One pathogen, a fungus (*Fusarium* sp.), is being investigated. Also, a fly species in the genus *Hydrellia* has been found to feed on *E. densa* in Argentina. Host specificity testing has shown it to be nearly an *E. densa* specialist, and to hold promise as a classical biocontrol agent. However, more testing must occur before any insects will be available for release (Walsh et al. 2013). A species of *Hydrellia* (identified as *H. harti*) was also collected on *E. densa* in a pond near Portland, Oregon. But this species is also known to eat the native *Elodea canadensis*. Additional studies would be necessary to see if this (presumably native) fly species has potential to control *E. densa* (Harms and Grodowitz 2010).

Egeria densa has nutritious (high protein and nitrogen) leaves and growing tips (Curt et al. 2010, Pennington and Sytsma 2009). This makes it appealing to vertebrate herbivores. Triploid grass carp (*Ctenopharyngodon idella*) find *E. densa* highly palatable and they have been employed as a management tool in several lakes in the northwest. However, in several of these cases, grass carp have removed the entire submersed aquatic community making the lakes prone to toxic algae blooms and high levels of suspended sediment. Grass carp are nearly impossible to remove, so restoring these lakes to native aquatic plant habitat is very difficult.

Waterfowl also feed on *Egeria densa*. Curt et al. (2010) reported *E. densa* control when domestic Peking ducks (*Anas platyrhynchos*) were let loose on a small *E. densa* infested reservoir in Spain. *Egeria densa* is also important as a food for South American swans (Yarrow et al. 2009) and black swans in New Zealand (J. Clayton, personal communication). In one Washington lake formerly infested with *E. densa*, a wintering flock of wild trumpeter swans may have selectively eaten and eliminated the *E. densa* (Parsons, personal communication 2014). However, waterfowl also have downsides such as being prone to flying off and nutrient and bacteria input to the water from their large volumes of waste.

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