WRITTEN FINDINGS OF THE
WASHINGTON STATE NOXIOUS WEED CONTROL BOARD
(February 1996; Updated May 2013)

Scientific Name: *Cabomba caroliniana* A. Gray

Common Name: Fanwort, cabomba

Family: Cabombaceae

Legal Status: Class B: (a) Region 1, except Grays Harbor
(b) Regions 2, 4, 5, and 6
(c) Region 3, except Cowlitz County

Additional listing: Washington state quarantine list (WAC16-752)

Images: Left. Line drawing of *Cabomba caroliniana* plant parts. Image credit USDA PLANTS Database, USDA NRCS PLANTS Database, Bugwood.org. Center. Leaf detail. Image credit Leslie J. Mehrhoff, University of Connecticut, Bugwood.org. Right. *C. caroliniana* infestation. Image credit Leslie J. Mehrhoff, University of Connecticut, Bugwood.org.

Description and Variation: *Cabomba caroliniana* is a submersed, rooted, perennial plant.

Roots:
Roots grow from rhizomes in the sediment and also from nodes along the stem. The roots are initially white and unbranched, but become dark and branched with age. New stems and rhizomes grow from numerous axillary rhizome branches at the sediment, allowing for formation of dense clones (Wilson et al. 2007, Orgaard 1991).

Stems:
Cabomba caroliniana stems are grass green to olive green or sometimes reddish brown. They can grow up to 10 m long, but typically are 1 to 3 m, are round to slightly angular, and 2 to 4 mm in diameter. Up to 40 stems can come from a single root mass. Stems are sometimes coated in a thin mucilage (slime) and are generally pubescent (fine hairs), with denser pubescence at the nodes.

Stems can lie on the sediment or become partly buried as rhizomes (van Oosterhout 2009, Wilson et al. 2007, Orgaard 1991).

Leaves:
Cabomba caroliniana has two types of leaves: submersed and floating. Submersed leaves are light to dark green, or sometimes red to purplish. They are usually opposite, but occasionally in whorls of three. Leaf petioles are 0.5 to 4 cm long (as short as 0.5 mm (Wilson et al. 2007)). Leaves are finely divided and fan-shaped, with overall dimensions of 1 to 3.5 cm by 1.5 to 6 cm. The leaf blade branching pattern produces 20 to 200 fine segments at the outer edge. Floating leaves are small and inconspicuous, with an alternate arrangement. They are green to dark green, oval to diamond or arrow-shaped, from 5 to 30 mm long by 1 to 4 mm wide. The leaf blade attaches to the petiole in its center, where there is sometimes a slight constriction (van Oosterhout 2009, Wilson et al. 2007, Orgaard 1991).

Flowers:
Flowers are white, yellowish or purple and small (6 to 15 mm in diameter), and they float on or rise slightly above the water surface. Each flower has 3 petals and 3 similar-looking sepals. Flowers are insect pollinated, and are borne on a long pubescent stalk arising from the axils of floating leaves (van Oosterhout 2009, Wilson et al. 2007, Orgaard 1991).

Seeds:
Seeds are found in pods slightly below the water surface. The pods are 4 to 7 mm. Seeds are 1.5 to 3 mm by 1 to 1.5 mm in size (Wilson et al. 2007, Orgaard 1991).

Similar species and variations:
Cabomba is a small genus of aquatic plants originating in the neotropics and adjoining warmer temperate zones. There is a great deal of vegetative similarity among the taxa, making the genus taxonomically difficult (Orgaard 1991). Generally 5 species are recognized, some with additional divisions at the variety level. *Cabomba caroliniana* is sometimes reported to have 3 varieties; var *caroliniana*, var *pulcherrima* and var *flavida*, separated by flower color. These will occasionally show up in the aquarium trade as separate species. Additional confusion exists in morphological and color differences between populations found introduced in the northeastern U.S. (green leaves) compared with native plants in the southeastern U.S. (purplish leaves). These populations also respond differently to pH, temperature and herbicides (Bultemeier et al. 2009). Morphological differences have also been noted in Australia, with some differences attributed to hybridizations between the varieties (Australian Weeds Committee 2012).

Cabomba caroliniana is the only species of *Cabomba* widely introduced outside its native range (Wilson et al. 2007). The other member of the family Cabombaceae is *Brasenia schreberi* (water shield), a plant native to Washington.

Economic Importance: *Detrimental - Cabomba caroliniana* is an extremely persistent and competitive plant. Under suitable environmental conditions, it can form dense stands of up to 500 stems per square meter, crowding out previously well-established plants (Wilson et al. 2007, Riemer and Inicki 1968). Once established, this plant can:

- clog drainage canals and freshwater streams which increases sediment build-up and flooding,
- degrade water quality by increasing temperature and reducing dissolved oxygen during the night and fall die-back,
- interfere with recreation, block agricultural pumps, and decrease aesthetic value (van Oosterhout 2009, Wilson et al. 2007).

In areas where it is well established, control is difficult and costly (van Oosterhout 2009).

Beneficial - Cabomba caroliniana is commonly used as an aquarium plant because of its delicate appearance. Large numbers of plants are sent from Florida and Texas to the rest of North America for commercial use (sale is prohibited in Washington State by WAC 16-752). *C. caroliniana* is also grown commercially in Asia for export to Europe and other parts of the world. Small-scale, local cultivation occurs in some areas (Orgaard 1991). In its native habitat, *C. caroliniana* is eaten by waterfowl and some fish. In addition, it provides cover for some small fish and plankton (Mitchell 1979 c.f. Orgaard 1991).

Geographic Distribution: *Cabomba caroliniana* is native to the subtropic-temperate regions of eastern North and South America. It has been cultivated since the late 1800's, and has spread to other parts of the globe through disposal of aquarium material and escape from culture (Bickel 2012). It is invasive in North America outside its native range, including states north of Virginia to New England, Ontario, Canada and west to the Great Lakes region and Midwestern states. In the western U.S. it is found in California, Oregon and Washington. *C. caroliniana* is a large problem in the coastal lakes of Oregon (personal communication, M. Sytsma 2008). It is a weed of national significance in Australia, and also considered a serious weed in China, Japan and parts of Europe (van Oosterhout 2009).

History and distribution in Washington:
So far, *Cabomba caroliniana* is only known in Washington from side channels of the Columbia River, near Longview. There is no direct evidence of how or when *C. caroliniana* was introduced to Washington. The species was introduced to other parts of the world via discarded or deliberately scattered aquarium plants (Orgaard 1991), and then spread by fragments transported by water currents or human activity. This was the likely method of introduction in Washington, as well. Sale of *C. caroliniana* is currently banned in Washington State.

Habitat: The species grows rooted in the mud of stagnant to slow flowing water, including streams, rivers, lakes, ponds, sloughs, and ditches. Its roots and stems break easily, so it isn't found in areas of high flow (van Oosterhout 2009). In Australia it has been reported growing to 6 m deep (Schooler 2008). It is native to tropical and sub-tropical climates, but can survive and thrive in eastern Canada where thick ice covers lakes through winter (Wilson et al. 2007).

Growth, Development, and Reproduction: *Cabomba caroliniana* is an herbaceous perennial that spreads primarily by stem fragments or rhizomes. The species forms large clones as new rhizomes and shoots arise as axillary branches. Rhizomes and stems are fragile and easily broken, and stems will fragment naturally at the end of the growing season, facilitating vegetative spread and transport to new water bodies (van Oosterhout 2009, Orgaard 1991). New plants will grow from a stem fragment containing only one node – as short as 1 cm (Bickel 2012).

Plants will also spread by daughter plants; when stems lose buoyancy and sink, new plants develop at nodes and stem growing tips. The stem then breaks down, removing the connection to the mother plant. This can allow *Cabomba caroliniana* to colonize deeper water, since mother plants will support the deeper daughter plants until they grow to reach enough light to sustain themselves (van Oosterhout 2009).

Plants flower from May to September in temperate climates (Radford et al. 1968) or year-round in tropical climates. In the southeastern U.S., *Cabomba caroliniana* is self-pollinating and seeds readily germinate. Seeds collected from New Jersey failed to germinate, and no seedlings have been observed in the field (Riemer and Ilnicki 1968). In Australia, despite widespread introduction, viable seeds are only known from one population in Queensland (Bickel 2012) where plants are thought to be the pure strain of *Cabomba caroliniana* var *caroliniana*. Genetic analysis indicates other populations in Australia are hybrids of *C. caroliniana* varieties (Australian Weed Committee 2012). There is speculation that drying may improve germination, thus seeds may be a strategy for surviving drought. Seeds remain viable at least 2 years (van Oosterhout 2009). No information is available on seed production and viability in Washington (Gibbons 1993). Seedlings initially have opposite narrow leaves that are undivided. The plant then grows transitional leaves before developing fully formed submersed leaves (van Oosterhout 2009).

In tropical climates growth occurs year-round. Growth rates there have been recorded as high as 5 cm per day (van Oosterhout 2009). In sub-tropical areas, growth slows in winter and plants tend to sink, but biomass will remain high. In temperate climates, peak biomass is attained in late summer when plants produce turion-like structures (a segment of compact dense leaf growth) at the shoot tips. These lie on the sediment, remaining green under ice, and begin growing rapidly in spring (van Oosterhout 2009, Wilson et al. 2007).

Although there are differences in optimal pH and temperature between different varieties or strains of *Cabomba caroliniana* (Bultemeier 2008), densest growth is attained in lakes with low to neutral pH (between 4 to 6). Above pH 7, growth is greatly reduced. High calcium (>4 ppm) inhibits growth (van Oosterhout 2009) and *C. caroliniana* also prefers low magnesium (Bickel 2012). It can grow well in low nutrient waters, but does best in water with high nutrients and high turbidity (van Oosterhout 2009). It prefers silty sediment with low organic content (Bickel 2012), and clay, sand or stone tends to inhibit growth (van Oosterhout 2009). Densest growth occurs at moderate depths (2 to 3 m); though plants have been recorded to 6 m deep (van Oosterhout 2009, Schooler 2008). Plants will survive on damp soil for extended periods (van Oosterhout 2009). Optimum growth occurs at temperatures between 13 to 27 °C (Australian Weed Council 2012).

Control:

Prevention: Nursery and aquarium shop inspectors should remain vigilant for presence of *Cabomba caroliniana* sold under one of its variety names. Public education on the harm of dumping unwanted aquarium contents is also valuable. Sale via internet or hobby trade should be discouraged. Because *C. caroliniana* spreads easily by fragments, public education about the importance of cleaning, draining and drying all boats, fishing gear and other recreational equipment between uses is critical.

Response to Herbicides: *Cabomba caroliniana* has a reputation for being difficult to control with herbicides, which has been borne out by laboratory experiments and field trials. Complicating matters, different strains react differently. In laboratory experiments, a green invasive strain growing in the northeastern U.S. was more tolerant to herbicides than the native purple strain from Florida, with intermediate-looking plants from the aquaculture trade responding intermediately (Bultemeier et al. 2009). The following summarizes some of the results to date, but researchers acknowledge more work is needed to find reliable herbicide options.

Contact herbicides:

- Endothall - According to Westerdahl and Getsinger (1988), Endothall provided excellent control. In more recent laboratory studies, the amine salt of endothall reduced the invasive green strain of *Cabomba caroliniana*, but the herbicide concentration used was high, which may preclude its use where sensitive fish or wildlife occur (Bultemeier et al. 2009). In Washington the amine formulation is not permitted for aquatic plant control (J. Jennings personal communication 2013).
- Diquat - provided fair control in Australia with a 50% reduction in plant mass but rapid regrowth. However, in laboratory experiments, diquat, and diquat combined with copper did not provide good control of an invasive *Cabomba caroliniana* strain at the maximum concentration (370 ppb) and a 24 hour exposure (Bultemeier et al. 2009).
- Carfentrazone-ethyl - Carfentrazone-ethyl is currently being used for *Cabomba caroliniana* management in Australia (Australian Weeds Committee 2012). However Bultemeier et al. (2009) did not get good control of an invasive *C. caroliniana* strain with Carfentrazone.
- Flumioxazin – Flumioxazin provided the best control of the invasive green *Cabomba caroliniana* strain out of the 10 herbicides tested by Bultemeier et al. (2009). Additional mesocosm trials continued to show promise, with greater than 95% biomass reduction at 200 and 400 ug/l concentration (Bultemeier 2008).

Systemic herbicides:

- Fluridone - Fluridone showed promise at high concentrations (20 ppb) in laboratory experiments, but it did not work well in field trials in Australia.
- 2,4-D - In Australia, 2,4-D ester was used to successfully eradicate a *Cabomba caroliniana* infestation (van Oosterhout 2009). However in other trials this product was not effective against the invasive strain at concentrations allowed under the U.S. label (Bultemeier et al. 2009).
- Triclopyr – was not effective in laboratory trials (Bultemeier et al. 2009).

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.

Response to Cultural Methods: In the southern U.S. and Australia, drawdowns have been used to reduce and eradicate *Cabomba caroliniana* growth. Extreme drying is required to prevent regrowth, as the roots need to completely dry (Australian Weeds Committee 2012, Gibbons et al. 1993).

Response to Mechanical Methods: Harvesting is used to reduce plant presence in swimming and boating areas. Because harvesting generates fragments, this method is only advisable where *Cabomba caroliniana* has spread throughout the system, and fragment containment methods should be employed. Hand pulling by wading or with divers can eliminate small patches. Shading with the use of landscape fabric or other materials such as burlap, can be effective on small populations, especially in areas where no viable seeds are produced. Cover times of 3 to 4 months will kill the underlying plants (Australian Weeds Committee 2012).

Biocontrol Potential: Grass carp will eat *Cabomba caroliniana*, but it is not a preferred food, so their use should be limited to small ponds where total submersed vegetation loss is acceptable (Gibbons et al. 1993; K. Hamel, pers. comm.) Grass carp are only available as sterile triploid fish by permit from the Department of Fish and Wildlife. In Australia, a weevil native to South America, *Hydrotimetes natans*, has been identified as a potential biocontrol agent. This weevil is a *C. caroliniana* specialist, and spends its entire life cycle on the plant. Testing is on-going with the hope of eventual release in Australia (Australian Weeds Committee 2012). Currently no insects are approved for biological control in the United States.

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Rationale for Listing: *Cabomba caroliniana* is an extremely persistent and competitive plant that can form dense stands and crowd out native species. Once established, this plant can clog drainage canals and freshwater streams, preventing recreational activities and normal water flow, and requiring costly control measures. The *C. caroliniana* invasion in Washington is in a pioneering stage. Listing this species will encourage monitoring and prompt action to prevent further spread, decreasing future management costs and environmental damage.