DRAFT: WRITTEN FINDINGS OF THE
WASHINGTON STATE NOXIOUS WEED CONTROL BOARD
Updated in 2020, original draft from 2008

Scientific Name: *Butomus umbellatus* L.

Synonyms: *Butomus junceus* Turcz, *Butomus umbellatus* L. f. *vallisneriifolius* (Sagorski) Glnck

Common Name: Flowering-rush (sometimes known as grass rush)

Family: Butomaceae (Flowering-rush family)

Legal Status: Class A noxious weed; Quarantine List (WAC 16-752)

Images: left, flowering rush with emergent leaves growing along a shoreline; center, rhizome with leaf bases and developing bud; right, piece of flowering rush rhizome with leaves, all images by Greg Haubrich.

Introduction:

Flowering rush is an invasive aquatic perennial monocot that is able to exploit a wide range of aquatic habitats. It grows emergent along the shoreline of lakes and rivers out to water depths of 7 m (24 ft.) or more where it is fully submersed. It will grow in still water with muddy substrate to flowing water with rocky substrate and everything in between. It thrives in areas with fluctuating water levels, but also persists and spreads in stable water conditions (Hroudová 1989, Hroudová et al. 1996). It will invade and dominate native plant beds (Madsen et al. 2012, Harms 2020) and can also colonize habitats previously barren of plant growth (Parkinson et al. 2010). When growing submersed, the leaves are stiff relative to other submersed plants, and thus in flowing water they are present higher in the water column. It has been termed an ecosystem engineer for its ability to alter habitat by sediment accretion (Gunderson et al. 2016). These characteristics, along with the rapidly expanding population, have raised concern about potential impacts on habitat and water delivery if flowering rush becomes well established throughout its potential range in western North America.

There are two flowering rush cytotypes, a fertile diploid (2n = 2x = 26), and a (mostly) sterile triploid (2n = 3x = 36). The majority of known flowering rush populations in the northwestern US are the triploid cytotype.

Flowering rush is not a true rush (family Juncaceae). It is in the Butomaceae, a monogenetic plant family, with *Butomus* the only genus in this family, and *Butomus umbellatus* is the only species in the genus.

<u>Overall Habit and Description:</u>
Each plant consists of a rhizome, which produces triangular, upright leaves that grow to about one meter (3 ft.) tall if emergent, and up to 3 m (10 ft.) long when growing submersed. Axillary meristems along the rhizome can develop into either rhizome branches or peanut-sized corm-like buds that can easily detach from the rhizome (Hroudová 1989). Rhizomes also break easily, and the rhizome fragments and buds float to disperse on water currents and start new populations elsewhere (Parkinson et al. 2010). The inflorescence develops from an axillary meristem on the rhizome and consists of a long thin cylindrical stalk terminating in a cymose umbel (round-topped flower cluster with individual flower stalks originating from a common point) of 20 – 50 light pink flowers. Each flower usually consists of three pink sepals, three slightly larger pink petals, nine stamens (an outer whorl of six and an inner whorl of three) and six carpels. Each carpel contains about 200 seeds in fertile diploid plants. In triploid plants very few, if any, viable seeds form. Viable bulbils (small vegetative reproductive bulbs) may also form at the base of the inflorescence (Hroudová et al. 1996). Thus, this species can propagate through rhizome branches, rhizome buds, inflorescence bulbils and seeds (usually only diploids for the seeds).

<u>Roots/Rhizomes:</u>
The fleshy, prostrate, rhizome grows from the apical tip and lateral branches, forming a dense mat that can be up to 10 cm thick (Cahoon 2018). The rhizomes of both diploid and triploid cytotypes develop lateral buds, which are connected to the rhizome by a narrow base, thus they tend to break off easily (Hroudová and Zakravsky 1993). Research found that a rhizome from one plant produced 196 lateral rhizome buds over six years (Hroudová 1989). The rhizomes also become brittle with age and develop structurally weak constrictions along their length which spontaneously fragment or break readily following minor disturbance such as waves, passing boats, waterfowl, and people. The resulting fragments and buds float and disperse easily on water currents to start new populations elsewhere (Hroudová 1989, Brown and Eckert 2005).

Most of the biomass of flowering rush is in the rhizomes, with triploid plants allocating more resources to the rhizome than diploid plants (Harms 2020, Marko et al. 2015). Rhizome biomass increases substantially year to year, with an increase of 20 times over a 6 year period in one study (Hroudová 1989). Yearly, the greatest increase in rhizome biomass occurs late in the growing season (Hroudová et al. 1996). Some parts of the rhizome may stay dormant during the growing season (Hroudová 1989). Leaves and flower stalks arise directly from the rhizomes.



Images: left, flowering rush rhizome; flowering rush emergent leaf with slightly twisted growth, image by Jennifer Andreas, WSU Extension; cross-section of flowering rush emergent leaf, left and right image by WA State Noxious Weed Control Board.

Leaves:

The leaves can be emersed, submersed, or a combination. The blade is triangular in cross section at the base and flattens toward the tip – though even the flattened portion tends to retain a prominent mid-rib. Emersed leaves stand upright, often twist and often are purplish toward the base. Submersed leaves are dark green occasionally tending toward coppery and are flexible. Emersed leaves are generally 1 m (3 ft.) or less long, but submersed leaves can be to 2.7 m (9 ft.) or more long (Parkinson et al. 2010, Haynes 2000).

Leaves grow directly from the rhizome, without any stem or stalk. They are slightly sheathed around the adjacent leaves at the base. The leaves usually die back in winter and sluff off or form a duff on top of the sediment in areas of water level draw-down.

Flowers:

The inflorescence is produced on emergent plants, and is taller than the leaves. Flowers occur in a rounded cluster (umbel) of 20 or more light pink flowers with red or purple veins at the end of the flower stalk (Haynes 2000). Occasionally, bulbils are produced in the flower cluster (Hroudová 1996), which look like tiny bulbs.

The flowers are perfect – containing both male and female flowers parts. Each flower is radially symmetrical with three pink sepals, three slightly larger pink petals, nine stamens (an outer whorl of six and an inner whorl of three) and six carpels. Each carpel contains about 200 seeds in fertile diploid plants.

Flowers produce abundant nectar from nectarines at the base of the carpels. Pollinators are primarily honey bees, flies, bumble bees, and wasps (Bhardwaj and Eckert 2001).

Triploid plant populations have pollen grains that are significantly larger and frequently misshapen when compared with diploid plant populations (Lui et al. 2005, Krahulcová and Jarolimová 1993).

Images: left, blooming flowering rush inflorescence; center, individual flowering rush flower with three pink petals and three pink sepals, left and center images by WA State Noxious Weed Control Board; right, developing follicles post flowering, image by Jennifer Andreas, WSU Extension.

Fruits and Seeds:

Fruits are beaked leathery follicles to 1 cm (0.39 inch) long, containing multiple seeds in fertile plants (Haynes 2000). There are up to six follicles per flower. The seeds are very small, 0.25 by 1 mm (Rice 2008).

Triploid varieties produce very little viable seed (Lui et al. 2005, Hroudová 1996). However, diploid plants produced an average of 8,800 seeds per inflorescence (Lui et al. 2005). The seeds float, and are at least somewhat viable, with a range of seed viability reported in the literature. A long cold stratification is required for good germination success (Eckert et al. 2000, Hroudová and Zakravsky 1993).

<u>Habitat:</u>

Flowering rush is considered a wetland obligate species, where it grows in only freshwater habitats. This species can be found rooted in the mud along shorelines, and growing in shallow to deep waters (to a depth of about 7 meters (24 ft.)) in a variety of habitats including wetlands, the shoreline and littoral zone of lakes and slow to fairly swift rivers. It will also grow in a wide variety of substrates, from muck to sand to gravel and even rocky areas.

Fluctuating water levels facilitate flowering rush colonization and increased stand abundance. However, flowering rush will also thrive under stable water levels. (Hroudová et al. 1996). Drawdowns to unvegetated sediments provide ideal sites for new establishment from rhizome buds and fragments. In addition, the warmer water temperatures of exposed sediment or the water/sediment interface at shallow depths promotes sprouting and growth of buds, rhizome fragments and seeds. Warmer sediment and shallow water column temperatures also promote new sprouting from established rhizomes and lead to stand thickening (Hroudová et al. 1996).

Images: left, flowering rush leaves emerging from the Columbia River, exhibiting the challenge of finding flowering rush infestations when only a few leaf tips are visible; center, clump of flowering rush leaves growing in Lake Spokane, left and center image by Jenifer Parsons, DOE; right, flowering rush plants growing in a wetland at Joint Base Lewis-McChord, image by Wendy DesCamp, WSNWCB.

<u>Geographic Distribution:</u>

<u>Native distribution:</u>

Flowering rush is native to Eurasia. This species is indigenous to most of Europe, the United Kingdom, Ireland, and temperate western Asia (Kliber and Eckert 2005). It is classified as critically endangered in Norway, vulnerable in Switzerland, and near threatened in Croatia (IUCN 2018).

<u>Distribution in North America:</u>

The first record of flowering rush in North America was in 1897, growing in mud flats of the St. Lawrence River near Montreal, Canada (Countryman 1970). By 1950 it was considered the dominant species in some wetland habitats in southern Quebec (Les and Mehrhoff 1999).

In 1918 it was recorded from the River Rouge near Detroit, MI where it then spread to MI, OH, and Southwestern Ontario around Lake Erie and Lake Saint Clair by the mid 1900's (Kliber and Eckert 2005, Eckert et al. 2000).

In western North America, flowering rush was first recorded from the Snake River, Idaho in 1949 (Anderson et al. 1974) and has been a management challenge in irrigation canals in that region for many years (Steve Howser, manager Aberdeen-Springfield Canal Co. pers. comm. 2016). Next it was documented in Flathead Lake, Montana in 1962 (Consortium of Pacific Northwest Herbaria 2020). Within Flathead Lake, it has spread to colonize at least 2,000 acres of the littoral zone and moved downstream through the Clark Fork River into Lake Pend Oreille, Idaho and the Pend Oreille River in Idaho and Washington (Parkinson et al. 2010, J. Parsons personal observation 2010). It was collected from southwest British Columbia in 1978, and then just across the border in Silver Lake, WA in 1997 (Consortium of Pacific Northwest Herbaria 2020). In Washington, separate populations were found in the Yakima River in 2008, in the Spokane River system in 2010, and the Columbia River near Wenatchee in 2015.

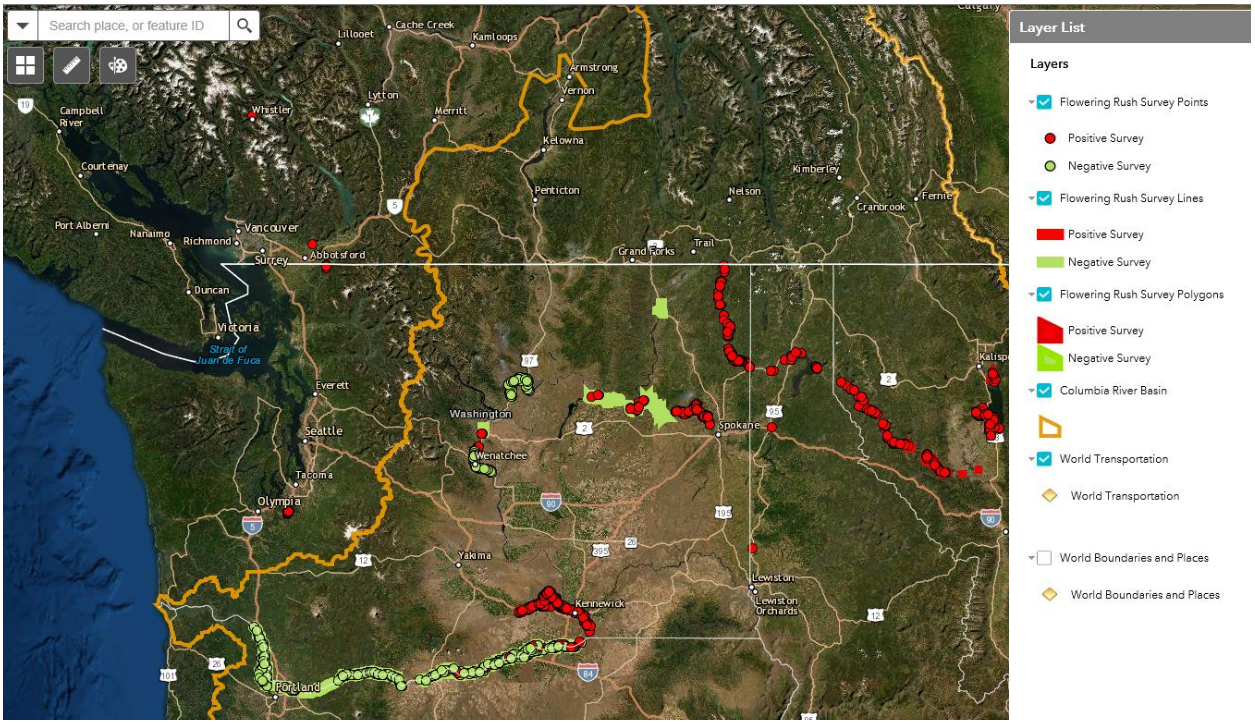
Nurseries have been implicated in introducing flowering rush to the Great Lakes region from seeds purchased from Toledo (Gaiser 1949). Another introduction method may have been from the effort to propagate and distribute waterfowl food plants, as it was shown to be consumed by a green-winged teal (Martin and Uhler 1939). Geese and other waterfowl have also been noted to graze exposed rhizomes and flowerheads, likely contributing to its spread (T. Woolf, pers. comm. 2018, Rice 2008). Muskrats have been documented to transport flowering rush parts and use it in dens (Gaiser 1949).

Genetic analysis has found low genetic diversity in North America compared with European populations. Kliber and Eckert (2005) found that most eastern North American populations were diploid, and triploids were found more in the west. Triploid genotypes were closely related to native genotypes from the Netherlands and northern Germany. The introduction of these triploids to North America was facilitated by their export as horticultural plants from the Netherlands to North America.

More recent work using amplified Polymorphic Length Polymorphisms (AFLPs) has identified 7 genotypes from 72 North American populations. Most of the western North American plants were the triploid genotype 1, with genotype 2 found at Bouchie Lake, B.C. and Lake Entiat, WA and genotype 3 in a pond in Klamath County, OR (Gaskin 2020). Most nurseries have been found to sell the triploid genotype (Eckert et al. 2016), further evidence that populations in the northwest likely originated as escaped ornamental plantings.

History and Distribution in Washington:

As of spring 2020, flowering rush is known from the locations listed below. The Columbia Basin Cooperative Weed Management Area maintains a flowering rush distribution map with additional details:
https://wsda.maps.arcgis.com/apps/webappviewer/index.html?id=9d3b3f18dc3e4b33bb4ca9db923882e3



Map: Columbia Basin Cooperative Weed Management Area flowering rush distribution map as of October, 2020.

Information on select rush locations in Washington:
Silver Lake (Whatcom County): Flowering rush was first documented in Silver Lake in 1997, but it was already well-established. Silver Lake is located about 15 miles from Hatzic Lake, B.C. where flowering rush was identified in 1978.

Yakima River (Benton County): Flowering rush along the Yakima River just downstream of Prosser was brought to the attention of noxious weed personnel in 2008. Control work began in 2015 and is on-going as of 2020. The population is scattered between Prosser and the confluence with the Columbia River.

Pend Oreille River: Flowering rush was found in the Washington portion of the Pend Oreille River in 2010. Since then control work has been on-going, however a continual flux of plant fragments and rhizome buds is floating down from the Idaho section of the river. The flowering rush has spread as patches throughout the Washington section of the river.

Spokane River: Flowering rush was found in the Spokane River at Lake Spokane in 2010. This population has since been found in 9-Mile reservoir, and has moved downstream into Little Falls Reservoir.

Lake Roosevelt: Flowering rush was found in Lake Roosevelt in 2019 across from the confluence with the Spokane River and scattered patches to Grand Coulee Dam.

Lake Entiat: Flowering rush was reported as a small patch near the Orondo boat launch in 2014 and verified in 2015. Control work is on-going.

Lakes and wetlands on Joint Base Lewis McCord: Flowering rush was reported in a wetland on the base in 2011 by local biologists. It has spread to downstream lakes and wetlands, control work is taking place by county and Base staff.

Biology:

Growth and development:
Flowering rush is a perennial. This species has the capacity for both sexual reproduction via seeds (mainly diploid plants) and clonal reproduction via rhizome shoots and vegetative buds and bulbils borne on the rhizomes and inflorescences, respectively.

Flowering rush exhibits a seasonal growth pattern. It is dormant in winter, and generally the leaves die back to the rhizomes. However, the collapsed dead leaves will occasionally persist through winter, or leaves can also remain upright and green. It begins growing in early spring; in Flathead Lake, Montana it has been recorded to start growing between late February and mid-April on exposed sediment (Parkinson et al. 2010). Leaf growth is rapid, peaking in mid-summer (Gunderson et al. 2016), then senescing, usually in September to October. Flowering occurs in July and August in Washington.

Reproduction:
Flowering rush reproduces both sexually through seeds (diploid plants) and clonally through the production of numerous vegetative buds and bulbils on the rhizomes and inflorescences and by rhizome fragmentation. Both native and introduced populations have a wide variation in seed production, depending on whether the plant is diploid or triploid, with triploid plants producing very few seeds. Diploid populations produce abundant seeds (mean 260 seeds/fruit). Diploid populations are also reported to produce more frequent inflorescences, however triploids also readily produce flowers (Lui et al. 2005, Eckert et al. 2000, Krahulcová and Jarolimová 1993, J. Parsons personal observation).

Diploid populations are capable of self-pollination (Eckert et al 2000), however it is also dichogamous – the pistils and stamens mature at different times to prevent self-fertilization. More specifically, the anthers release pollen for about one day, then the flower stops pollen release for about one day before the stigma is receptive to pollen. Moreover, this trait is synchronized throughout the umbel, in multiple cohorts, to avoid self-pollination. These traits are reduced or lost in triploid (sterile) plants (Bhardwaj and Eckert 2001). After pollination, as seeds mature, the developing fruit expands, and mature seed are released when carpels split down their inner seams.

There is evidence that diploid and triploid plants can cross-pollinate when growing near each other, creating plants with different chromosome numbers (aneuploidy) (Cahoon 2018, Krahulcová and Jarolimová 1993).

Control:
Response to herbicide:
Use of pesticides in water is regulated in Washington State. 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 https://ecology.wa.gov/Regulations-Permits/Permits-certifications/Aquatic-pesticide-permits for details.

Many herbicides have been tested on flowering rush, yet so far no chemical has been identified that will provide complete control with one or a few treatments. There are several herbicides that will provide partial to good control, but efficacy varies depending on the plant's growth form and treatment conditions. The following recommendations are provided in Columbia Basin Cooperative Weed Management Area flowering rush plan (CBCWMA 2019).

Emergent growth: At least 2 ft. of exposed leaf should be present above the water to treat. Use an approved surfactant combined with the herbicide. The most promising herbicides tested so far are imazapyr and glyphosate.

Spring dry-ground treatments: Imazapyr and imazamox are effective when treatments take place after the plants have started spring growth (at least 1 inch of new-growth). Treatments should take place at least 1 week prior to inundation.

Submersed growth: Repeated treatments with diquat have been shown to be effective at reducing rhizomes, leaves and rhizome buds. At least 2 years of treatment are required, and more would likely be necessary to maintain a reduced population. One to two treatments per year were found to be sufficient to maintain control of leaf biomass and reduce rhizome biomass and bud density (Parsons et al. 2019, Turnage et al. 2019).

<u>Response to cultural methods</u>:
Flowering rush rhizomes are not deleteriously affected by freezing, so winter drawdown to promote freezing of sediment does not provide control (CBCWMA 2019).

Flowering rush establishment is encouraged by fluctuating water levels (Parkinson et al. 2010). Because exposed bare or sparsely-vegetated substrates are ideal for seed, rhizome, and bulbil sprouting (Hroudová et al. 1996), maintaining stable water levels or increasing levels with flooding events have been explored as a management option. Neither type of water level manipulation has successfully suppressed flowering rush populations once the plant is established (Marko et al. 2015).

<u>Manual Methods</u>:
Manual control methods that have been used on flowering rush include hand digging exposed and shallow-water plants, Diver Assisted Suction Harvest (DASH) on submersed plants, and benthic barriers to cover plants. All three methods require follow-up inspection and usually re-treatment.

Hand digging can be done in areas where plants are above the waterline or in areas of shallow water that allow for removal of the entire rhizome using simple hand tools. Care must be taken to avoid leaving rhizome buds and fragments behind to form new plants. Follow-up visits are required to ensure the removal of all of the plant was successful. This method is only practical in areas where individual plants and patches are small (CBCWMA 2019). All plant parts should be bagged and disposed of in the trash.

SCUBA divers can use hand digging methods underwater, and either use mesh bags to collect plants or a DASH system (a suction dredge that will take pulled plants to a disposal container on a boat and return the water to the waterbody). The success of this method is dependent on how well-established the flowering rush is, and how meticulous the divers are. Sometimes this method has been combined with benthic barriers to help prevent remaining rhizome pieces from growing. In flowing water, use of netting downstream to help contain escaped fragments can be helpful (S. Sorby, pers. comm.). Follow-up visits are required to ensure all of the plants were controlled. (CBCWMA 2019)

Benthic barriers are landscape fabric or other material (not plastic) that is laid on the sediment surface to suppress plant growth. They are often pre-made by attaching the barrier material to a metal frame to aid in deployment and anchorage. The fabric must be held in place, often rocks or bags of gravel or sand are used. In deep water, a snorkeler or diver can aid with placement, but framed mats have been successfully placed from boats when conditions are right (calm winds and clear water). Flowering rush will grow out from under barriers, so the material must be much larger than the plant being covered. Materials that will allow gases to pass through should be used to help prevent bubbling up as organic matter under the barrier decomposes and produces gas. One study in Idaho found that flowering rush was still viable after five years of cover, thus covers may need to be maintained in place for an extended period (T. Woolf, pers. comm., CBCWMA 2019).

Mechanical Methods:
Mechanical control methods such as mowing or rototilling are likely to increase the rate of flowering rush spread through root and rhizome disturbance and fragmentation (Marko et al. 2015).

However, in areas where flowering rush is contained to an isolated waterbody and already well-established, harvesting with an underwater weed cutter that removes cut foliage from the water column to dry land may reduce growth. Repeated cuttings during the growing season was shown to reduce flowering rush in an Alberta lake after 20 years of treatments (Cahoon 2018).

Using machines such as back-hoes to dig flowering rush also creates fragments. However, a specially designed bucket, referred to as the Aquatic Vegetation Rake4, attached to a back-hoe has proven successful at reducing flowering rush biomass and improving water delivery in irrigation canals in southeast Idaho where chemicals cannot be used (Steve Howser, pers. comm.).

Biological control:
Flowering rush is an excellent candidate for biological control because it is the only species in the Butomaceae family. This lack of closely related species increases the likelihood of finding a host-specific insect or pathogen. In 2012, a biological control research and development project was initiated for flowering rush. Research has been taking place in the plant's native range by CABI (Centre for Agriculture and Bioscience International) with funding from a consortium of federal, state and provincial partners. So far two insects and one pathogen have been identified as promising agents, though field release in Washington is still several years away (CBCWMA 2019).

Economic importance:

Detrimental:
Flowering rush is considered an aggressive colonizer in many ecological circumstances and may specifically hinder recreational and industrial uses of shallow water habitat (Les and Mehrhoff 1999, Boutwell 1990). In areas where dense infestations grow adjacent to the shoreline and docks, such as Flathead Lake, MT, recreational use has been impaired. In southeasten Idaho, mechanical control of flowering rush is conducted annually on nearly 322 km (200 mi) of irrigation canals. Initial costs to develop a specialized rake were $75,000, not including operational costs (S. Howser, pers. comm.). Control with herbicides must take place repeatedly to maintain control, at costs ranging between $500 to $700/acre (V. Dupuis, pers. comm.). Invasive aquatic plants also can reduce water-front property values; one study found a 19% decrease in mean property values at Washington lakes with Eurasian

watermilfoil compared with properties on lakes free of that invasive plant (Olden and Tamayo 2014).

Flowering rush also provides habitat for the pond snail that is the host for one stage of the life-cycle of the parasite that causes swimmer's itch. In Silver Lake near Bellingham, swimmer's itch prevented swimming at camps and public beaches during summers until flowering rush was effectively controlled (L. Baldwin, pers. comm.).

The above mentioned environmental impacts, such as crowding out native species and impacting native fish habitat would also cause economic impacts to tourism, fishing and hunting opportunities, including commercial salmon fishing. As an example, the impact due to invasive *Elodea* spp. in Alaska has been examined and suggests that the probable economic loss to commercial fisheries and recreational floatplane pilots may be $97 million per year (Schwoerer 2017). In addition, climate change is likely to increase the range of flowering rush to further areas in North America, increasing its potential for impacts (Banerjee et al. 2020).

Beneficial:
Wildlife are known to consume the rhizomes, buds and leaf bases of flowering rush (Countryman 1970). It has been sold as an ornamental pond plant, though that is no longer legal in Washington.

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