WRITTEN FINDINGS OF THE
WASHINGTON STATE NOXIOUS WEED CONTROL BOARD
November 2, 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: Proposed Class A
Whatcom County Parks & Recreation Commission proposed adding it to the Noxious Weed List as a Class A.

Description and Variation:

Flowering rush is an emergent, aquatic, perennial. Monocotolydon. It is considered a wetland obligate species, found in a variety of shallow (3 meters or less), fresh water only habitats, especially the along the shoreline of lakes and slow-moving rivers.

Flowering rush is not a true rush (family Juncaceae).

Butomaceae is a monogenetic plant family, with *Butomus* the only genus in this family. *B. umbellatus* is the only species in this genus.

Overall Habit:

Each plant consists of a monopidal rhizome (branches arise from a single main axis) that produces thin, upright leaves that grow to about one meter tall. An axillary meristem can develop into either rhizome branches or pea-sized cormlike bulbils that can easily detach from the rhizome (Wilder 1974; Lieu 1979 as referenced in Kliber and Eckert 2005). Bulbils are often produced in great numbers, quickly germinate on the soil or water surface. An axillaray meristem on a rhizome may also develop into an inflorescence that 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 ovules (immature seeds). Viable bulbils may also form at the base of the inflorescence (Lohammar 1954 as referenced in Kliber and Eckert 2005).

This species can propagate through rhizome branches, rhizome bulbils, inflorescence bulbils and seeds – depending on whether the plant is the sexually fertile diploid ($2n = 2x = 26$), or the sterile triploid ($2n = 3x = 36$). Sexually fertile diploid plants – produce hundreds of clonal bulbils which readily detach from rhizomes, quickly develop on moist substrate and exhibit very high survivorship. These plants can also produce viable bulbils that form at the base of the inflorescence (Brown and Eckert 2005).

Sterile triploid plants – produce no bulbils at all and propagate only through occasional rhizome fragmentation. (Thompson and Eckert 2004; Lui et al. 2005 as referenced in Kliber and Eckert 2005). This big difference in clonal reproduction seems peculiar to North America. Experimental comparison of diploids from North America versus Europe indicated that introduced plants invest far more in bulbil production than native plants (Brown and Eckert 2005).

Data supports an association between sexual sterility and polyploidy in regards to pollen size and shape. Sterile (triploid) plant populations had pollen grains that were significantly larger and frequently misshapen as compared to fertile (diploid) plant populations. Pollen size and shape was also diagnostic of sexual fertility for individual plants (Lui et al. 2005).

The literature mentions ‘two growth forms’ of *B. umbellatus* as a response to water depth. When rooted in water that is 1.5 meters deep or less, one form has erect stiff leaves (Andersson 2001). In deeper water the submerged form (*B. umbellatus* forma *vallisneriifolius*) has flexible floating leaves reaching the surface and moving with the water movements. This form was considered sterile (Core 1941). Both forms of flowering rush are present in Flathead Lake, MT. It is also indicated that a third form is also present, a purely terrestrial plan that can grow along the borders of infested waters (All references above are found in Rice, 2008).

<u>Roots/Rhizomes:</u>
The fleshy, prostrate, monopodial rhizome grows from the apical tip. The trailing portion of the rhizome dies at the end of each growing season. Vegetative growth involves extension and branching of the rhizome and the production of leaves from rhizome meristems. (Wilder 1974; Lieu 1979 as referenced in Lui et al. 2005). Sexual reproduction involves the development of axillary meristems on the rhizome into inflorescences, each of which contains an umbel of about 20-50 light pink flowers on a long thin stalk (Wilder 1974).

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<u>Leaves</u>: The long, thin, straight linear leaves from the rhizome meristem, grow to about 1 meter long.

<u>Flowers</u>: The flowers are perfect – containing both male and female flowers parts. The inflorescence consists of a long thin cylindrical stalk terminating in a cymose umbel (flat-topped flower cluster with individual flower stalks originating from a common point) of 20 – 50 light pink flowers.

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 ovules (immature seeds). Flowers produce abundant nectar from nectarines at the base of the carpels. Pollinators are primarily honey bees, flies and wasps (Eckert et al. 2005).

Fruits and Seeds:
Butomus seeds retain 68% viability after five years of coldwater storage (Muenscher 1944 as cited in Les and Mehrhoff 1999). Seeds can float for 2 days, have a dormancy period and remain viable for many years (Ridley 1939; Hroudova and Zakravsky 2003 as referenced in Rice 2008). The seeds are very small, 0.25 by 1 millimeter (Rice 2008). European invasive species biologists have published a number of management relevant papers on the seed biology and ecology of flowering rush – Lukina and Papchenkov; Lukina and Papchenkov 1995; Hroudova and Zakravsky 2003. (Rice 2008).

Habitat:
Flowering rush is considered a wetland obligate species, where it grows in only freshwater habitats. This species can be found rooted in the mud and growing in shallow waters (to a depth of about 3 meters) in a variety of wetlands, particularly along the shoreline of lakes and slow moving rivers.

Fluctuating waterlevels facilitate flowering rush colonization and increase in stand abundance (Hroudova et al. 1996; Delisle et al. 2003 as referenced in Rice 2008). Drawdowns to unvegetated sediments provide ideal sites for new establishment from rhizome bulblets and lateral rhizome fragments. In addition, the warmer water temperatures of exposed sediment or the water/sediment interface at shallow depths promotes sprouting and growth of bulblets, rhizome fragments and any seeds. Warmer sediment and shallow water column temperatures also promote new sprouting from established rhizomes and lead to stand thickening (Hroudova et al. 1996; Delisle et al. 2003 as referenced in Rice 2008). Stable water levels do not cause a decrease in abundance of established stands (Hroudova 1989 as referenced in Rice 2008).

Geographic Distribution:

Native distribution: Flowering-rush is native to Eurasia. This species is indigenous to most of Europe, the United Kingdom, Ireland and temperate western Asia (Kliber A. et al. 2005). It is considered endangered in its native Israel because of habitat loss.

Distribution in North America:
Flowering rush spread from Eurasia to northeastern North America after it was introduced almost 100 years ago. 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. It continued to expanded westward and eastward to encompass most states and provinces along the Canada/US border. Flowering rush continues to spread westward throughout the US and southern Canada. (Eckert et al. 2000, Kliber et al. 2005).

Flowering rush is considered an invasive weed in the Great Lakes region of the Midwest. The species currently listed as "invasive" on the E-Flora BC atlas pages from the BC Ministry of Forests BC Flora 2004 Provincial Species List/database (considered incomplete and in draft).

Flowering rush is known from Flathead Lake and River, MT.

A more detailed look at introductions and spread across North America:
1897 is the estimated initial discovery of flowering rush introduction to North America. In 1905 it was discovered at Lapprairie, Quebec. By 1950 it was considered the dominant species in some wetland habitats in southern Quebec. 1928 dates the first US herbarium specimen, from the shores of Lake Champlain. 1943 is the first record of plants collected from the airport at New Haven, CT, where *Butomus* was thought to originate from discarded bouquets or disposed packing material. In 1978 and 1992 two populations were reported near Hartford, CT. The 1978 site was a flowering population. The 1992 record was from a vegetative site, and plants later propagated from this site during a research project, failed to flower. *B. umbellatus* was promoted as a water-garden ornamental for about 10 years before it was first noticed in a natural area pond near Ottawa, Canada. Flowering rush may have moved along the St. Lawrence River as ballast disposal. Nurseries have been implicated in introducing flowering rush to the Great Lakes regions, from seeds purchased from Toledo (Gaiser 1949). Another introduction was from the effort to propagate and distribute *B. umbellatus* as waterfowl food plants (Martin and Uhler 1939). The corms are consumed in abundance by the green-winged teal. (All references above are from Les and Mehrhoff 1999). Geese and other waterfowl may graze flowerheads (Rice 2008).

The theory that this species was introduced at least twice to North America, (the populations near Lake Erie region came from Europe, and the populations from the St. Lawrence and eastern Lake Ontario came from Asia) was disproved. Genetic research proved that the populations from both Europe and Asia were almost exclusively diploid in both regions, and all diploid plant samples expressed a single widespread genotype. This research shows that a more likely explanation is that *B. umbellatus* was transported from the eastern Great Lakes to southwestern Lake Erie early it its colonization of North America (Kliber and Eckert 2005).

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. (Kliber and Eckert 2005).

<u>History and Distribution in Washington:</u>
At this time, flowering rush is known from two locations in Washington State - Silver Lake in Whatcom County and along the Columbia River in Benton County.

<u>Silver Lake (Whatcom County).</u> Flowering rush was first found/documented in Silver Lake in 1997. Most of the shoreline is now populated with varying levels of flowering rush (see map). At this time, the total coverage in Silver Lake is estimated to be about 4.5 acres. Flowering rush plant samples from this site were sent to Montana for analysis to determine if these plants are diploid or triploid. It is suspected that these plants might be the sterile triploid (it rarely flowers

and most western US plants are triploid). Laurel Baldwin (Whatcom Co. Noxious Weed Board), Dr. Tim Miller (WSU Cooperative Extension) and Alison Halpern (Washington State Noxious Weed Board) set up several control plots, and these plots were treated in August (2008) with triclopyr, glyphosate and imazapyr. Research data will be collected and analyzed in spring 2009.

Silver Lake is located in the northeastern part of Whatcom County near a town called Maple Falls, which is very close to Canada. Background research indicates that there are flowering rush sites from Mission, British Columbia, on Hatzic Lake. This lake drains directly into the Fraser River and is about 15 miles from Silver Lake. The drainages of both lakes are not considered to be connected, but more information is being gathered. Laurel Baldwin is working with Linda Wilson (from B.C.). (Personal communication with Laurel Baldwin).

<u>Yakima River (Benton County).</u>

Flowering rush was found in 2003 by Dr. Steven Link while floating the Yakima River for a weed/plant survey. The current site (reached by going thru private property) runs for about 120 yards along the Yakima River, and the plants extend about 2 yards deep from along the shoreline. There are an estimated 3,000 – 5,000 plants from this site. The plants are growing, but they do not appear to be spreading since the site size remains the same as 2003. No flowering rush has been found down river.

Control is a concern. The Yakima River is a Heritage River and it is a Federal Waters River and there are salmon. The Yakima River has sediment. The water level fluctuates, it is used for irrigation, and if there is a schedule for water use, it is unknown. This location of this flowering rush site has continually fluctuating water levels and scouring of the Yakima River because of irrigation, flushing and spring floods with continual highs and lows. Research is needed in this type of waterway. Research up to this point has been on lakes, with a static water level. The river is protected and any control may have to go through federal agencies. The rhizome bulbils are a concern. At this time the impact of hand-pulling these plant populations (and dispersing the bulbils) are unknown. (Personal communication with Marc Stairet, Benton County Noxious Weed Control Program).

<u>Biology:</u>

<u>Growth and development</u>:

Flowering rush is a perennial. This species has the capacity for both sexual reproduction via seeds and clonal reproduction via rhizome shoots and vegetative bulbils borne on both rhizomes and inflorescences. Fertile introduced populations are highly self-compatible (Eckert et al 2000).

<u>Reproduction</u>:

Flowering rush reproduces both sexually through seed and clonally through the production of numerous vegetative bulbils on both the rhizomes and inflorescences and by small-scale rhizome fragmentation. Both native and introduced populations have a wide variation in seed production, depending on whether the plant is diploid or triploid (Krahulcova and Jarolimova 1993; Eckert et al. 2000; K. Lui, F.L. Thompson and C.G. Eckert unpublished data – as referenced in Eckert et al. 2003).

Diploid populations are self compatible and produce abundant seed (mean 260 seeds/fruit) that readily germinate under green house conditions. Almost all diploids produce multiple inflorescences each flowering season. Triploid populations very rarely produce flowers and they produce very little or no viable seed. (F.L. Thompson and C.G. Eckert unpublished data – as referenced in Eckert *et al*. 2003). Self pollinations produced no seed (Eckert *et al*. 2003).

Fertile populations differ strongly from sterile populations in regards to clonal reproduction (F.L. Thompson and C.G. Eckert unpublished data re: Eckert et al. 2003). Greenhouse experiments show that fertile plants produced numerous clonal bulbils (~300 /plant/growing season) on rhizomes. Bulbils also develop on inflorescences but in much small numbers (~10 bulbils/plant/season). In natural settings, the rhizome bulbils easily detach then scatter and quickly develop on the water surface. (Eckert et al. 2003).

Sterile plants (triploid) do not produce rhizome bulbils – not in the greenhouse or in natural populations. These plants do produce a large branched rhizome. Since sterile plants seldom flower, they almost never produce inflorescence bulbils (Eckert et al. 2003). The numerous tiny bulbils may be ecologically similar to seed and thus may outcompete them for safe sites.

Sterile plants produce very little or no viable seeds. European populations produced almost no seed, and the few seeds produced usually failed to germinate under greenhouse conditions. North American plants produced no seed at all (or a maximum of 5). North American triploids only rarely produce flowers under greenhouse or field conditions. (Kliber, Eckert 2005).

Flowering rush is dichogamous – the pistils and stamens mature at different times to prevent self-fertilization. More specifically, this species in considered proterandrous – the anthers release pollen before the stigma is receptive.

Field observations of 35 umbels during June and July 1999 showed that flowers appear to go through three distinct sexual phases. (All information on these three phases is from Bhardwaj and Eckert 2001). First is the male phase (fresh pollen in dehisced anthers); followed by a neuter phase (no pollen visible on anthers, stigma surfaces not yet exposed); followed by the female phase (stigma surfaces exposed).

Each phase lasts about one day. In the male phase, most anthers dehisce within the first day. The second day is the neuter phase, pollen removal is complete, but stigmas remain closed. The neuter phase time can vary, depending on pollination. The females phase is the third day after the flowers fully open. While some phase times vary, particularly the neuter phase, by the time the stigmas were exposed, there was no pollen in the anthers.

In more detail: During the first stage (male phase) the bud develops and the subtending flower stalk elongates. The six petals open, and expose 9 large bright orange stamens. The anthers dehisce, usually on the first day – the 6 in the outer whorl first, then the 3 of the inner whorl. Insects quickly remove the pollen. The pollen grains are bright orange and easy to see, whether on the anthers or stigma. Any remaining pollen fades to white in a couple of days. During the male phase, carpels are small and light pink and stigmas are tightly closed.

In the neuter phase there is no pollen visible in the anthers. This phase ends the male phase. The carpels swell and turn a dark burgundy color, but the stigmatic surfaces remain closed. A flower is considered in the neuter stage when there is no visible pollen in the anthers and there are no visible stigma surfaces.

The female phase begins when stigma surfaces are exposed and collect pollen. This phase ends when enough pollen fertilized all the ovules, which eventually develop into seeds. The stigmatic papillae are covered with faded pollen and the petals turn brown and wilt. The dark, burgundy-black carpels are noticeably swollen. The developing fruit expands, and mature seed are released when carpels split down their inner seams. (Bhardwaj and Eckert 2001).

Resource allocation in flowering rush is divided into sexual reproduction, clonal reproduction and vegetative growth. Vegetative growth involves the growth and branching of the rhizome and the production of leaves from rhizome meristems (Wilder 1974; Lieu 1979 as referenced in Kliber and Eckert 2005). Sexual reproduction involves the development of axillary meristems on the rhizome into inflorescences. Seeds produced from sexually fertile populations are highly viable (Eckert et al. 2000). Research continues on clonal reproduction. Experiments with native populations from the Czech Republic showed that sexually fertile diploids produce fewer rhizome bulbils than sterile triploids (Hroudova and Azhravsky 1993). Sterile populations (triploid) use almost no resources in producing sexual structures. These sterile plants rarely produce flowers, so they do not have the ability to produce clonal inflorescence bulbils. Sterile plants do produce a more branched rhizome that could fragment into new plants. Basically, sexually sterile plants have an extremely limited capacity for clonal multiplication and dispersal (Eckert et al. 2005).

In flowering rush, the fertile and sterile populations vary geographically. The highest number of fertile populations of flowering rush are near the two areas where this plant was initially introduced (St. Lawrence River/eastern Lake Ontario and western Lake Erie/Lake Saint Clair). The less common, sterile populations are found in the northwest. This regional variation may explain the previous conflicting reports on the sexual fertility of flowering rush in North America. Genetic evidence suggests that the sterile triploid plants are widespared because of their use in and their escape from horticulture. North America is being colonized by two distinct forms of *B. umbellatus* that differ strongly in reproductive strategy as well as the vectors and pathways of invasion. (Eckert et al. 2005).

<u>**Control**</u>:
Flowering rush has a flexible multifaceted reproductive strategy. Determining the distribution of fertile versus sterile populations and understanding the factors limiting sexual fertility can inform policy and programs designed to control the spread of introduced flowering rush. (Eckert et al. 2000).

<u>Response to herbicide</u>:
Herbicide plots and trials are underway in Whatcom County, WA (Silver Lake site).
Herbicide plots and trials are underway in Flathead Lake, MT.
Data should be available in 2009.

Response to cultural methods:

Response to mechanical methods:
The following mechanical control information is referenced in: Rice 2007 Draft.
Digging or suction dredging by hand may be a control option for isolated or individual plants in areas of low density populations. Or on sites smaller than 2 acres or smaller than 10 acres with a density of 10 plants per 100 square feet or less. (Maine Department of Environmental Protection 2006 #14790 as referenced in Rice 2007 draft). To be successful, the entire rhizome system must be removed without dislodging the rhizome bulbils. Land disposal of plant material is necessary. No plants or sediments can be returned to the water. This method might be an option if sites have sensitive plants or potable water restrictions.

Harvesting with an underwater weed cutter, to remove cut foliage from the water column to dry land. This does not remove rhizomes. Repeated cuttings, during the growing season and over the course of years could deplete carbohydrate reserves, to reduce the plant numbers. Even a slight bottom disturbance causes the rhizome bulbils to release. (Hroudova et al.1996).

The Pelican River Watershed District in Minnesota used a 10 year underwater cutting and harvesting program in a series of three lakes. It was not successful and the harvesting may have contributed to its spread within the watershed (Terra Guetter 2005 personnal communication with Peter Rice).

Bottom barriers have not been tried. They are expensive and they have a negative effect on benthic communities.

Biological control potential:

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 (Boutwell 1990) Les and Mehrhoff 1999), and threaten other shallow water emergents. Because this species has monotypic tendencies, it may affect native shoreline species (Boutwell 1990; Les and Mehrhoff 1999).

Lavoie et al. 2003 attempted to determine whether flowering rush had a negative impact on the diversity of wetland communities in North America, and found that flowering rush did not show a strong impact on wetland plant diversity – as compared to *Phragmites* and reed canarygrass. The way flowering rush grows prevents it from completely overtaking shoreline space, thereby letting other plants establish. On the other hand, what their study pointed out that it was ‘much easier to control a regional invasion by curbing the growth of small nascent colonies than large well-established populations’ (Moody and Mack 1988). Lavoie et al. conclude that focusing only on a few highly invaded sites could not predict the global impact of an invader.

Beneficial: The rhizomes are a food source in parts of Russia (Wikipedia).

Rationale for listing:
Flowering rush has been identified as a non-native, invasive aquatic plant in parts of the northeastern United States and Canada. It is considered an aggressive colonizer

Currently there is a very limited distribution Washington (2 sites), and in the northwest.

Research continues on control options. Education and outreach to gardeners and the nursery industry would help contain and stop the introductions – as it was specifically mentioned in the literature that the source of the triploid populations in our area were most probably from the horticultural trade.

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