11/23/2009

FLOWERING RUSH: AN INVASIVE AQUATIC MACROPHYTE INFESTING THE HEADWATERS OF THE COLUMBIA RIVER SYSTEM

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Summary

Flowering rush (*Butomus umbellatus*) is an invasive Eurasian aquatic macrophyte with emerged and fully submerged forms that can dominate irrigation systems, wetlands, littoral zone of lakes, river edges and sloughs. Mapping of Flathead Lake in Montana has delineated ~ 2,000 infested acres. It has passed through Kerr Dam and colonized the Flathead and Clarks Fork Rivers 165 miles downriver into Lake Pend Oreille in north Idaho. There is also a large infestation near the headwaters of the southern reach of the Columbia Rivers System in an irrigation system that spills into American Falls Reservoir on the Snake River. These large infestations at the headwaters of the Columbia River will continue to spread downstream and infest much of the main stem of the system. The Flathead Lake hydroelectric facility is operated to reach low pool in early spring, whereas an unregulated natural lake would reach low pool in late summer. This unnatural late summer through winter high pool with spring drawdown creates conditions that are favorable for establishment of flowering rush infestations and disadvantages to native macrophytes evolved to a hydrologic cycle with a late summer low pool. It colonizes previously unvegetated portions of variable drawdown zones. These monotypic colonies in previously open water littoral zones are likely to induce cascading ecosystem and trophic effects on the Columbia River System. However higher order impact have not yet been studied. They are likely to include alteration of sediment transport and deposition, and formation of new habitat favorable to introduced fish and disadvantages to native trout and salmon.

Origin and Distribution

Flowering rush is native to temperate Europe and western Asia (Tutin and others 1980). It was first noted in North America between 1897 and 1905 along the St. Lawrence River in Quebec (Fletcher 1908; Stuckey 1968), then was reported to be spreading down river by 1918 (Knowlton 1923), and was well dispersed along the St. Lawrence by 1938 (Marie-Victorin 1938). It was first observed in the United States in 1929 around Lake Champlain in New York (Muenscher 1930). In 1949 it was observed on the banks of the Snake River at Idaho Falls (Anderson and others 1974). By 1967 it was widely distributed into at least western Lake Erie (Stuckey 1968). The first Flathead Lake Montana report dates to 1964 at Peaceful Bay in the northwest corner of the lake (Rice 2009). By 1974 it had become extensively naturalized in Canada and the northern parts of the United States (Anderson and others 1974). In 1997 it was found in Silver Lake in northwest Washington (Rice 2009). As of 1999 to ~ 2007 flowering rush is know to have spread westward throughout Canada and most of the northern tier states (Kartesz and Meacham 1999; PLANTS 2009). In 2008 an infestation was found in the Yakima River (Washington) above its confluence with the Columbia (Rice 2009)

Anderson et al. (1974) recognized three areas of infestation in North America and suggested that because of morphological and size differences the St. Lawrence River region, Great Lakes region, and western U.S.-Idaho Snake River populations possibly came as three separate introductions. The four sexually sterile triploid genotypes found in North America were closely related to native genotypes from the Netherlands and northern Germany (Kliber and Eckert 2005). Kliber and Eckert's (2005) genetic evidence further suggested that the introduction of these triploids to North America was facilitated by export as horticultural plants from the Netherlands to North America. Kliber and Eckert (2005) also detected two sexually fertile diploid genotypes in North America; but their investigation did not clearly match the two North American diploid genotypes to any of the genotypes they had sampled in the native Eurasian range.

Biology and Ecology

Flowering rush, a monocot, is phylogenetically unique in that it is the only species in the Butomaceae family. This aquatic macrophyte has emergent and fully submerged phenotypes. The emergent form with rigid vertical leaves is present in Flathead Lake at full pool depths to ten feet. A fully submerged form with lax leaves that wave in the current is present at full pool depths of 10 to 20 feet. The rigid leaves of the emergent phenotype are up to six feet long and the lax leaves of the submerge phenotype can reach ten feet in length and float up to the surface. The leaves are distinctively triangular in cross section. Flowering rush is a non-persistent emerged macrophyte. After the leaves senesce in the fall they collapse to the lake bed unlike cattail and bulrush which although senesced remain erect throughout the year. The inflorescence of flowering rush has an umbel-like form with usually 20 to 50 individual 3 petal plus 3 sepal pink flowers on 5 inch long pedicles arising from a round flowering stalk.

The most relevant morphological feature of flowering rush is a monopodial rhizome approximately one foot long that can form branches from lateral rhizome buds. These are clonal infestations and individual plants are called ramets. The karyotype present in Flathead Lake is known to have a mean of 22 rhizome branches per ramet (Lui and others 2005). A study of a European population revealed that individual flowering rush ramets produced an average of 196 lateral rhizome buds over a six year duration (Hroudova 1989).

There are two karyotypes, a diploid (2n = 2x = 26) cytotype and a triploid (2n = 3x = 36) (Krahulcova and Jarolimova 1993). The diploid is self compatible and the triploid is self-sterile within clones. Depending on karyotype and genotype flowering rush can reproduce and be dispersed in four forms:

1. seeds
2. vegetative bulblets formed in the inflorescence
3. vegetative bulblets formed on the side of rhizomes
4. larger lateral rhizome fragments

The plant is sold globally to people doing water gardening. Seeds allow long distance dispersal from one water body to another. The rhizome bulblets (also called bulbils), inflorescence bulblets, and rhizome fragments facilitate spread within an infested water body.

Kliber and Eckert (2005) determined the ploidy of specimens collected from Flathead Lake and these Flathead Lake flowering rush were a triploid karyotype. Although about one in a thousand of the triploid ramets can produce a flowering stalk, these flowers are sterile (Eckert and others 2003) (Rice, Dupuis & Mitchell unpublished data). This Flathead Lake triploid genotype also does not produce any significant number of bulblets in the inflorescence or on the rhizome (Rice, Dupuis & Mitchell unpublished data), a local observation which is consistent with the reports for this triploid elsewhere in North America (Thompson and Eckert 2004; Lui and others 2005). Reproduction and subsequent dispersal by this Flathead Lake sterile triploid is entirely by rhizome fragmentation.

The rhizomes are extremely friable. Lateral rhizome buds develop a constriction between the bud and the main rhizome itself. This constriction allows spontaneous release of lateral rhizome structures by flowing water, waves, ice scour, passing boats, waterfowl, animals and any other disturbance of the littoral zone and the rhizome mat (Marie-Victorin 1938). The same disturbances, including waterfowl feeding on the rhizomes, break the rhizomes into pieces. These rhizome propagules are buoyant and this facilitates their dispersal (Marie-Victorin 1938). Propagule pressure is lower from the sterile triploid than the diploid which can also release bulblets and seeds, but the probability of establishment from rhizome fragments is probably much greater because of the high amount of stored carbohydrate available to facilitate expansion of the initial root system.

Susceptible Habitat

Water level drawdowns above unvegetated sediments allows flowering rush establishment from previously floating rhizome fragments. Wave action also deposits rhizome fragments along the shoreline. Fine sediments (Rice, Dupuis, & Reddish unpublished data), particularly silty substrates, and current speeds less than 2 mph enable rhizome fragments to root and establish new plants. In addition, the warmer temperatures of drawdown exposed sediments or the water/sediment interface at shallow depths promotes root development, leaf sprouting and rapid growth of rhizome fragments. Warmer sediment and shallow water column temperatures also promote regrowth from established rhizomes and lead to stand thickening (Hroudova and others 1996; Delisle and others 2003). Any subsequent year drawdowns allow the flowering rush population to be renewed by vegetative reproduction (Hroudova and others 1996). The Kerr Dam hydroelectric facility on Flathead Lake is operated to reach low pool in early spring, whereas an unregulated natural lake would reach low pool in late summer. This unnatural late winter/spring drawdown creates seasonal conditions that are favorable for the establishment of flowering rush infestations in previously unvegetated littoral zones. In native vegetation populated littoral zones and wetlands flowering rush has a phenological and hydrologically derived competitive advantage over the native macrophytes which have evolved to a hydrologic cycle with a late summer low pool. Sloughs, backwaters, and other area with slow current speeds and fine sediments allow establishment of flowering rush in rivers.

Impacts

Other than a strong propensity to form monotypic or near monotypic stands, the higher order impacts of flowering rush have not received any scientific study. It is widely accepted that flowering rush has strong impacts on recreational, irrigation, and industrial use of shallow waters, and that its monotypic tendencies may be affecting desirable native littoral species (Boutwell 1990; Les and Mehrhoff 1999). Obvious impacts for Montana and southeast Idaho are resultant from the occlusion of open water and restrictions on flow.

Water delivery in irrigation ditches in the Flathead valley is starting to be reduced by flowering rush invasion. This flowering rush impact on irrigated agriculture is well recognized in southeast Idaho (Steve Howser Aberdeen-Springfield Canal Company personal communication). The Aberdeen-Springfield canal system provides water for sprinkler irrigation of potatoes and other cash crops. Approximately 150 miles of the 300 miles of the main delivery canals are infested with flowering rush and require some removal by chaining every second or third year.

Recreational use of Flathead Lake is being impaired by dense monotypic infestations adjacent to the shoreline and docks. This includes impediment of boat passage due to prop fouling, blockage for swimming, and loss of open water for near shore fishing. The flowering rush infestations provide ideal habitat for great pond snails (*Lymnaea stagnalis*), which are an intermediate host for the trematode parasite (*Trichobilharzia ocellata*) that causes swimmer's itch.

The most critical environmental aspect of the flowering rush invasion is that it is forming dense stands in previously unvegetated littoral zones. As the extent of unchecked infestations increases there are likely to be trophic and ecosystem cascades. These would be the result of increased water temperature, nutrient transfers from the hydrosoil to the water column (Van Eeckhout and Quade 1994; James and others 2003), altered sediment transport, deposition, and accretion rates. Swimmers inch may be dismissed as a simple nuisance however it is indicative of other higher order biotic impacts that are reasonable hypotheses of long term consequences of this invasion. Aquatic food webs are likely to be changed. Of particular relevance for Montana and the Pacific Northwest are the potential negative impacts on the maintenance and restoration of native salmonids. The expanding stands of flowering rush provide habitat for structurally orientated introduced fish species that are obligate vegetation spawners and/or ambush predators of cutthroat trout, bull trout, and juvenile salmon. These vegetation adapted piscivorous species include small and large mouth bass, yellow perch, and northern pike (Tabor and others 1993; Fritts and Pearsons 2004; Bonar S. A. and others 2005; Schultz 2006; Cooper and others 2008). The negative impact of structurally orientated introduced fish on open water native salmonids throughout the Columbia River Basin is well documented (Sanderson and others 2009). Northern pike have been confirmed as having serious impacts on cutthroats and bull trout in the Flathead (Muhlfeld and others 2008). Some of the sloughs on the Upper Flathead River that are being utilized by radio tagged northern pike are heavily infested with flowering rush (Peter Rice, personal observation).

<u>Current Status Of Flowering Rush In Montana And Adjoining States/Provinces</u>

Since the first colony was noticed in Peaceful Bay in 1964 flowering rush has spread around the circumference of Flathead Lake, with the possible exception of the northeast shore where heavy wave action may be retarding maintenance of permanent infestations along most of the shoreline. Based on remote sensing and spatial modeling the current minimum acreage estimate for the littoral zone for the 0 to 10 ft depth is 1,039 acres (Table 1). It must be noted that image classification generally identifies only areas of high density. There likely are many more acres of low-density or interspersed flowering rush that were not identified in this initial remote sensing classification. We do not currently have the capability to directly assess the extent of infestation by the fully submerged phenotype, but our best estimate is that at least a thousand acres of the10 to 20 ft deep littoral zone is infested. As a minimum to the 20 ft depth we estimate that 2,039 acres or 14% of the littoral zone is currently infested. There are also 1,536 acres of wetlands immediately adjacent to Flathead Lake. The current investigations of these adjacent wetlands have been limited to a 133 acre block along the North Shore (Lorang & Reddish unpublished data). Flowering rush was identified there in 8.6 acres or 6.5% of that wetland. Projected to all the adjacent wetlands this sample would yield a best estimate of 100 wetland acres currently infested at density high enough to be detected my remote image analysis.

Table 1. Flathead Lake acreage estimates of current flowering rush infestations and area susceptible to infestation based on a remote sensing spatial analysis (Rice, Reddish, Dupuis & Mitchell unpublished data).

Initial Results Spatial Modeling	Current		Susceptible	
Habitat	Habitat Size Acres	Infested* Acres	Maximum Acres	% of Lake
0-10’ Littoral	5,823	>1,039	4,364	3.5
10-20’ Littoral	8,375	?>1,000	6,546	5.3
	14,558	?>2,039	10,910	8.8
% Current & Susceptible of the Littoral Zone		>14	75	
Adjacent Wetlands	1,536	100	?1,536	

*dense infestations with high cover value

Spatial modeling, primarily based on remote sensing and spectral image analysis of lakebed substrate exposed at low pool, suggests that 10,910 acres of the 0 to 20 ft littoral zone are susceptible to infestation. Which is 75% of the littoral zone and equivalent to 8.8% of the Lake surface area (Rice, Reddish, Dupuis & Mitchell unpublished data). All of the 1,536 adjacent wetlands acres may ultimately be susceptible, but flowering rush displacement of the native macrophytes is occurring at a considerably slower rate than flowering rush establishment in previously unvegetated littoral zones.

Flowering rush rhizomes have been discharge through Kerr Dam into the lower Flathead River and continued down the Clark Fork River reaching the Clark Fork delta at the head of Lake Pend Oreille. Then the infestation extends as currently scattered small colonies along the northeast shoreline of Lake Pend Oreille to Sandpoint, reaching into the part of the Pend Oreille River impounded by Albeni Dam. Current acreage estimates for impoundments downriver of Kerr dam on Flathead Lake are Thompson Falls Reservoir 28 acres, Noxon Reservoir 46 acres, present at trace levels in Cabinet Gorge Reservoir (Madsen and Cheshier 2009); and 50 to 200 acres in Lake Pend Oreille (Madsen and Wersal 2008)(Kate Wilson & Tom Woolf personal communication). There is no current quantitative estimate for flowering rush in the Flathead and Clark Fork rivers, but it is not infrequent in sloughs, backwater eddies, and low flow areas proximal to boat launch sites.

In Idaho, in addition to Lake Pend Oreille, the Snake River from Idaho Falls to American Falls has a number of known infestations (Rice 2009). Below Idaho Falls, the Aberdeen-Springfield Canal system, which provides sprinkler irrigation water for potatoes and other crops in southeast Idaho, has significant infestations in ~150 miles of the 300 miles of its high delivery volume canals (Steve Howser, personal communication). The manager of the Aberdeen-Springfield Canal Irrigation System estimates that properly managing flowering rush in that system would increases the costs to farmer shareholders by 8% a year (Steven Howser, personal communication). There are reports of smaller infestations in other irrigation systems in that area of southeast Idaho. Flowering rush has been drawn up out of the Flathead River at the Pablo Reservoir lift station and is now being redistribution through the irrigation system on the floor of the Flathead Valley in Montana. Idaho has the most acreage irrigated from the Columbia River System with over 3 million acres under irrigation at any given time, while Oregon irrigates 1.9 million acres and Washington 1.8 million acres. All these irrigation systems are at risk to flowering rush infestation by rhizome fragments suspended in the water being withdrawn from the Columbia System below the Snake River and Flathead River infestations.

In Washington there are disjunct (relative to the main stem of the Columbia River System) infestations in Silver Lake (northeast WA) and the Yakima River above its confluence with the Columbia (Rice 2009). There are no reported infestations for Oregon. However North and South Dakota, Alberta, and British Columbia have reports of flowering rush but details have not been compiled (PLANTS 2009). Washington added flowering rush to its noxious weed list in January 2009, Oregon added it in February 2009, and Idaho is currently in the process of adding it to its state list.

Current Research in Montana

The University of Montana and Salish Kootenai College have been conducting applied research since 2007 that would provide scientific information and applied techniques for the management of flowering rush. Topics include phenology, rhizome dispersal, inventory, karyotyping, herbicides, digging trials for low density infestations, and a spatial model to estimate the current extent of infestation in Flathead Lake, identify susceptible habitats, and predict the maximum infestation in Flathead Lake. Foliar applied herbicides are being tested in replicated plots at Flathead Lake sprayed when the water is off the site due to late winter/early spring drawdown but the new leaves are emerging (May). And also foliar spraying at high pool when as much as 5 ½ feet of leaf is below the water line and only 6 to 18 inches of leaf is elevated above the water line (July). The goal of these foliar treatments, which began in 2008, is to kill the rhizomes, but it is too early to determine if multi-year suppression is being obtained. Eight water column injection herbicides are being screened in greenhouse trials for efficacy on flowering rush as a treatment for submersed plants. A number of these aquatic herbicides are showing high activity on flowering rush but the concentration exposure times (CETs) have not yet been determined. Some of the preliminary results of this applied research work have been incorporated in this document.

Management Options

Management options for flowering rush are not well developed. Montana is taking a pioneering role in developing control strategies.

- Habitat at 2 to 3 quarts/acre and Clearcast at 2 quarts/acre and all with an MSO adjuvant can provide season long (May through September) suppression of top growth when applied as foliar spray to emerged leaves during the spring drawdown period (Figure 1).

- Water column injection herbicides would be necessary for suppression of the fully submerged phenotype and the emergent form when there is only a short length of leaf elevated above the water line.
- Mechanical harvesting has been used in Midwestern lakes and ponds but most of the shoreline owners groups that were harvesting have now concluded that the mechanical removal approach was only increasing rhizome dispersal, and at great cost.
- It may be possible to dig out the rhizomes for low density (~1 ramet per 100 ft^2) infestations at drawdown or in shallow water, but it would require great care to remove and retain all the friable rhizome fragments.
- Signage at boat access points and other public notification processes could reduce the probability of transport to other water bodies and reduce the disturbance/rhizome fragmentation within an infested waterway.

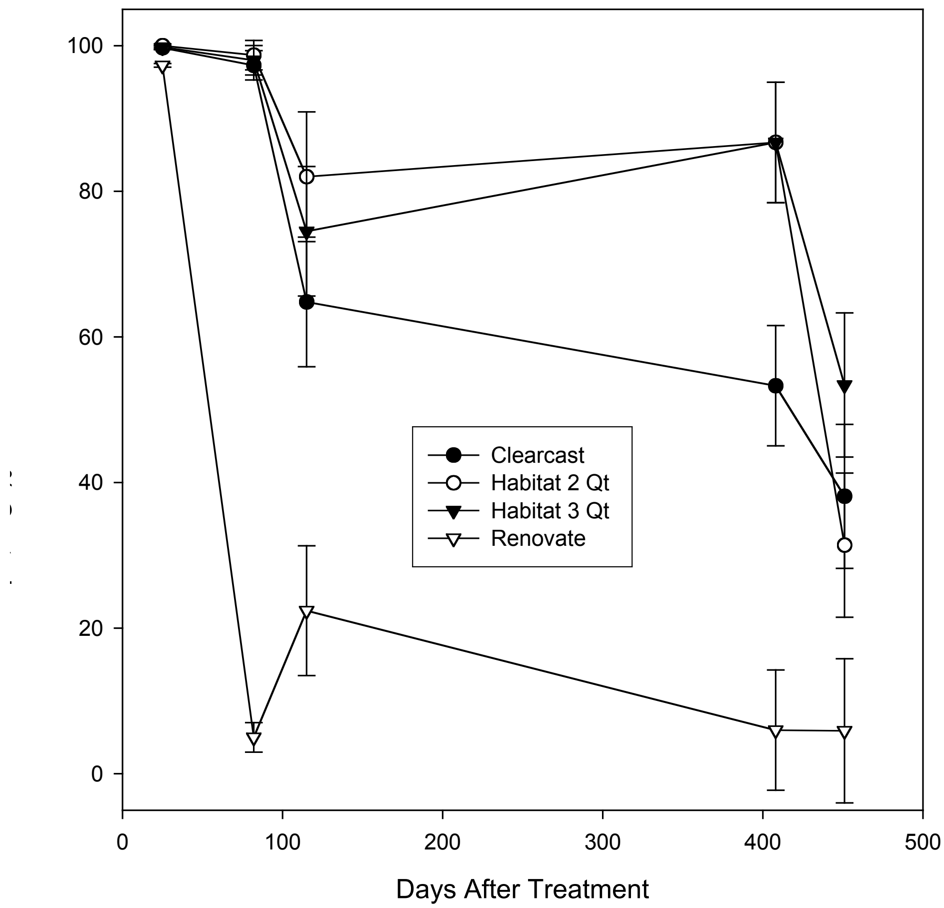

Figure 1. . Percent control of flowering rush ∀ one standard error after low pool (exposed sediments) foliar treatments on May 27, 2008.

A suite of suppression methods applicable to flowering rush infestations at different site types with different management concerns would be an important element in a strategic plan to contain flowering rush to the headwaters of the Columbia River system. These control options need to be developed in a timely manner relative to the rather slow spread rate of this aquatic weed while it is still at an early stage of invasion of the Columbia River system. Demonstrating the possibility of effective suppression removes a barrier to motivating the numerous local, state, and regional natural resource jurisdictional entities from coalescing on the development and implementation of an aggressive early response to this invasion of a large and critical aquatic resource that provides a high level of ecosystem services.

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