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The Impact of Endothall on the Aquatic Plant Community of Kress Lake, Washington

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ABSTRACT

A dense mat-forming population of Eurasian watermilfoil (*Myriophyllum spicatum* L.) was interfering with fishing and recreation in a small western Washington lake. A low concentration (1.5 mg/L active ingredient) of the herbicide endothall formulated as Aquathol® K was used in 2000 to attempt to selectively control the Eurasian watermilfoil. Aquatic plant biomass and frequency data were collected before treatment, ten weeks after treatment and during the growing season for 3 additional years. Macrophyte data were analyzed to assess the herbicide's impacts on Eurasian watermilfoil as well as the rest of the aquatic plant community. Results showed a significant decrease in Eurasian watermilfoil biomass and frequency 10 weeks after treatment. The Eurasian watermilfoil continued to be present, but at a significantly reduced level through the remainder of the study (3 years after treatment). Of the native plant species, large-leaf pondweed (*Potamogeton amplifolius* Tucker.) frequency and biomass was significantly reduced after treatment. Common elodea (*Elodea canadensis* Rich.), muskgrass (*Chara* sp. Vallaint.) and bladderwort (*Utricularia* sp. L.) all increased significantly after treatment.

Key words: Myriophyllum spicatum L., Eurasian watermilfoil, Aquathol® K, aquatic herbicide selectivity, native aquatic plants.

INTRODUCTION

Eurasian watermilfoil was first identified in Washington State in 1965. Since that time it has spread to well over 100 lakes and rivers throughout the state (Parsons et al. 2003). As with other parts of temperate North America where this plant has become established, it is considered highly invasive and detrimental to both lake ecology and recreation. Its habit of quickly growing to the water surface in the spring and branching to form a surface mat can reduce the diversity and abundance of the native plant community, reduce dissolved oxygen, increase water temperature and impact nutrient cycling (Aiken et al. 1979, Nichols and Shaw 1986, Frodge et al. 1991, Madsen et al. 1991). The dense surface growth can also entangle swimmers, reduce fishing opportunities, and frustrate boaters (Newroth 1985, Smith and Barko 1990).

In Washington State many lake front home owners are interested in reducing or eliminating populations of Eurasian watermilfoil. Because it is included on the State's noxious weed list, local weed control districts and the state are also interested in managing this plant. In areas where the population is very limited, diver hand pulling or benthic barriers can be used to good effect. But in many cases other methods of control such as mechanical, biological or herbicides are preferred.

The herbicide endothall (7-oxabicyclo (2.2.1) heptane-2,3-dicarboxylic acid) was first distributed for aquatic use in 1960 (Ecology 2000). This herbicide acts as a contact chemical and is used to control a wide variety of submersed weeds (Ecology 2000, MacDonald et al. 2003). Several studies have defined contact and exposure time requirements to control Eurasian watermilfoil with endothall (Netherland et al. 1991, Getsinger and Netherland 1997, Sprecher et al. 2002). These studies have shown that Eurasian watermilfoil is highly susceptible to endothall. More recently, work has been done to investigate the tolerance of native plant species to this herbicide (Skogerboe and Getsinger 2001, Skogerboe and Getsinger 2002). These studies indicate that endothall used at concentrations that control Eurasian watermilfoil does minimal damage to many native plant species. The purpose of this study was to investigate the potential for endothall formulated as Aquathol® K to enhance the native submersed plant community and improve angler satisfaction in a small lake dominated by Eurasian watermilfoil.

MATERIAL AND METHODS

Study Site

Kress Lake was selected as the test site because it is both a popular fishing lake and had a nuisance population of Eurasian watermilfoil. It was also attractive because the State owns the lake and shoreline, so no lake front property owners would be impacted by the study.

Kress Lake is a 12 ha flooded gravel pit located near U.S. Interstate 5 about 13 km south of Kelso in southwest Washington State (Figure 1). It is more or less trapezoidal in outline with a maximum depth of 5.5 meters. The shoreline consists of a short steep bank with trees and shrubs. A walking trail circles the lake at the top of the embankment. The lake is managed by the Washington Department of Fish and Wildlife (WDFW) for recreational fishing from shore or small boats. No combustion engines are allowed.

The WDFW has managed Kress Lake for a mixed fishery since at least 1982. Various strategies have been employed including fertilization, aeration and rotenone. Fish species currently present include rainbow trout (*Oncorhynchus mykiss*

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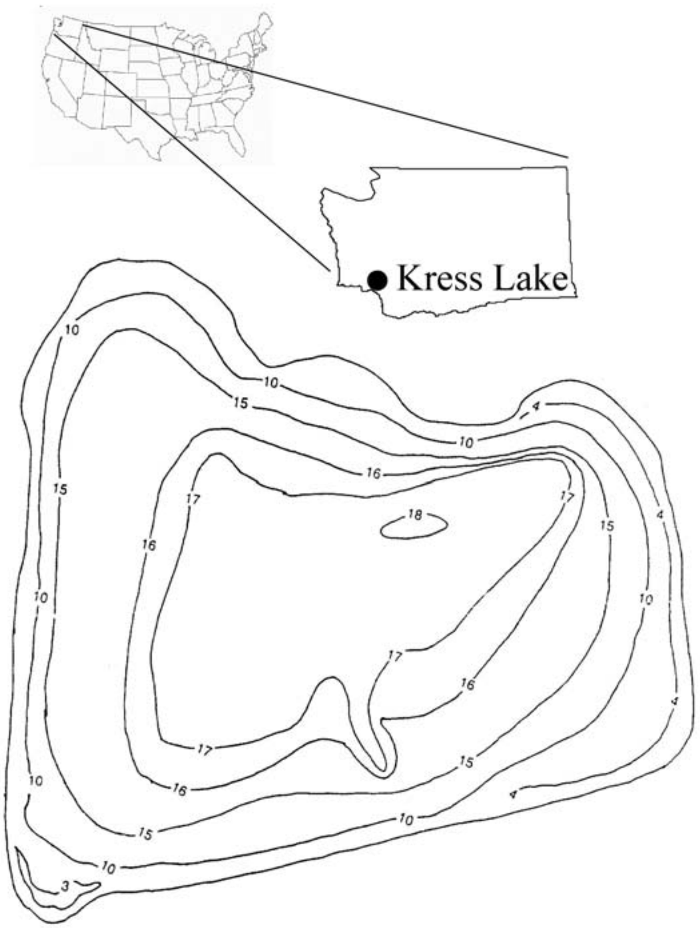

Figure 1. Kress Lake, Washington. Depth contour intervals marked in feet.

Walbaum), brown trout (*Salmo trutta* L.), cutthroat (*Salmo clarki* Rich.), channel catfish (*Ictalurus punctatus* Rafin.), largemouth bass (*Micropterus salmoides* Lac.), bluegill (*Lepomis macrochirus* Rafin.), pumpkinseed (*Lepomis gibbosus* L.), yellow perch (*Perca flavescens* Mitchill) and warmouth (*Lepomis gulosus* Cuvier). It is a popular recreation area for anglers as well as recreational boaters, hikers, and horseback riders (S. Kelsey, WDFW Inland Fish Program 2004, pers. comm.).

Prior to initiation of this study the aquatic plant community extended throughout the lake. Eurasian watermilfoil was first identified in Kress Lake in 1995, and by 1999 it was the dominant plant, forming a ring of surfacing vegetation around the lake edge. Large-leaf pondweed and the macroalgae muskgrass made up the majority of the remaining submersed plants. A 1999 fish population assessment found that bluegill, pumpkinseed and yellow perch were stunted and in poor condition (S. Kelsey, WDFW Inland Fish Program 2004, pers. comm.). This situation can result from very dense surfacing aquatic plant growth (Engel 1995, Dibble et al. 1997, Valley and Bremigan 2002).

Herbicide Application

Due to heavy plant growth, the lake was divided into two sections that were treated with herbicide about a month apart. This treatment strategy was designed to prevent a reduction in dissolved oxygen caused by any large scale plant die-off that might occur. During the first application on June 21, 2000, 4 ha around the lake edge were treated by subsurface injection using an airboat. The application rate was 1.5 mg/L active ingredient dipotasium salt of endothall (or 1.05 mg/L acid equivalent), using about 56 L/ha. This application rate is above the minimum of 0.5 mg/L active ingredient recommended to control Eurasian watermilfoil, but below that which controls many native species (Sprecher et al. 2002). The second treatment was a month later when another 4 ha were treated out from the shoreline toward the center of the lake using the same application rates, amounts and method.

Aquatic Plants

The aquatic plant community was assessed seven times for this study: before the herbicide treatment on June 13, 2000, ten weeks after initial treatment on August 24, 2000, at the beginning and end of the summer in 2001 and 2002, and in June 2003. Frequency data were collected on all sampling dates, and biomass data were collected on all dates except the end of summer 2001 and 2002 following Madsen (1999). In addition to the quantitative data, a composite species list and secchi depth data were collected on each sample date. Aquatic plants were identified according to Hitchcock and Cronquist (1973) and Hickman (1993).

Point-intercept Frequency. Plant samples were gathered systematically at points on a 30.5 m grid for the frequency data analysis. Point locations were located in the field with the aid of aerial photographs and maps overlaid with the sample grid.

A total of 660 frequency samples were collected on the seven sample dates: 91 in June 2000, 95 in August 2000, 95 in June 2001, 94 in September 2001, 95 in June 2002, 95 in August 2002 and 95 in June 2003. At each point, samples were gathered from the port side of the boat using a sampler consisting of two metal leaf rakes bolted back to back and weighted with a metal plate. The handles were removed and replaced with a 30 m marked rope. The rake was thrown approximately 5 m twice and drug along the substrate back to the boat. All recovered species and the depth of the sample were recorded.

Data were entered into a relational database and a Chi-square two-by-two analysis was performed on the species with greater than 50 occurrences for all sample dates combined. The probability was adjusted using a Bonferroni correction to account for multiple comparisons.

Biomass. During each biomass sampling event, data were gathered at randomly selected points located on the same grid used for the frequency data collection. Samples were collected at 30 points in June 2000, August 2000 and June 2001, 2002 and 27 points in 2003. The samples were collected with a metal garden rake attached to a long aluminum handle. The rake was lowered to the substrate and turned 360° to collect the plants within the circle scribed by the rake tongs. The rake was 0.38 m wide, and therefore sampled a 0.11 m^2 area. The sample was brought to the surface, rinsed with lake water, and placed into a plastic bag labeled with the sample location and depth. The samples were transported to the lab where they were sorted by species and placed into pre-weighed and numbered paper bags. They were dried in a forced air oven until they reached a constant weight. They were then weighed to 0.01 gram accuracy and the bag weight was subtracted to give the plant dry weight.

The data were entered into a relational database and the common species were analyzed for differences among the dates using one-way Analysis of Variance (ANOVA). We performed a $\log_{10}+1$ transformation on the data to approximate a normal distribution. The resultant p-values were adjusted using a Bonferroni correction to account for multiple comparisons. Post-hoc analysis determined which of the comparisons were significant.

RESULTS AND DISCUSSION

Aquatic Plant Community

A list of the submersed species from each sample date is provided in Table 1. The species varied from year to year, but overall a greater number of submersed taxa were present post-treatment. It is interesting to note that a number of species absent before treatment, particularly different pondweed (*Potamogeton* L) species, were detected in 2001 and 2002, but not in 2003. One species, water star-grass (*Heteranthera dubia* (Kacq) Macmill.), was identified before treatment but not during any of the sampling events after treatment. However, a recent concentration and exposure time study found that Aquathol® K had no impact on water star-grass at the concentration used in this study (Skogerboe and Getsinger 2001). So it is possible this plant disappeared from the lake for some reason other than a direct impact of the herbicide.

Point-Intercept Frequency and Biomass

A graph of the species percent frequency is presented in Figure 2 and significance levels for comparisons of June 2000 and June2001 with subsequent dates are in Table 2. Results from the biomass ANOVA are presented in Table 3, and a graph illustrating the changes over time is in Figure 3.

Both the frequency and biomass of the target plant, Eurasian watermilfoil, were significantly lower in all post treatment samples compared with the pretreatment sample (June 2000). However, its frequency increased significantly from its lowest level in June 2001 (present in 15% of samples) and all subsequent sample dates. This rebound stabilized and Eurasian watermilfoil maintained a frequency of 36-39% of samples through 2003, compared with a pretreatment frequency of 85%. Skogerboe and Getsinger (2002) found Eurasian watermilfoil to be very sensitive to endothall, and attained a 99% reduction in biomass even at the lowest treatment rates in their experiment (0.5 mg/L). In Kress Lake we saw a 99% reduction in Eurasian watermilfoil biomass the year of treatment. One year after treatment biomass was reduced by 69% and at 2 and 3 years after treatment the biomass declined again and was reduced by greater than 97% from pretreatment levels.

Large-leaf pondweed followed a pattern similar to the Eurasian watermilfoil, with a significant reduction in at least some post treatment biomass and frequency samples compared with pre-treatment levels. Sprecher et al. (1998) found sago pondweed (*Stuckenia pectinata* L. Börner) to be more sensitive to Aquathol® K than Eurasian watermilfoil and Skogerboe and Getsinger (2002 and 2001) found curly leaf pondweed (*Potamogeton crispus* L), Illinois pondweed (*P. illinoensis* Morong.) and American pondweed (*P. nodosus* Poiret) were susceptible to Aquathol® K at concentrations similar to that used in this study, so perhaps large-leaf pondweed is also susceptible. The Aquathol® K label suggests large-leaf pondweed is moderately susceptible, with control achieved at a concentration of 2 to 3 mg/L.

The frequency and/or biomass of three species increased significantly post-treatment. Muskgrass frequency was significantly higher in all post treatment samples compared with the pre-treatment sample. The muskgrass biomass was excluded from analysis because its sprawling growth form resulted in consistent over-sampling using the biomass sampling rake. Because muskgrass is an algae it is resistant to the dipotasium salt of endothall at the concentrations used. Common elodea frequency and biomass increased significantly starting the year after treatment (2001). Common elo-

TABLE 1. LIST OF SUBMERSED SPECIES FROM KRESS LAKE AND THE DATES WHEN THEY WERE FOUND.

Species	6/13/00	8/24/00	6/21/01	9/6/01	6/11/02	8/27/02	6/2/03
Bladderwort	√		√	√	√	√	√
Bur-reed (*Sparganium* sp. L)					√		√
Common elodea	√	√	√	√	√	√	√
Coontail (*Ceratophyllum demersum* L.)			√	√		√	√
Curly leaf pondweed			√	√			
Eel-grass pondweed (*Potamogeton zosteriformis* Fern.)			√				
Eurasian watermilfoil	√	√	√	√	√	√	√
Large-leaf pondweed	√		√	√	√	√	√
Muskgrass	√	√	√	√	√	√	√
Other pondweed species		√				√	
Stonewort (*Nitella* sp.)				√	√	√	√
Thin leaved pondweed (*Potamogeton* sp.)		√	√	√			
Water star-grass	√						
White water-buttercup (*Ranunculus aquatilis* L.)					√		

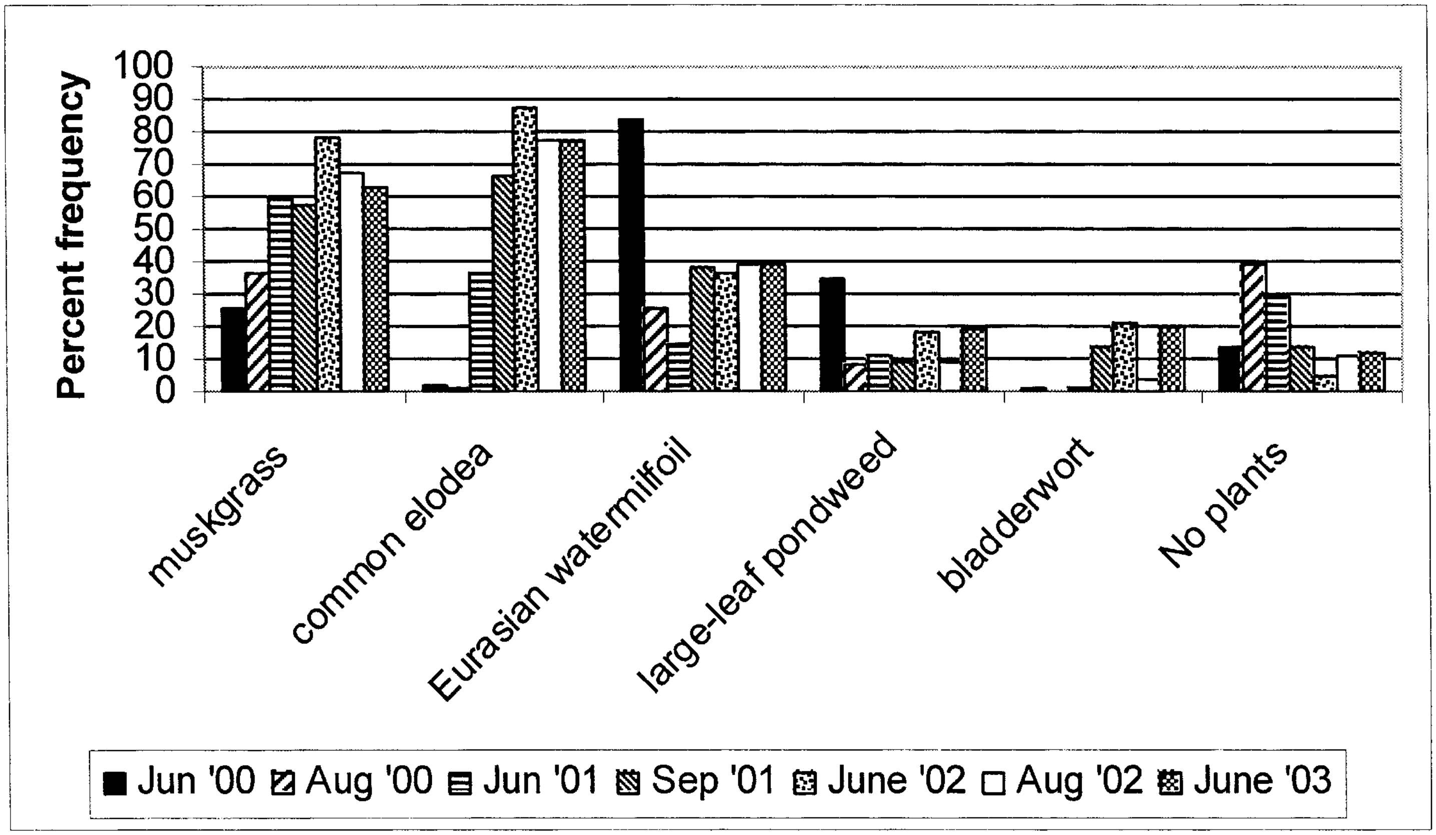

Figure 2. Frequency of occurrence for common plant species by sample date in Kress Lake, Washington.

dea is resistant to Aquathol® K and tends to thrive in disturbed conditions (Sprecher et al. 2002). Bladderwort frequency increased significantly in September 2001, June 2002 and June 2003 compared with pretreatment and 1 year post treatment frequency (June 2000 and June 2001). This would suggest that bladderwort is also resistant to low levels of endothall, and that conditions after treatment somehow favored this plant.

The frequency of samples where no plants were collected increased significantly 3 months after treatment and decreased significantly between June 2001 and the last three sample dates. This is likely due to increasing native plant growth gradually filling in the areas left bare of Eurasian watermilfoil immediately after the treatment.

The sum of biomass for all species combined (excluding muskgrass) was reduced substantially 10 weeks after treatment, and then recovered to close to pretreatment levels 1 and 2 years after treatment (Figure 3). Thus, although biomass of milfoil had declined, other species have increased such that the lake continued to support similar levels of plant growth. This pattern is similar to other studies on milfoil declines, where the native plant community will replace the declining Eurasian watermilfoil (Trebitz et al. 1993, Getsinger et al. 1997). It is not clear why the total biomass declined in 2003, as observations by field personnel did not indicate a distinct drop in plant cover. The spring of 2003 was unusually cool and cloudy, so perhaps the plants were behind in their annual growth compared with the other years.

TABLE 2. CHI-SQUARE ANALYSIS P-VALUE RESULTS OF THE FREQUENCY DATA COMPARISONS FOR SUBMERSED PLANTS IN KRESS LAKE, WA.

	June 2000 with						June 2001 with			
Species	Aug '00	June '01	Sep '01	June '02	Aug '02	June '03	Sep '01	June '02	Aug '02	June '03
Muskgrass	0.12	**0.000***	**0.000***	**0.000***	**0.000***	**0.000***	0.721	0.008	0.291	0.655
Common elodea	0.535	**0.000***	**0.000***	**0.000***	**0.000***	**0.000***	**0.000***	**0.000***	**0.000***	**0.000***
Eurasian watermilfoil	**0.000***	**0.000***	**0.000***	**0.000***	**0.000***	**0.000***	**0.000***	**0.001***	**0.000***	**0.000***
Large-leaf pondweed	**0.000***	**0.000***	**0.000***	0.008	**0.000***	0.013	0.637	0.146	0.809	0.102
Bladderwort	0.306	0.976	**0.001***	**0.000***	0.19	**0.000***	**0.001***	**0.000***	0.174	**0.000***
No plants	**0.000***	0.012	0.929	0.037	0.436	0.582	0.009	**0.000***	**0.001***	**0.002***

*Significant at $p \leq 0.005$.

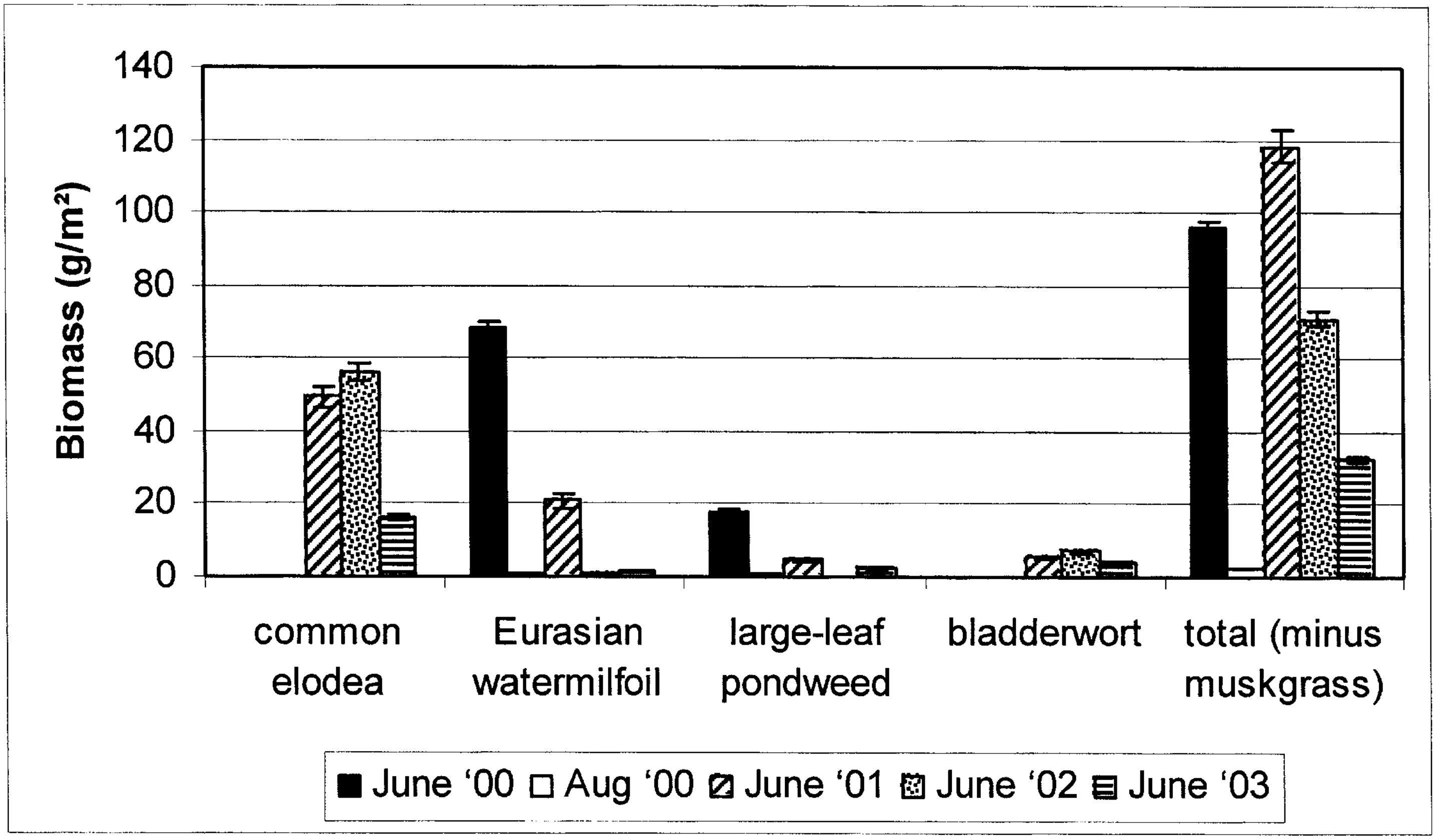

Figure 3. Mean biomass (g/m^2) of selected species and total plant biomass (g/m^2) for each sample date with standard error bars.

TABLE 3. MEAN BIOMASS (WITH STANDARD DEVIATION IN PARENTHESES) AND ANOVA RESULTS FROM COMMON SUBMERSED PLANT SPECIES IN KRESS LAKE, WA.

	Biomass (g/m^2)				
Species	June '00	Aug '00	June '01	June '02	June '03
Common elodea	0.03 (0.16)	0.01 (0.06)	**49.57 (143.14)***	**56.20 (104.38)***	**16.33 (23.27)***
Eurasian watermilfoil	68.58 (73.86)	**0.77 (1.98)***	**21.10 (100.92)***	**0.69 (2.72)***	**1.73 (3.70)***
Large-leaf pondweed	17.76 (46.72)	**0.77 (4.18)***	4.71 (25.79)	**0***	2.15 (7.94)
Bladderwort	0	0	5.34 (29.21)	7.13 (20.85)	3.68 (10.01)

*Significantly different from pretreatment biomass (June '00) at $P \leq .0125$.

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