Ecology of Flowering Rush (*Butomus* umbellatus) in Detroit Lakes Becker County, Minnesota

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Executive Summary

Flowering Rush, *Butomus umbellatus*, has been an increasing problem in the Detroit Lakes chain of lakes for more than 45 years. Flowering rush dominates ecosystems by crowding out native species including hardstem bulrush, *Schoenoplectus acutus*; a vital part of native ecosystems. Furthermore, flowering rush creates boating hazards and hampers recreational activities on the lakes. The phenological differences between the macrophyte species flowering rush and the native hardstem bulrush were examined as part of a project determining the best management practices for this invasive species. Biomass allocation, plant height and reproductive structures of flowering rush were examined in the Detroit Lakes system.

- Flowering rush and hardstem bulrush exhibited similar times of emergence, maximal growth and senescence. Hardstem bulrush was approximately one meter taller than flowering rush during mid-summer.
- Flowering rush continually produced rhizome buds as their primary mode of reproduction. Approximately one bud per every two grams of rhizome, or 400 buds per square meter were produced within the midst of a flowering rush bed.
- The number of leaves sprouting from rhizomes (ramets) was greatest in mid-summer in both 2010 and 2011.
- 50 – 100% of the biomass of flowering rush plants was found below ground.

Research is ongoing on the life history and carbohydrate allocation of this aquatic invasive, as well as possible treatment methods.

Introduction

Flowering Rush, *Butomus umbellatus* is an invasive species that originated in Europe. Flowering rush is a perennial monocot from the Butomaceae family. It is native to Eurasia and was first discovered in North America in 1905 in Quebec (Les and Mehrhoff 1999). Flowering rush appeared in the Detroit Lakes chain sometime in the 1960's, and has been gradually spreading throughout the chain. The asexually reproducing triploid form of flowering rush is the variety that is currently plaguing the Detroit Lakes area (Eckert et al. 2000). New vegetative growth can occur through primary rhizome fragmentation (Brown and Eckert 2005). The leaves of the plant are triangular in shape and vary in color from light to dark green. The leaves may be submersed or emergent. The typical habitat of flowering rush is less than 1m, however, flowering rush is known to grow in water deeper than 3 m (Hroudová 1989). Over the course of the current study flowering rush has been observed growing in over 3m. Little is known about the preferred habitat of the plant, especially in northern lakes or how those changes in habitat affect the growth pattern and spread of flowering rush. The relative allocation of biomass to emergent and submersed leaves as well as to below ground material could impact its ability to spread, to compete with native vegetation and to withstand environmental fluctuations.

In the changing environment caused by global warming, invasive species may be more of a problem in upcoming years. Changes in global climate along with the growing human population will exacerbate existing severe stresses to freshwater resources (Shimoda et al. 2011). If invasive plants are able to outcompete native species then it will be difficult for the native species to survive. With increasing CO_2 levels and a change a rising global temperature, it is apparent that Global warming will have a major effect on our future environment (Peterson 2011). Global warming and other climatic changes will affect the growth, phenology and geographical distribution of macrophytes. It is not clear whether climate change or invasive competitiveness (Wolkovich 2011) will be more influential in the success of the native species. Climate change may impact the annual interactions of the native and the invasive species. Phenological differences between exotic and native species may contribute to the success of the invaders (Wolkovich 2011).

Phenological studies have assisted in coming up with treatment solutions for many other aquatic invasive plants including alligatorweed (Weldon and Blackburn 1968), curlyleaf pondweed (Woolf and Madsen 2003), Eurasian watermilfoil (Madsen 1997), hydrilla (Madsen and Owens 1998), waterhyacinth (Madsen et al. 1993), and waterchestnut (Madsen 1993b). It is not applicable to abruptly eradicate an invasive species because it may be detrimental to the animal communities. In this study the phenology of flowering rush was compared to that of the native hardstem bulrush, *Schoenoplectus acutus*. A phenological study also took place to determine the life history of flowering rush, especially in the northern region because little is known about its impact on native species in this region.

Methods

Plot information
Sampling started in May 2010, and was conducted through September 2012. Four phenology plots were chose before the sampling began on the Detroit Lakes Chain; phenology plots are located on Little Detroit, Big Detroit, Lake Sallie and Curfman Lake. There are also nine treatment plots that are spread across Little Detroit, Curfman, and Big Detroit in 2010 and four treatment plots on Big Detroit in 2011. The treatment study is reported on elsewhere. Thirty samples were taken at each phenology plot during every sampling period which occurred every three weeks during the summer and three times over the winter of 2010. Non-destructive sampling took place on the phenology plots and on four hardstem bulrush plots located on Little Detroit, Lake Sallie, Lake Melissa and Curfman Lake (fig. 1).

Non-destructive Sampling Method
Both flowering rush and hardstem bulrush sampling was done using a non-destructive method. Twenty plants from each bulrush plot were measured for their leaf emergence out of the water and water depth was recorded. This process was repeated for the flowering rush plots. Thirty flowering rush plants were measured for their emergence out of the water and water depth was recorded as well once the coring was completed.

Destructive Sampling Method
Biomass sampling was done using a 6" coring device constructed of PVC pipe and/or metal pipe to suction plant mass up from the ground (Madsen et al. 1997). Plants were washed in the field, and more thoroughly back at the lab. The majority of samples were collected in the dense part of the flowering rush beds at a depth of 1-2 m. Plants were separated into above- and below-ground biomass. For each sample collected, rhizome buds, shoots, and ramets were counted and recorded. A flowering rush ramet is a single section of leaves growing from a rhizome bud. There may be several ramets per rhizome. A wet weight was then taken for above-and below-ground masses for each sample. Above-ground biomass was dried in a forced air oven (60 °C) or lyophilized. Dry weights were then recorded and the samples were ground into a fine powder to using a blender and Wiley mill, mesh #60, for carbohydrate analysis.

Carbohydrate Analysis Method
Soluble sugar standards were made using with glucose. Starch standards were made using potato starch and glucose. A double extraction was done on both starch and carbohydrate samples using a methanol, chloroform, formic acid extraction solution as seen in (Gent 1984, 1986). Colormetric analysis of the sugars was done using potassium ferricyanide in a sodium phosphate solution. The starch analysis was started using a solution of ethanol and acetate buffer, Samples were then allowed to aspirate, were boiled, and a starch digestion enzyme was added. Overnight incubation followed by dilution prepared samples for finding the absorbance at 422 nm using the potassium ferricyanide solution.

Water Quality Parameters
Water quality measurements, dissolved oxygen, temperature, pH, conductivity, depth, and turbidity, were collected within each plot and at a deep site elsewhere in the lake with a water

profiler (Hydrolab MS5, Loveland, CO). Due to a connection malfunction, water quality parameters were not available for every sampling period.

Point Intercept Survey Methods
A point intercept survey was conducted on all five lakes that are involved in the study to determine plant composition in this chain of lakes. The lake was divided into a grid with a point assigned to the middle of each grid square, at each square a rake was thrown and the plants collected there were recorded. Results are reported in Madsen et al. 2012 (fig. 2).

Depth Allocation Survey
A flowering rush depth allocation survey was taken to determine if there was an optimum

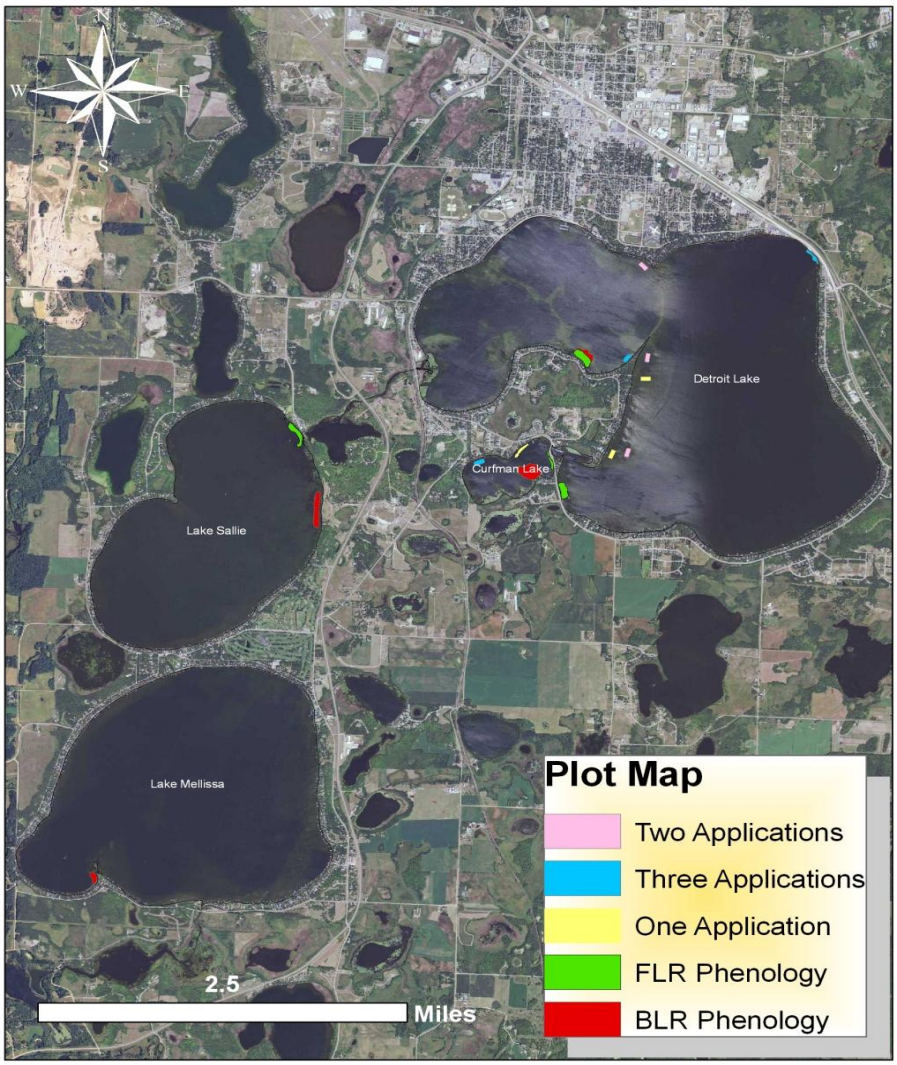

Figure 1: Detroit Lakes Chain plot map

growing depth for the plant. Ten transects were chosen throughout Curfman and Big Detroit. Each transect started at one foot ran out to ten feet and three cores were pulled at every foot depth increment if flowering rush was present.

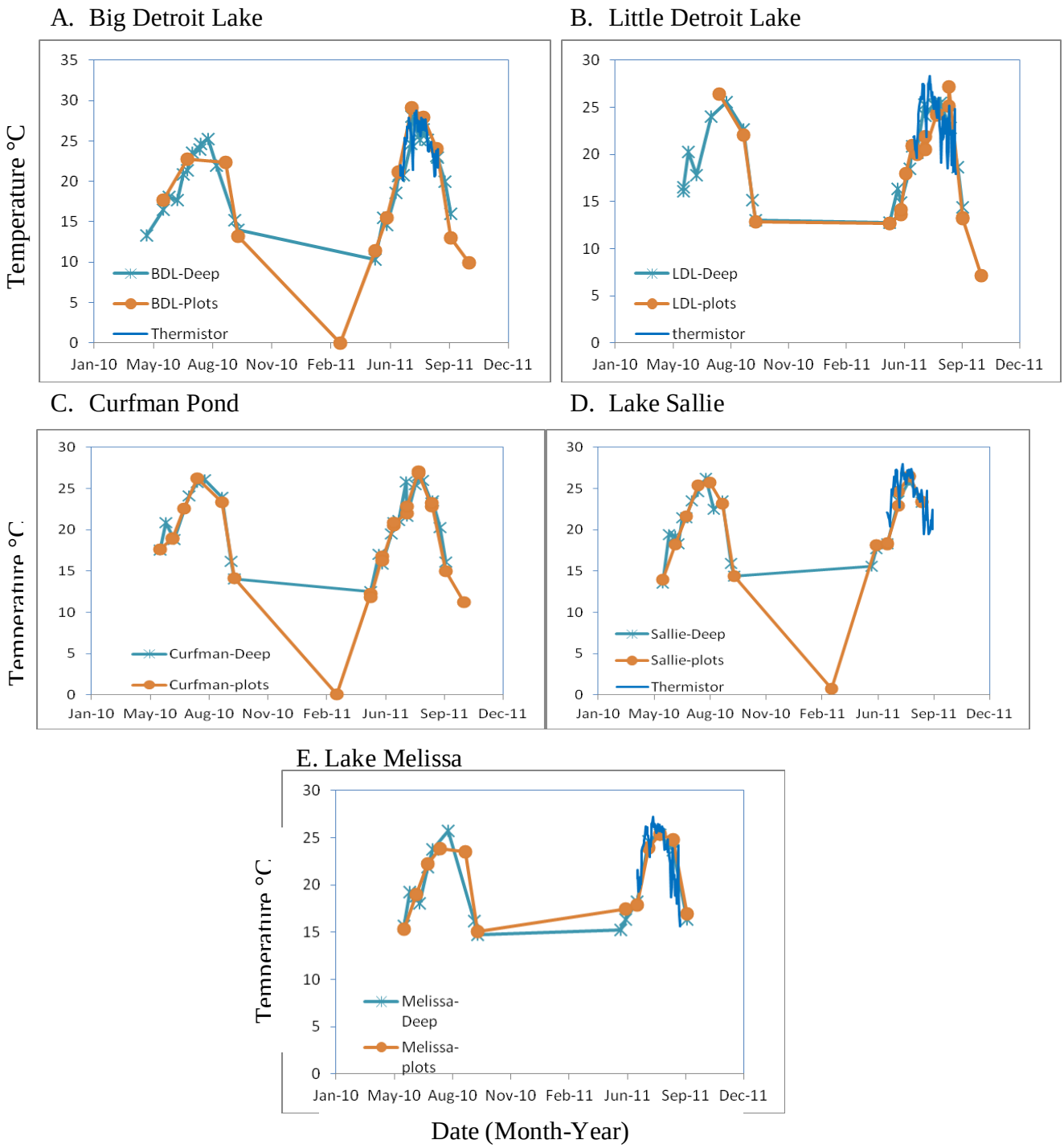

Figure 2. Surface temperature of A. Big Detroit, B. Little Detroit, C. Curfman Pond, D. Lake Sallie, and E. Lake Melissa over 2010 and 2011. Temperatures were taken in Hardstem Bulrush and Flowering Rush (plots) and in a nearby deep site within the lake. Thermistor temperatures were taken at a nearby dock.

Water Quality Parameters
Water quality parameters were taken over the course of 2010 and 2011 using a Hydrolab MS5 with Depth, Temperature, Conductivity, pH, Turbidity and LDO sensors (Hach, Inc., Loveland, Co). Thermistors were placed in Big Detroit Lake, Little Detroit Lake, Curfman Pond, Lake Melissa, Lake Sallie at docks located nearby the plot sites. One thermistor was lost from Curfman Pond. Additional water quality data was obtained from the Pelican River Watershed District. All sampling sites remained above 80% oxygen saturation except for sampling in March of 2011, where the Oxygen content was at approximately 55% below the ice. Data are summarized by site for surface temperatures (Figure 2).

Results and Discussion

Hardstem bulrush and flowering rush emerged at the same time (Figure 3). Hardstem bulrush was approximately one meter taller than flowering rush. Throughout the season hardstem bulrush had a significantly higher percentage of leaf emergence. (logistic regression: date $p<0.0001$; species $p<0.0001$). Both species began senescence at the same time, however, flowering rush fell below the water surface up to one month before hardstem bulrush (figure 4). Plant height above or below the water surface was significantly different by species, date and their interaction term (species by date: $F=62.08$, df=3, $P=0.0001$). There was a lower percentage of flowering rush emergent compared to hardstem bulrush in 2010. In 2011, more than 95% of both species were emergent (Figure 4).

Emergence and senescence above water surface occurred over very short time frame in early summer. Hardstem bulrush was approximately 1m taller than Flowering rush (fig 8). Plant height above or below the water surface was significantly different by species, date and their interaction term (species by date: $F=62.08$, df=3, $P=0.0001$). Rhizome bud production was found to be consistent throughout the year at each site (fig. 9). Date and site were not found to be significant at each site (date: df=17, $F=2.65$, $P=0.0041$ site: df=3, $F=0.46$, $P>0.01$). One bud per two grams of below ground biomass was the average amount of buds found throughout the sampling season.There were peaks in Little Detroit Lakes and Lake Sallie in summer, but they were only noticed in 2011 (fig. 9).

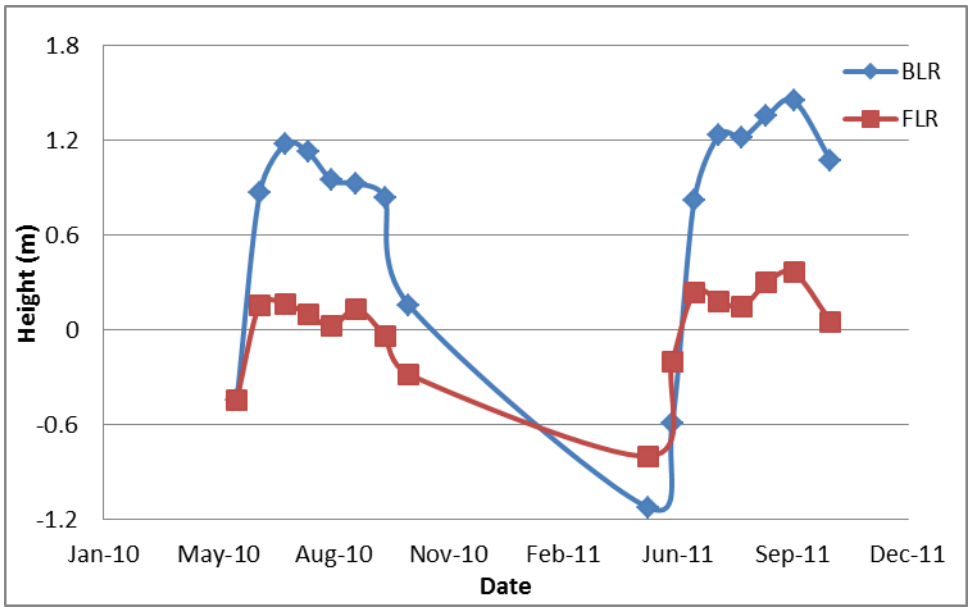

Figure 3: Mean of the difference in the height above water between flowering rush and hardstem bulrush.

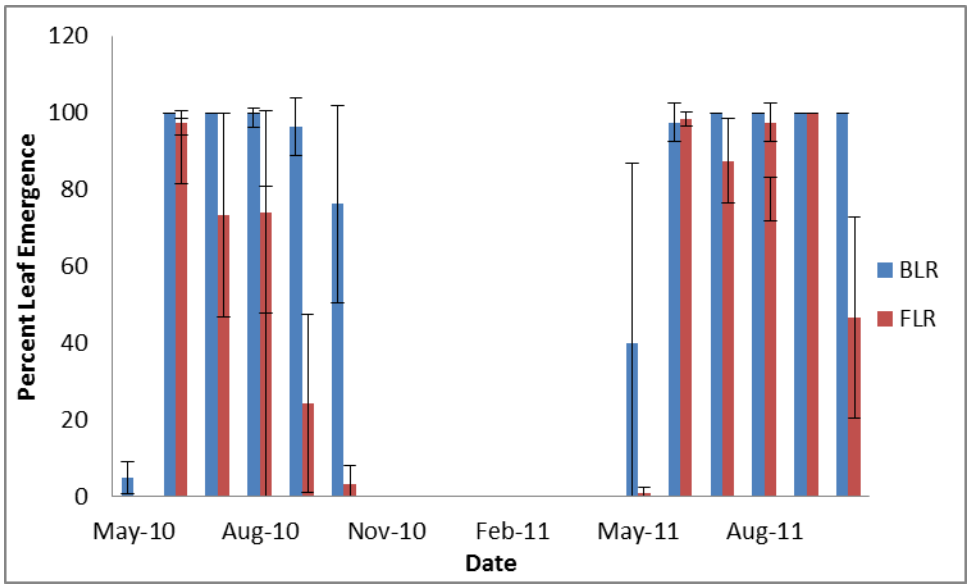

Figure 4: Percentage of leaves emergent above water level for hardstem bulrush and flowering rush in 2010 and 2011.

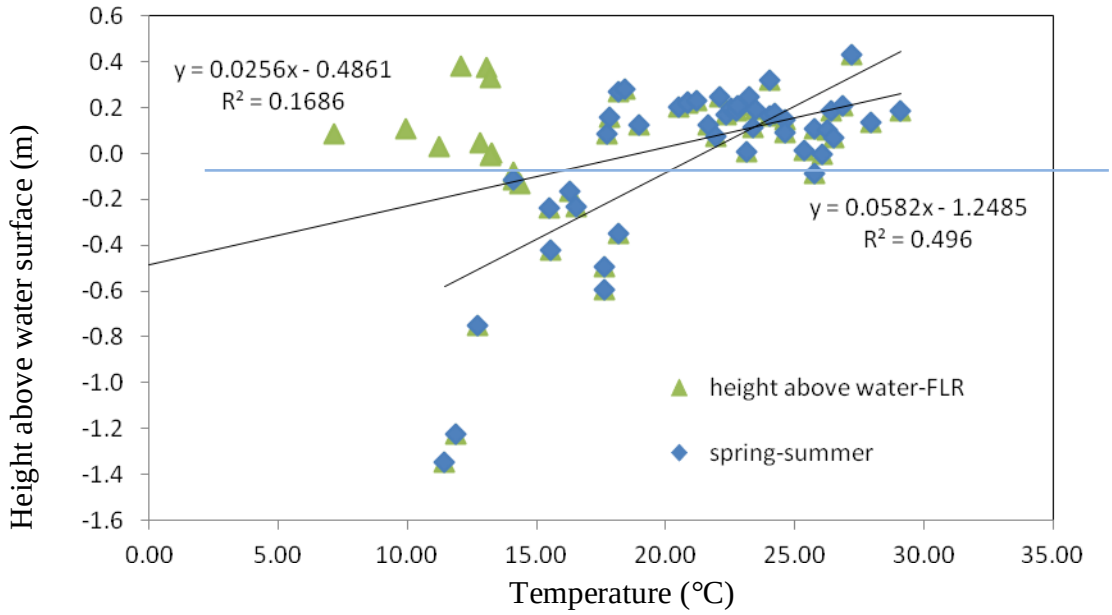

Figure 5. Regression of flowering rush plant height above the water and water temperature. Plants typically were not above the water surface until 14 °C. The green dots represent data from the fall. Regression lines for all data (green dots) and only the spring and summer data (blue dots) are presented.

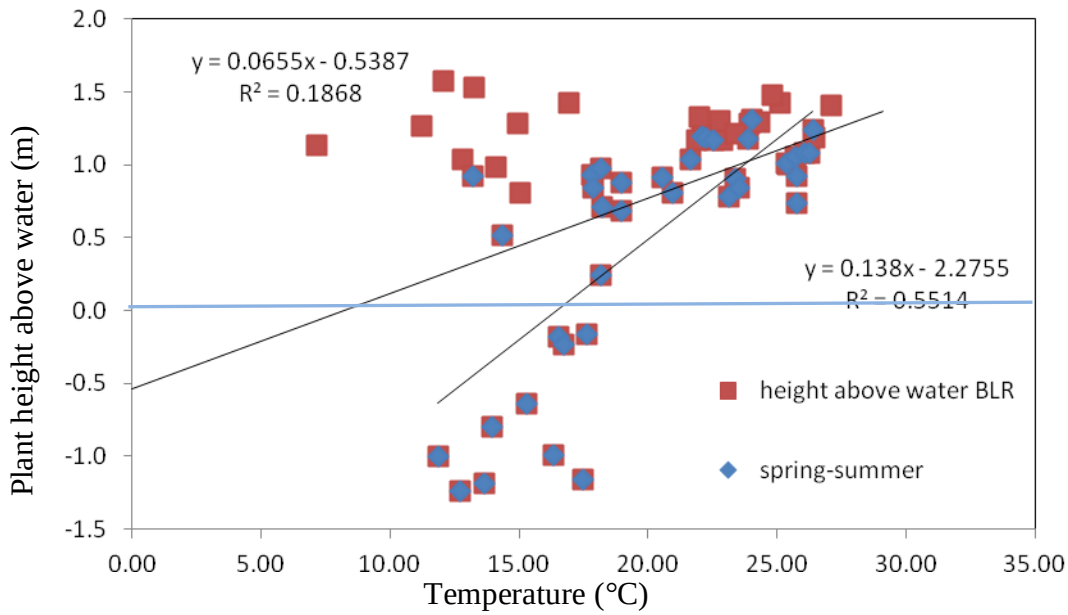

Figure 6. Regression of hardstem bulrush plant height above the water and water temperature. Plants typically were not above the water surface until 12 °C. The red dots represent data from the fall. Regression lines for all data (red dots) and only the spring and summer data (blue dots) are presented.

Height of flowering rush and hardstem bulrush above the water surface was positively correlated with water temperature (Flowering Rush: F=11.6, p-0.0012; Hardstem bulrush: F=12.8, p-0.0007) (Figures 5 and 6). Plants remained emergent into the fall even when water temperatures cool. Plant height was more strongly associated with water temperature when fall data were removed (Flowering rush: F=44.3, P<0.0001; Hardstem Bulrush: F=43.0, P<0.0001). Hardstem emerges from water at 12 °C, whereas flowering rush emerges when the water temperature reaches 14 °C. This observation was true for 2010 and 2011, however, much more extensive study is needed before this trend could be considered a rule by which to manage the plants.

In order to present the variation that was observed due to regional differences, data are presented by site. Rhizome bud production was found to be consistent throughout the year at each site (Figure 7). Date and site were not found to be significant as at each site (date: df=17, F=2.65, P=0.0041 site: df=3, F=0.46, P>0.01). One bud per two grams of below ground biomass was the average number of buds found throughout the sampling season, or over 400 buds were produced per square meter. Total bud number was significantly different by date and site (df=17; date F=25.33, p<0.0001; site: df=3, F=9.56, p<0.0001). Peak bud production was observed during the summer in Little Detroit Lake and Lake Sallie in 2011 (Figures 7 and 8). It is unclear when most buds drop off of the rhizome, although the greatest number of ramets observed was during mid-summer (df=17; date F=10.0, p<0.0001; site: df=3, F=30.15, p<0.0001) (Figure 9). Likely, this corresponds to the most buds becoming independent shoots.

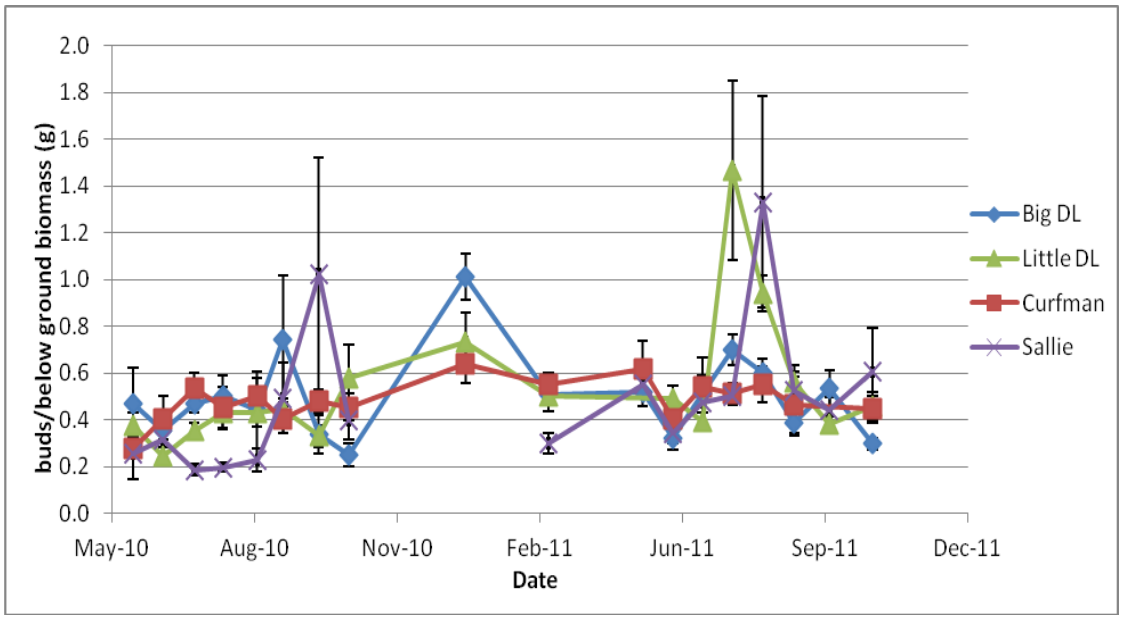

Figure 7: Mean number of rhizome buds (mean ± 1 standard error) produced per gram of belowground biomass.

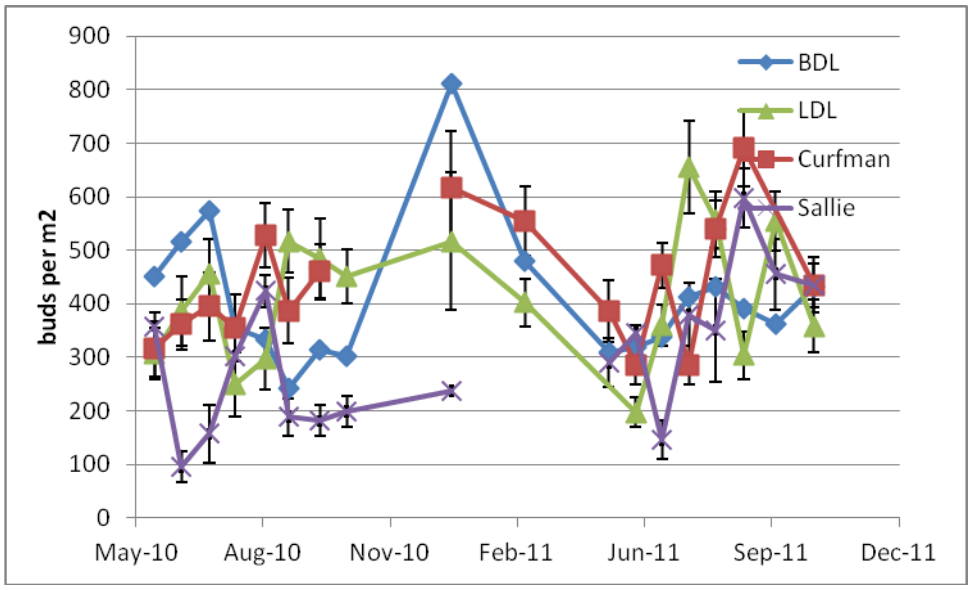

Figure 8. Mean number of buds (mean ± 1 standard error) produced in 2010 and 2011 per square meter in Big Detroit Lake, Little Detroit Lake, Curfman Pond and Lake Sallie. The majority of samples are from depths of 1-2 meters.

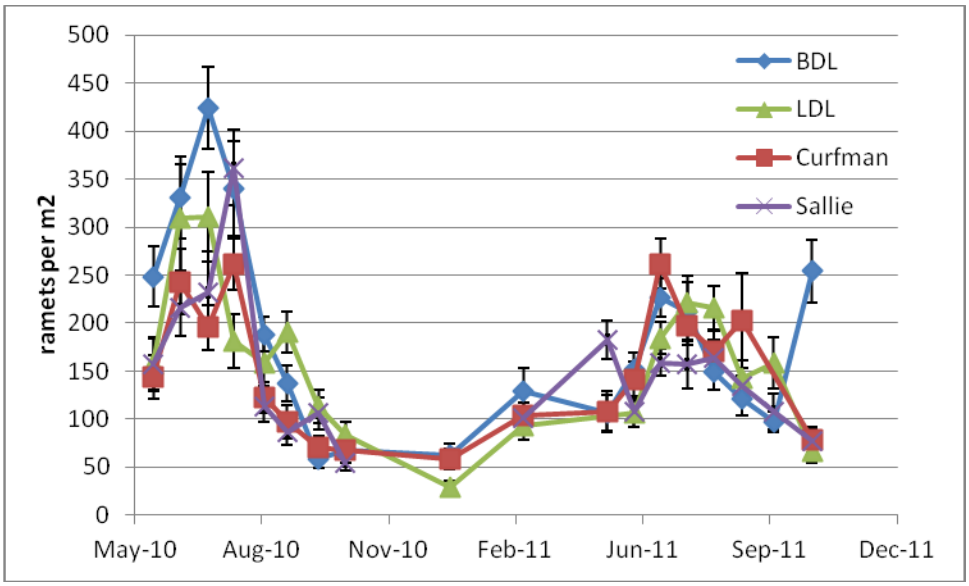

Figure 9. Mean number of ramets (mean ± 1 standard error) per square meter for 2010 and 2011 sampling in Big Detroit Lake, Little Detroit Lake, Curfman Pond, and Lake Sallie. Peak ramet production was apparent in mid-summer of both years.

Some significant differences were observed with dry above ground biomass by date and site (date: df=17, F=67.0, P<0.0001; site: df=3, F=3.45 P=0.016). As expected, above ground biomass was highest over the summer and absent over winter collections (Figure 10). Dry below ground biomass was found to be largely consistent throughout the year (Figure 11). However, significant differences were found by lake and date (date: df=17, F=8.46, P<0.0001; site: df=3, F=24.25P<0.0001). In particular, the below ground biomass of Curfman Lake was consistently greater than the other lakes. (fig. 11). About 80% of the total biomass was found to be below ground, which varied by season (Figure 12).

Biomass of above ground material leaves increased as the temperature increased (F=13.7, P=0.0005), but there was no relationship between below ground biomass and temperature (P>0.1) (Figure 13). The positive relationship between temperature and leaves reflects the growth that occurred during the summer. The absence of a relationship between temperature and below-ground biomass reflects the continually high biomass present in rhizomes that alters little with seasonal changes. An analysis of spring - summer data, and summer fall data, still showed no relationship (Figure 13).

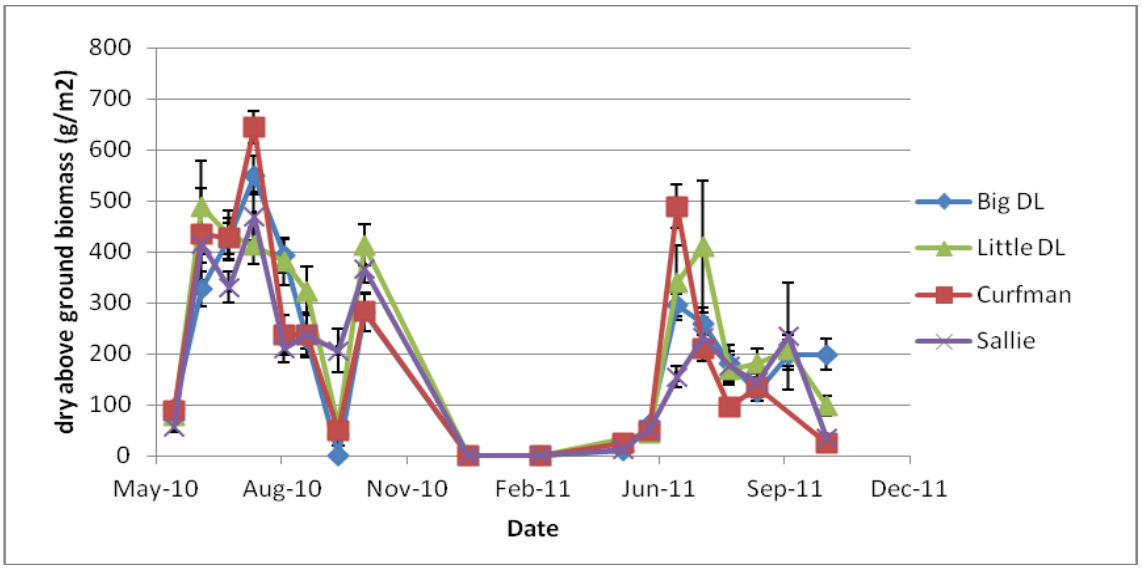

***Figure 10*:** Mean (± 1 standard error) of Flowering rush aboveground biomass per square meter (gm^{-2}) of lake bottom.

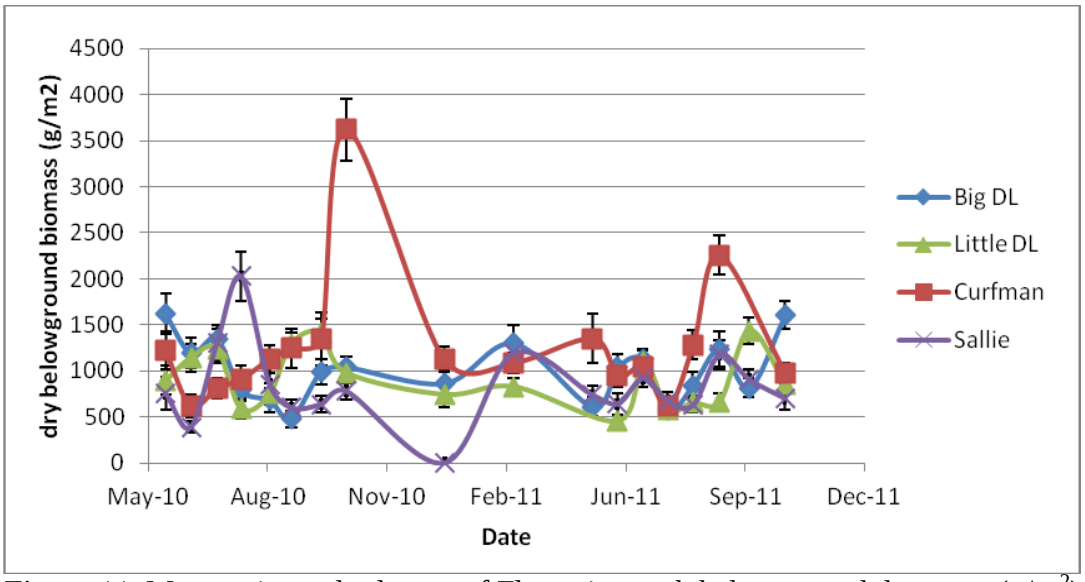

Figure 11: Mean ± 1 standard error of Flowering rush belowground dry mass (g/m^2).

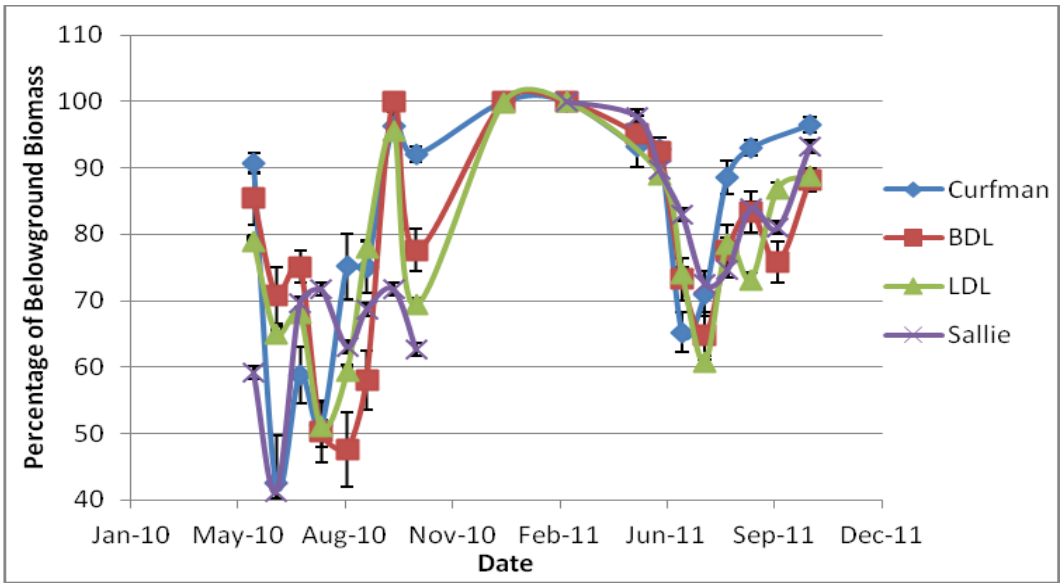

Figure 12: Mean percent ± 1 standard error of belowground biomass compared to total biomass.

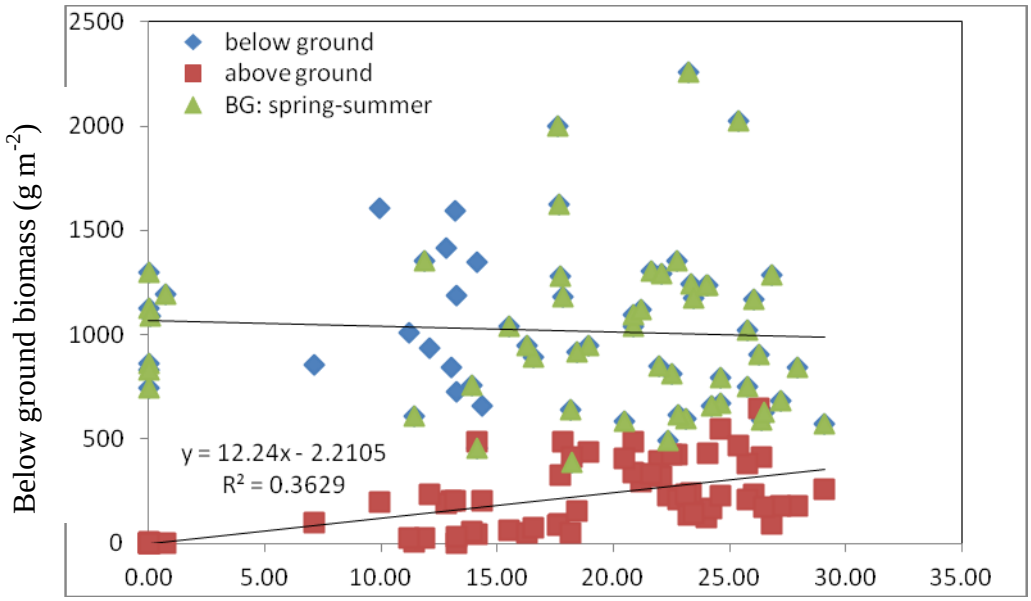

Figure 13. Regressions of above (red squares) and below-ground (blue and green dots) biomasses (grams per square meter). Above ground biomass increased linearly with water temperature, but below-ground biomass was affected very little by water temperature. Separate analysis of spring and summer below ground biomass (green dots), excluding fall (blue squares) below ground biomass, still showed no relationship to water temperature.

Carbohydrates

Starch content was significantly different by date and plant part (date: df= 19, F= 3.07, p=0.0023; part: df=1, F=14.69, p=0.0005). Below ground rhizomes had significantly more starch than above ground leaves. Some differences were observed by date, however no trends appear in this preliminary analysis. Glucose content did not differ by date or plant part. These are preliminary results. Further analyses will be performed when chemical analyses are completed.

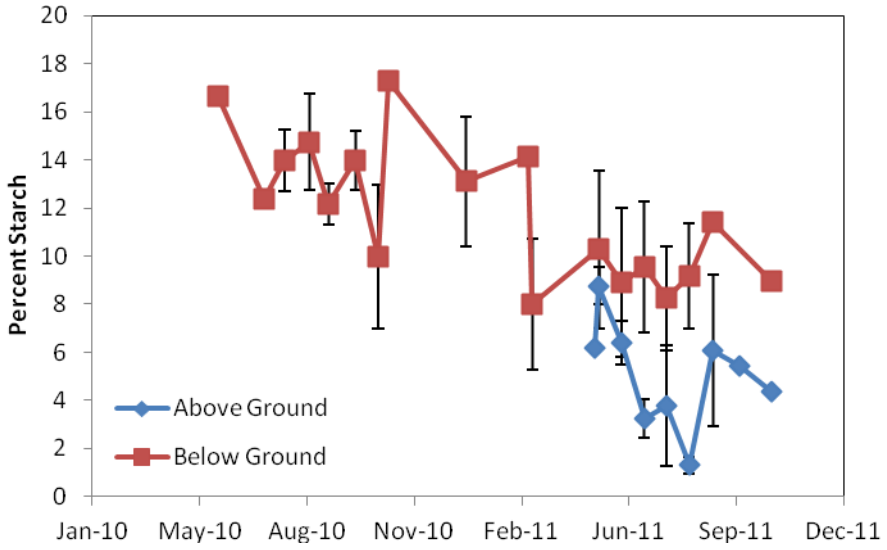

*Figure 14. Percent starch content (*mean ± 1 standard error) *in above ground and below ground plant material.*

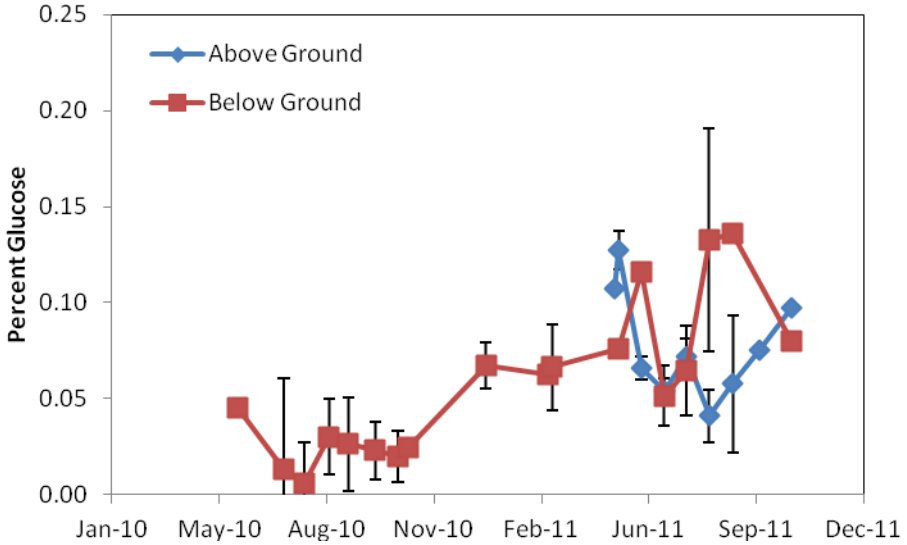

Figure 15. Percent glucose content (mean ± 1 standard error) in above ground and below ground plant material.

Conclusions

Flowering rush is well established in the Detroit Lakes Chain of Lakes in dense beds. These beds are characterized by dense mats of flowering rush rhizomes that may consist of more than 800 grams per m^2. For every 2 grams of rhizome, approximately 1 bud is produced. These buds have the potential of becoming a new plant. More work is needed to determine when rhizome buds become separate plants, however, the number of ramets is likely an indication of new plants. Ramets number is greatest in mid-summer. Therefore, we would expect an increase in new plants by mid-summer each year. Control options should seek to prevent the establishment of new plants. Notably, buds are abundant throughout the year, even below the ice, indicating a ready supply of new propagules each year. Further research is needed to determine which control options most successfully minimize the production of buds as buds are always being produced.

One possible indicator of flowering rush growth is water temperature. We found water temperatures were indicative of plant growth for both hardstem bulrush and flowering rush, with hardstem bulrush emerging when temperatures reached approximately 12 °C and flowering rush emerging from the water surface when temperatures were approximately 14 °C. Unfortunately this is a very short window of time in the spring and daily observations of plant height are needed to determine exactly when flowering rush and hardstem bulrush in the spring. Further analysis of degree days may provide some more insight regarding the different phenologies of these two species.

We avoided destructive sampling of hardstem bulrush in order to prevent damage to this valuable ecological resource. However, a sampling regime of hardstem bulrush that includes a minimum of destructive sampling of hardstem bulrush may provide for some better comparisons regarding above and below ground biomass allocation and may provide more information regarding when hardstem bulrush is most susceptible to herbicide treatments.

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