Influences of light intensity variations on growth characteristics of parrotfeather (*Myriophyllum acquaticum* (Vell.) Verdc.)

Ryan M. Wersal and John D. Madsen
GeoResources Institute, Mississippi State University
rwersal@gri.msstate.edu

Parrotfeather (*Myriophyllum aquaticum* (Vell.) Verdc) is a nonnative aquatic heterophyllous plant. Having both a submersed and emergent growth form may allow *M. aquaticum* to invade and colonize highly disturbed or less than optimal environments through changes in growth habit. The reallocation of resources to emergent or submersed growth likely allows *M. aquaticum* to overcome changes in light availability. Currently, little is known regarding the ecological and biological responses of *M. aquaticum* to perturbations in environmental factors. The objective of this study was to quantify *M. aquaticum* growth under different shading regimes. We hypothesized that *M. aquaticum* growth would increase as shading levels increased to a maximum of 70% of full sun light. The study was conducted using potted *M. aquaticum* plants growing in 24, 1100-liter tanks. Light treatments consisted of full sun, 30% shade, 50% shade, and 70% shade achieved using shade cloth with each treatment replicated six times. Biomass was harvested in two-week intervals for 12 weeks. Two pots from each tank were collected and both the roots and shoots of *M. aquaticum* were harvested. Measurements were taken of total plant length, emergent shoot length, submersed shoot length, and the total of number of emergent and submersed shoots were recorded. Plants were sorted to emergent shoots, submersed shoots, roots, stolons, and dried at 70 °C to a constant mass then weighed. *Myriophyllum aquaticum* biomass was significantly different ($F = 18.1$, d.f. = 47, $p < 0.01$) at the conclusion of 12 weeks between shade treatments. Differences in biomass were a result of greater emergent shoot growth in the 50% shade treatment and a reduction in the 70% shade treatment. Total plant length was also significantly different ($F = 7.44$, d.f. = 95, $p = 0.02$). The greatest plant length was observed in the 50% shade treatment with reductions in overall plant length observed in full sunlight. Both emergent and submersed shoot lengths were greatest in the 70% shade treatments. The total number of emergent and submersed shoots was not different between shade treatments. Our data suggests that intermediate light availability may be optimal for *M. aquaticum* growth.

Keywords: Invasive Species, Ecology, Water Use, Wetlands

Introduction

Parrotfeather (Myriophyllum aquaticum (Vellozo) Verdecourt) is a non-native invasive aquatic plant from South America. Populations of parrotfeather can impede stream flow and run off resulting in increased flood duration and intensity (Timmons and Klingman 1958). In South Africa, parrotfeather infests all of the major river systems where it poses a direct threat to the country's water supply (Jacot-Guillarmod 1977). Parrotfeather provides mosquito larvae a refuge from predation, which may ultimately lead to increases in diseases that can be transmitted to humans (Orr and Resh 1989). Plants are easily cultivated and transported often leading to new infestations. The aquaria landscaping trade is an avenue where plants are easily purchased and shipped throughout the world (Sutton 1985). Aiken (1981) reported observations of aquarium plant providers in the San Francisco Bay area placing parrotfeather into local waterways to have a convenient source of saleable material.

Parrotfeather is heterophyllous, meaning the plant has two distinct leaf forms that grow together on the same plant. Emergent leaves are feather-like and grayish green, stiff, and grow in whorls around the emergent shoot (Godfrey and Wooten 1981). Submersed leaves are typically orange to red and also grow in whorls around submersed shoots (Mason 1957). The emergent and submersed leaf forms can occur simultaneously on the same plant, or parrotfeather can persist as one growth form or the other converting when the environment changes. The light saturation point of emergent leaves is thought to approach full sunlight where as the light saturation point of the submersed leaves is between 250-300 μ-Em-2 s-1 indicating that photosynthesis of submersed plants is adapted to a shade environment (Salvucci and Bowes 1982).

Little is known of the ecology of parrotfeather as the majority of previous studies have focused strictly on management. Having both an emergent and submersed growth form may allow parrotfeather to invade and colonize highly disturbed or less than optimal environments through changes in growth habit. The reallocation of resources to emergent or submersed growth likely allows parrotfeather to overcome changes in light availability. Understanding of the environmental constraints posed by light intensities will indicate what environments parrotfeather can colonize and exploit to establish new infestations. These areas can be targeted for more aggressive monitoring to identify infestations at their onset before plants become firmly established. Our objective was to determine the effects of light intensity on growth characteristics of parrotfeather and to identify the light intensity at which growth was reduced.

Materials and Methods

Studies were conducted from May to August in 2006 and 2007 for 12 weeks at the R.R. Foil Plant Science Research Center at Mississippi State University. Twenty-four 1100 liter tanks were filled with water to a depth of approximately 50 cm. A total of 336 pots were planted and divided evenly so each tank contained 12 pots. Two parrotfeather shoots approximately 20 cm in length were planted into 3.78 liter plastic pots filled with a mixture of sand, silt, and top soil. Each pot was amended with Osmocote fertilizer (19-6-12) at rate of 2 g L-1 pot-1. Light intensity manipulations consisted of full sun, 30% shade, 50% shade, and 70% shade which was achieved using shade cloth. Each treatment was replicated in six tanks.

Parrotfeather mass was harvested in 2 week intervals for 12 weeks, however only the final harvest data are reported in this paper. Harvesting consisted of removing two pots from each tank and collecting both the roots and shoots of parrotfeather plants. Measurements of total plant length, emergent shoot length, and submersed shoot length were recorded. Additionally, the total number of emergent shoots and submersed shoots were recorded. Plants were then divided into emergent shoots, submersed shoots, stolons, and roots. Plant parts were dried at 70 C to a constant mass and then weighed to obtain the dry mass of parrotfeather. A mixed procedures ANOVA model using year as a random effect was developed using SAS (Littell et al. 1996) to assess differences in parrotfeather growth between treatments in 2006 and 2007. Treatment differences were separated using the Least Squares Means method.

Results and Discussion

At the conclusion of 12 weeks, parrotfeather mass was different ($p < 0.01$) between shade treatments (Figure 1). Differences in plant mass were a result of greater plant growth in the 30% and 50% shade treatment. Plants grown in full sun light had approximately a 30 g reduction in total plant mass. The increases in plant mass observed in the intermediate light levels may be partially explained by the fact that total plant length was also greatest ($p < 0.01$) in the 50% shade treatment with a reduction in plant length observed in full sunlight (Figure 2). However, the total plant length of plants grown in 30% and 70% shade were also greater than plants grown in full sun. When individual plants were divided it was found that emergent shoot length was reduced ($p < 0.01$) in full sun light with increased shoot elongation occurring when shade was provided (Figure 3). Submersed shoot length increased ($p < 0.01$) only when plants were grown in the 70% shade treatment. Although there were differences observed in overall plant mass and plant length, there were no differences in emergent shoot number ($p = 0.87$) or submersed shoot number ($p = 0.96$); indicating that plants were growing larger instead of producing more shoots in response to varying light intensities. Similar results were reported for Eurasian watermilfoil (Myriophyllum spicatum L.), hydrilla (Hydrilla verticillata Royle), and egeria (Egeria densa Planch.) submersed aquatic plants where shoot length increased with increasing levels of shade (Barko and Smart 1981). In low light environments, these submersed species reallocated energy to the development of a canopy through shoot elongation and an increase in upper branches and leaf whorls (Barko and Smart 1981). The anatomical and morphological differences in the emergent and submersed form of parrotfeather likely result from physiological adaptations to conditions in their respective environments (Sculthorpe 1967, Salvucci and Bowes 1982).

Parrotfeather has a light saturation point that approaches full sunlight (Salvucci and Bowes 1982). However, based on our data of reduced mass and shoot length, increases in light may not be optimal for this species. Increased light availability is often correlated to increases in temperature which may have resulted in water stress of parrotfeather in this study where transpiration from emergent shoots exceeded water uptake. However, in laboratory studies Sytsma and Anderson (1993) concluded that water loss due to transpiration was only 15 ml d-1 and biomass was produced with and economy of water use similar to C4 terrestrial plants. Parrotfeather, however, is a C3 plant (Salvucci and Bowes 1982) therefore photorespiration may have decreased as temperatures increased resulting in greater energy use in full sun light and an overall reduction in plant growth. Parrotfeather photorespiration ranges from high to very low depending upon the environment in which it is growing (Salvucci and Bowes 1982). Aquatic habitats that subject plants to reduced CO_2 availability, high O_2, light, and temperature may enhance CO_2 loss via photorespiration and adversely impact plant growth (Van et al. 1976).

Our results indicate that optimal growth of parrotfeather occurs in intermediate light intensities, although it can thrive in full sun light or survive in low light conditions primarily by submersed shoots. Adaptations that allow a species to optimize its capture and use of light are important determinants for success, especially in low light environments (Barko et al. 1986). Both plant morphology and specific leaf morphology are responsive to light regimes, in general producing fewer, longer shoots and leaves under reduced light conditions (Barko and Smart 1981, Barko et al. 1982). Species such as parrotfeather that are capable of elongating to the water surface and forming a canopy may have a competitive advantage over other species (Haller and Sutton 1975, Barko and Smart 1981).

Acknowledgements
We would like to thank the United States Geological Survey, Aquatic Ecosystem Restoration Foundation, and the Aquatic Plant Management Society for funding this project. We thank Dr. Patrick Gerard for assistance in developing the statistical model used for data analysis. We also thank Jimmy Peeples, Matt Gower, Waldemar Robles, Wilfredo Robles, and Joshua Cheshier for assisting during the study set up and countless hours of counting parrotfeather stems.

Literature Cited

Aiken, S. G. 1981. A conspectus of Myriophyllum (Haloragaceae) in North America. Brittonia 33: 57-69.

Barko, J. W. and R. M. Smart. 1981. Comparative influences of light and temperature on the growth and metabolism of selected submersed freshwater macrophytes. Ecological Monographs 51:219-235.

Barko, J. W., D. G. Hardin, and M. S. Mathews. 1982. Growth and morphology of submersed freshwater macrophytes in relation to light and temperature. Canadian Journal of Botany 60:877-887.

Barko, J. W., M. S. Adams, and N. L. Clesceri. 1986. Enviromental factors and their consideration in the management of submersed aquatic vegetation: A review. Journal of Aquatic Plant Management 24:1-10.

Godfrey, R. K and J. W. Wooten. 1979. Aquatic and Wetland Plants of Southeastern United States: Dicotyledons. University of Georgia Press, Athens, GA.

Haller, W. T. and D. L. Sutton. 1975. Community structure and completion between Hydrilla and Vallisneria. Hyacinth Control Journal 13:48-50.

Jacot-Guillarmod, A. 1977. Some water weeds of the Eastern Cape Province. II. Myriophyllum. Eastern Cape Naturalist 61:14-17.

Littell, R. C., G. A. Milliken, W. W. Stroup, and R. D. Wolfinger. 1996. SAS® System for Mixed Models. SAS Institute Inc., Cary, NC, USA.

Mason, H. L. 1957. A Flora of the Marshes of California. Universtiy of California Press, Berkeley, CA.

Orr, B. K. and V. H. Resh. 1989. Experimental test of the influence of aquatic macrophyte cover on the survival of Anopheles larvae. Journal of the American Mosquito Control Association 5:579-585.

Salvucci, M. E. and G. Bowes. 1982. Photosynthetic and photorespiratory responses of the
Aerial and submerged leaves of Myriophyllum brasiliense. Aquatic Botany 13:147-164.

Sculthorpe, C. D. 1967. The Biology of Aquatic Vascular Plants. Edward Arnold Publishing,
London.

Sutton, D. L. 1985. Biology and ecology of Myriophyllum aquaticum. Proceeding, 1st
International Symposium on watermilfoil (Myriophyllum spicatum) and Related Haloragaceae Species. 23-24 July 1985. Vancouver, B.C. pp. 59-71.

Sytsma, M. D. and L. W. J. Anderson. 1993. Transpiration by an emergent macrophyte: source of water and implications for nutrient supply. Hydrobiologia 271:97-108.

Timmons, F. L. and D. L. Klingman. 1958. Control of aquatic and bank weeds. Soil
Conservation 24:102-107.

Van, T. K., W. T. Haller, and G. Bowes. 1976. Comparison of the photosynthetic characteristics
of three submerged aquatic macrophytes. Plant Physiology 58:761-768.

Figure 1. Mean (±1 SE) total mass of parrotfeather grown in different light environments.

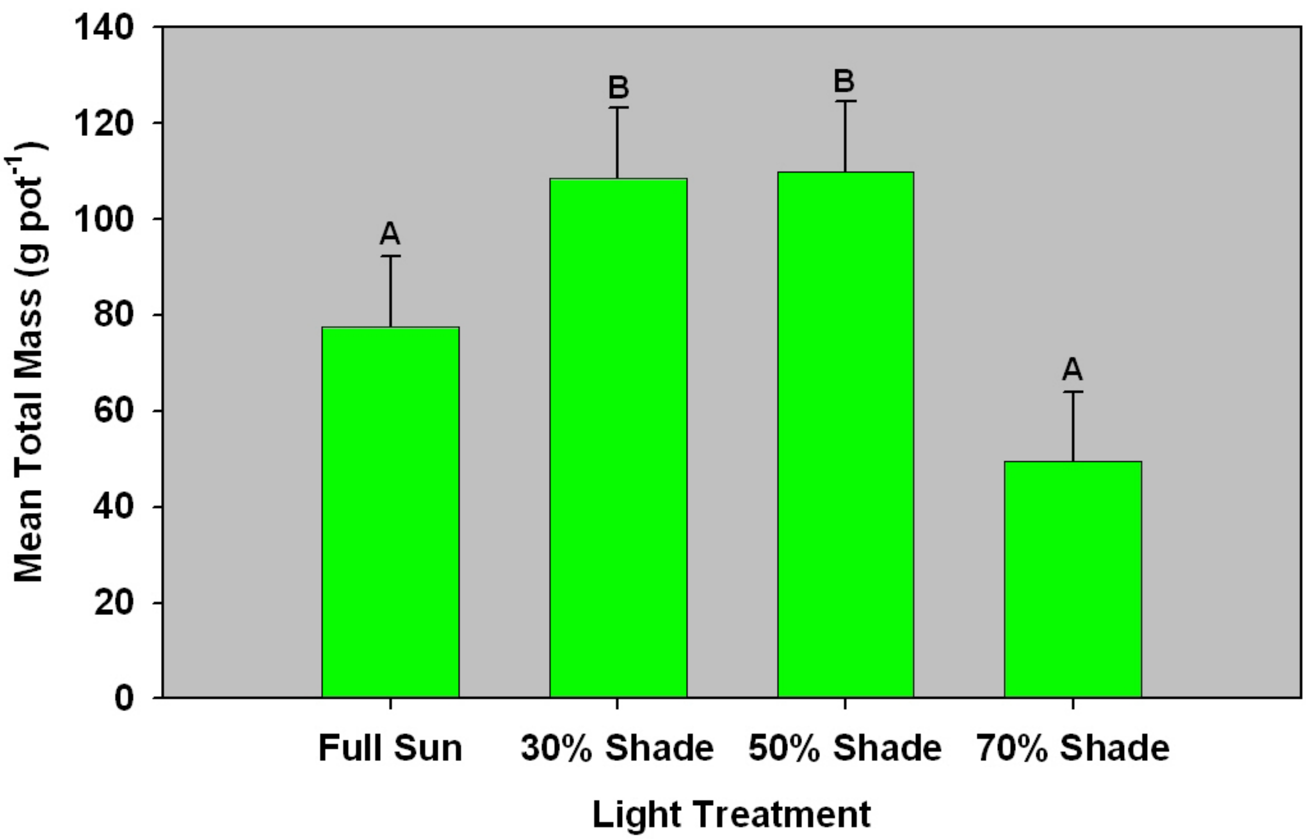

Figure 2. Mean (±1 SE) total plant length of parrotfeather grown in different light environments.

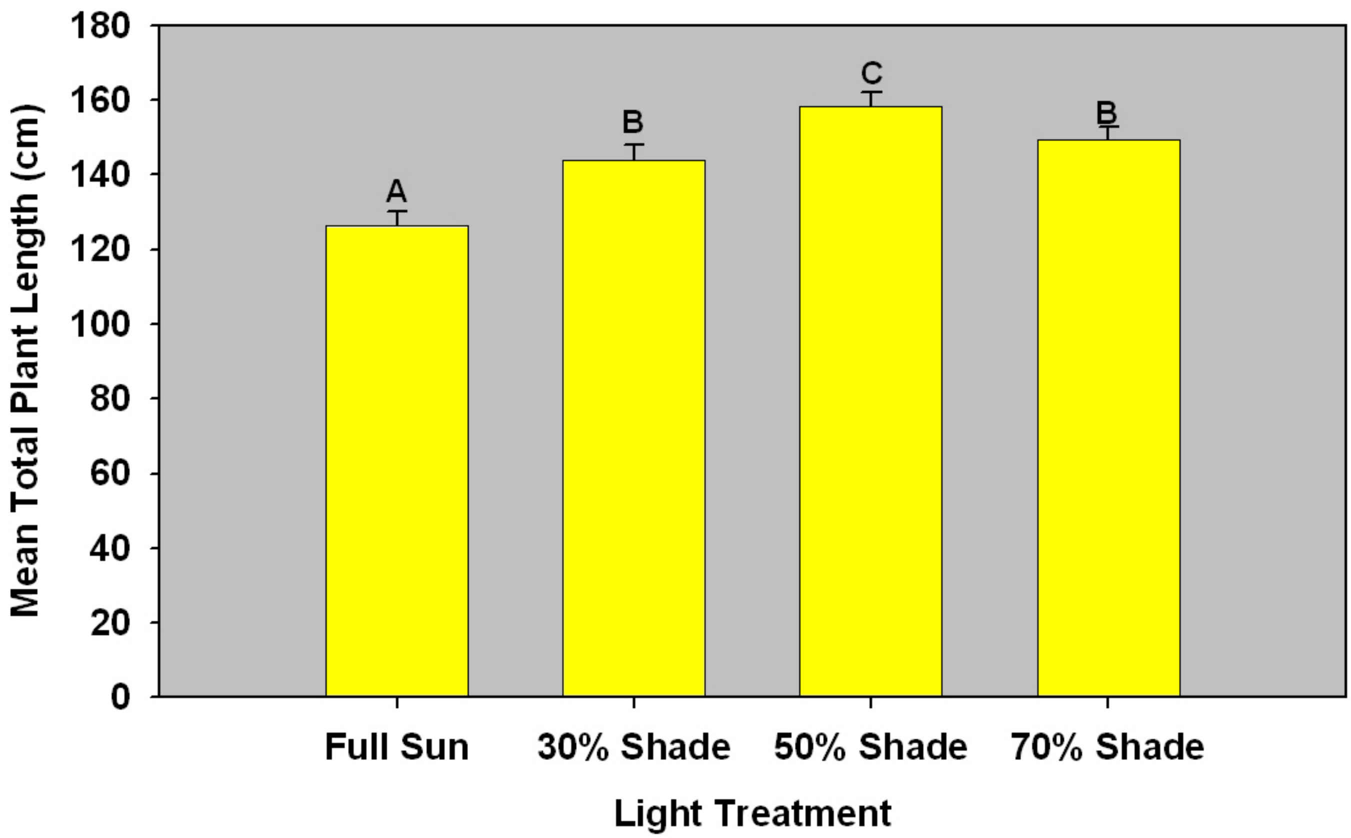

Figure 3. Mean (±1 SE) emergent shoot length of parrotfeather grown in different light environments.

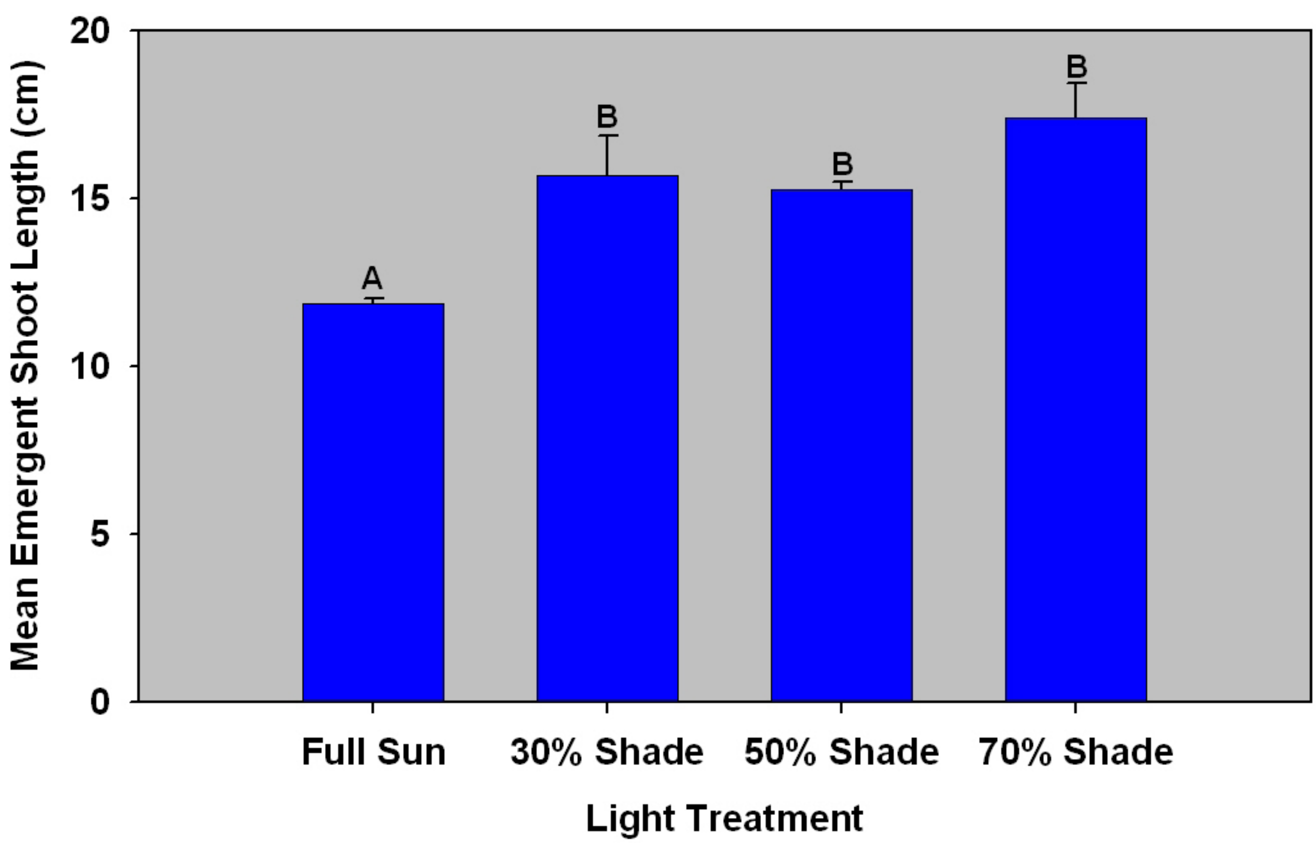

Figure 4. Mean (±1 SE) submersed shoot length of parrotfeather grwon in different light environments.