Survival of *Elodea nuttallii:* Competition with indigenous species and exposure to limiting factors

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Abstract

Elodea nuttallii is an invasive aquatic plant species that is known to survive extreme conditions and compete with native Alaskan aquatic plants such as *Hippuris vulgaris*. *E. nuttallii* was discovered in Chena slough in 2009; its effects in Alaskan environments have not been determined. To test competition, *E. nuttallii* and *H. vulgaris* were grown in various arrangements for 28 days. Fragments of *E. nuttallii* were laid on damp and dry surfaces to test survival when exposed to air for different durations and exposed to different aeration and light levels. The overall biomass of *E. nuttallii* was significantly larger than that of *H. vulgaris*; the *E. nuttallii* biomass was significantly higher than *H. vulgaris* biomass within mixed arrangements. A significantly larger number of damp *E. nuttallii* survived than dry *E. nuttallii* for every time duration. There was significantly higher growth in aerated treatments than there was in non-aerated treatments, not light treatments. My results indicate that *E. nuttallii* can grow well in limiting conditions and is likely to outcompete native Alaskan species in the wild. This adds to the need for public awareness of the harm of this species and for its management.

Introduction

Species that invade natural areas often harm local ecosystems and limit resources for local plants (Barrat-Segretain, 2004). The term "invasive" is used to refer to a non-native species that increases dramatically in its spread (Wolkovich, 2010) and does or is likely to cause environmental damage (The National Invasive Species Council, 2006). The specific effect of the species on the local environment depends not only on the plant itself, but also on the traits of the community being invaded (Barrat-Segretain, 2005). Invasive species are found throughout the plant and animal kingdoms. In Daab's study (2010) of the invasive mountain pine beetle in North Central Colorado, for example, the insect destroyed millions of trees. Because this area had been disturbed prior to invasion due to rapid economic as well as landscape-oriented development, the local forests were damaged, and the devastation wrought by the beetles was especially great. In the case of the emerald ash borer, an invasive beetle, the eradication of trees in order to rid the environment of these harmful insects promoted the growth of other invasive species (Hausman, 2009). These invasive organisms, such as the land plants *Cirsium arvense, Rhamnus cathartica*, were able to grow in the empty plots of land where infested trees had been removed; this was another case in which the effect of the species on the area depended greatly on the characteristics of the environment itself.

Changes in natural environments can be irreversible if there is an excess of invasive species. Studies have found that as a proliferation of non-native plants settled in an aquatic ecosystem, there was a noticeable drop in the richness of native plants and their biomass (Santos, 2009). Patches of aquatic plants may be destroyed due to certain disturbances of the environment, such as floods or droughts. Recovery from these types of disturbances involves recolonization of the area by flora and fauna from external areas, or by fragments remaining inside the patches (Barrat-Segretain, 1996). One study found that an invasive species of *Elodea* appeared in disturbed plots of land just three weeks following the complete clearing of a plot of the river, showing the ability of this species to thrive with very limited resources (Barrat-Segretain, 1996).

Native aquatic plants, such as *Hippuris vulgaris*, play a major role in keeping aquatic ecosystems functioning properly through their effects on the sediment, the process of nutrient cycling, and the effects on the animals of the surrounding community (Santos, 2011). Submersed aquatic plants affect availability of oxygen and the cycle of nutrients of the underwater ecosystem (Santos, 2011). Aquatic plants trap sediment, increase the clarity of the water, limit sunlight for other organisms, and increase temperature variability (Santos, 2011).

In contrast, invasive aquatic plants such as *Elodea nuttallii* grow profusely, clogging up waterways and therefore restricting the passage of water. This is harmful, for stagnant water can cause serious environmental problems, ranging from extensive bacterial growth to providing a breeding ground for mosquitoes. *E. nuttallii* disturbs other organisms as it spreads rapidly through rivers and streams, taking nutrition away from insects and other plants by growing rapidly and blocking out the light on the surface of the aquatic ecosystem (Barrat-Segretain, 2004).

E. nuttallii is considered invasive to Alaska, and a large infestation was recently discovered in Chena Slough near Fairbanks, AK (Klein, 2011). The first herbarium collection of *E. nuttallii* in Alaska was during a 1982 survey of Eyak Lake in Cordova (ARCTOS database, 2011). The next sample was collected in 2009 from Chena Slough. Both collections were initially identified as *Elodea canadensis*, but recent DNA analysis by Dr. Donald Les of the University of Connecticut has found that all samples that had been tested from Alaska are *E. nuttallii* (2011). It is important to examine *E. nuttallii* in order to try to understand the effect of this species on the particular ecosystem in Chena Slough in order to prevent the possible negative effects of this invasive plant.

My first objective was to find out how the invasive species of *E. nuttallii* competes with the Alaskan native species *H. vulgaris*. *H. vulgaris* was tested by Barrat-Segretain in her 1996 study, and it was shown to have recovered inconsistently from disturbances in relation to other native and non-native species. Using a later study by Barrat-Segretain (2005) as a basis for my study, I realized the need for further experimentation specific to Interior Alaska because, to my knowledge, no studies have been done with *Elodea* in Alaska.

My second objective was to test the extremes of the conditions that *E. nuttallii* can survive. I put out strands of *E. nuttallii* on dry and damp surfaces to test if the plant could re-root successfully after a time of not being fully submerged in water. A final objective dealt with similar issues of survival, but in this part, the independent variables were the amount of light and the presence of aeration in the water.

Based on results from previous studies, my hypothesis for the first part of my experiment was that *E. nuttallii* would outgrow and outroot the native plant, *H. vulgaris*. *E. nuttallii* has a reputation for survival in tough conditions and the ability to thrive in damaged environments, so my hypothesis for the second section of the experiment was that it would survive well after being exposed to both damp and dry conditions if they were resubmerged after being exposed to these conditions. Because light is necessary for photosynthesis, my third hypothesis was that light would affect the growth of *E. nuttallii* more than aeration.

Methods and Materials

E. nuttallii and *H. vulgaris* were collected in July on the upstream side of the Peede Road Crossing in the Chena Slough of Fairbanks, Alaska. These samples were tested in a greenhouse growth chamber at the Institute of Arctic Biology Greenhouse at the University of Alaska Fairbanks from July 14th to August 11th 2011. The growth chamber was set at 18º C with half of the fluorescent lights on for three hours to simulate night conditions, and at 20º C with all of the fluorescent lights on for 21 hours to stimulate the mid-summer photoperiod at the latitude of the Chena Slough. Sediment from the bottom of the Chena Slough was placed at the bottom of each plastic container (15.5 x 15.5 x 18.5 cm) in an approximately 1.5-cm thick layer. De-ionized water was used. The water level in the containers was adjusted once every week to be consistent throughout the experiment. After the first day, uprooted plants were not re-planted. All fragments were cut to 5 cm at the date they were planted. Only fragments without branches were used. After all fragments were cut, a randomization table was generated by using the website Randomization.com to determine which treatment each fragment would be placed in (http://www.randomization.com).

Competition Experiment

To determine how competition affected plant growth, monospecific, "solo," containers of *E. nuttallii* and *H. vulgaris* and mixed containers with both species were grown for 28 days in plastic containers in a greenhouse growth chamber. In the solo containers, 12 shoots of *E. nuttallii* and *H. vulgaris* were planted. For the mixed containers, six shoots of *E. nuttallii* and six shoots of *H. vulgaris* were planted in haphazard mixture. For the aggregated containers, 6 shoots of *E. nuttallii* and 6 shoots of *H. vulgaris* were planted in an aggregated pattern: *E. nuttallii* was planted on one side of the container, and *H. vulgaris* was planted on the other side of the container. There was no physical separation, only separation in location of each grouping. There were three replicates of each treatment.

Dry-Time Experiment

For every time duration, six 5-cm long tips of the *E. nuttallii* were laid on either damp or dry surfaces to test the survival of fragments when exposed to air for 1, 2, 4, 6, 12, 24, or 72 hours. For each time duration, six fragments were towel dried, weighed, then placed on the "dry" surfaces; six additional fragments were towel dried and weighed then placed on a "damp" plastic surface with approximately 5 mL of de-ionized water. At each time interval all of the remaining fragments were towel dried and weighed then were returned to their plastic surfaces. For example, after 6 hours had passed, samples in the treatments 6 hour, 12 hour, 24 hour, and 72 hour were weighed. Then, the 12 hour, 24 hour, and 72 hour samples were returned to their treatment areas. After reaching the prescribed time and weighing, the fragments were placed in a cup of de-ionized water for 1 week to see if the fragments were still viable. Fragments were considered viable if they grew roots or increased in length.

Aeration and Light Experiment

For the aeration and light treatments, each container was planted with 8 shoots of *E. nuttallii*. The treatment levels were light with aeration, light without aeration, reduced light with aeration, and reduced light without aeration. The *E. nuttallii* in the "light" containers were exposed to 25.52 µmol of light in a clear, lidless container. The *E. nuttallii* in the "reduced light" containers were exposed to 17.95 µmol of light in a clear container with an opaque lid; light was allowed to enter through the sides. At the end of the experiment all the plants were harvested (above and underground parts), dried at 70º C for 48 hours and weighed to determine final biomass.

Data Analysis

For the light and aeration trials as well as the dry-time trials, final biomass was measured and then analyzed using an ANOVA comparison. For the dry-time trials, the number of surviving *E. nuttallii* fragments was also analyzed using an ANOVA. T-tests were performed to analyze the competition biomasses, the number of rootings for the light and the aeration trials.

Results

Competition

I compared the growth patterns of *E. nuttallii* and *H. vulgaris* among plants that were grown in solo, mixed, and aggregate arrangements (Fig.1). The biomass of *E. nuttallii* was significantly greater than the biomass of *H. vulgaris* for all arrangements (t-test, $p = 0.01$). When testing the plants that were grown separately within the arrangements, however, the biomass of *E. nuttallii* was significantly greater than that of *H. vulgaris* only in the mixed arrangement (t-test, $p = 0.05$).

There was no statistical difference between the biomass of *E. nuttallii* and *H. vulgaris* within the solo arrangement, or within the aggregate arrangement.

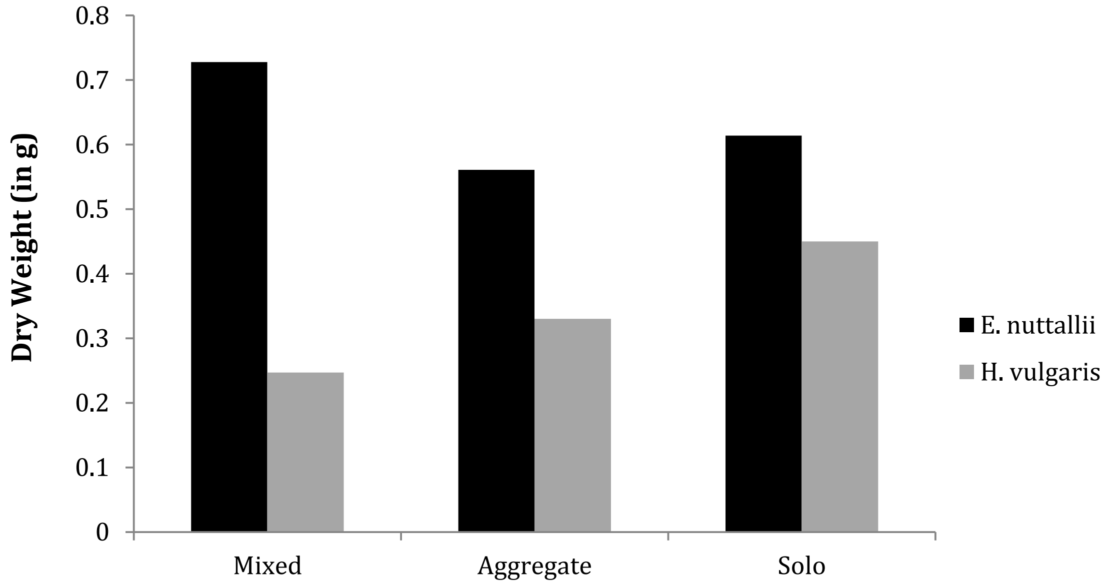

Figure 1. Growth of *E. Nuttallii* and *H. Vulgaris* in Competition. A *t*-test was performed on these final biomass averages for *H. vulgaris* and *E. nuttallii*. I can reject the null hypothesis that the mean biomass for *E. nuttallii* and *H. vulgaris* is the same at the 1% significance level (t-test, $p = 0.01$).

Dry-Time

I compared the biomasses (Fig. 2) and survival rates (Fig.3) of each hour for damp and dry treatments of *E. nuttallii*. The change in biomass was more extreme for the dry treatment than for the damp treatment over time ($F_{1,8} = 6.29$, $P > 0.05$). More damp plants survived than dry plants ($F_{1,7} = 24.78$, $P < 0.01$). Plants after 1 hour of exposure grew more than 72 hour plants, growing in a range of 1.2 to 3.1 cm, while 72 hour plants only grew in a range of 0.7 to 2.4 cm. For dry plants, three 12-hour and one 72-hour plants survived but there was no increase in length.

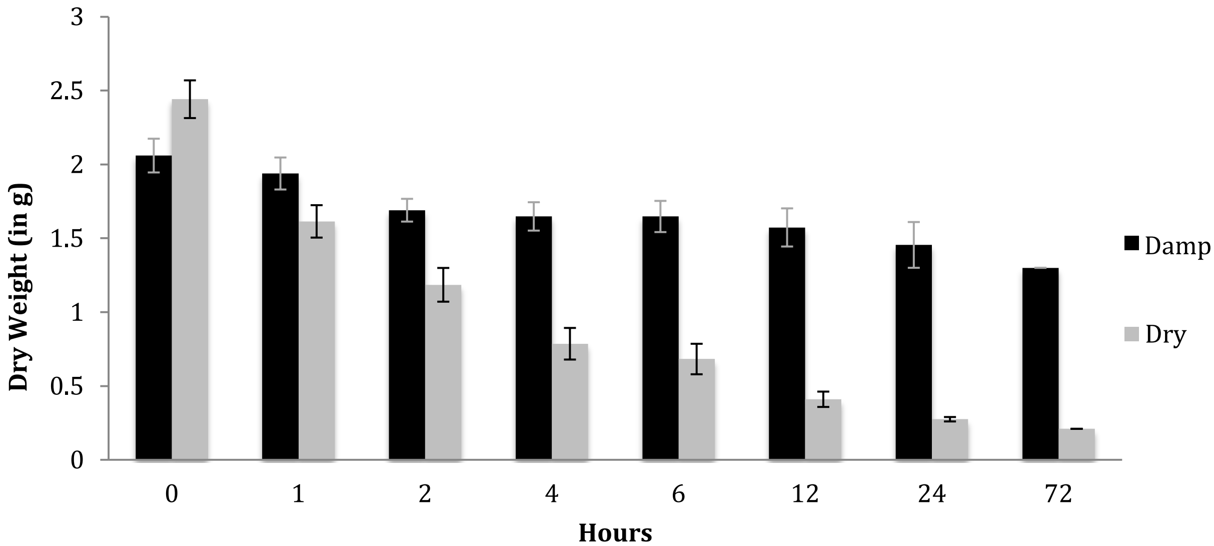

Figure 2. Dry-Time Experiments. I can reject the null hypothesis that the mean for wet mass and dry mass is the same, and accept that it is not the same. The biomasses of each hour of the wet plants did not vary as much as the biomasses of each hour of the dry plants did.

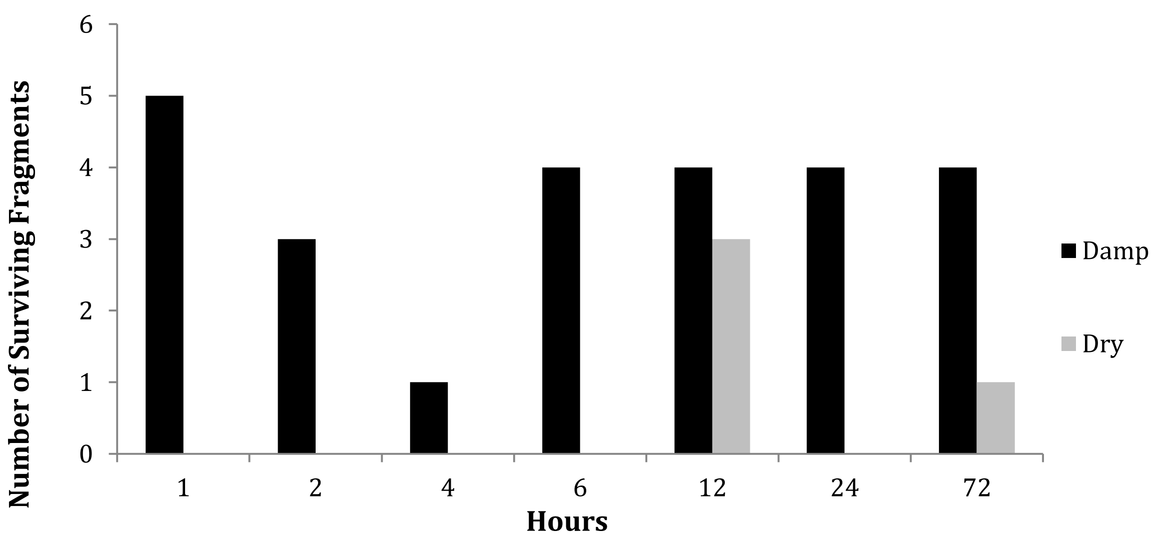

Figure 3. Growth of *E. Nuttallii* After Exposure to Dry Conditions. The only growth for *E. nuttallii* in dry conditions occurred for 12 and 72 hours. At least one plant in damp conditions survived for each time period. There was a total number of 6 fragments for each treatment and time trial.

Light and Aeration

I compared the number of rootings for the growth of *E. nuttallii* in varying light and aeration environments. There was not a difference in the mean number of rootings for the light and dark treatments. There was difference between the aerated and non-aerated treatments (Fig. 4, *t*-test, $p < 0.01$).

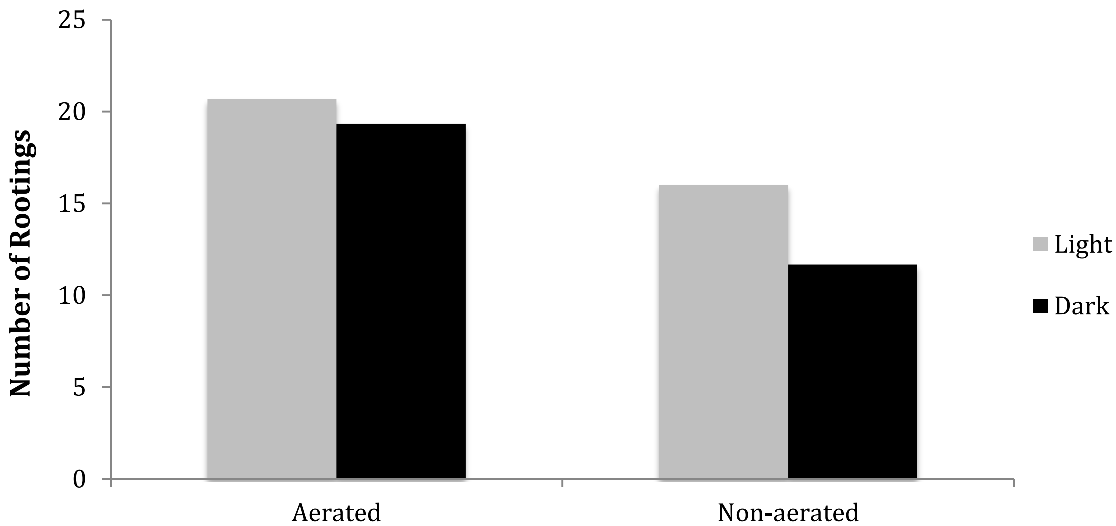

Figure 4. Growth of *E. Nuttallii* in Varying Light and Aeration Environments. Dry biomasses of each treatment to each trial were compared by performing a t-test. I failed to reject the null hypothesis that the mean for aerated and non-aerated plants is the same. These trials showed that aeration was not a major factor in the growth of the *E. nuttallii*. I was able to reject the null hypothesis that the mean for light and reduced light were the same in the non-aerated trials.

Discussion

E. nuttallii is a competitive species that is less sensitive to competition than native plants (Barrat-Segretain, 2004). In the competition and light aeration trials, as soon as they were planted, the fragments of *E. nuttallii* began to grow. The roots were visible after only one day, and the plants lengthened visibly after only a few days. Branches formed in addition to increase in length, and growth was very apparent. *H. vulgaris* stems and roots grew less quickly and showed less apparent growth in length. My hypothesis that *E. nuttallii* would outgrow and outroot the native plant, *H. vulgaris,* was partially supported. My results indicate that *H. vulgaris* plants grew less than *E. nuttallii* for all the arrangements. However, there was only a significant difference between the biomass of *E. nuttallii* and *H. vulgaris* when tested separately within the mixed arrangement. This may be due to the more direct interactions between the two species when mixed, than when arranged apart from each other, or separately. Previous studies have shown that *E. nuttallii* was able to grow fast and densely in a mixed arrangement due to its higher growth and rooting rate (Barrat-Segretain, 2004).

My results indicate that as long as fragments of *E. nuttallii* are kept damp, they have the ability to survive up to 72 hours out of water. My hypothesis that *E. nuttallii* would survive well after being subject to both damp and dry conditions if they were resubmerged after a period of exposure was partly supported. The biomass of *E. nuttallii* decreases more quickly when plants are on completely dry surfaces than when on damp surfaces. Additionally, the biomass of the plants in damp conditions stayed fairly constant from hour 2 to hour 72. In contrast, the low survival of dry plants may be due to the rapid loss in biomass. For all time durations, at least one plant survived for all damp treatments; in comparison only plants that survived from the dry treatment were those from hours 12 and 72. This may be due to the differences in health of the plants at the start of the experiment, but there were not visible differences between fragments and my randomization would have limited bias. However, plants placed on damp surfaces all exhibited growth, thus it appears that *E. nuttallii* has the capability of surviving even after being out of water, as long as they do not dry out completely. This adds to the evidence that *E. nuttallii* is a harmful invasive species with the ability to survive in harsh conditions. My results also indicate that *E. nuttallii* may be capable of invading new environments through fragments as short as 5 cm in length.

In the light aeration trials, there was a difference in the growth of *E. nuttallii* between those that grew in aerated and non-aerated water, but there was not a significant difference in their growth in the different levels of light. My hypothesis that light would affect the growth of *E.*

nuttallii more than aeration was not supported. This shows *E. nuttallii*'s ability to survive in environments with approximately one third of the light available in daylight. Aeration appears to be an important factor in *E. nuttallii* survival. According to my results, *E. nuttallii* would perform better in lotic systems, systems with flowing water, than in lentic systems, systems with still water.

A valuable next step could be to test *E. nuttallii*'s interactions with a wider variety of species in order to obtain more data of the behavior of *E. nuttallii* in competition. A further step that could be taken would be to test the effect of limiting factors on the behavior of *E. nuttallii* by simulating the conditions of different seasons in Alaska, such as the temperature and amount of light available. Invasive plants often have varied growth patterns from one another that would call for several management actions annually in order to overcome their competitive growth advantage; this would contribute to raising management costs greatly (Santos, 2010). Research on the phenology (periodic events such as budding and flowering) of invasive plants may be able to help with planning for the ideal times for such management (Wolkovich, 2010).

Throughout Europe, *E. nuttallii* has led to the widespread displacement of native species (Barrat-Segretain, 2004). Another invasive species, *Egeria densa,* has become overabundant in the Sacramento-San Joaquin River Delta in California, and has maintained biomass throughout all seasons, including the winter. It has limited growth of native aquatic plants, and may have worked in a mutualistic "invasional meltdown," where it would have helped ease the colonization of other invasive species, while the additional invasive species helped *E. densa* thrive, as well (Santos, 2010). This shows the adverse consequences that invasive species can have on the environment.

Conclusion

E. nuttallii appears to have the ability to outcompete the native species of *H. vulgaris*. In this experiment, *E. nuttallii* outcompeted *H. vulgaris*; *E. nuttallii* had a higher overall biomass, showing a higher growth rate. As long as *E. nuttallii* remained damp and did not dry out completely, it was able to survive for at least 3 days out of the water. The damp *E. nuttallii* biomass stayed generally consistent from the 2-hour to the 72-hour mark. The damp *E. nuttallii* all exhibited growth once resubmerged, displaying its capability of surviving even after being out of water for extended periods. *E. nuttallii* survived in dark environments and grew less efficiently in stagnant water. *E. nuttallii* will be able to invade more easily and efficiently because of its higher growth rate. This one species has the ability to have such a widespread and harmful impact on our local environment. Because of the potential for detrimental impact, widespread eradication of *E. nuttallii* should be implemented as funds become available. My results have highlighted the ability of *E. nuttallii* to thrive in various conditions, and provide information that may aid with preventing the further spread and disruption of additional ecosystems.

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Literature Cited

Barrat-Segretain, Marie-Hélène and Arnaud Elger. “Experiments on Growth Interactions Between Two Invasive Macrophyte Species.” Journal of Vegetation Science Vol. 15, No. 1 (Feb., 2004), pp. 109-114. Blackwell Publishing. JSTOR.

Barrat-Segretain, M. H. and C. Amoros. “Recolonization of Cleared Riverine Macrophyte Patches: Importance of the Border Effect.” Journal of Vegetation Science Vol. 7, No. 6 (Dec., 1996), pp. 769-776. Blackwell Publishing. JSTOR.

Barrat-Segretain, M.H. "Competition between invasive and indigenous species: impact of spatial pattern and developmental stage." *Plant ecology* 180.2 (2005): 153-160. *Agricola*. EBSCO. Web. 27 Sept. 2011.

Daab, Michael T. and C. Flint. “Public Reaction to Invasive Plant Species in a Disturbed Colorado Landscape.” *Invasive Plant Science and Management*. 3.4 (2010): 390-401. BioOne. Web. 30 November 2011.

Dallal, Gerard E. Randomization.com. 16 July 2008. 27 December 2011. <http://www.randomization.com>.

Hausman, Constance E., John F. Jaeger and Oscar J. Rocha. “Impacts of the emerald ash borer (EAB) eradication and tree mortality: potential for a secondary spread of invasive plant species.” *Biological Invasions* Vol. 12 (2010), pp. 2013–2023. 30 November 2011.

“Invasive Species Definition Clarification and Guidance White Paper.”*The National Invasive Species Council*. (2006). 23 December 2011.

Klein, Helen. “Canadian Waterweed.”*Alaska Natural Heritage Program.* (2011). 23 December 2011.

Mowry, Tim. *Fairbanks Daily News Miner.* 1 December 2010. 1 December 2011 <http://www.newsminer.com/view/full_story/10492772/article-Invasive-freshwater-plant-found-in-Chena-Slough--Chena-River>.

Santos, Maria J., Lars W. Anderson, and Susan L. Ustin. “Effects of invasive species on plant communities: an example using submersed aquatic plants at the regional scale.” *Biological Invasions* Vol. 13 (July, 2010), pp. 443-457. Springer publishing. 30 November 2011.

Wolkovich, Elizabeth M., and Elsa E. Cleland. “The Phenology of plant invasions: a community ecology perspective.” Ecological Environments (2010).The Ecological Society of America.

Hours	Mixed	Aggregate	Solo
E. nuttallii	0.728	0.561	0.614
H.vulgaris	0.2467	0.3303	0.45