Establishment of Submersed Aquatic Vegetation in Little Bear Creek Reservoir 2007-2009

A Summary Report to the Bear Creek Millennium Project and the Alabama Department of Conservation and Natural Resources

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Executive Summary

Project Information

- Aquatic plant communities constitute an important component of aquatic ecosystems and re-establishment of these communities is a technique that may be useful in areas where aquatic vegetation is sparse or non-existent.
- Aquatic plant re-establishment efforts and experimental hypothesis testing in Little Bear Creek Reservoir have yielded useful information regarding plant species survival.
- Phase I of the project in 2007 was successful in establishing American pondweed inside exclosures, but other planted species did not survive.
- Phase II in 2008 was also successful in establishing American pondweed inside exclosures and had limited success in establishing water celery.
- Experimental results from Phase II indicated that water depths from 0.3 to 1m did not influence survival of plant propagules.
- Phase II was continued in 2009 and was successful in establishing American pondweed inside exclosures of different sizes (1x1, 2x2, and 3x3m).
- Expansion of plants outside of protective exclosures did not occur during any phase of the project indicating herbivory may ultimately limit plant expansion.
- Water level manipulations have hindered planting efforts during every growing season throughout the duration of this project.

Recommendations for future work

- Continue exclosure experiments with American pondweed in existing planting areas.
- Identify new areas for re-vegetation efforts and seek permission to use new planting sites and plant species. This includes an expansion into other BCDA reservoirs.
- Continue experimental hypothesis testing in order to improve success rates of future planting efforts.
- Continue to monitor existing, successful enclosures to assess expansion.
- Complete an aquatic vegetation survey of all BCDA reservoirs to assess the potential for vegetation efforts in different locales and provide early detection of invasive species.

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INTRODUCTION

Little Bear Creek Reservoir (LBCR) is located in Franklin County in Northwest Alabama. It is one of four lakes that are part of the Bear Creek Development Authority (BCDA) Lakes and is within the Pickwick watershed of the Tennessee River System. Little Bear Creek Reservoir was impounded in 1975 as a flood control reservoir and has since become an important driving force for the local economy by providing opportunities for fishing, camping, boating, and other recreational activities. Little Bear Creek Reservoir has a total surface area (at full pool) of approximately 1600 acres and extends 8 miles upstream from the dam (Figure 1). LBCR has a fluctuating water level of approximately 12 ft (3.6m) each year with full pool occurring from mid-April until late October (TVA 2009).

The remnant flooded timber that once served as habitat for the fishery is in decline and needs to be replaced with a self-renewing habitat for forage fishes and young-of-the-year bass (Cheshier et al. 2008). The best replacement for the flooded timber would be a diverse community of native aquatic plants, such as American pondweed (*Potamogeton nodosus* Poir.) and water celery (*Vallisneria americana* Michx.; Smart et al. 1996).

Aquatic plants mediate physical and biological processes in aquatic systems, forming the basis of the aquatic food chain (Carpenter and Lodge 1986). In addition, native aquatic plants serve as refugia for fish fauna (Dibble et al. 1996). Currently, native vegetation communities in the reservoir are non-existent which may be problematic when trying to establish a productive fishery (Killgore et al. 1989). After impoundment, LBCR was reported to have contained submersed (e.g. *Potamogeton* spp.) and emergent (e.g. water-willow *Justicia americana* (L.) Vahl) aquatic plant species (Phillip Cooper and Gary Don Fleming, personal communication). However, in recent years, there has been no sign of submersed aquatic plant species, with the exception of muskgrass (*Chara* spp.), a non-vascular macroalgae. Additionally, there are local reports of a reduction in emergent plant communities.

In 2006, the Bear Creek Millennium Project under the leadership of Phillip Cooper approached Mississippi State University for assistance and guidance in establishing native submersed aquatic plants. That following year, initial planting trials were performed using five native species approved by the Tennessee Valley Authority. Using the results from 2007, planting trials again took place in 2008 with species observed to have the highest potential success. Of the five initial species, only American pondweed had significant success (Cheshier et al. 2008, Fleming et al. 2009). In 2009 we focused all of our efforts on American pondweed and shifted the variation in our experiments to exclosure dimensions with the goal of identifying a critical patch size for avoiding the devastating effects of herbivory. Even though a diverse community of native plants is desired, native species such as American pondweed occurring singularly can still provide physical structure and added complexity that likely benefits the aquatic environment (Dibble and Harrel 1997).

Problems with the planting trials have been attributed thus far to negative environmental conditions such as unpredictable draw downs, high water temperatures at shallow depths, and herbivory. The knowledge gained every year has resulted in the development of additional experiments to test hypotheses that will improve the rate of success and planting efficiency in the future.

OVERALL PROJECT OBJECTIVES

The objective in 2007 was to identify and successfully cultivate approved submersed aquatic plant species for habitat enhancement in Little Bear Creek Reservoir. This represented Phase I of our overall plans for aquatic plant re-vegetation in LBCR. In 2008, we began Phase II. Our goals of successfully cultivating approved submersed aquatic plants did not change, but we chose to use only three species and added an additional experimental variable (planting depth) in order to identify potential factors that would lead to future success.

In 2009 we further refined our experimental plan by reducing the number of species to one (American pondweed). Our objective in this experiment was to investigate the hypothesis that patch size may be an important factor in the persistence of native propagules. Additionally, we surveyed exclosures from 2008 to assess the survival of plants from one year to the next.

MATERIALS AND METHODS

The following summaries of materials and methods are presented along with the appropriate reference to the report in which each phase was described in more detail.

Phase I Study 2007 (Cheshier et al. 2008)

Submersed aquatic plants were planted in 3ft (1m) diameter enclosures made of PVC coated wire mesh & re-bar. The enclosures were placed in the littoral zone in two arms of reservoir. These arms, Cooper's Branch and Trace branch are located along the northern shore of the reservoir (Figure 1). Plantings consisted of American pondweed, northern and southern ecotypes of water celery, leafy pondweed (*Potamogeton foliosus* Raf.), waterstargrass (*Heteranthera dubia* (Jacq.) MacMill.), and sago pondweed (*Stuckenia pectinata* (L.) Böerner). Plants were first planted on May 14 and 15, 2007 and again on July 26 and 27, 2007. The May planting comprised twenty-four enclosures being planted at random within the littoral zone in Cooper's Branch and Trace Branch. Each enclosure had 2 pots of each species. Plants were cultivated in the greenhouse at the R.R. Foil Plant Science Research Center, Mississippi State University. Once established (plant lengths of 24 to 36 inches), they were transplanted to Little Bear Creek Reservoir for planting. The July planting consisted of twelve enclosures per branch. Each enclosure contained 4 pots of a given species; however, this trial only consisted of sago pondweed, the northern ecotype of water celery, and American pondweed. Data were pooled and a One-way Analysis of Variance (ANOVA) was used to determine differences in species survival at a $p<0.05$ level of significance.

Phase II Study 2008 (Fleming et al. 2009)

Three native submersed aquatic plant species were grown and transplanted in Little Bear Creek Reservoir and their survival was evaluated based on species, depth, and herbivore protection. Methods for this project generally follow recommendations of Smart and others

(2005). The plants were first propagated from tubers or fragments in April 2008, raised in a greenhouse and mesocosm at the R.R. Foil Plant Science Research Center, Mississippi State University, and then transplanted into LBCR. American pondweed was collected from a local source in Russellville, AL. Sago pondweed and water celery were ordered from Kester's Wild Game Food Nurseries, Inc., Omro, Wisconsin.

Water celery and sago pondweed were planted in 3-in peat pots and allowed to grow at Mississippi State University facilities for approximately 6 weeks. Osmocote fertilizer (19-12-6) was used in each pot to improve plant survival during initial growth periods. Two propagules of a given species were planted in each pot. Plants were transplanted (early July) when sufficient growth had occurred and water levels in Little Bear Creek Reservoir were stable and acceptable.

Specimens were transplanted among three sites approved by the Tennessee Valley Authority (TVA) in Little Bear Creek Reservoir. Two sites are located in Trace Branch and one site in Cooper's Branch (Figure 1). Plants were transplanted inside 1m diameter enclosures made of PVC coated wire mesh and re-bar. Sago pondweed and water celery were left in biodegradable peat pots and placed in a small excavated hole in the sediment. American pondweed (approximately 18in. stem length) was collected and directly transplanted with bare roots at the time of plantings.

Four pots of the same species were planted inside an exclosure (exclosures only contained one species). Approximately 15 stems of American pondweed were used as an alternative to four pots. Each planting location contained nine exclosures of each species, totaling twenty-seven (3 plant species X 9 exclosures per species at each site). The treatments of each species were planted along three contour intervals (0.3 meters, 0.6 meters, and 1.0 m) to assess the survival and growth of each species based on depth (Figure 2). Three additional "patches" of each species at each location were planted without exclosures at a depth of 60 cm. Three exclosures per location in which no pots were planted were used as a control (one exclosure at each depth). Each exclosure was evaluated individually, and the data from each site location was aggregated based on species, depth, and enclosed/not enclosed.

Plants were evaluated based on two factors: 1) presence/absence of plants planted in each location (exclosure or patch) to assess plant survival, 2) visual estimation of percent cover inside each exclosure to assess growth. Sites were checked daily for one week and then bi-weekly (once every two weeks) after plantings until October 2008. The results provided in this report are the survival of plant species, measured from presence or absence data. In addition, these results only include presence or absence from the last evaluation of the season in September 2008 and do not include bi-weekly results. By using data collected during the last evaluation survey, we can estimate survival of plants without the confounding effects of intermittent senescent periods that were observed during the summer months.

Data were analyzed using a generalized linear model in SAS. Presence/absence data do not fit assumptions of normality due to a binomial distribution. Therefore the analysis model (Proc Genmod) was set to analyze a binomial distribution using a link (logit) function. Significant differences were determined using a least square means (lsmeans) analysis at p = 0.05 level of significance.

Phase II Study 2009

Based on observations from the previous two years, in 2009 American pondweed was the only species involved in planting trials. Exclosures were constructed of PVC coated wire-mesh and re-bar. Exclosure size served as the variable of interest for this experiment, and removal of half of the exclosures served as the treatment. Three sized exclosures (1x1m, 2x2m, and 3x3m) were placed at each location. These treatments were replicated six times at random locations in the littoral zone of approved locations (Figure 3). Percent coverage was estimated for all exclosures and analyzed based on size and location using a one-way analysis of variance (ANOVA), and a Bonferroni test was used to detect mean separation at a $p = 0.05$ level of significance.

RESULTS

2007 (Cheshier et al. 2008)

Spring Planting

All of the plants that were planted during May resulted in 100% mortality with the exception of American pondweed and southern water celery. Eight enclosures from Cooper's Branch and twelve enclosures in Trace Branch had surviving populations of American pondweed. One enclosure in Trace Branch had one pot of southern water celery that survived but did not expand. The other submersed aquatic plant species; leafy pondweed, northern and southern ecotypes of water celery, water stargrass, and sago pondweed, were unsuccessful in the remaining enclosures in Cooper's Branch and Trace Branch.

Summer Planting

The July planting had similar results to those in May. American pondweed survived in all of the enclosures in both Cooper's Branch and Trace Branch. However, none of the sago pondweed and northern ecotype of water celery survived.

2008 (Fleming et al. 2009)

American Pondweed

Results from trials in 2007 indicated that American pondweed was the only species planted that had significant survival (Cheshier et al. 2008). In 2008, American pondweed had significant survival ($p < 0.05$) and expanded inside most exclosures; however, it did not expand outside. Approximately 93% of the exclosures planted with American pondweed had surviving plants in September 2008 (Figure 5). Specimens planted outside of protective exclosures were absent two days after planting.

Sago Pondweed

Sago pondweed never expanded beyond the initial propagules inside exclosures and was absent in many exclosures after only a few weeks. In September, no living plants could be detected inside any exclosures and resulted in 0% survival, which was significantly different from American pondweed and water celery (Figure 5). Specimens planted outside of protective exclosures were absent two days after planting.

Water Celery

Water celery survival in both Trace branch sites was similar to sago pondweed during the warm period of the summer. In Cooper's branch, water celery grew and expanded on the substrate but did not show significant vertical growth toward the surface. In September, with cooling water temperatures, water celery began re-growing in some exclosures. Approximately 63% of the exclosures planted with water celery had surviving plants in September 2008 (Figure 5). This was significantly higher than sago pondweed but lower than American pondweed. Specimens planted outside of protective exclosures were absent two days after planting.

Depths

In 2008, exclosures were planted along a depth gradient in order to assess the relative significance of water depth on propagated plant survival (Figure 2). Water levels did not reach full pool but were relatively stable throughout the study period (Figure 4). There were no significant differences detected among percent survival in any of the three depth treatments (Figure 6).

2009

Water levels were again a problem in 2009. In 2008 the planting was delayed due to a water level drop at the beginning of the growing season. In 2009, water levels were dropped before the end of the growing season (Figure 7). The experimental design for 2009 required American pondweed to expand from its original number of propagules until it reached ~100% coverage inside the exclosures. At the time that this occurred, the water levels were dropped far below the exclosures which did not allow the completion of the experiment. Presence and visual percent cover data were collected prior to the lowered water levels. Exclosure sizes 1x1, 2x2, and 3x3 had mean percent coverage of 66.89, 73.28, and 69.72 respectively, and were not significantly different ($p < 0.05$). Analysis of exclosures by location indicated mean percent coverage of 23.3 (Cooper's branch), 87.6 (Trace branch site 2), and 99.0 (Trace branch site 3). The two Trace branch sites were not significantly different but both of these sites were significantly different from the Cooper's branch site.

Survival from exclosures planted in 2008 was evaluated at the beginning of the 2009 growing season and just before water levels were dropped in 2009. Analysis of percent survival did not indicate significant differences from 2008 to 2009. This is interesting to note because it indicates that exclosures containing surviving plants at the end of the growing season in 2008 successfully perennated and re-established inside the exclosures in 2009 (Figure 8).

DISCUSSION

Re-establishment of native aquatic plants is potentially a technique used to restore aquatic habitats in the southeastern US (Smiley and Dibble 2006). Aquatic plant community restoration efforts have been attempted in Lake Guntersville, Alabama as well as in Oklahoma and Texas (Dick et al. 2004, Doyle and Smart 1993). Establishment of aquatic plant communities can have positive effects on water quality as well as provide habitat and sanctuary for fish fauna (Dibble et al. 1996). Successfully cultivating submersed aquatic vegetation in Little Bear Creek has been problematic thus far with difficulties being attributed to fluctuating water levels and high water temperatures. In 2007, water levels never reached full pool, thus complicating restoration efforts (Cheshier et al. 2008).

Results from 2007 indicated that American pondweed was the best candidate for restoration when compared to other species tested (Cheshier et al. 2008). In 2008, we again planted sago pondweed and water celery along with American pondweed to assess their survival potential for another year in case environmental conditions changed (Fleming et al. 2009). These species all produce some form of subterranean overwintering structures such as tubers or winter-buds. Tubers provide new plants with the necessary carbohydrates needed to initiate growth in subsequent growing seasons (Cronk and Fennessy 2001). Tubers may also serve as a mechanism to aid in plant survival during adverse environmental conditions. Given the nature of water level fluctuations in LBCR (Figure 3), focused re-vegetation efforts are only feasible for species adapted to survival when environmental conditions do not meet the necessary requirements for year-round growth.

Water depth may play a key role in the success of submersed macrophytes (Rea et al. 1998). Therefore, we stratified plantings at initially controlled water levels (depths) in order to evaluate this in LBCR. Water temperature in shallow areas can become a significant factor impacting plant growth (Barko et al. 1982, Pilon and Santamaria 2002). Our hypothesis was that water depth would facilitate temperature differences and thus cause differential survival and growth of plant species. However, our results indicated that water depths of 0.30, 0.60, and 1.0m did not have a significant effect on survival.

In spring 2008, water levels appeared to be rising in concordance with the operating guide for LBCR; however, structural complications with LBCR dam caused TVA to drop the water levels in order to implement repairs. Therefore, in 2008 water levels still did not reach full pool but were relatively stable throughout the study period. The unpredictable nature of water levels from year to year must be considered when planning additional re-vegetation efforts. Providing water levels respond in concordance with the operating guide for LBCR, future projects may be started sooner in the year to allow for a longer growing season.

Phase II (2008) of this project was successful in establishing American pondweed. After two years of study, it appeared that efforts should focus on this species in order to maximize our ability for re-vegetation. In 2009, we planned a continuation of Phase II with exclosure size as the variable of interest. American pondweed has shown promising results in the ability to grow and expand within exclosures. However, observations of plant growth outside of the exclosures are rare and have not been sustained. This is likely due to some form of herbivory from fauna that cannot penetrate the exclosures, but can consume plant material that attempts to grow beyond the 1m diameter protection of the exclosure. Therefore, in the 2009 study we focused on building larger protected areas in order to allow for greater expansion of plant populations. Our initial experimental design involved removing exclosures from well established patches to assess whether patch size had an effect on the ability of the plants to reproduce and continue to expand even in the presence of herbivory. Due to sudden water level changes, this experiment was not completed. However, an assessment of percent coverage within each exclosure indicated that American pondweed can spread into areas larger than we had previously tested (> 1m diameter), as long as herbivory protection is still present. Since the infrastructure is still in place, this experiment can potentially be completed in 2010.

Planting efforts should continue to be monitored and evaluated with similar methods used in Phase I and Phase II. Future work should focus on mitigating negative abiotic (water level fluctuations) and biotic (herbivory) factors in LBCR.

RECOMMENDATIONS FOR FUTURE WORK

There are several recommendations that should be considered for future re-vegetation plans in Little Bear Creek Reservoir. Exclosure experiments performed during the study yielded some useful information such as the relative unimportance of water depth in survival of propagules and the identification of suitable species. There is still a need for future experimentation with American pondweed exclosure dimensions as well as possible experimentation using different planting strategies (i.e. using winter-buds rather than rhizomatous specimens, planting during different seasons, photoperiods, or temperature regimes, etc.). It is apparent that the most efficient way to increase the success of plant survival is through this type of experimental hypothesis testing. Evaluation of previously planted exclosures should also occur in order to assess the long term persistence of plant patches.

This study was performed in only three areas in LBCR. Locating additional areas and obtaining permission from TVA to plant these areas is a logical step toward assisting the colonization of aquatic plants throughout the reservoir. This reservoir is one of four in the Bear Creek Watershed and it would be useful to expand experimentation and assessment to the other three reservoirs. This will provide the needed variability to test more complex hypotheses regarding plant survival and growth under different conditional factors such as water-level fluxuations, seasonality, and plant expansion. The first step of this process will be to develop a long term aquatic vegetation assessment for each of these reservoirs. Not only will this provide valuable information for assisted native aquatic plant establishment, but it can also provide early detection for undesirable invasive species.

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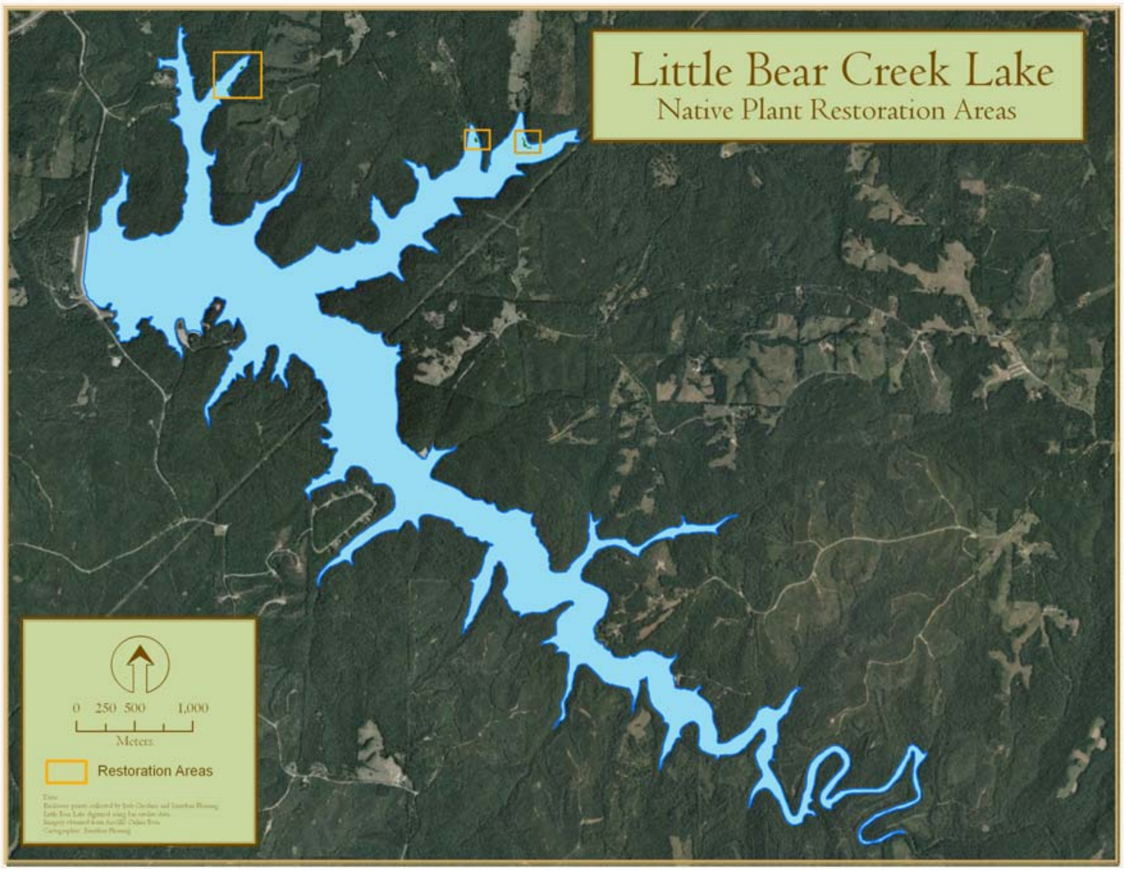

Figure 1. Current restoration areas in Little Bear Creek Reservoir 2008.

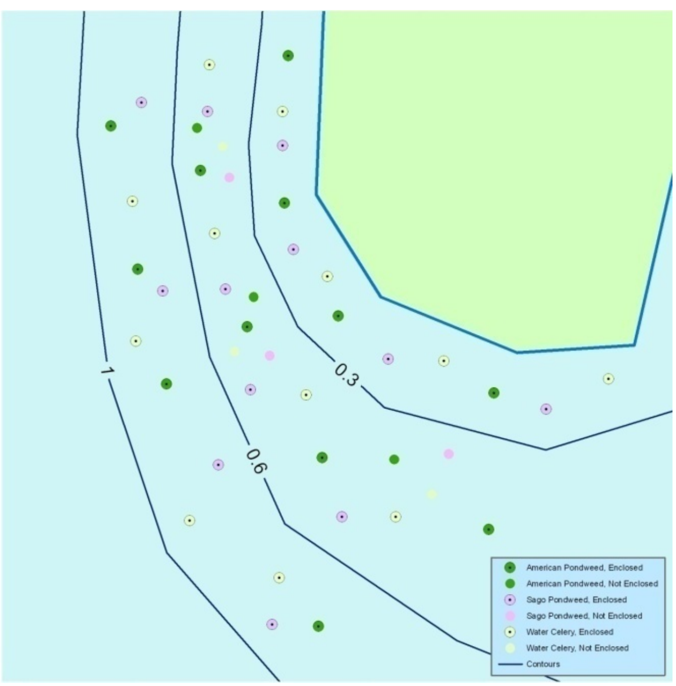

Figure 2. Diagram of planting along depth contours in 2008.

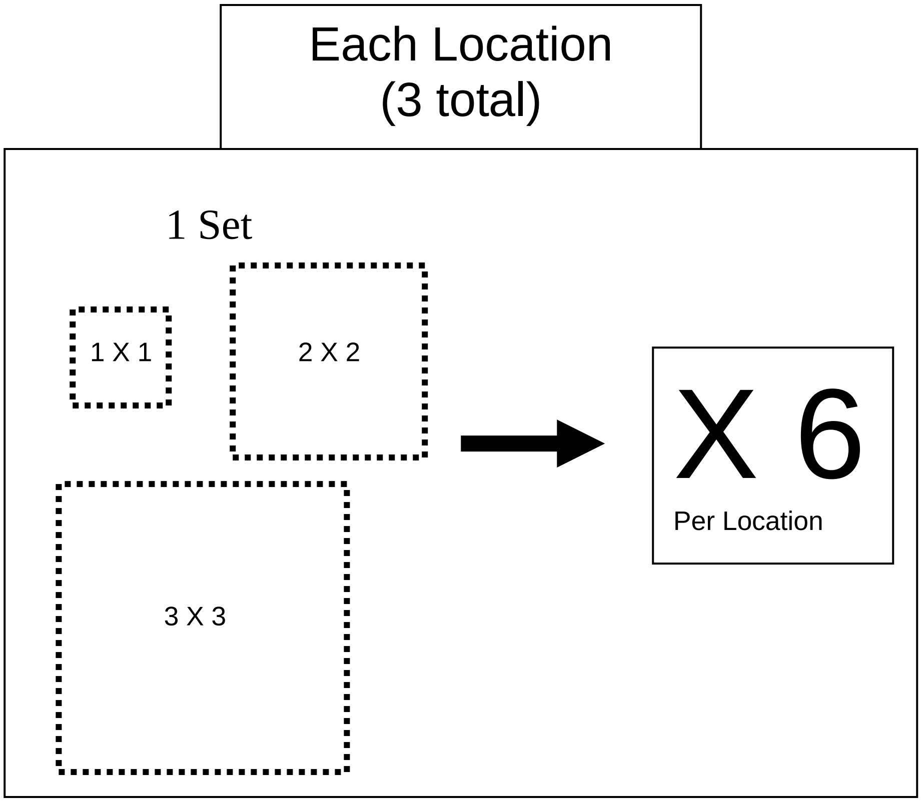

Figure 3. Diagram of experimental planting design for 2009.

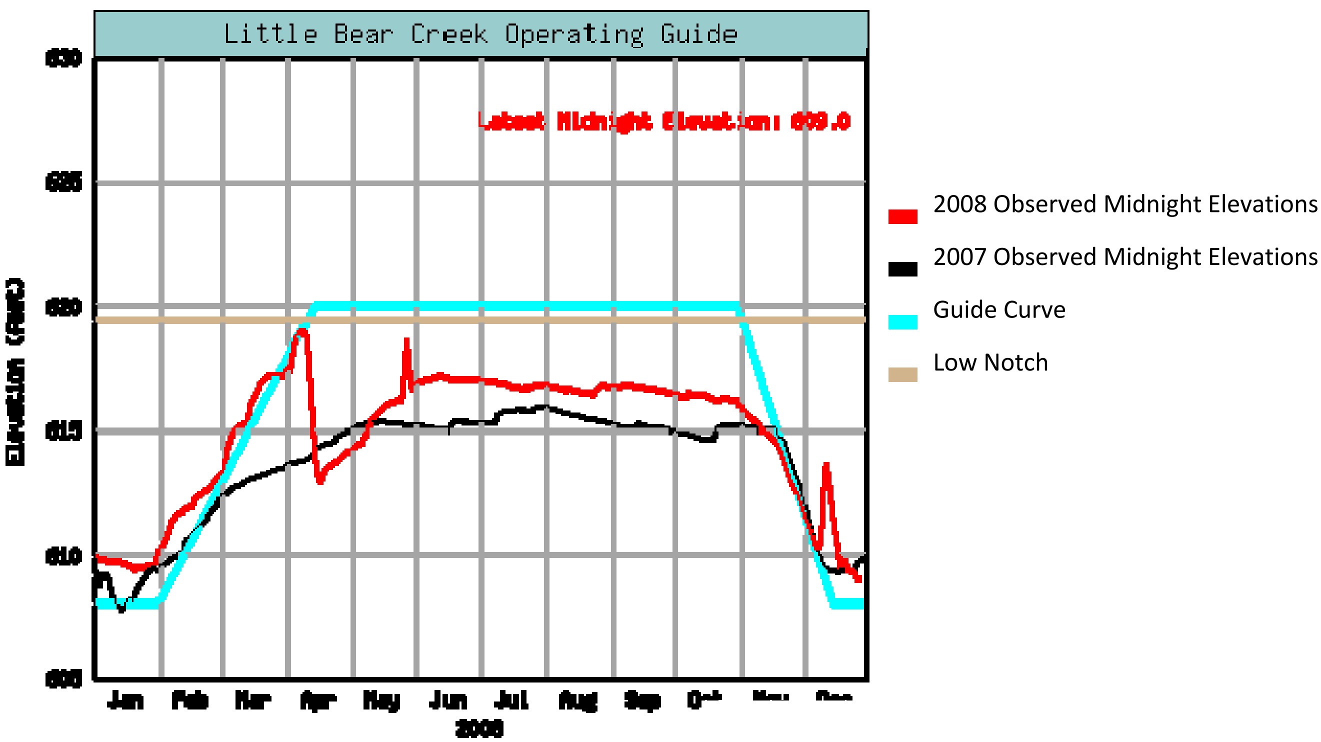

Figure 4. The 2007-2008 Little Bear Creek Reservoir operating guide from TVA (TVA 2009).

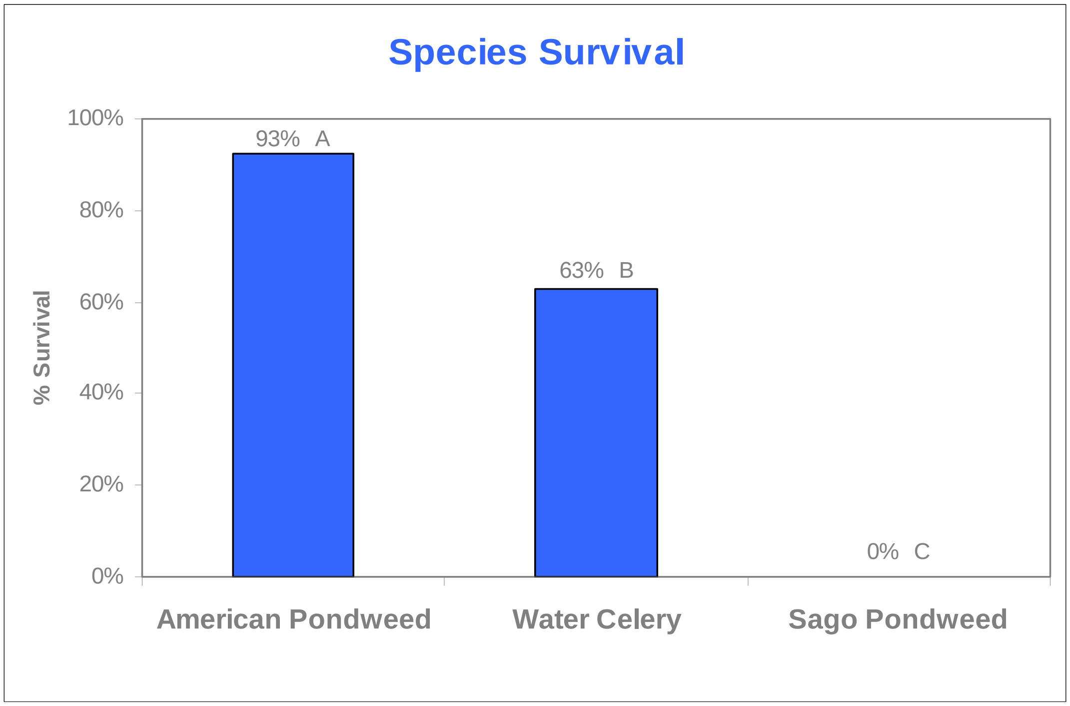

Figure 5. Percent survival of the three submersed aquatic macrophytes planted in exclosures in 2008. Mean survival is significantly different at the $p<0.05$ level if means have different letters, therefore each species had significantly different survival.

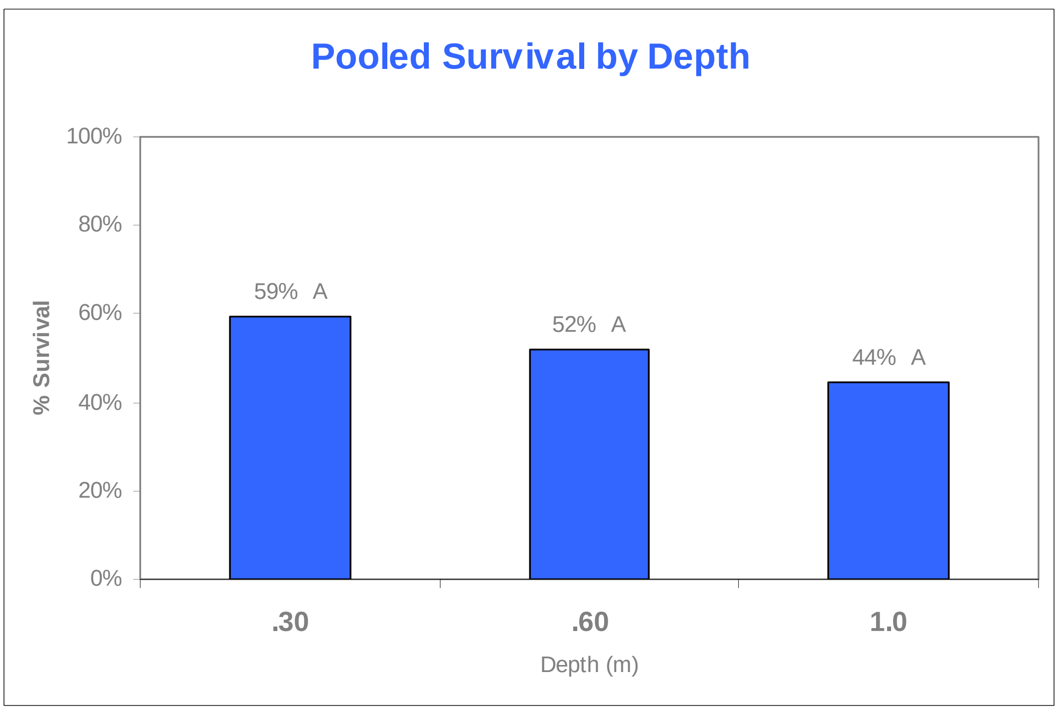

Figure 6. Percent survival of the all three species aggregated based on depth of exclosures in 2008. Mean survival is significantly different by at the $p<0.05$ level if means have different letters, therefore there was no significant difference in pooled survival rate among the three depths.

Figure 7. The 2008-2009 Little Bear Creek Reservoir operating guide from TVA (TVA 2009).

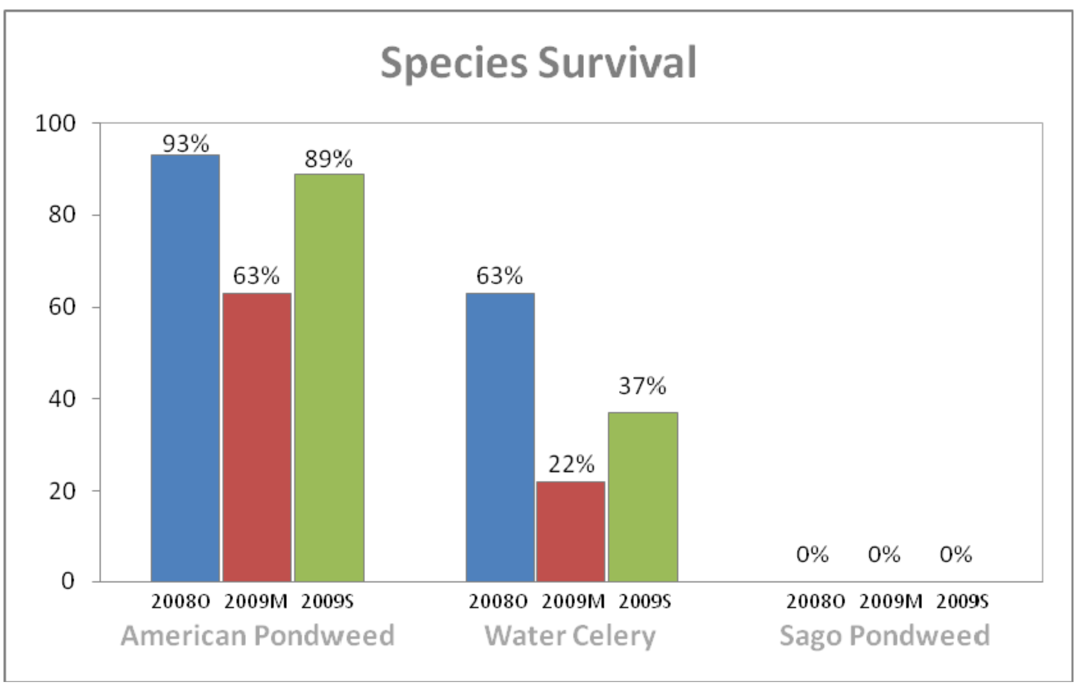

Figure 8. Percent survival of the three submersed aquatic macrophytes planted in exclosures in 2008. 2008O, 2009m, and 2009S indicate year and assessment month, October, May, and September respectively.