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Comparison of Four Techniques to Control Elephant Ear

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ABSTRACT

Elephant ear (*Colocasia esculenta* [L.] Schott), introduced to the San Marcos River (Hays County, Texas) in the 1900s, now forms dense stands and dominates many areas previously inhabited by native vegetation. Texas Parks and Wildlife Department lists the plant as an exotic species needing management consideration. Four potential vegetative control techniques (manual removal, application of glyphosate herbicide, mechanical cutting, and a combination of mechanical cutting followed by application of glyphosate to cut petiole) were applied to elephant ear growing in the San Marcos River at five-week intervals for one year. Effectiveness of each technique was evaluated based on three criteria: extent of decrease in elephant ear leaf cover, number of treatment applications required to achieve control, and time required to apply technique. Manual removal effectively achieved control with the fewest applications and resulted in the lowest overall elephant ear leaf cover. It also required the least application time. Herbicide application also effectively controlled elephant ear, although the technique required a longer application time and a greater number of applications. Neither mechanical cutting nor combined mechanical cutting/herbicide application resulted in control. Based on the three criteria, both manual removal and herbicide application are effective in controlling elephant ear.

Key words: Colocasia esculenta, exotic species, glyphosate, invasive species.

INTRODUCTION

The impacts of invasive species to ecosystems are well documented. Biological invasion now ranks among the world's greatest threats to native ecosystems (Zavaleta 2000). Invasive species pose a serious threat to biodiversity (Sakai et al. 2001), and there is clear evidence that biological invasions contribute substantially to an increasing rate of extinction (Vitousek et al. 1996). Exotic species have contributed to the decline of 42% of federally listed endangered and threatened species, illustrating the severe impact they have on surrounding ecosystems (Schmitz and Simberloff 1997, Burkhart 1999). Common effects of plant invasions include changes to local biodiversity; competition with native species for nutrients, light, and space; reduction in oxygen levels; increase in water loss due to evapo-transpiration; and restriction of navigation and recreational activities (Parker and Reichard 1998, Xiaoyan et al. 2003). These impacts can lead to a reduction in species richness, plant diversity, and community productivity (DiTomaso 2000).

Numerous case studies have shown the impacts of nonnative plant species on biodiversity (Maffei 1997). An example of a wetland ecosystem that has been highly invaded by exotic plant species is the San Marcos River (Hays County, Texas). The U.S. Fish and Wildlife Service (USFWS 1996) lists the introduction of nonnative flora into the San Marcos River ecosystem as problematic for native species. With an average spring flow of 4.81 m^3/s and a mean water temperature range of 21.5-22.5 C (Groeger et al. 1997), the springs at San Marcos have exhibited the greatest flow dependability and environmental stability of any spring system in the southwestern United States (USFWS 1996). Environmental constancy has allowed the invasion of a number of exotic species that significantly influence this ecosystem (Groeger et al. 1997). Four dams, erected in the 1930s, have provided deeper areas (Owens et al. 2001) and a

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reduction in peak flood energy that has led to an increase of nonnative vegetation within the San Marcos River (Earl and Wood 2002). These encroaching exotic species are adversely affecting and displacing native aquatic species. Nearly 80% of all native aquatic plants along the shoreline of the river have been replaced by introduced nonnative plant species since the 1930s (Owens et al. 2001). Lemke (1989) found that 8 of 31 macrophyte species, or 25%, of plant taxa collected in the upper San Marcos River were nonnative.

The USFWS (1996) lists several nonnative species that have invaded the San Marcos River ecosystem, including the nonnative elephant ear, or wild taro (*Colocasia esculenta* [L.] Schott). Furthermore, Texas Parks and Wildlife Department (2001) lists elephant ear as an exotic species needing management consideration in the San Marcos River ecosystem. Elephant ear, a member of the Arum family (Araceae), is an emergent aquatic and semi-aquatic herbaceous species. The plant is a perennial capable of producing large (60 cm length and 35 cm width) leaves on 1-2.5 m petioles (Weber 2003) that emanate from an upright corm. Under ideal growing conditions, a single elephant ear plant can grow 2.4 m tall with a similar spread in width. Reproduction of elephant ear is mostly vegetative, rarely by seed (Kikuta et al. 1938), and occurs when whole corms divide in winter or early spring. Only a portion of the corm crown and petiole is needed to establish a new plant.

Elephant ear is cultivated for its edible corm and is the fifth most consumed root vegetable worldwide (Mace and Godwin 2002). It was originally brought from Africa to the Americas as a food crop for slaves (Akridge and Fonteyn 1981) and introduced into Florida and other southern states in 1910 by the U.S. Department of Agriculture as a substitute crop for potatoes. Evidence suggests introduction of elephant ear to the San Marcos River headwaters occurred in the early 1900s, with floods encouraging the spread of corms downstream where dense stands developed along the riverbanks (Akridge and Fonteyn 1981). The plant occupies a variety of habitats along the river. It has been found growing in high and low light regimes and all types of substrate from rock, gravel, and silt to deep mud (Staton 1992), but it seems to grow best in the silty anaerobic soils lining the riverbanks (Akridge and Fonteyn 1981). The rate of water current where the plant is found varies from slower pools to steady current to swift current (Staton 1992). It occurs from the river's edge to 1-2 m toward mid-channel with individual stands measuring up to 35 m in length and up to 5 m in width.

One of the major impacts of elephant ear invasion is displacement of native shoreline vegetation (Staton 1992). Extensive stands of elephant ear alter the vegetational structure and dynamics of riparian plant communities (Weber 2003). Listed by the Florida Exotic Pest Plant Council as a category 1 species, elephant ear is known to disrupt native plant communities in Florida to the point of eliminating native plant species (Christman 2003). The same impacts that have occurred in Florida are occurring in the San Marcos River ecosystem. Staton (1992) conducted a species diversity comparison study in the San Marcos River from 1975 to 1991 that indicated an overall decrease in population size of native plant species with an increase in exotic species. Elephant ear demonstrated its superior competition ability during the 16 years of Staton's study by increasing in frequency by 33% and occupying 16.1% of total area. It showed potential for dominating many sites previously inhabited by native vegetation.

Elephant ear invasion of the river edge has also narrowed the river and crowded other aquatic species in many places (USFWS 1996). The federally endangered Texas wild rice (*Zizania texana*) now grows only in mid-channel, possibly due to competition with elephant ear in the shallower, slower waters (Staton 1992). Elephant ear also occupies the same habitat as the federally endangered San Marcos gambusia (*Gambusia georgei*) and may have decreased the habitat suitability and contributed to the gambusia's decline (USFWS 1996). One rationale for managing an invasive nonnative species is to increase diversity and abundance of native species (Morrison 2002).

Control of invasive species has become a significant environmental issue (Gutin 1999). We tested the effectiveness of four techniques for ability to control elephant ear by reducing biomass of existing stands and preventing vegetative regrowth from those stands. The techniques tested were manual removal, herbicide application, mechanical cutting, and a combination of mechanical cutting followed by herbicide application. Effectiveness of each technique was evaluated based on three criteria: extent of decrease in elephant ear leaf cover, number of treatment applications required to achieve control, and time required to apply technique.

MATERIALS AND METHODS

The experimental design consisted of a randomized block design (Krebs 1999) to test the effects of four potential vegetative control techniques. Six blocks were established along the banks of the San Marcos River in San Marcos, Hays County, Texas.

Each of the six blocks contained five 1-m^2 quadrats. To ensure minimal encroachment from surrounding plants, a buffer zone of 61 cm was established and maintained by manually removing all elephant ear plants, including corms, from the adjacent area outside the individual quadrats within each block. A control and the four potential vegetative control techniques (manual removal, herbicide application, mechanical cutting, and combined mechanical cutting/herbicide application) were randomly assigned to the quadrats within each block. Manual removal consisted of hand pulling the entire plant, including the corm, from the soil. In herbicide application, a sponge was used to wick the entire surface area of each individual leaf blade epidermis with a 1% solution of the herbicide glyphosate (Rodeo® Monsanto Co., St. Louis, MO), which is approved for use in aquatic systems. A 1% aqueous solution of glyphosate was used because this concentration was previously found effective in controlling elephant ear (Nelson and Getsinger 2000). Nelson and Getsinger (2000) included a non-ionic surfactant in the spray mixtures used in their experiment. However, a study of the efficacy of glyphosate and five surfactants in controlling giant salvinia found no significant effect of presence or absence of surfactant (Fairchild et al. 2002). Therefore, a surfactant was not added to the glyphosate solution in this study. Mechanical cutting used hand shears to cut the petiole 2 cm above ground or water level. In the combined mechanical cutting/herbicide application, cutting was followed by slowly dripping glyphosate (using a plastic drop bottle) onto the cut surface of the petiole until the petiole absorbed no more glyphosate (approximately 74.4 ml). Because glyphosate is a broad-spectrum herbicide and could threaten adjacent vegetation, the herbicide was not sprayed but was applied directly to the blade with a sponge (herbicide application) and to the cut petiole using a dropper bottle (combined mechanical cutting/herbicide application) to ensure that stands of Texas wild rice and other nontarget species were not impacted.

Elephant ear plant cover was measured prior to the application of control techniques, then at five-week intervals for one year (November 2004-November 2005). A leaf area index measurement was recorded for individual blades of elephant ear within each quadrat at each five-week interval. Leaf blade area was estimated by the equation (Lu et al. 2004):

$$A = K \times L_{SA} \times W_P$$

where K is the leaf area coefficient (set at 0.87), L_{SA} is the leaf length measured from the sinus base to the leaf apex along midrib, and W_P is the leaf width passing the petiole-attaching point and perpendicular to L_{SA}.

The individual control techniques were applied and the amount of time required for application of each technique was recorded. These data were collected at five-week intervals for one year and the total number of applications for each technique was calculated. The interval at which no elephant ear plant cover was present in any quadrat of a given technique, with no subsequent regrowth, was recorded as the point at which control had been achieved. Once control was achieved, applications were discontinued.

A single factor ANOVA was conducted to analyze elephant ear plant cover data. A test of homogeneity of variances was established and a Dunnett C post hoc test was used when significance was shown (confidence interval 95%), or a Tukey's HSD post hoc test was used if no significance was expressed. A single factor ANOVA, followed by the appropriate post hoc test, was also used to determine significance between the number of applications needed to achieve control, as well as the amount of time required to perform each technique.

RESULTS AND DISCUSSION

Elephant ear Leaf Cover

Prior to the initial application of control techniques, there was no significant difference ($F_{4, 25} = 0.191$, $p = 0.941$) in elephant ear leaf cover between quadrats assigned to control and individual vegetative control techniques. Elephant ear leaf cover was greater at the end of the experiment than at the onset of the experiment in the control (Figure 1). However, leaf cover of plants treated with each of the four control techniques showed an overall decrease.

Following the last treatment application, there were significant differences in elephant ear leaf cover ($F_{4, 25} = 34.704$, $p = <0.001$) (Figure 1). Leaf cover was significantly higher in the control than in any of the vegetative control techniques. Leaf cover in both manual removal and herbicide application was significantly lower than leaf cover in mechanical cutting. Mechanical cutting and combined mechanical cutting/herbicide application were not statistically different. Combined mechanical cutting/herbicide application was also statistically similar to both manual removal and herbicide application.

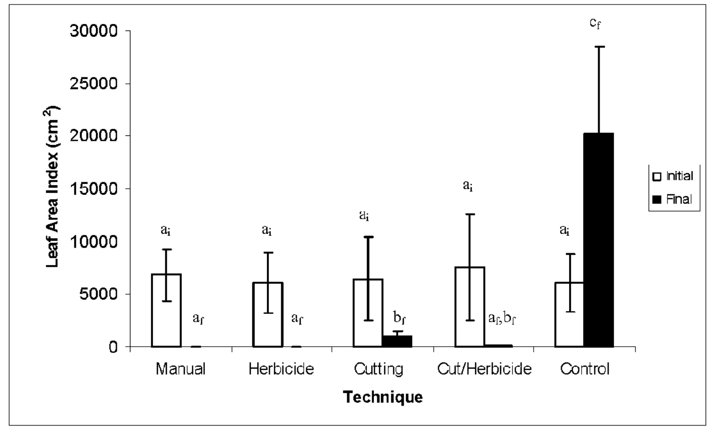

Figure 1. Leaf area index (cm²) of *Colocasia esculenta* prior to application of control techniques (initial = $_i$) and following the last treatment application (final = $_f$). Techniques coded with the same letter are not significantly different (Single Factor ANOVA; $F_{4, 25} = 34.704$, $p = <0.001$).

Number of Application Treatments

Manual removal was significantly different ($F_{4, 25} = 16.671$, $p = <0.001$) in the number of treatment applications needed to achieve control of elephant ear compared to mechanical cutting and combined mechanical cutting/herbicide application (Figure 2). Manual removal required the least number of applications and achieved control in an average of 5.2 applications. Herbicide application achieved control in an average of eight treatments. Neither mechanical cutting nor combined mechanical cutting/herbicide application resulted in complete control.

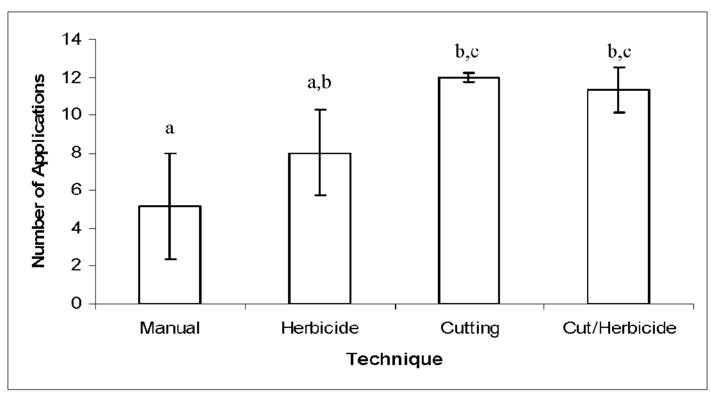

Figure 2. Number of treatment applications (mean and SD). Control of *Colocasia esculenta* was achieved in manual removal and herbicide application. Cutting and combined mechanical cutting/herbicide application did not achieve control in the eleven treatment applications. Techniques coded with the same letter are not significantly different. (Single Factor ANOVA; $F_{4, 25} = 16.671$, $p = <0.001$).

Application Time

Initially, herbicide application required the most time, followed by manual removal. However, by the second application, due to the small amount of plant cover remaining, manual removal ranked lowest in application time and remained the lowest throughout the experiment.

The total amount of time required for the application of control techniques was significantly different ($F_{4, 25} = 17.364$, $p = <0.001$) in manual removal compared to both mechanical cutting and combined mechanical cutting/herbicide application (Figure 3). Manual removal required the least amount of application time followed by herbicide application. Combined mechanical cutting/herbicide application required the greatest amount of application time, but did not differ significantly from herbicide application.

Evaluation of Effectiveness of Eradication Techniques

Manual removal has been shown to be very effective at removing emergent weeds (Seagrave 1988). This method has demonstrated success in controlling wetland plants such as *Phragmites australis* (Moreira et al. 1999b) and *Lythrum salicaria* (Morrison 2002). However, previous studies refer to this method as being potentially slow and laborious, as well as causing changes to river bank dynamics (Seagrave 1988). In this study, manual removal effectively achieved control with the fewest applications and resulted in the lowest overall elephant ear leaf cover. It also required the least application time. This method was slow and laborious in the beginning; however, it proved very effective in reducing elephant ear cover and rapidly became the least time consuming and least laborious technique. Manual removal did impact the habitat. Following the application of this technique, we observed a change in riverbank dynamics through erosion and disruption of the soil bed.

Herbicide application as a control method of nonnative plant species is well documented. Control has been shown in many emergent invasive species such as *Monochoria vaginalis*, *Sagittaria sagittifolia*, *Polygonum* sp., *Cyperus difformis*, *Scirpus* sp., *Typha* sp., *Crassula helmsii* (Child and Spencer-Jones 1995), and *Phragmites australis* (Moreira et al. 1999b). In this study, even though control was not achieved as quickly as in manual removal, herbicide application effectively controlled elephant ear in eight applications. This technique required more application time than manual removal; however, it required approximately half the amount of time as mechanical cutting and less than a third the amount of time as combined mechanical cutting/herbicide application. This control technique caused little disruption to the soil bed and less severe erosion than the manual removal technique.

Mechanical cutting as a control technique can be effective and is very selective (Seagrave 1988) but tends to offer only a short-term method of control in many species (de Waal 1995). Control by cutting has been shown in common reeds from riverbanks (Moreira et al. 1999a). Mechanical cutting achieved poor control in this study. With exception of the control, it had the highest overall mean value for elephant ear leaf cover and required the second longest application time of any technique.

Combinations of techniques have also been applied to control other nonnative plant species. Cutting followed by an herbicide application has been successful on *Melaleuca quinquenervia* (Tenenbaum 1996), *Fallopia japonica* (de Waal 1995), *Typha* sp. (Moreira et al. 1999b), *Phragmites australis* (Monteiro et al. 1999), and *Lythrum salicaria* (Carroll 1994). The positive effect of plant cutting on herbicide efficacy may be due to the depletion of rhizome reserves (Monteiro et al. 1999, Moreira et al. 1999a). This method often results in a shorter treatment period to achieve success (Child et al. 1998); however, combined mechanical cutting/herbicide application did not control elephant ear in this study. This technique required the greatest amount of application time, necessitating more than eight times the amount of application time than required for manual removal.

After decades of control in North America, invasive plants cover an estimated 405 million ha and continue to increase in area by nearly 14% per year (Sheley and Clark 2003). Land managers may be skeptical of control efforts due to feasibility, cost, and possible collateral damage (Simberloff 2003); however, many control programs of terrestrial and wetland plant species are in the process of succeeding (Simberloff 2003, Dybas 2004). Both manual removal and herbicide application were found to be effective in reducing biomass and preventing vegetative regrowth of elephant ear in this study. This study was conducted on a relatively small scale, and efforts on a much larger scale over a longer period of time would be required to remove this invasive species from the San Marcos River ecosystem.

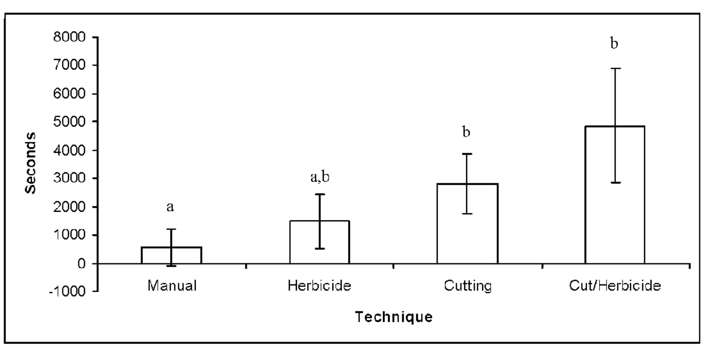

Figure 3. Total time (mean and SD) required to apply each control technique. Techniques coded with the same letter are not significantly different. (Single Factor ANOVA; $F_{4, 25} = 17.364$, $p = <0.001$).

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