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The Effects of Athel (*Tamarix aphylla*) on Riparian Habitats

Willard E. Hayes II, Lawrence R. Walker Ph.D.

Introduction

Tamarix aphylla (L.) Karst, (athel) is an introduced tree at Lake Mead National Recreation Area (LMNRA). Recently, *T. aphylla* has spread to areas beyond where it was introduced at LMNRA, and under the right conditions *T. aphylla* can reproduce sexually as well as vegetatively despite previous assumptions that it was benign (Walker et al. 2006). *Tamarix aphylla* can also hybridize with saltcedar (*Tamarix ramosissima*), a highly invasive species in the southwest United States (Gaskin and Shafroth 2005). In Australia, *T. aphylla* is considered a Weed of National Significance and has been the focus of large restoration efforts because of its ability to reduce biodiversity, out-compete native vegetation, increase soil salinity, and choke riparian corridors (Griffen et al. 1989). The recent and ongoing drawdown of Lake Mead exposes large muddy areas where invasion can occur. It is important to determine how threatening *T. aphylla* may be to the ecosystems around Lake Mead and what its competitive abilities might be so that management and restoration efforts can be decisive and timely to avoid situations similar to the *T. aphylla* invasion in Australia, and the *T. ramosissima* invasion in the southwestern U.S.

This project studied the competitive interactions between *T. aphylla* and the invasive *T. ramosissima*, as well as between *T. aphylla* and the native *Salix gooddingii* (Goodding's willow) by planting experimental plots at field sites at Lake Mead and performing similar nursery experiments. Field visits to *T. aphylla* and *T. ramosissima* sites were used to evaluate each

species relative impacts on soils, ground litter, vegetative cover, and local vegetation composition.

Methods

A. Site Characterization

Vegetation

In spring 2005, I characterized the vegetation of the two largest stands of *Tamarix aphylla* and two adjacent stands of *T. ramosissima* on the shores of LMNRA (Boulder Beach and Bonelli Landing). Canopy cover (total and by species) was estimated using three parallel 50 m line intercepts spaced two meters apart (% cover = distance of transect intercepted by vegetation / total transect length). Within the 4 x 50 m area created by the transects, I counted all individuals of each woody species, measured height and basal diameter of each woody plant, and the canopy size of each woody plant was calculated from two perpendicular diameters. Within the same area, the abundance of each herbaceous species was estimated (1= sparse, 2= few, 3= common, 4= abundant).

Soils

Within the 4 x 50 m vegetation plots, 12 *T. aphylla*, 12 *T. ramosissima*, and 12 open sites near each species were randomly chosen for soil sample collection. The base of each plant chosen was at least 2 m from the base of any other woody plant, and there was no overlap with canopies of any adjacent woody plant. Open sites were a minimum of 2 m from the canopy of any woody species and were sparsely vegetated. At N, S, E, and W aspects halfway between the edge of each canopy and the base of each plant, and within a 1 m diameter area for the open sites, litter depth was measured and soil was sampled at depths of 0 - 10 cm and 10-20 cm. Large rocks and organic matter were removed and the samples were passed through a 2 mm sieve and

pooled across aspects for each depth per plant or open site. Soil samples were kept cool in sealed plastic bags and transported to the lab for air-drying immediately after collection. Soils were then analyzed for salinity (electrical conductance with a conductivity bridge on extracted water-soluble salts; Rhoades 1982), pH (1:1 ratio of soil to water; Mclean 1982), particle size (hydrometer method; Scheldrick and Wang 1993), soil organic matter by combustion, and total Kjeldahl nitrogen (automated salicylate procedure; Alpkem 1991).

B. Competition Experiments

Nursery Experiment

For the field and nursery competition experiments, a response surface design was used to determine treatments. Between zero and three plants of either *T. ramosissima* or *S. gooddingii* were grown in pots with between zero and three plants of *T. aphylla* (Fig. 1). I used the LMNRA nursery facility near the Boulder Beach site for the nursery portion of the study. Under a shade structure that reduced ambient light by 55%, I filled 150, 15 gallon plastic pots (30 cm diameter x 55 cm deep; ~ 2827.4 cm^3) to ca 10 cm from the top edge with soil (3:1 sand: organic matter; sand particles were < 2.0 mm in diameter and from a local source; organic matter was debris from landscaping waste).

Cuttings approximately 30 cm long and 2 cm diameter of the three species were collected in March 2005 for the nursery experiment. The cuttings were from the distal branches of at least ten healthy, pest-free plants of each species found in the LMNRA. The cuttings were dipped in Rootone® root promoter and soaked in water to initiate root growth and budding. Within two weeks of collecting the cuttings, many had initiated root growth and/or buds, and they were separated into five size classes based on length and diameter, and similar size cuttings were planted with each other in pots by removing the top 5 cm of soil, pushing the cuttings into the

soil, then replacing the top 5 cm of soil and saturating the pot with water. Cuttings were individually labeled and weighed before planting randomly into one of six equidistant spaces in a 15 cm circle located in the center of each pot (Fig 2). Five cuttings of each species from each size class were weighed then dried at 70° C to determine initial dry mass of each plant using a wet: dry mass ratio. Tensiometers were placed at a depth of 15 cm in 1 randomly chosen pot of each treatment density with both combinations of species, and pots were manually watered to saturation when soil moisture exceeded -0.4 MPa (40 centibars). The position of the pots in the shade structure and the orientation of the pots were rotated randomly at five-week intervals. Reproductive structures were removed from all plants as soon as they were observed to avoid inadvertent dispersal into the LMNRA. The dry mass of these reproductive structures was added to the final plant biomass.

After 19 weeks I counted the number of stems for each plant, measured the tallest stem, and separated new above ground growth into stems and leaves. All stems, leaves and roots were dried to a constant mass at 60° C and relative growth rate (RGR) was calculated as final dry mass / initial dry mass/ days of growth. Plants that died before the halfway point in the experiment, or that did not reach 20 cm in height were not considered in the analysis of growth data. Leaf samples from each species in each pot were analyzed for total Kjeldahl nitrogen (Alpkem 1991)

Field Experiment

Seven field sites were chosen at the water's edge in LMNRA that had sandy soil texture and slopes of < 5° to facilitate planting of cuttings. The sites were: Saddle Cove North, 33 Hole, Las Vegas Bay, Gypsum Wash, Crawdad Cove, Echo Bay, and Bonelli Wash (Fig. 3).

Cuttings were collected in April 2005 for the field experiment using the same criteria for selection as in the nursery experiment. Following initiation of root growth and/or buds, the

cuttings were separated into five size classes, weighed and labeled, then pushed into wet sand at the edge of the water, with individuals of the same size class planted at the same site, and similar sized individuals in each treatment. The field cuttings were planted in the same randomized scheme that was used in the nursery (Fig. 2). Each treatment was placed at least two meters from the nearest neighbor treatment, along shoreline transects 54-100 m long, as extremely rocky areas were avoided. Five cuttings of each species from each size class were weighed and dried at 70° C to determine wet: dry mass ratios. At the time of planting the experiments, vegetation within a 30 cm diameter of the center of the plot was pulled, and all vegetation within two meters of the plots was cut to a height of approximately 10 cm, creating a buffer zone. To deter herbivory, all plots were enclosed in 1 m tall fences using poultry netting with 2.5 cm openings. During the field experiment, voluntary plants growing within 30 cm of the center of the plot were pulled every 4-5 weeks, and the buffer zone was maintained.

After 17.5 weeks (September 2005), I counted the number of stems for each plant, measured the tallest stem (cm), and separated the stems and leaves of each plant before drying to a constant mass at 60° C. I also measured the height of the vegetation immediately above and below each treatment, and estimated adjacent vegetation cover (1= 0-25%, 2= 25-50%, 3= 50-75%, 4= 75-100%). Relative growth rate was calculated as initial dry mass/ final dry mass/ days of growth. Plants that died before reaching 20 cm in height were not considered in the analysis of growth data.

Data Analysis

For the growth experiments I built linear models composed of significant predictors to determine relative influence of species densities on relative growth rate (RGR, g/g/day), root: shoot ratio, health, number of stems and relative growth rate for height (RGRH cm/g/day). At the

same time I ruled out any adverse influence of cutting size, pot # (nursery), plot # (field) or plant position in the scheme, or controlled for any influence by using the influential variable as a covariant. For soil and vegetation characterization, means for each species were compared using ANOVA and post hoc t tests to determine whether there were significant differences in parameters measured.

Results (preliminary, final results will follow in Masters thesis and publication(s))

A. Site Characterization

Vegetation

When comparing vegetation characteristics at *T. aphylla* and *T. ramosissima* sites with Bonelli Bay and Boulder beach sites combined for each species, there were no significant differences in total woody plant cover, the percent of *Tamarix* species cover, woody plant species density, *Tamarix* species density, native woody species density, the number of native herbaceous species present, or the abundance of native species. There were significant differences in Native woody cover, which was higher in *T. aphylla* sites, and *T. aphylla* plants were significantly taller and had significantly larger canopies and basal diameters.

Soils

The parameters of soil organic matter and pH were significantly different between the Bonelli Bay and Boulder Beach sites, so comparisons were made between species at each site. Soil organic matter tended to be higher under the canopy of both species than in the open areas nearby at both field sites, but there was only one significant difference out of eight comparisons. Soil organic matter tended to be higher *T. ramosissima* than under *T. aphylla*, and the difference was significant in one of four comparisons, which was at the 10-20 cm depth at the Bonelli Landing site. Soil pH was significantly different between species at both depths for both sites,

with soil pH being higher under *T. aphylla* at Boulder Beach, and higher under *T. ramosissima* at Bonelli Landing. Soil pH was also higher in open areas near *T. aphylla* at Bonelli Landing, but not at Boulder Beach.

B. Competition Experiments

Nursery Competition Experiment

Overall, *T. ramosissima* had the highest mean RGR, followed by *S. gooddingii* and *T. aphylla*. *Tamarix ramosissima* and *S. gooddingii* had significantly higher growth rates than *T. aphylla*, but did not differ from each other (Fig. 4). The only response and predictor variable combination to show significant interactions were RGR and species densities. In competition with *T. ramosissima*, *T. aphylla* RGR was decreased by increases in densities of either species, but the effect of *T. ramosissima* was more negative, with the densities of both species and the interaction of those densities being significant predictors (Fig. 5). *T. ramosissima* was similarly negatively affected by increases in density of either species, but less negatively affected by increases in *T. aphylla* density than it was by increases in its own density, with the densities of both species being significant predictors (Fig. 6). Regarding competition between *T. aphylla* and *S. gooddingii*, *T. aphylla* RGR was negatively affected by increases in either species, but was more negatively affected by increases in its own density than by increases in *S. gooddingii* density, with the densities of both species being significant predictors (Fig. 7). *Salix gooddingii* RGR was also negatively affected by increases in either species, but was more negatively affected by increases in *T. aphylla* density than by increases in its own density, with the densities of both species and the interaction of the densities of both species being significant predictors (Fig. 8). Linear equations for each paring of species and correlation coefficients are listed in table 1.

Field Competition Experiment

In the field there was high mortality with 59.9% survival of *T. aphylla*, 47.2% survival of *T. ramosissima*, and 37.5% survival of *S. gooddingii*. Overall, *S. gooddingii* had the highest mean RGR. The RGR of *S. gooddingii* was significantly higher than that of either *T. aphylla* or *T. ramosissima*, which did not differ significantly in their mean RGR's, though the mean RGR for *T. aphylla* was slightly higher than that of *T. ramosissima* (Fig. 9). In competition with *T. ramosissima*, *T. aphylla* RGR tended to decrease with increases in *T. ramosissima* density, but *T. aphylla* RGR significantly increased with increases in its own density. *Tamarix ramosissima* RGR tended to decrease with increases in its own density and increases in *T. aphylla* density, but there were no significant interactions. In competition with *S. gooddingii*, *T. aphylla* RGR tended to decrease with increases in *S. gooddingii* density, and again *T. aphylla* RGR significantly increased with increases in its own density. *Salix gooddingii* RGR tended to decrease with increases in its own density, and increase with increased density of *T. aphylla*, but there were no significant interactions. Because of the lack of significant predictor variables in the field experiment, no linear equations are listed.

Summary

Specific questions that were to be addressed as per the proposal were:

1. Does athel (*T. aphylla*) colonization inhibit saltcedar (*T. ramosissima*) colonization and stand development? Does athel colonization inhibit colonization and stand development of native lakeshore plants? From the results of the nursery growth competition experiment, it appears that while increases in the density of *T. aphylla* do have a negative effect on the RGR of *T. ramosissima*, the negative effect of the increase of *T. ramosissima* density on its own RGR is greater. Concerning native plants, there was no difference between the effect of *T. aphylla* and *T.*

ramosissima on parameters of herbaceous species diversity and abundance, but there was higher native woody plant cover in *T. aphylla* stands. This indicates that *T. ramosissima* may be more detrimental to native plants, but it is not certain whether the native woody plants were present before *T. aphylla* invaded.

2. Does *T. aphylla* colonization increase soil salt levels beyond the tolerance levels of *T. ramosissima*? Does *T. aphylla* colonization increase colonization of native lakeshore plants? Analysis of soil salinity is ongoing, and results will be presented in the completed thesis and publication(s) to follow.

3. Does *T. aphylla* colonization reduce soil moisture below levels found under developing stands of *T. ramosissima* or native lakeshore plants? Data for soil moisture could not be collected because soil samples had to be collected ahead of schedule and in a shortened time period during the abnormally wet spring of 2005 due to efforts to control *T. aphylla* in LMNRA.

4. Does *T. aphylla* colonization alter major soil nutrients in ways that favor its growth over *T. ramosissima* or native lakeshore plants? The differences in pH between *T. aphylla* and *T. ramosissima* stands were inconsistent, and will be further analyzed to determine their potential influence on the growth native and non-native plants. The tendency for soil organic matter to be higher under *T. ramosissima* may result in better growing conditions for plants if there is increased nitrogen as a result without severely increased soil salinity. Soil nitrogen and salinity analysis ongoing, and more detailed results will be presented in the completed thesis and publication(s) to follow.

Deliverables as per the proposal were:

1. Quarterly reports submitted to the Clark County MSHCP database.
2. Final Project Report submitted to the Clark County MSHCP database.

3. Written and oral reports to the Clark Count and/or the Implementation and Monitoring Committee upon Request.
4. Final Report due June 30, 2006.
5. A Masters thesis through the University of Nevada Las Vegas Biology Department (Lawrence Walker, Committee Chair) on this topic and paper submitted for publication produced by the third or fourth year after the initiation of the project.

All deliverables will be fulfilled when Masters thesis and publication are complete.

Appendix A. Figures

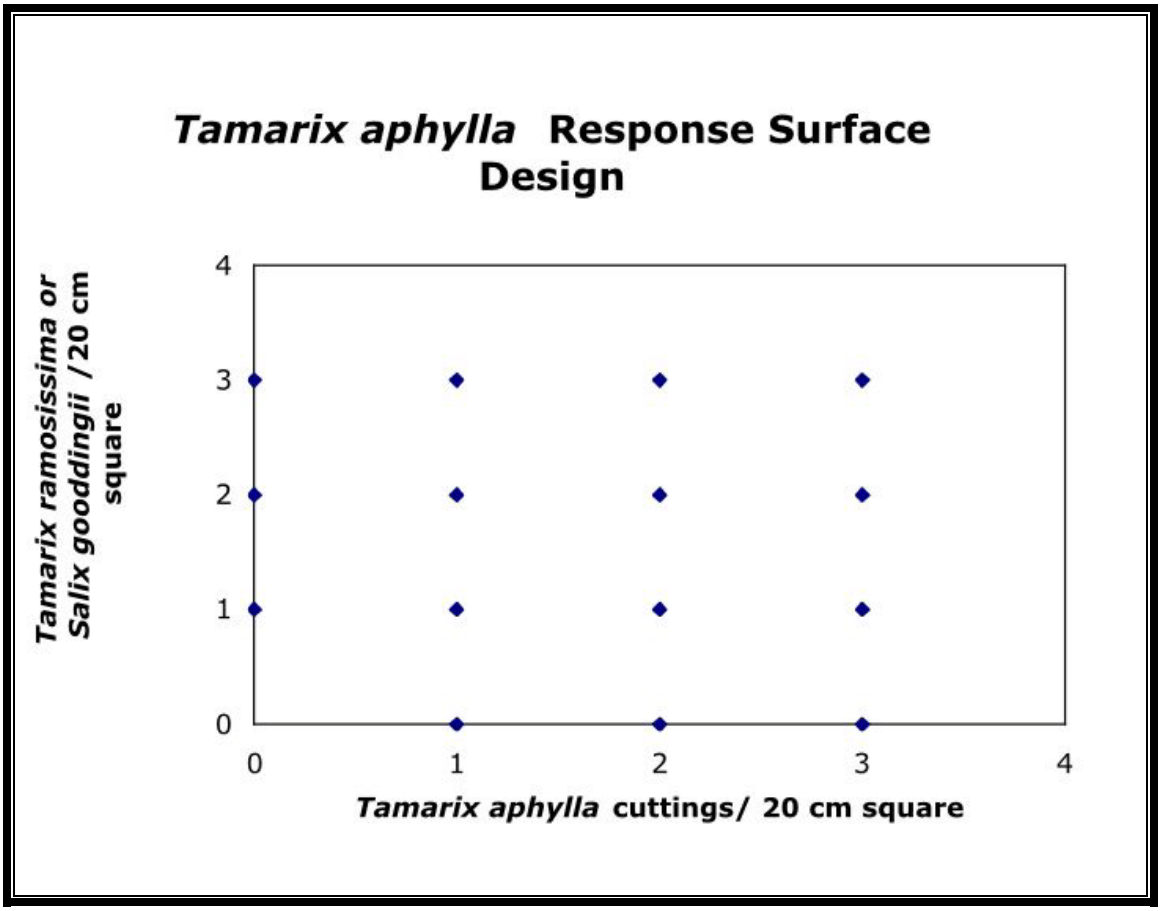

Figure 1. Response surface growth competition design.

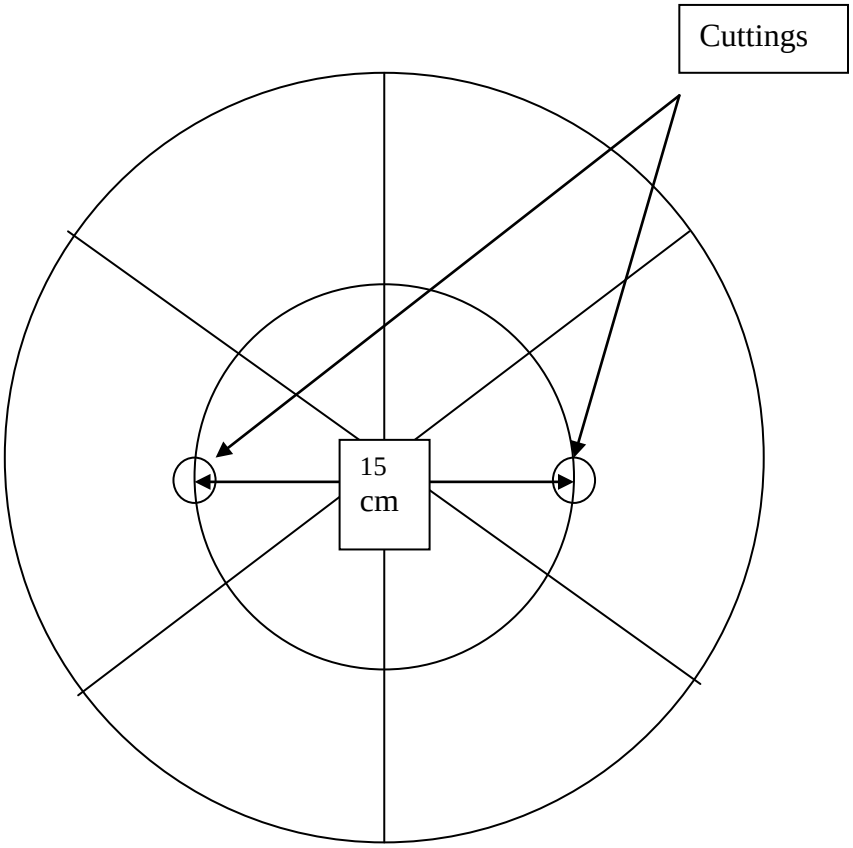

Figure 2. Top view of the arrangement of two plants within a pot in the nursery competition experiment.

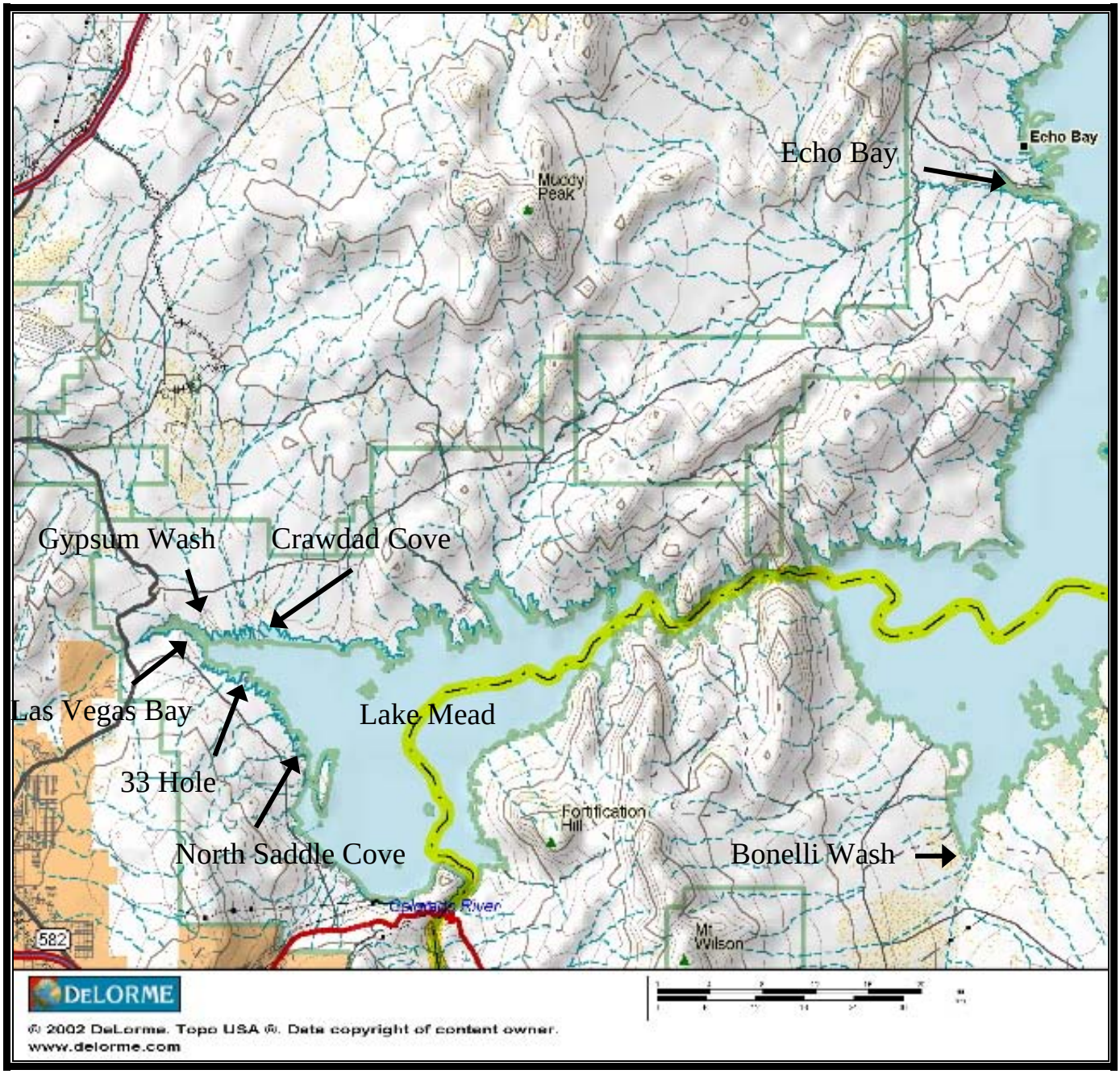

Figure 3. Field competition experiment sites.

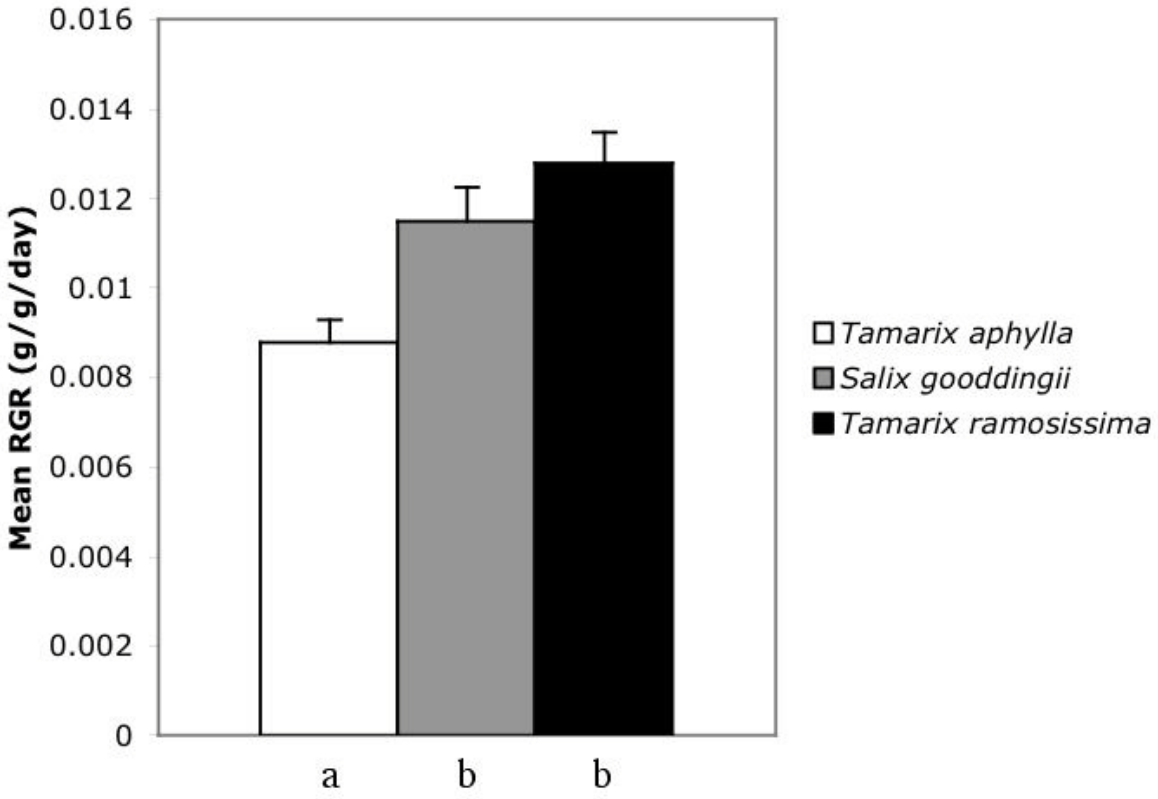

Figure 4. Relative growth rates (RGR, g/g/day) of each species in the nursery competition experiment with standard errors. Different letters indicate significant differences in RGR.

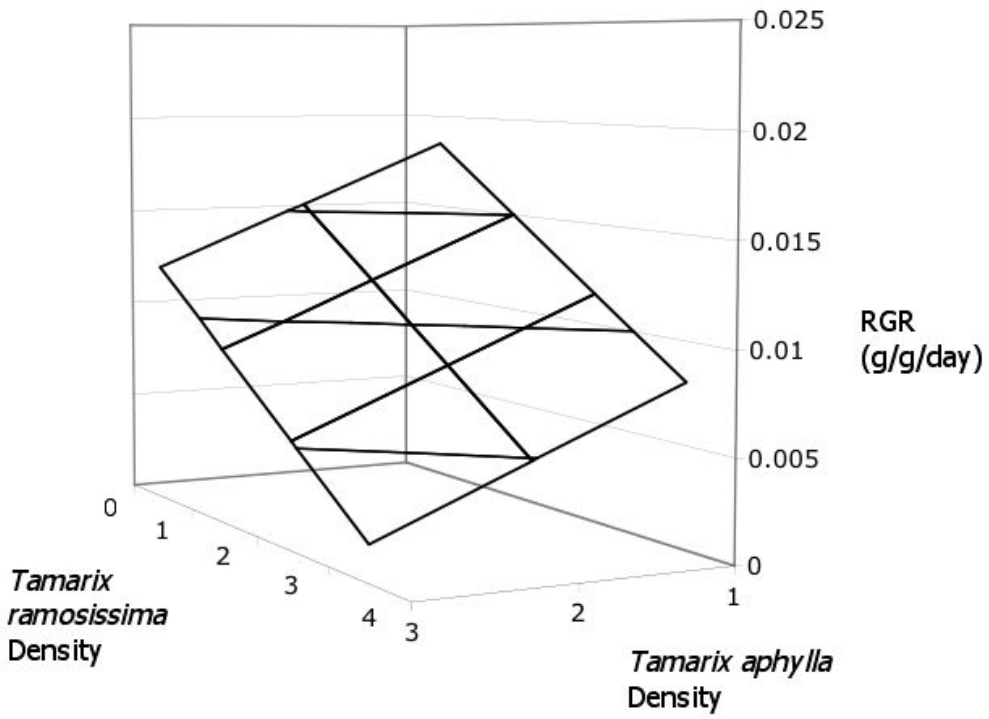

Figure 5. The response of *T. aphylla* relative growth rate (RGR) in competition with *T. ramosissima*.

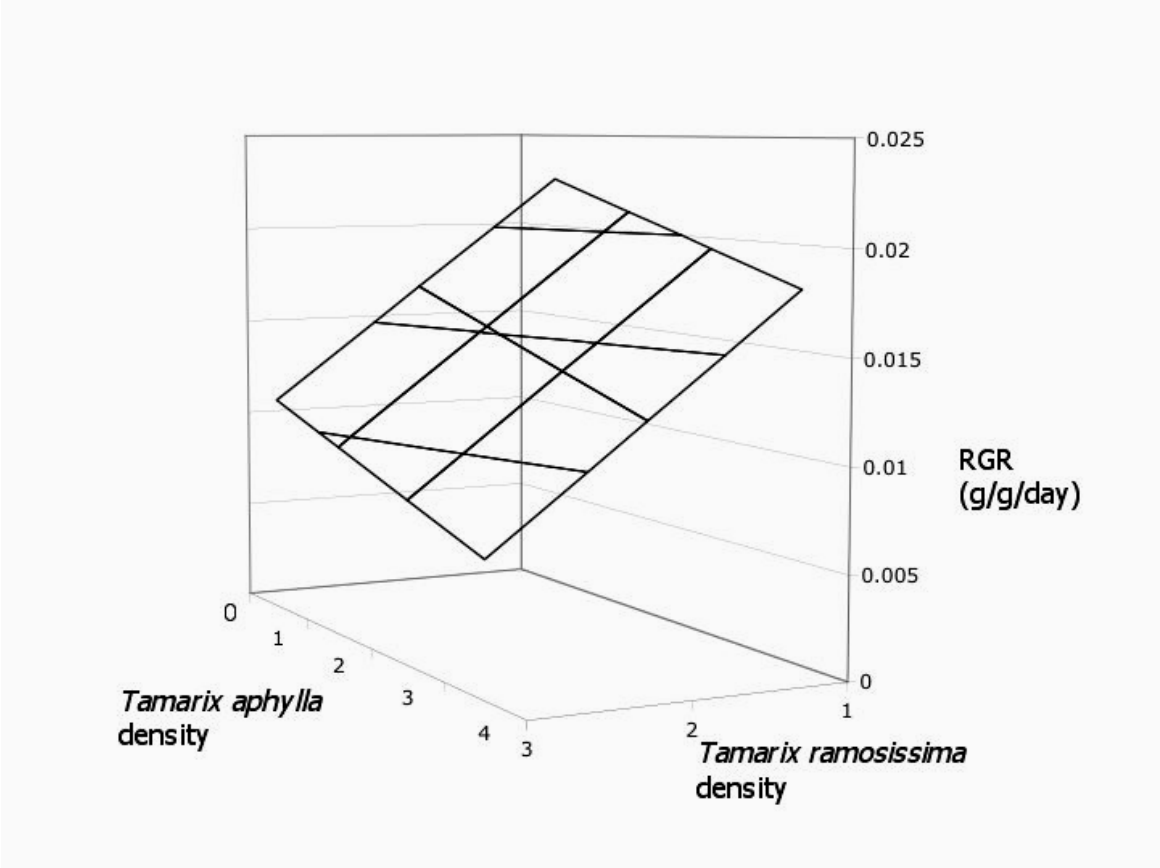

Figure 6. The response of *T. ramosissima* relative growth rate (RGR) in competition with *T. aphylla*.

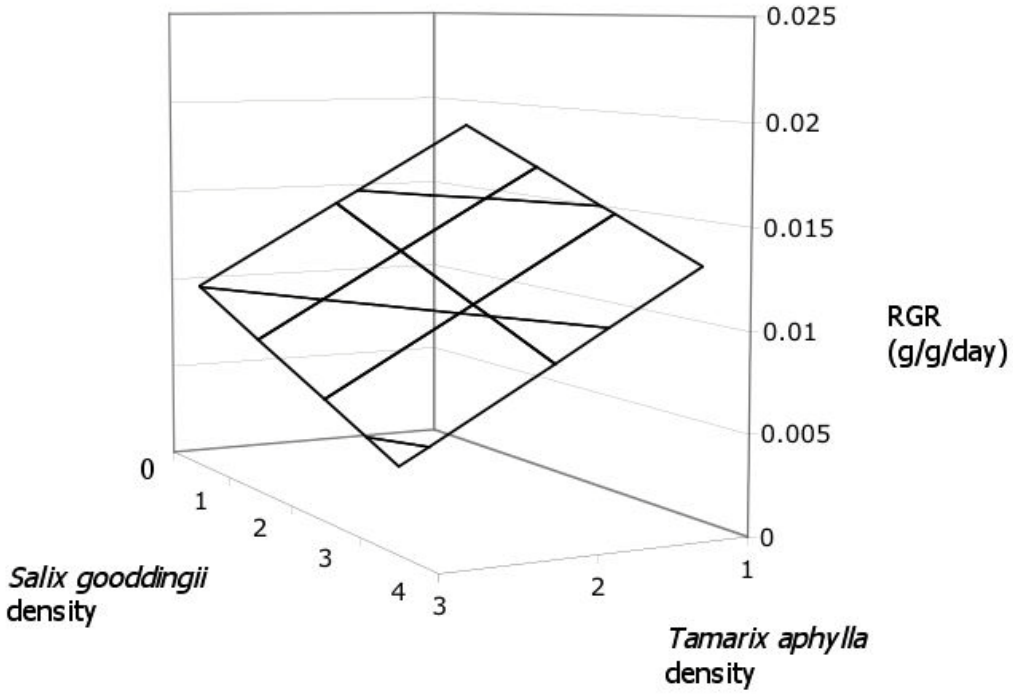

Figure 7. The Response of *T. aphylla* relative growth rate (RGR) in competiton with *S. gooddingii*.

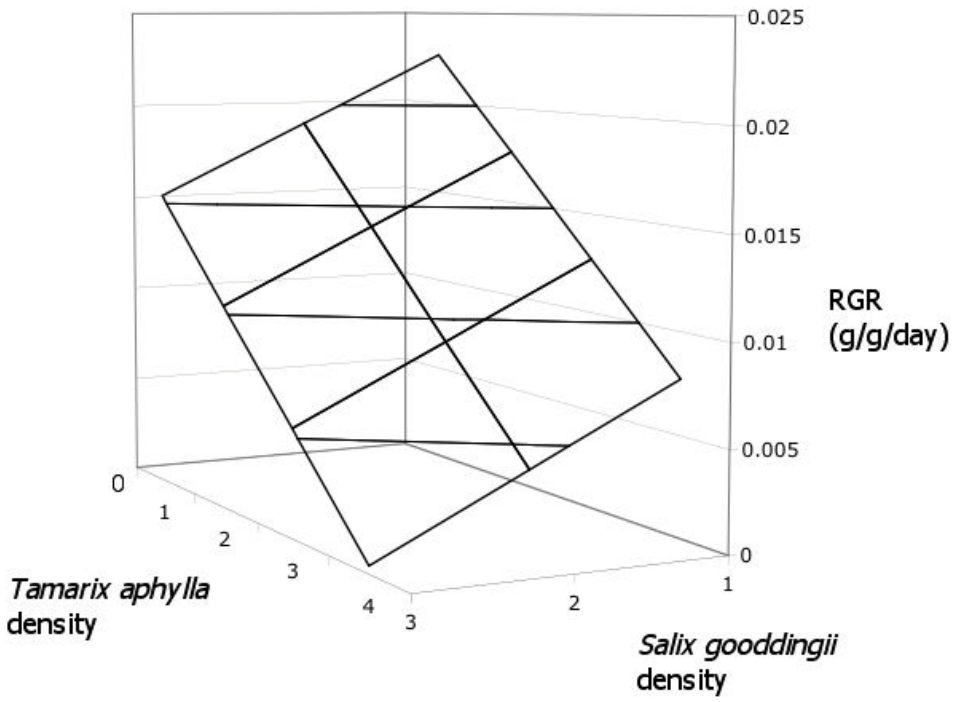

Figure 8. The response of *S. gooddingii* relative growth rate (RGR) in competition with *T. aphylla*.

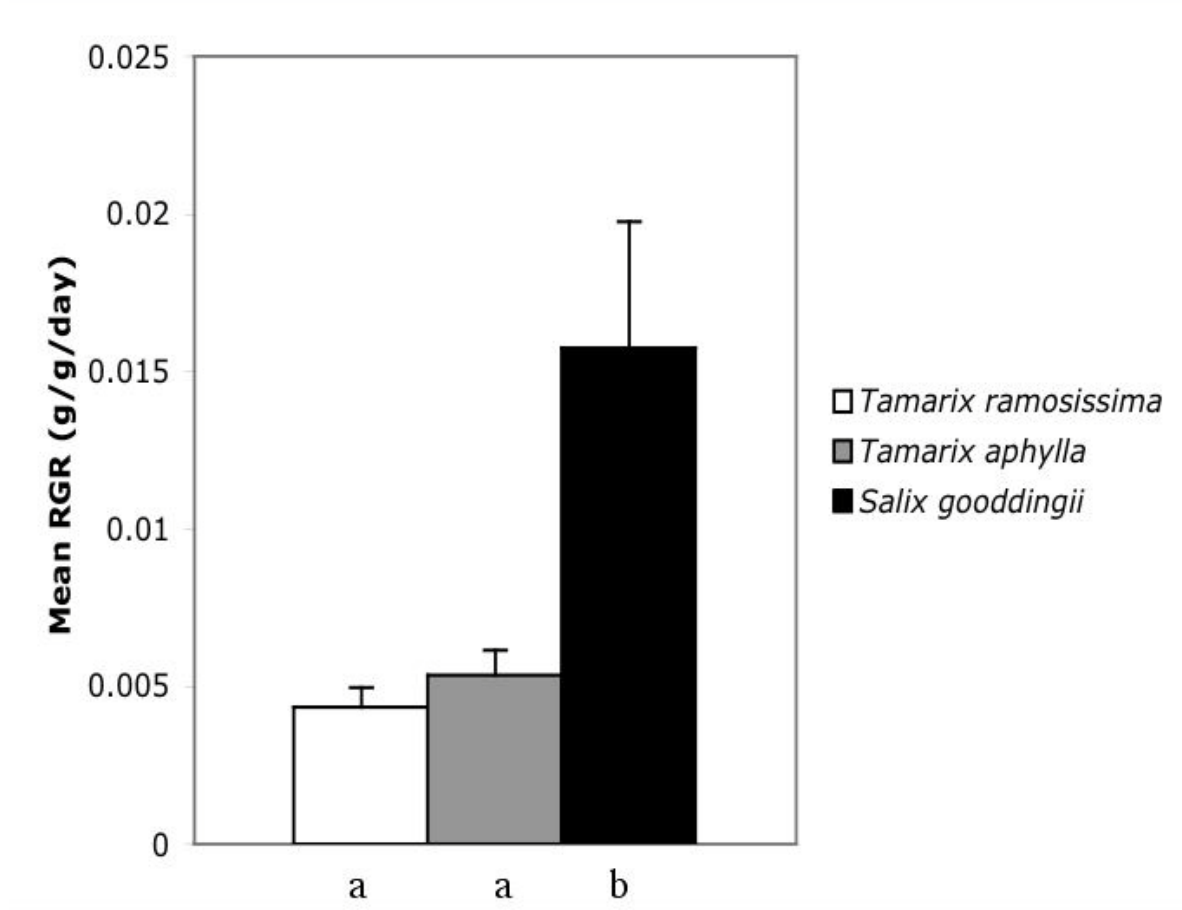

Figure 9. Relative growth rates of plants in the field competition experiment with standard errors. Different letters indicate significant differences in RGR.

Appendix B. Tables

Table 1. Linear equations and correlation coefficients for the nursery growth competition experiment.

Species	Linear Equation	Correlation Coefficient (r^2)
T. aphylla RGR vs. *T. ramosissima*	RGR = 0.01969 - 0.03134 (*T. aphylla* density) - 0.003486 (*T. ramosissima* density) + .0019391	0.58
T. ramosissima RGR vs. *T. aphylla*	RGR = 0.02834 – 0.005751 (*T. ramosissima* density) - .001562 (*T. aphylla* density)	0.33
T. aphylla RGR vs. *S. gooddingii*	RGR = 0.02285 – 0.004269 (*T. aphylla* density) – 0.001954 (*S. gooddingii* density)	0.43
S. gooddingii RGR vs. *T. aphylla*	RGR = 0.02634 – 0.03662 (*S. gooddingii* density) – 0.004984 (*T. aphylla* density) + 0.003441	0.57

Appendix C. Literature Cited

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