The Effect of Tamarisk on Biodiversity and Soil Salinity in Western Colorado Ecosystems - *Winner of the 2007 Robert N. Hancock Memorial Scholarship for the best original technical paper written by a student on a topic in the fields of science or engineering (not peer reviewed)*

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Introduction

Invasive species are non-native species that invade undisturbed or lightly disturbed habitats (T. Minnick, unpublished). In the early 19th century, the invasive shrub, tamarisk, was imported into the United States from Eurasia to be sold as an ornamental shrub, and for windbreaks, shade, and erosion stabilization (T. Minnick, unpublished). During the 1870s, in addition to intentional plantings, tamarisk began to spread on its own accord (Hart 1999). It has a long life span, rapid reproduction, a fast growth rate of up to 4 centimeters per day, high water consumption, and an ability to grow and thrive in a variety of environmental conditions (Zavaleta 2000).

Tamarisk tend to develop into dense stands along riparian corridors, aggressively competing with native plant species (Tamarisk Coalition 2003). Its presence alters the natural dynamics of the ecosystem, which frequently leads to a decline in native species biodiversity (T. Minnick, unpublished). The 20th century saw a reduction in the number of native cottonwood and willow species on the majority of the major rivers in the southwestern United States, while tamarisk has become increasingly more prevalent (Nagler et al. 2005). In addition to the native plant species being affected, wildlife has also suffered as a result of the presence of tamarisk (Nagler et al. 2005).

Tamarisk is a salt-tolerant halophyte that is capable of surviving even extremely salty soils (T. Minnick, unpublished). This ability proves favorable for tamarisk by allowing it to flourish in conditions that are not conducive to many native plants.

Furthermore, tamarisk undergoes processes that lead to an increase in soil salinity in the areas that they occupy (Barrows 1996). For the more salt-intolerant plants such as cottonwoods and willows, high soil salinity inhibits seed germination and transpiration abilities (T. Minnick, unpublished). These factors culminate in an environment that becomes more suitable for tamarisk and less conducive for the success of many native species.

The objective of this study was to determine the effects that the presence or absence of tamarisk has on biodiversity, as well as how the proportion of tamarisk factors into this. Furthermore, this study sought to compare soil salinity measurements among sites inhabited by, or lacking, tamarisk. The following questions were asked: 1) Does the presence of tamarisk reduce biodiversity? 2) Does the presence of tamarisk lead to increased soil salinity? 3) How does the proportion of tamarisk infestation relate to biodiversity and soil salinity?

Materials and Methods

Site Descriptions

For the purposes of this study, four areas were sampled on public land west of Grand Junction, Colorado. The areas were Blue Heron, Devil's Canyon streamside, Devil's Canyon upland, and Bang's Canyon. At Blue Heron, the data were acquired on the outskirts of the Blue Heron lake basin, off the edge of a sloped embankment that separated the lake from the Colorado River. At this site there were dense, monotypic stands of tamarisk, and kochia populations were prevalent in the undergrowth. Devil's Canyon streamside was an ephemeral stream canyon with dense stands of tamarisk along the stream corridor interspersed with sporadic rabbitbrush and sparse populations of inland saltgrass. Devil's Canyon upland was a sloped shrubland hillside descending from a plateau ridge characterized by patches of exposed sandstone bedrock and no localized waterways. This site contained old-growth pinyon/juniper stands interspersed with small sagebrush and snakeweed. This site had no tamarisk. Bang's Canyon was a higher elevation (above 6000 ft) ephemeral stream canyon with steep topography and cliff-forming sandstone faces. The biotic environment was comprised of dense, woody vegetation dominated by native plant species. Among the plant species present were pinyons, junipers, and sagebrush in the surrounding areas, and young cottonwoods, willows, and various brush species along the stream channel. At this site, there was no tamarisk within any of the sample areas, but a single tamarisk was present in an adjacent area.

Transect Setup and Plant Measurements

For the purpose of collecting the biodiversity data, a 50-meter transect was placed at random within the test area. The data were collected by positioning 1-meter-square quadrats along the transect, from which the measurements of canopy cover for each plant species present were estimated by using one clenched fist to represent 2 percent of the quadrat. The plant species were properly identified and the percent of cover for each was recorded. The data were acquired from a total of 11 sample areas along the transect, whose locations, as such, were chosen by random number generation.

Soil Electrical Conductivity Measurements

Soil samples were collected to measure the salinity of the soil. The samples were collected from the approximate center of the quadrats as previously placed along the transect for the biodiversity measurements. The top surface of the soil was scraped away to remove the potential for contamination of the sample by vegetation prior to soil collection. An electrical conductivity meter was used to measure soil salinity in µS/cm by testing a mixture of 25 grams of soil and 50 mL of distilled water.

Statistical Analysis

The collected data set were subjected to statistical analysis for the purpose of comparing each of the sample areas to one another. Canopy cover of each species in their respective sample areas was analyzed to determine the relative abundance of each, and the proportion of the total coverage that was tamarisk. These data were used in a Shannon Calculation to derive the H' value for each of the areas based on the means of the 11 data sets taken from each area. Variance and standard error were calculated for the derived data, and t-tests were performed comparing H' values, proportion of tamarisk, and soil conductivity between each of the four test sites.

Results

H' Values for Biodiversity Comparison

The H' values for each area allow the areas to be compared to one another in order to ascertain the differences in biodiversity among the sample areas. Blue Heron yielded an H' value of 0.65 (SE 0.03), which was not significantly different from Devil's Canyon upland at 0.78 (SE 0.09), or Bang's Canyon at 0.65 (SE 0.13) (Fig. 1, Table 1). Devil's Canyon streamside had the lowest H' value at 0.1 (SE 0.05), and was significantly different from the other three areas.

Proportion of Tamarisk

The proportion of the total coverage of the plant species present in each area that was tamarisk was figured for comparison purposes. Blue Heron and Devil's Canyon streamside had tamarisk as 65% (SE 0.04) and 97% (SE 0.02) of the total coverage, respectively (Fig. 2), and there was a significant difference between the two (Table 2). Devil's Canyon upland and Bang's Canyon each had no tamarisk present.

Soil Conductivity

Soil conductivity measurements revealed a higher rate of salinity in the two areas that had tamarisk populations than the two that did not. On average, Blue Heron had an electrical conductivity measurement of 1136.36 µS/cm (SE 181.55) (Fig. 3). Devil's Canyon streamside had an average measurement of 1645.55 µS/cm (SE 637.05), and was not significantly different from Blue Heron (Table 3). Devil's Canyon upland and Bang's Canyon yielded much lower average measurements with 47.95 µS/cm (SE 6.84) and 36.18 µS/cm (SE 2.58), respectively, and were significantly different from Blue Heron and Devil's Canyon streamside, but not from each other.

Discussion

Biodiversity of the Sample Areas

The hypothesis that the presence of tamarisk reduces biodiversity was supported by the data when Devil's Canyon streamside was compared to Devil's Canyon upland and Bang's Canyon, but was not supported by data obtained at Blue Heron. Blue Heron was somewhat anomalous in that it was heavily infested with tamarisk, but still produced a high H' value. This is explained by the dense populations of kochia in the undergrowth, which had a high rate of coverage, nearly paralleling that of the tamarisk. The importance of this is to note that for this study, the Shannon Calculation does not analyze what plants are present in a sample area, or whether or not they are beneficial, weedy, or invasive. Therefore, the H' values obtained for an area in this study only distinguish a figure of biodiversity and not the intrinsic value of the species in that area.

Another interesting discovery from the biodiversity data is the level of variance that existed among the sample areas. Devil's Canyon upland and Bang's Canyon, which had higher levels of native plant species, showed a higher level of variance than Blue Heron and Devil's Canyon streamside, suggesting that from the 11 quadrats at each transect, the previous two had a greater difference in the type and amount of species present, while the latter two were confined to more monotypic populations.

Proportion of Tamarisk and Soil Salinity

Of the sample areas, Blue Heron and Devil's Canyon streamside had high proportions of tamarisk while Devil's Canyon upland and Bang's Canyon did not. This becomes significant when the soil salinity results are considered. Although it is impossible to conclude from the tests that were conducted during this study whether the tamarisk caused the soil salinity levels to be high, or if the salinity levels were already high, thereby catering to the tamarisk's halophytic tendencies, the data support that the soil salinity levels are substantially higher in areas that contain tamarisk populations. The hypothesis that the presence of tamarisk increases soil salinity can, therefore, not be determined by this study, but the data obtained from it corroborates other scientific studies that have shown that the tamarisk draws deeply buried salts up from the soil and ground water and deposits them on the surface, thereby increasing the salinity of the soil to as much as 41,000 parts per million (ppm) (approx. 28,700 µS/cm) (Barrows 1996).

Soil salinity becomes especially important when considering the ability of native plant species to exist in highly saline soils. Native cottonwoods and willows are only able to withstand salt levels of up to 1500 ppm (approx. 1050 µS/cm), whereas the tamarisk, as a highly adept halophyte, can tolerate levels of up to 36,000 ppm (approx. 25,200 µS/cm) (Hart 1999). From these data, it is suggested that current soil salinity levels at Blue Heron and Devil's Canyon streamside are such that they would prevent cottonwoods and willows from being able to exist at these locations.

Conclusions

The overall impression acquired from being at the test sites is that tamarisk develop into dense, seemingly impenetrable, monotypic stands. This is supported by the proportion of tamarisk data obtained at Blue Heron and Devil's Canyon streamside. It is this ability of tamarisk to develop into stands where as many as 3000 of these plants may occupy a single acre of land that leads to the decimation of the native plant species, resulting in a potential for the complete loss of native plant species biodiversity (Tamarisk Coalition 2003). Furthermore, although not addressed in this study, tamarisk's thirst for up to 300 gallons of water per shrub per day creates intense competition for this resource between the tamarisk and native species, especially in drier areas, which has a direct impact on the biodiversity of native plants (Tamarisk Coalition 2003). It is also noteworthy that the Blue Heron site is located in immediate proximity to the Colorado River, and in the Western United States, the economic loss due to the tamarisk's consumption of water that may otherwise usefully contribute to the river systems is estimated at $284.5 million annually, posing yet another concern for losing this water to the tamarisk (Zavaleta 2000).

Soil salinity bears consequences for both the ability of native plants to exist in areas inhabited by, and potentially previously inhabited by, tamarisk. There are also other issues brought on by increased soil salinity. Once the salts are brought up to the surface of the ground, they become a part of the environment that they would not have otherwise been a part of. They change the chemistry of the soil, which affects the plant species, and they also affect the water systems by being washed or leached into waterways. This has economic implications by creating a need to desalinate the water, which costs the United States millions of dollars each year (Mielke 1999).

The data from this study support the conclusion that the tamarisk alters the ecosystems in which it inhabits. There is a reduction in the biodiversity of, and occurrence of, native plant species in the presence of tamarisk. Once established, the tamarisk form dense stands, reducing the ability of native plants to compete successfully, especially in disturbed areas. And finally, soil salinity levels are substantially higher in areas occupied by tamarisk, which is detrimental to many native species.

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Biography of Author

Scott Distel is a junior at Mesa State College in Grand Junction, Colorado, majoring in environmental science and technology. He graduated from Olathe (CO) High School in 1997 where he was a member of the National Honor Society and the National Vocational-Technical Honor Society. Beginning in middle school and throughout high school, he was one of the founding members of an environmental awareness and recycling club, Students Against a Vanishing Earth (S.A.V.E.), that continues at the school to this day. He graduated from Intellitec College, a technical college in Grand Junction, Colorado, in December 2000, earning an Associate Degree of Occupational Studies in Electronic Engineering Technology, and became certified in electronics and microcomputers. In addition to Mesa State classes, he is in the early stages of an ecosystem restoration project, working in cooperation with local landowners and the Natural Resources Conservation Service to remove the invasive species tamarisk and Russian olive from Dry Creek Basin, a natural watershed in his local area.

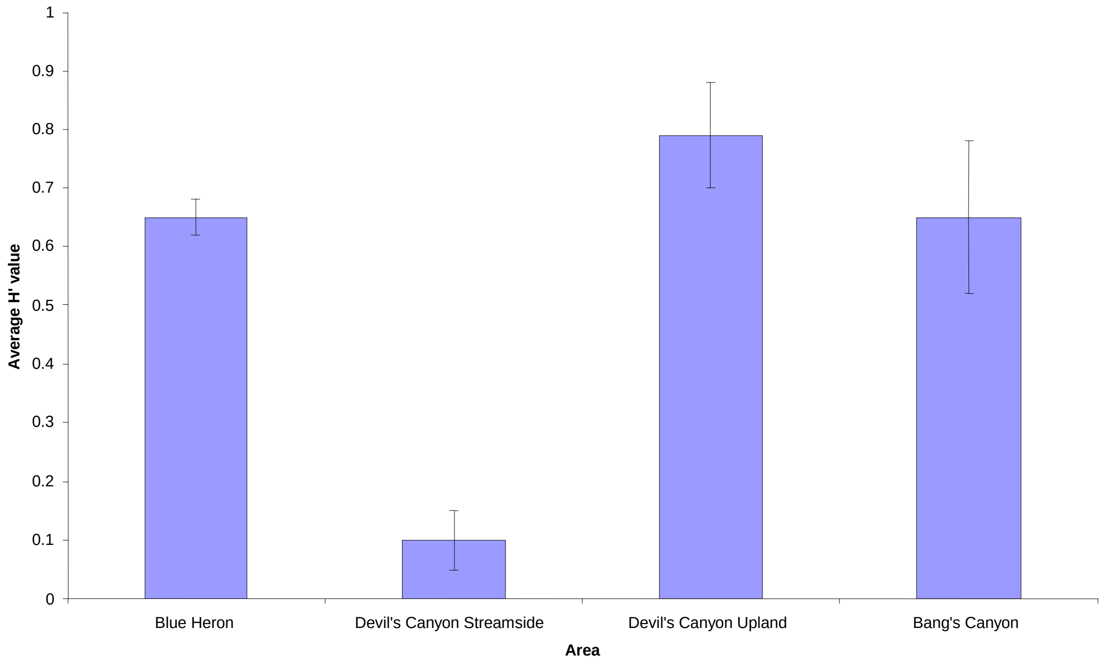

Fig. 1. The average H' values are given for each area. (Error bars are +/- 1 SE).

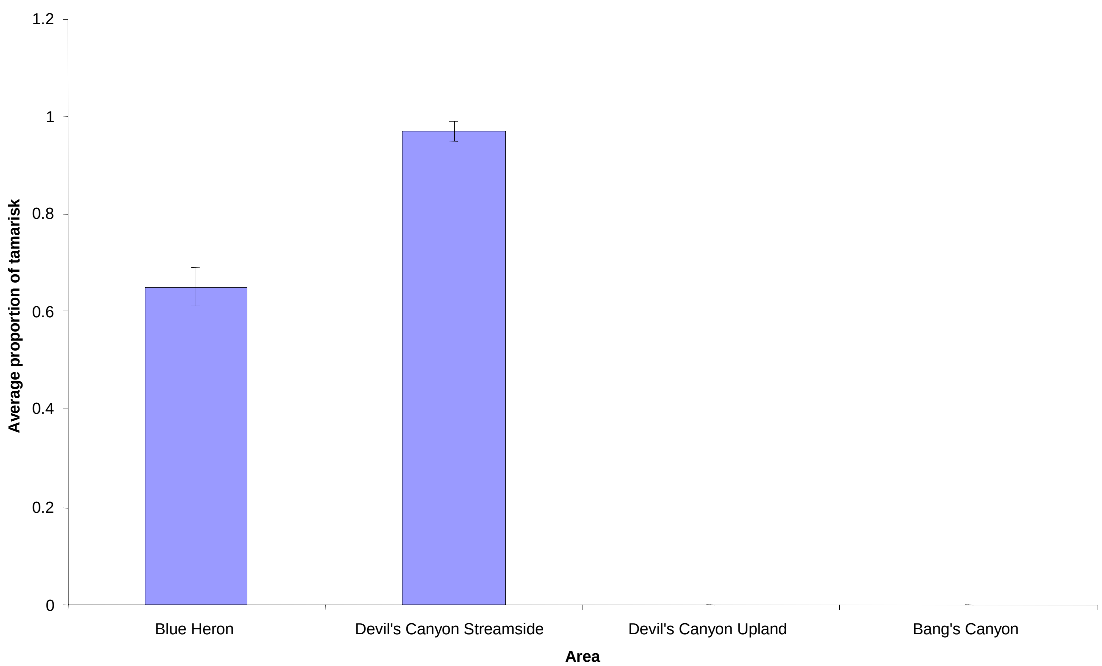

Fig. 2. The proportion of tamarisk is given for each area. (Error bars are +/- 1 SE).

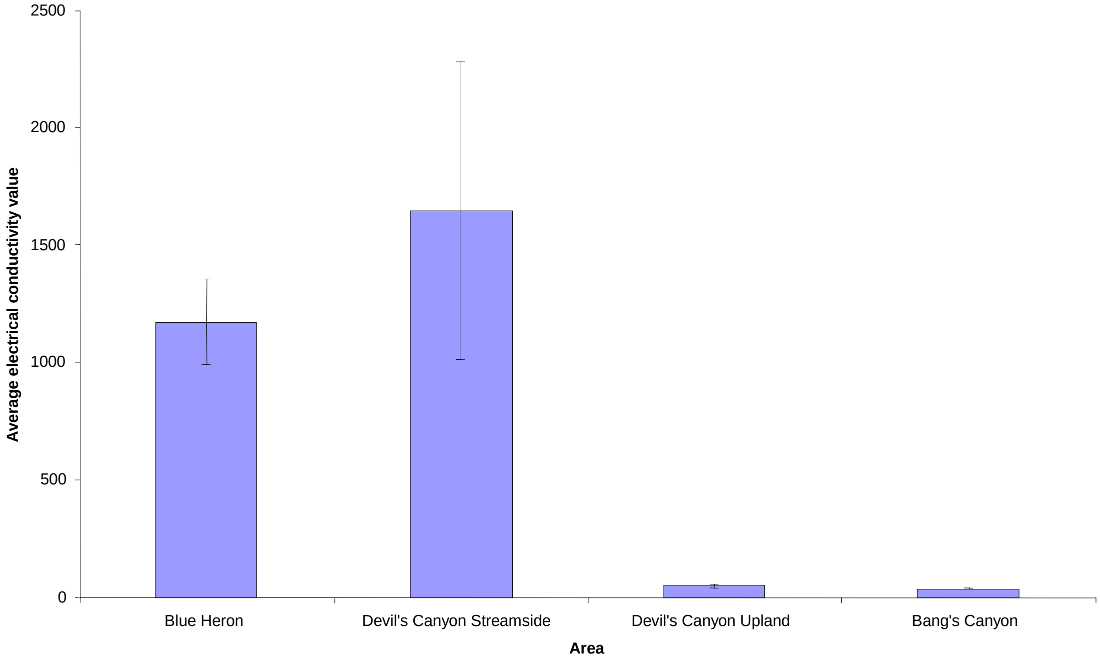

Fig. 3. The average electrical conductivity values in uS/cm are given for each area. (Error bars are +/- 1 SE).

Table 1. The T-test results for H' are shown for the areas: Blue Heron (BH), Devil's Canyon Streamside (DCS), Devil's Canyon Upland (DCU), and Bang's Canyon (BC).

Comparison	T-stat	T-critical	Df	P	Conclusion
BH vs. DCS	9.121	2.086	20	P < 0.05	There is a significant difference between the means.
BH vs. DCU	1.363	2.086	20	P > 0.05	There is no significant difference between the means.
BH vs. BC	0.014	2.086	20	P > 0.05	There is no significant difference between the means.
DCS vs. DCU	6.511	2.086	20	P < 0.05	There is a significant difference between the means.
DCS vs. BC	3.889	2.086	20	P < 0.05	There is a significant difference between the means.
DCU vs. BC	0.815	2.086	20	P > 0.05	There is no significant difference between the means.

Table 2. The T-test results for proportion of tamarisk are shown for the areas: Blue Heron (BH), Devil's Canyon Streamside (DCS), Devil's Canyon Upland (DCU), and Bang's Canyon (BC).

Comparison	T-stat	T-critical	Df	P	Conclusion
BH vs. DCS	8.970	2.086	20	P < 0.05	There is a significant difference between the means.
BH vs. DCU	21.558	2.086	20	P < 0.05	There is a significant difference between the means.
BH vs. BC	21.558	2.086	20	P < 0.05	There is a significant difference between the means.
DCS vs. DCU	50.867	2.086	20	P < 0.05	There is a significant difference between the means.

Table 3. The T-test results for soil electrical conductivity are shown for the areas: Blue Heron (BH), Devil's Canyon Streamside (DCS), Devil's Canyon Upland (DCU), and Bang's Canyon (BC).

Comparison	T-stat	T-critical	Df	P	Conclusion
BH vs. DCS	0.719	2.086	20	P > 0.05	There is no significant difference between the means.
BH vs. DCU	6.173	2.086	20	P < 0.05	There is a significant difference between the means.
BH vs. BC	6.241	2.086	20	P < 0.05	There is a significant difference between the means.
DCS vs. DCU	2.508	2.086	20	P < 0.05	There is a significant difference between the means.