Russian Olive Invasion: A Case Study at Aztec Ruins National Monument

Bethany Reed
Mentor: Dr. Cynthia Dott
Environmental Biology
Fort Lewis College

Abstract

The purpose of this case study was to investigate the impact of ecological and historical factors on the Russian olive invasion in the Animas River Watershed in Aztec, New Mexico. Russian olive is a prominent invasive species found in many riparian corridors in the southwestern United States. Though its success can be inhibited by the flow fluctuations of unregulated rivers, the banks of the Animas River in and around Aztec are heavily infested with this species. Data collected from treated, untreated, and recently infested areas of land at Aztec Ruins National Monument showed significant differences in understory composition and retention of Russian olive seeds in the soil. Regression analyses of tree size vs. tree ring number allowed for the calculation of average tree age as well as variance in age distribution in untreated and agricultural areas. Ground water wells revealed that proximity to ground water is not a limiting factor in Russian olive growth rate. Examination of historical aerial photos provided some evidence that all areas were used for agricultural purposes and may contribute to why this and surrounding areas are uniquely affected by Russian olive. The complete removal of Russian olive is still a controversial topic in the southwest. Land managers must make decisions on a case by case basis, as the success of Russian olive establishment and the rate of succession into previously uninfected areas is likely linked to several biotic and abiotic variables.

Introduction

Invasive species like Russian olive, tamarisk, and non-native knapweed have altered ecosystems in the southwest by outcompeting native species and turning once biologically diverse areas into single species stands or wastes. This dramatic change in vegetation has in turn altered habitats for native animals and reduced overall biodiversity. Some invasive species even alter soil composition by increasing salinity or nitrogen levels, and often uptake greater amounts of water than native species, depleting one of the Southwest's most valuable resources. Riparian ecosystems provide a variety of niches and can often host more specialized species, which are especially susceptible to invasives. These delicate systems are in need of careful consideration when studying the effects of invasive species in the Southwest.

Species Description

Russian olive (*Elaeagnus angustifolia*) is one of the most prominent invasive species in the southwestern United States. Native to eastern Europe and central Asia, Russian olive was intentionally brought to the States as a hearty plant that could withstand high levels of soil salinity, high winds, and little water (Kats and Shafroth, 2003). Since its arrival in the early 1900s, it has escaped cultivation and spread throughout the southwest. It is now commonly found alongside rivers as well as part of sage steppe communities (Collette and Pither, 2015).

Russian olive ranges in size from small shrubs to medium-sized trees. It can be easily recognized by the silvery-grey color of its leaves which contrast against the greener color of native riparian species, such as cotton woods. Russian olive takes three years to reach maturity and produces large seeds that can be viable for up to ten years. It is also a nitrogen fixer, which gives it a distinct advantage when competing with native species (Kats and Shafroth, 2003).

Like other invasives found commonly in the southwest, Russian olive is a generalist species, able to tolerate a wide range of abiotic conditions, including variable levels of shade, water, and soil composition. These qualities give Russian olive advantages when competing with native species, especially those in riparian areas. However, Russian olive is different from other invasive species in that it does not seem to heavily rely on disturbed areas to establish (Kats and Shafroth, 2003; Lesica and Miles, 2001). Areas that have been altered by humans, such as agricultural land, as well as naturally occurring changes in landscape and vegetation, are usually at a higher risk for hosting invasive species. Unlike tamarisk, a similarly prevalent invasive species in the southwest, Russian olive has been observed to succeed by sprouting in the understory of already established stands of native trees, with no sign of local disturbance (Kats and Shafroth, 2003). This deviation from the norm leaves us to question what, if anything, leads Russian olive to establish in some places rather than others.

History of Russian Olive in New Mexico

The earliest mention of Russian olive at a specific location in New Mexico is Mesilla Park in Las Cruces. Fabián García, a former researcher at current day NMSU, described Russian olive in his book published in 1903. Garcia only hints at the extent of Russian olive range at that time by mentioning that it was used in some portions of the west as a hedge plant and wind break (Garcia, 1903).

By 1915, Russian olive was being cultivated at many more locations throughout New Mexico (Finch and Wolters, 1995) and was well established in nearby states by 1924 (Christensen, 1963). Though the exact date Russian olive was brought to the American southwest is uncertain, it is clear that this relatively slow-growing plant has had more than enough time to become an established part of our river systems.

Age of Russian Olive stands and Individuals

The relative ages of Russian olive individuals in a particular stand may provide evidence as to where the stand first established. Age of individuals can be determined using dendrochronology and examining tree cores or tree cookies (cross-sections). There are several methods to interpreting tree rings and differing levels of reliability when it comes to the accuracy of data across different species and locations (Douglass, 1941). Determining relative ages of trees in the same population is simpler by comparison and consists of counting the rings of a sample taken from the base of an individual. (Lesica and Miles, 2001). Growth rate can also be calculated from the age and size of an individual. Researchers along the Marias and Yellowstone rivers in Yellowstone National Park were able to compare the growth rate of Russian olive to native species in the same area and found that Russian olive grew at a faster rate when in closer proximity to alluvial ground water. Additionally, they found that the recruitment of Russian olive seedlings was not significantly affected by stand age or stand proximity to ground water. (Lesica and Miles, 2001)

Limiting Factors In Russian Olive Growth and Establishment

It has been observed in several studies that Russian olive neither relies on, nor is prone to establish on bare alluvium (Kats and Shafroth, 2003; Lesica and Miles, 2001). Lesica and Miles noted a difference in the ratio of cottonwood to Russian olive depending on the level of river flow regulation. The regular flooding and new channel development of the un-dammed Yellowstone River provides ample habitat for cottonwoods to establish and compete with Russian Olive. In contrast, the Marias River, whose flow is regulated by the Timber Dam, has less disturbance and fewer locations for cottonwoods to establish. Lesica and Miles predict that on the Marias River, Russian olives will eventually take over as old cottonwoods die without being able to recruit new seedlings (Lesica and Miles, 2001).

Though there is little information on Russian olives' toleration of proximity to groundwater or the water level of the active river channel, native plants such as cottonwoods and willows rely heavily on the natural flow regime to establish and grow. Such native plants require bare moist alluvium for germination, correct flood water recession to allow roots to access water, and subsequent floods that either do not drown the plant or do not occur until the plant is large enough to resist damages. Such conditions are most likely to occur in unregulated rivers and would provide native, flood-reliant species a chance to compete with non-flood-reliant invaders (Naglar and Glenn 2011).

Vegetation has also been used as an indicator for infested and uninfested sites. In Utah, there is a strong correlation between the presence of Russian olive and the presence of bearded wheatgrass, and a higher frequency of downy brome and common spikerush in uninfested areas

(Garman and Brotherson, 1982).

Russian Olive Removal

The USDA recommends a combination of methods for removing Russian olive along riparian corridors. Seedlings can be hand pulled or pulled with a weed wrench, while older individuals should be removed with heavy equipment and immediately spot treated with a selective, systemic broadleaf herbicide such as Garlon. Annual or bi-annual followup treatments are necessary to control new seedlings and re-sprouts. Since Russian olive seeds can be viable in the earth for up to ten years, followup treatments should be carried out long term (USDA 2014).

Further Questions

Despite its unregulated status, the southern quarter of the Animas River is lined with Russian olive. With no detailed record of the spread of Russian olive throughout the Southwest, and no significant correlation between water availability and the establishment of seedlings, there are few clues as to what has influenced these stands to thrive. Though proximity to groundwater has been studied in detail in regards to native, flood-dependent species, no such studies have been done with Russian olive. Other indicators of native vegetation recovery after Russian olive removal, and changes in understory and seedbank composition may provide insights into the seemingly contradictory success of this invasive species at this location.

Methods

Study Site

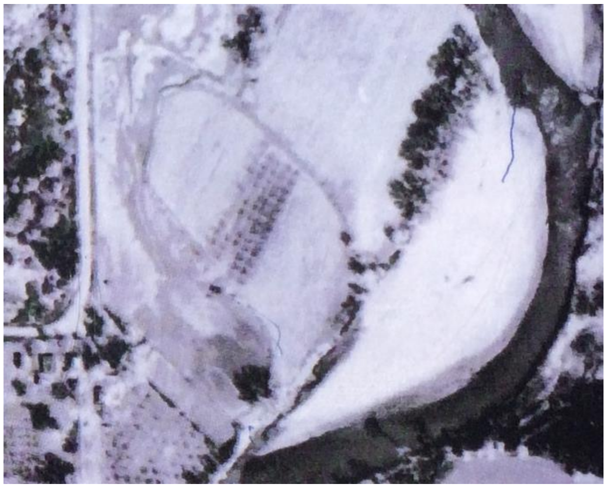
This study took place at Aztec Ruins National Monument in Aztec, New Mexico. Aztec New Mexico is an arid region of the southwest United Stated with an elevation of around 1707 meters and an average annual rainfall of 28 centimeters. Average summer temperatures (June through August) range from 10 to 32 degrees Celsius. Aztec Ruins National Monument is located in the northern part of Aztec. Several of the monument's 27 acres are infested with Russian olive, especially along the Animas River which runs along the southeast border of the property. The Animas River watershed spans from the San Juan Mountains north of Silverton Colorado to its confluence with the San Juan in Farmington New Mexico and its hydrology is influenced by snowmelt in spring as well as monsoons in mid to late summer.

Figure 1:

The southernmost acres (area 1) of Aztec National Monument's Russian olives were cleared in 2014. Large trees were cut and treated with Garlon and younger trees were hand-pulled. Followup treatments have taken place once or twice a year since the initial removal and similar procedures were used. An effort to re-vegetate the treated area is currently underway, and a mix of native grasses have been planted at flagged locations throughout this site. The easternmost area of the stand, (Area 2), has been left untreated and remains very dense. The northernmost part of Figure 1 (Area 3) was acquired most recently by the Monument in 1990. This portion of the property is dotted with younger Russian olives and is roughly a meter higher in elevation than areas 1 and 2. Area 3 is known to have been used for agriculture before being acquired by the monument, and the other two areas have likely been used for agriculture as well.

Figure 2:

Map A.



Map B.

Figure 2 provides further evidence that multiple parts of this property were used for agriculture. Parallel lines in the northern field of Map A suggest tilling, and the evenly spaced dots to the southwest are most likely an orchard or other planted crop. The row of trees separating the fields from the point bar are unidentifiable and may or may not be Russian olive. Also along this tree line is evidence of the construction of a barricade, most likely used to protect crops from flooding. This barricade exists in present day and can be seen on site as many old cars and other metal objects buried or half-buried in the ground. Though much is still unknown about the history of this location, the movement of Russian olives into the area over the past century is quite apparent.

To understand why Russian olive is so successful at this location, I examined growth patterns of stands by determining the relative ages and locations of individual trees, including their proximity to ground water. I measured Russian olive establishment by recording the differences in seed number and seed type found in the soil of infested versus cleared areas. To understand the effect of Russian olive on other species, I compared the understory vegetation of infested and cleared (treated) sites.

Age and Distribution Experimental Design

To gain insights into the history of Russian olive stand establishment and spread, I created a regression model using data from 60 Russian olive trees or stumps from across areas 1 2 and 3 that represented good variation in location, size, distribution, and proximity to the active channel. In the case of the untreated portion of the stand (area 2) and the agricultural portion (area 3), I collected tree cores from the base of the trunk of each individual, mounted the cores on a board, sanded them to make the rings more visible, and counted their rings to determine age. In the treated site (area 1), I cut tree cookies from the existing stumps, and mounted, sanded, and counted their rings similarly. All individuals were measured for their circumference which I later converted to diameter. Once the regression models were complete, I returned to the field and measured the DBH of all trees in 40x20 meter plots in areas 2 and 3. I did not conduct the same measurements in area 1 because many of the cut stumps were buried in tall grass and I wasn’t confident that I would be able to find and record all of them. Using Excel, I performed statistical analyses as well as created graphs showing the size and age distribution of trees in areas 2 and 3.

Additional methods included general investigation of the property to more accurately determine its historical use as well as the possibility of intentional Russian olive cultivation.

Depth to groundwater was monitored in two shallow wells installed on the floodplain. Wells were not installed until August 9th and because groundwater depth was expected to fluctuate over the course of the growing season as the river rises and falls due to snowmelt and rainfall, this study could benefit from a full season of water monitoring in the future.

Seed Bank Experimental Design

To determine the difference in seed type and seed number in soil, I collected and cultivated soil samples from plots in areas 1 and 2. To determine plot locations I used a stratified randomization method by dividing both the treated and untreated sites into five sections of equal area before randomly selecting plot locations using ArcGIS. Each area consisted of 5 sections for a total of ten sections. I then used ArcGIS to randomly select 2 points in each section to be the northwest points for the seed bank plots. This added to a total of twenty plots; ten in the treated area and ten in the untreated area. In each 0.5 x 2 meter plots I collected five 40 ml samples and combined them to create a total of twenty 200 ml soil samples. Before beginning seed germination, I manually sorted through each soil sample and recorded the number of Russian olive seeds from each plot. I then combined each sample with 200 ml of sterilized potting soil and spread each sample into a tray. I watered each tray with 40ml of water daily, and kept them in the greenhouse under a UV lamp until seedlings immerged. I recorded the number and type of seedlings every five days and identified them where possible.

Plot locations in area 1 were not completely random, as I avoided locations that are in the process of being revegetated.

Understory Experimental Design

I also categorized the understory of the infested vs. cleared areas by recording the species and percent coverage of plants in each plot.

Materials

A handheld GPS and a compass were used in the field to find plot locations, mark locations of individual trees and wells and other relevant features as they arose. A tree-corer was used to take cores from living, uncut trees and a chainsaw was used to take tree cookies from the bases of cut trees. Other materials used were for collecting and growing soil samples, and mounting and sanding tree cores and tree cookies.

Analysis

All data was entered into excel, and summaries of data as well as explanatory graphs and tables were made using excel. Statistical analyses were calculated using SPSS.

The relationship between size and age of Russian olives was analyzed using a Pearson's correlation coefficient. Histograms were created to show the compared distribution of age and size of Russian olives between areas 2 and 3.

Significant differences in seedling characteristics (number, species,) between infested and treated sites were analyzed using independent sample t tests. The difference in number and species of understory vegetation was also analyzed using a paired sample t test.

Results

Age and Distribution:

Figure 3:

Untreated **Agricultural**

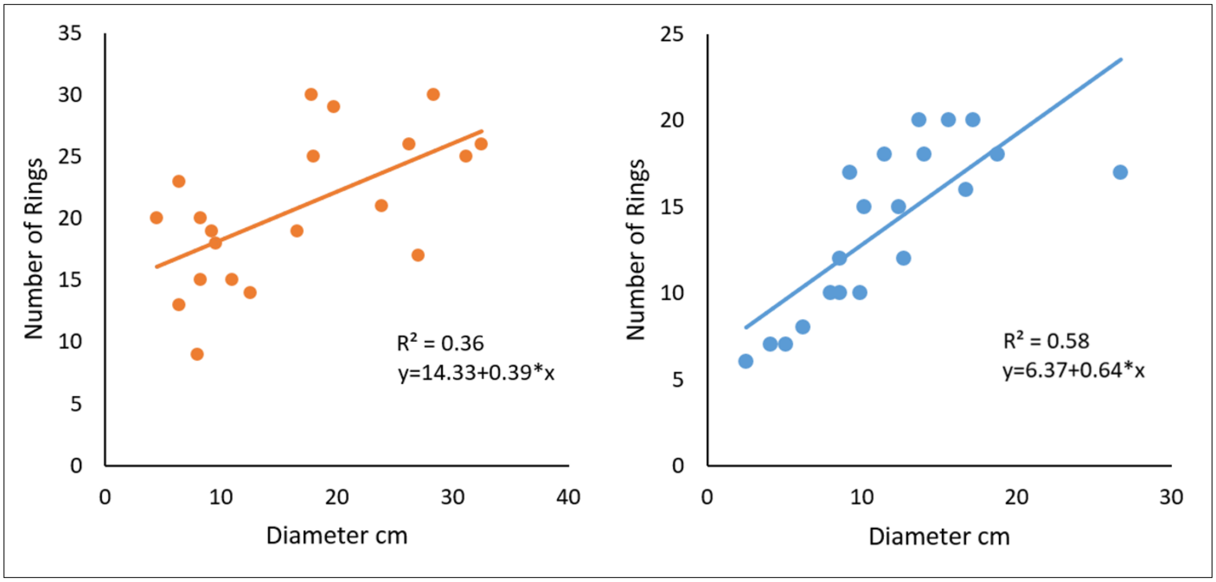


Figure 3: Regression analyses of the diameter (cm) and the number of rings of Russian olive individuals in the untreated and agricultural areas. A Pearson's correlation coefficient produced an r^2 of 0.36 for the untreated area, and an r^2 of 0.58 for the agricultural area.

The growth rate of Russian olive in the agricultural area was accelerated when compared to the growth rate in the untreated area. The r^2 value was also higher in the agricultural area than the untreated area.

Figure 4:

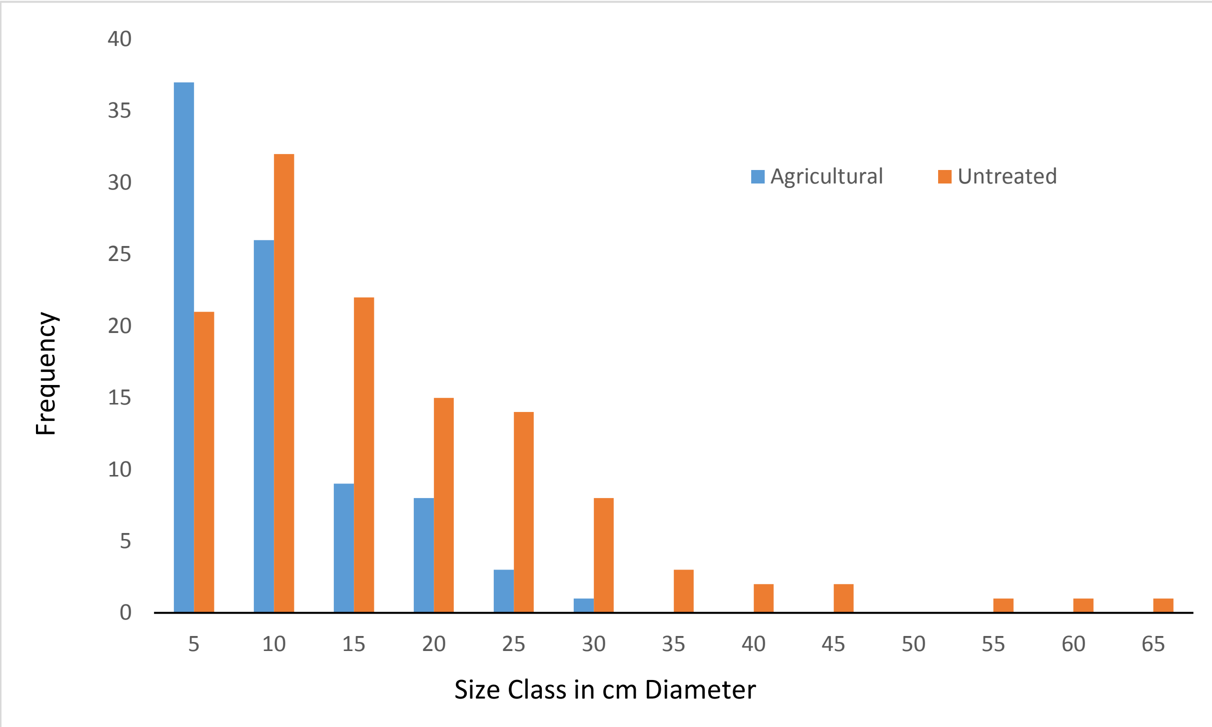


Figure 4: Histogram comparing the frequency of trees within size classes between untreated and agricultural areas.

Relative size class abundance was strikingly different between untreated and agricultural areas. The agricultural area had a high frequency of smaller individuals, the most frequent class being 0-5 cm diameter. The biggest Russian olives recorded in this area were no bigger than 30 cm in diameter. The most abundant class for the untreated area was 6-10 cm diameter, and the frequency of the 0-5 cm size class was almost half that of the agricultural area. The untreated area had many larger trees, the largest growing up to around 65 cm in diameter.

Figure 5:

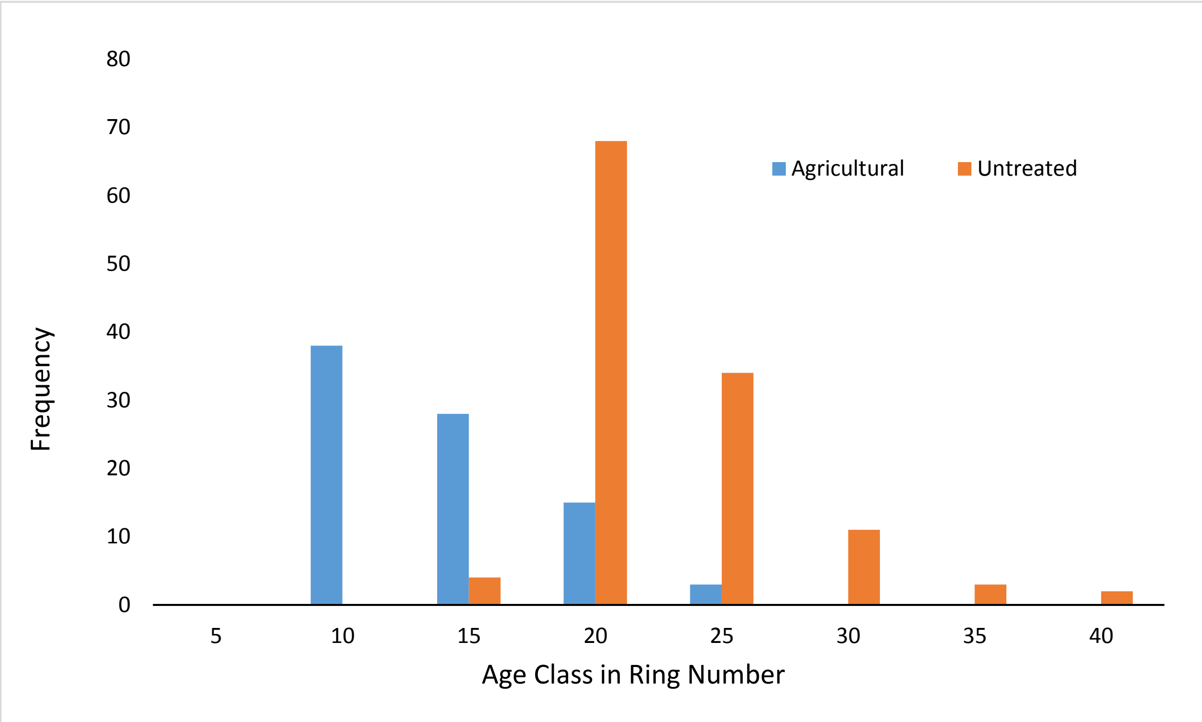


Figure 5: Histogram showing the frequency of trees within age classes between treated and agricultural areas. Age determined from tree ring data and regression models in figure 3.

Figure 5 somewhat mirrors figure 4 in the frequency of Russian olive across classes, though figure 5 may do a better job of displaying the higher overall abundance of trees in the untreated area. The oldest trees in the untreated area were between 36 and 40 years old, while the oldest trees in the agricultural area were no older than 25 years. The most frequent age class in the untreated area was 16-20 years while the most frequent class in the agricultural area was between 6 and 10 years.

Understory:
Figure 6:

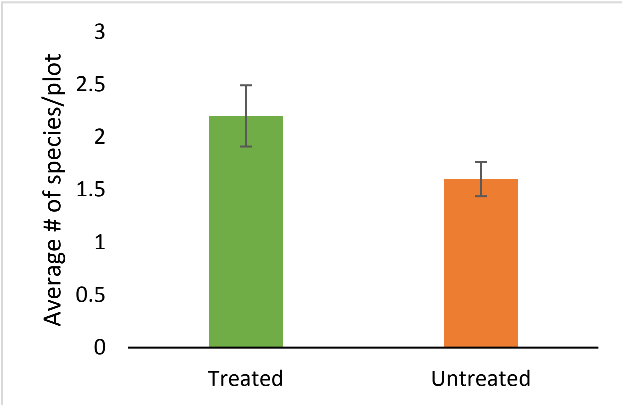


Figure 6: The difference in average number of species per plot in the treated area vs. the untreated area. A Mann-Whitney U test produced a p-value of 0.110.

Understory species diversity was greater in the treated area than the untreated area. Though they didn't show up in the understory plots, I observed many cottonwood seedlings growing along the pointbar in the treated area. No such seedlings were spotted in the untreated or agricultural areas.

Figure 7:

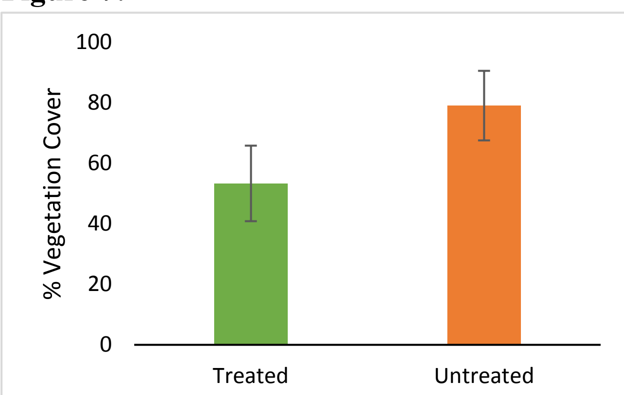


Figure 7: Average percent cover of Bromus inermis in treated vs. untreated areas. A Mann-Whitney U test produced a p-value of 0.033.

Out of all species identified, Bromus inermis covered the highest percent of the understory in both the treated and untreated areas. A Mann-Whitney U test found no significant differences in *total* percent vegetation cover when comparing these two areas.

Seed Bank:

Figure 8:

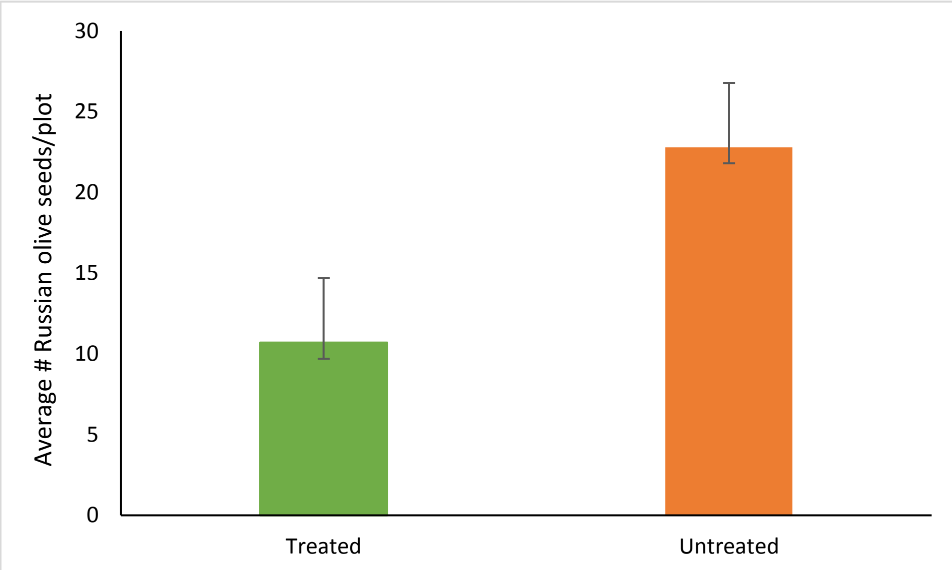


Figure 8: Average number of Russian olive seeds per plot counted from soil samples taken from treated and untreated areas. A Mann-Whitney U test produced a p-value of 0.041.

The number of intact Russian olive seeds found in soil samples was significantly higher in the untreated area than the treated area.

The cultivation of soil samples taken from treated and untreated areas produced a number of seedlings which died before they grew old enough to be identifiable. Cotyledons were, however, different enough from one another to allow for the calculation of species diversity in both areas. Plots in the untreated area had an average species number of 0.5 while plots in the treated area had an average species number of 0.7. Though these averages were not found to be significantly different, it is worth noting that the only Russian olive seedlings that emerged (2 individuals), came from an untreated plot.

Imagery:

Figure 9:

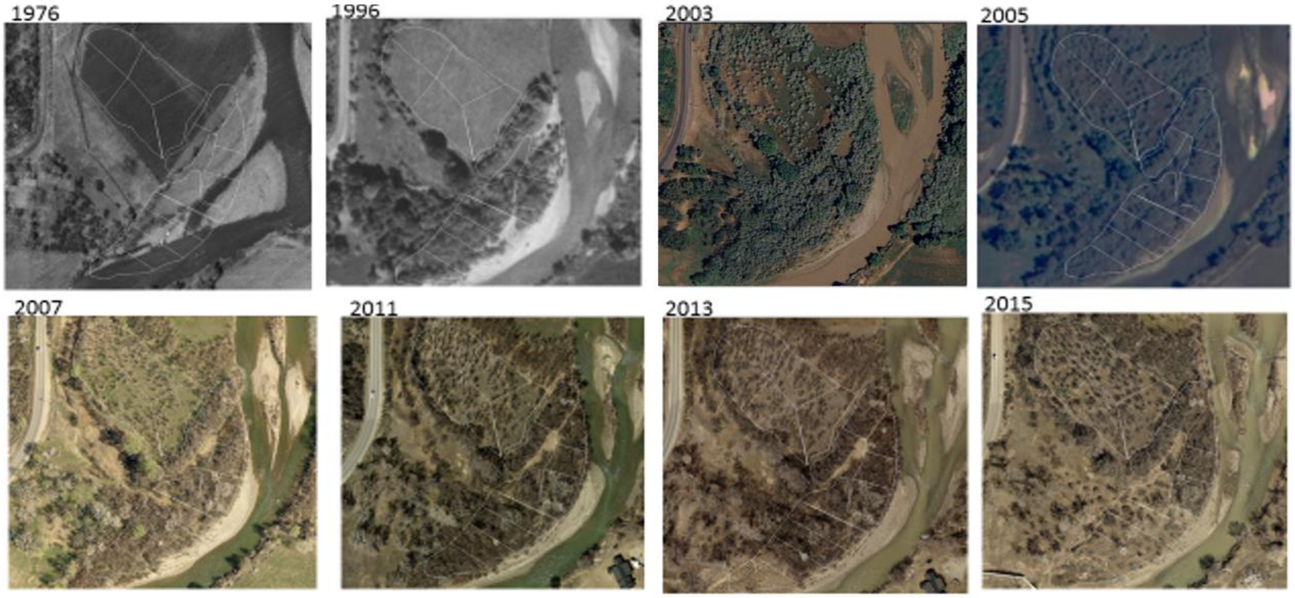


Figure 9: Historical images pulled from San Juan County GIS showing the movement into and subsequent removal of Russian olive at this location.

Images show an almost complete lack of trees in 1976. By 1996 areas 1 and 2 are heavily populated by trees, though it cannot be said definitely that said trees are Russian olive. The color photograph in 2003 reveals the distinct silvery-grey color of Russian olives in areas 1 and 2, and the following images through 2011 show the slow but steady expansion of the stand. In 2013 the southern tip of area 1 has been treated and by 2015, area 1 has been fully treated.

Ground water:
Figure 10:

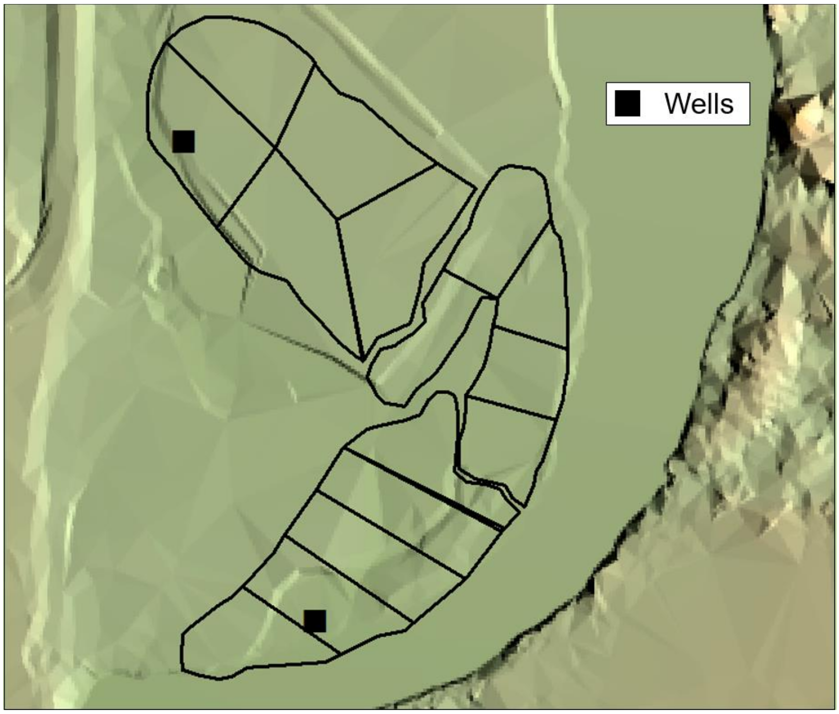


Figure 10: Digital Elevation Model (DEM) of study area with ground water well locations.

Differences in elevation between areas can be seen in this DEM. The well in area 1 was placed at almost the same elevation as the active river channel, while the well in area 3 is somewhat higher. The area 1 well was wet throughout the month of August, while the area 3 well was completely dry.

Key Findings and Conclusions:

The history of the land at Aztec Ruins National Monument is certainly unique, but its agricultural past is something that many riverfront locations along the Animas River share. Russian olive does not seem to need environmental disturbance to successfully establish, but disturbance may give it an extra advantage. This location in particular has human-made berms that run parallel to the river channel, most likely built in an attempt to hinder flooding of agricultural land. In some places, berms are made of earth and stone and in others, they are made of scrap metal, old cars, and machinery, that are now buried or half buried in the ground. Since Russian olive does not normally thrive in areas that regularly flood, it is worth considering that these flood mitigation efforts have made it easier for Russian olive to thrive and establish, while at the same time limiting the possible success of native species like cottonwood, which rely on flooding.

Interestingly, the oldest tree recorded was estimated, using the 'Untreated' regression model from Figure 3, to be 40 years old. This would mean that it established in 1976, the exact date of the first aerial photo from Figure 9. Though the exact age is an estimate, it tells us that these trees were around while the land was still being used for agriculture, and perhaps were planted there intentionally. The age class distribution of the trees in the untreated area (Figure 5) can also be corresponded with the aerial photos in Figure 9. Though the 1996 photo is in black and white, the ages of trees as seen in Figure 5 tell us that there were certainly Russian olives at this location twenty years ago.

Growth rates for both the untreated area and the agricultural area were graphed, and at this time the growth rate in the agricultural area seems to be greater than the growth rate of the untreated area. This is to be expected when one compares the size classes and frequency of trees in these two areas. There is no lack of Russian olive seeds in the untreated area, but few to no seedlings. It is likely the dense canopy of larger trees is keeping new ones from establishing. Competition for resources in this area has slowed the overall growth rate and made it extremely difficult for seedlings to grow. The agricultural area, in contrast, has plentiful sunlight, less tree and canopy density, and less competition for resources, so young saplings are plentiful and growing rapidly. I predict that if the Russian olives in the agricultural area are left to grow, their growth rate will eventually slow to match that of the untreated area.

Seed bank analysis showed significantly fewer intact Russian olive seeds in the treated area than the untreated area. This is encouraging from a managerial perspective, as Russian olive seeds are known to be viable in the ground for up to ten years (Katz and Shafroth 2003). The treated area's Russian olives were removed only a few years before this study took place, so to have significantly fewer seeds is quite a success in the attempted total removal of the species at this location. As far as Russian olive establishment in the treated area, Russian olive seedlings appeared neither in the understory vegetation plots nor in the cultivated soil samples. All Russian olive growth observed was regrowth from previously cut stumps.

The elevation of the untreated area, as seen in Figure 10, is almost that of the river itself, and the ground water well in this area had water in it throughout the month of August. It is possible that the soil moisture of this area is causing seeds to rot and disintegrate before they have the chance to germinate. If this is the case, then seeds in higher, drier locations may be viable for longer periods of time. This would be worth considering if the Monument decides to remove the Russian olives in the agricultural area, which is slightly higher in elevation, and whose ground water well was dry throughout the month of August.

The lack of water observed in the ground water well in the agricultural area, as well as the decreased proximity to the active river channel, does not seem to impede the growth rate of Russian olive individuals. Contrarily, the young trees in this area are growing faster than the older trees in the untreated area. This is discouraging information in the case of Russian olive removal, but is consistent with the knowledge of this being a hearty and drought tolerant species. This finding is also consistent with Lesica and Miles, 2001, who found that Russian olive establishment was not significantly affected by proximity to ground water.

The complete removal of Russian olive is a controversial subject, as many people believe this invasive species provides food and habitat for native animals. I myself noticed deer and bear scat within the untreated area. Ripe Russian olive fruit is sweet and plentiful and a good food source for birds and mammals (Stoleson and Finch 2001), but studies have shown that while this is true, Russian olive stands cater to a lower diversity of bird species than do native riparian habitats. Knopf and Olson, 1984, examined 3 different riparian sites in three states, including Russian olive dominated sites and native riparian sites. They found an overall greater number of birds in the Russian olive sites, but a greater number of bird species in the native sites. These findings are consistent with my understory vegetation categorization, in that there was significantly greater species diversity in the treated area than the untreated area. But this information alone is not enough to condemn Russian olive. Knopf and Olson also found a greater number of small mammal species in their Russian olive sites than in their native vegetation sites. Studies done in New Mexico have found little evidence that Russian olive gives significant advantages to breeding birds (Stoleson and Finch 2001), but studies examining small mammal diversity within and outside of Russian olive stands have yet to be performed in New Mexico. It is this conflicting evidence, along with the human-specific benefits this tree offers, that has hindered the process of developing and releasing a biological control (Bean et al, 2008). For now, land managers must make removal decisions based on their unique situations and management goals.

References

Bean, D., Norton, A, Jashenko, R., Cristofaro, M., and Schaffner, U. 2008. Status of Russian Olive Biological Control in North America. Ecological Restoration 26:2.

Christensen, E. M. 1963. Naturalization of Russian Olive. The American Midland Naturalist 70:133.

Douglass, A. E. 1941. Crossdating In Dendrochronology.

Espeland, E. K., Perkins, L, B., and Leger, E. A. 2010. Comparisons of Seed Bank Estimation Techniques Using Six Weed Species in Two Soil Types. Rangeland and Ecology Management 2:243.

Finch, D. M., Wolters, G. L., and Wang, Y. Ecology, Diversity, and Sustainability of the Middle Rio Grande Basin. Fort Collins, CO: United States Department of Agriculture Forest Service; 1995. Report nr RM-GTR-268.

García, F. 1903. Shade Trees and Other Ornamentals. New Mexican Printing Company, Santa Fe, New Mexico.

Garman, J. G., and Brotherson, J. D. 1982. Comparisons of Sites Infested and Not Infested with Saltcedar (Tamarix pentandra) and Russian Olive. Weed Science 30:360.

Gurnell, A., Goodson, J., Thompson, K., Mountford, O., and Clifford, N., 2007. Three Seedling Emergence Methods in Soil Seed-Bank Studies: Implications for Interpretation of Propagule deposition in Riparian Zones. Seed Science Research 17:183.

Katz, B. L., and Shafroth, P. B. 2003. Biology, Ecology and Management of *Elaeagnus angustifolia* L. (Russian Olive) in Western North America. Wetlands 23:763.

Knopf, F. L., and Olson, T. E. 1984. Naturalization of Russian-Olive: Implications to Rocky Mountain Wildlife. Wildlife Society Bulletin.12:3.

Lesica, P., and Miles, S. 2001. Natural History and Invasion of Russian Olive Along Eastern Montana Rivers. Western North American Naturalist 61:1.

Nagler, P. L., Glenn, E. P Jarnevich, C. S., and Shafroth, P.B. 2011. Distribution and Abundance of Salt Cedar and Russian Olive in the Western United States. Critical Reviews in Plant Sciences 30:509.

Stoleson, S. H., and Finch, D. M. 2001. Breeding bird use of and nesting success in exotic Russian olive in New Mexico. The Wilson Bulletin 113:4.

Ter Heerdt, G. N. J., Verweij, G. J., Bekker, R. M., and Bakker, J. P. 1996. An Improved Method for Seed-Bank Analysis: Seedling Emergance after Removing the Soil by Sieving. Functional Ecology 10:144.

USDA. 2014. Field Guide for Managing Russian Olive in the Southwest. Forest Service.