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Impacts of the Species Elaeagnus umbellate on the Soil and Water Quality of the Pierce Cedar Creek Institute Ecosystem

Yacoub Aljobeh
Valparaiso University, yacoub.aljobeh@valpo.edu

Kristin Engerer
Valparaiso University, kristin.engerer@valpo.edu

Impacts of *Elaeagnus umbellata*
on soil and water quality
at the Pierce Cedar Creek Institute

Student Researchers: Yacoub Aljobeh, Kristin Engerer
Faculty Mentor: Professor Zuhdi Aljobeh, Ph.D., P.E.

1900 Chapel Drive
Valparaiso University
Valparaiso, Indiana 46383

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Abstract

The shrub *Elaeagnus umbellata*, more commonly known as the autumn olive, is an exotic and invasive species. It is an extremely hardy plant that has the added ecological boost of being a nitrogen fixer and therefore able to reduce atmospheric nitrogen to a form useful to the plant. Release of biologically available nitrogen to the soil makes autumn olive a potentially significant threat to the watershed of its host environment, especially in areas such as Pierce Cedar Creek Institute which are set aside as nature preserves. The purpose of this study was to examine the effect of autumn olive on the chemistry of its surrounding soil environment. Soil water samples were collected from underneath both autumn olive plants and nearby control areas at ten day intervals, and analyzed for the respective concentrations of nitrate, ammonia, total nitrogen, potassium, calcium, and magnesium. The data obtained from these tests was analyzed using 2-sample t-tests. These statistics showed that the autumn olive is indeed having an effect on its surrounding environment, with the concentrations of nitrate, ammonia, and nitrogen being significantly higher underneath the shrub than underneath the control areas.

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Introduction

Elaeagnus umbellata was introduced into the United States in the 1830s (Rehder, 1940) and planted in disturbed landscapes along many highways and riparian zones to control erosion and provide habitats to native bird species in the 1960s and 1970s (Allan and Steiner, 1972, Friedrich and Dawson, 1984, and Catling, et.al, 1997). Aside from its positive attributes, this shrub was found to have negative impacts on ecosystems when available in mass quantities. Shrub populations readily dispersed through the fruit and seed it produces (Hilty 2002). Even though the *E. umbellata is* not native to North America, it was able to thrive and adapt to the new environment by using its ability to fix nitrogen. Nitrogen fixation is a process where plants absorb molecular nitrogen from the atmosphere and convert it into reduced forms like nitrate that it can use for growth (Deacon 2003). This conversion is completed through a symbiotic relationship that *E. umbellata* has with the nitrogen-fixing actinomycete Frankia bacteria in root nodules (Eastman 208). The shrub thrives in many different soil textures including sand, clay, and silt.

The properties that the *E. umbellata* possesses allow it to thrive in many environments. *E. umbellata* is considered an invasive species because it can outcompete native species in their environment. One of the potential negative impacts of this invasive species because of its ability to fix nitrogen, is the release of higher than normal nitrate in the surrounding soil environment. Nitrate is a form of nitrogen that is used by plants for growth. If the *E. umbellata* produces excessive amounts of nitrate through the symbiotic relationship with the nitrogen-fixing actinomycete *Frankia* bacteria, the nitrate may leach into the surrounding soil and ground water. Nitrate in soil is mobile and can eventually end up in nearby water bodies which may result in higher levels. High levels of nitrate in water are toxic to the wildlife and human beings and may cause chemical imbalance in the watershed (Killpack 1993). In return, the *E. umbellata* shrub raises concern because of its potential to produce higher than normal nitrate levels in natural environments.

This study was conducted at Pierce Cedar Creek Institute to determine the effects this invasive species has on the chemical balance in the soil and water. For the purpose of this study, the concentrations of nitrate and other forms of nitrogen that the *E. umbellata* gave off into the surrounding soil and water were measured and compared with similar measurement from control plots dominated with grass.

Materials and Methods

A) Site Selection

Fifteen sites were chosen across the Pierce Cedar Creek Institute consisting of two plots in each, an experimental and a control sampling sites at each plot. The fifteen sites were split into three groups. A cluster of five sites was located in the same vicinity. One cluster was located near the Pierce Cedar Creek Research Laboratory, another was located off of the Orange trail, and the third was off of the Yellow trail. The experimental plot was selected by locating a mature cluster of *E. umbellata spelling.* The control plot was selected at least fifty feet away from the experimental and was usually composed of open grassland with no *E. umbellata* or known nitrogen-fixer plants present. All of the experimental and control sites were chosen to be similar in composition. This includes similar sized *E. umbellata* shrubs for the experimental plots and similar silty sandy soil composition for both the experimental and control plots.

B) Lysimeter Installation

Twenty-four inch lysimeters manufactured by SoilMoisture® were installed and utilized to collect ground water samples from each plot. A lysimeter collects water samples through a porous cup at the end of the PVC tube when under vacuum pressure. Manufacturer recommended procedures were followed for installation. The soil in each plot where the lysimeter was installed was carefully selected to be similar in composition, a sandy silty soil. A hole was dug at each plot using a clean and decontaminated auger that was 2 inches in diameter.

Silica sand slurry was mixed and poured in before the lysimeter was placed into the ground. After placing the lysimeter in the hole, the ground was compacted around the lysimeter and a bentonite ring was placed around the opening of the ground to seal the hole. Each lysimeter was then vacuum pressurized to -60 kPa.

C) Sample Collection

The ground water samples were collected in seven rounds starting on June 7 and ending on August 9, 2010. These rounds were separated by approximately ten days which allowed a sufficient amount of water to be collected in the lysimeter. Within the ten days, each of the three site clusters was repressurized and eventually soil water samples were collected from the lysimeter using SoilMoisture® sample collectors. The sample collectors were decontaminated by rinsing them with 70% alcohol and deionized water. The water samples from each plot were collected into clean plastic bottles and stored in the refrigerator at 4ºC. Soil samples were also collected in two rounds. The first round of soil collection was done at the beginning of the season after the lysimeters had been installed. The second round was done at the end of the season during the final round of water sample collection.

D) Testing

The testing of the water samples was done using a Hach DR 4000 Spectrophotometer. The water samples were tested for six parameters including, nitrate, total nitrogen, ammonia, potassium, calcium, and magnesium. The target concentrations tested for were for nitrogen and its different forms. Each analysis method was selected based on its detection limits and expected range of values for specific parameters. This selection process was guided by the results obtained from analyzing soil water samples collected at the Pierce Cedar Creek Institute during summer 2009 (Boroski and Aljobeh, 2009). To test for nitrate, the cadmium reduction method, method was used. The results were reported as mg/L as nitrate-nitrogen (NO3—N). The Standard Methods persulfate digestion method, , was used to test for the total nitrogen concentration in the water samples. These concentrations were expressed in units of mg/ L as nitrogen. The Standard Methods nessler analysis method was used to determine the concentration of ammonia in the water samples. The results were expressed in units of mg/L as NH3 – N.

The water samples were also tested for positive ion concentrations, as it was predicted that the excessive nitrate levels would have an effect on the positive ions in the nitrogen cycle. Three ions were analyzed including potassium and total hardness, which consisting of the concentrations of calcium and magnesium. Potassium concentration was measure using the tetraohenylborate method, standard method #8049. Total hardness was determined using the calmagite colorimetric method, standard method #8030.

Results

The samplers in the vicinity of the PCCI Laboratory were labeled LS1 through LS5 and their paired control samplers were labeled LC1 through LC5 respectively. The samplers in the vicinity of the PCCI Orange Trail were labeled OS1 through OS5 and their paired control samplers were labeled OC1 through OC5 respectively. The samplers in the vicinity of the PCCI Yellow Trail were labeled YS1 through YS5 and their paired control samplers were labeled YC1 through YC5 respectively. All analyses results for samples collected during summer 2010 are presented in Table A-1 in Appendix A.

A) Total Nitrogen

The concentrations of total nitrogen varied significantly by sampling date for each collected soil water sample. The averages of each cluster were found, and these results plotted in a bar chart for better visual comparison. This can be seen in Figure 1.

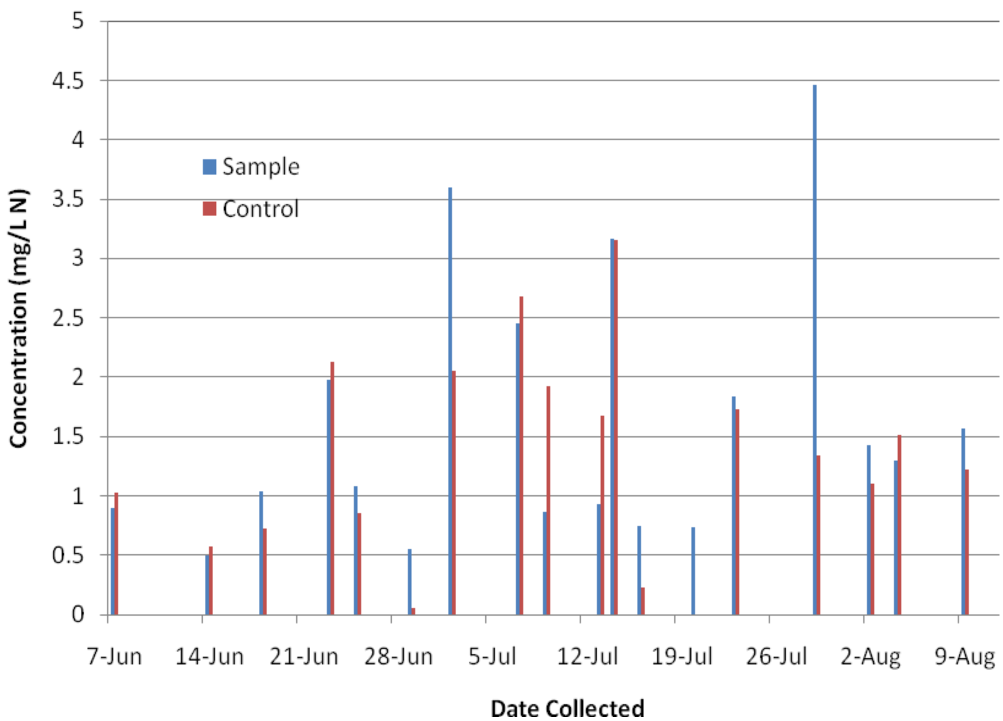

Figure 1. Concentrations of total nitrogen at each plot for each sample round.

The 2-sample t-test compared the means of the two plots, with the null hypothesis that there would be no difference in the average concentrations found that the p-value for this test was 0.088 indicating that differences were not significant. However, the data show that the concentration of nitrogen is may be greater under the autumn olive shrub as compared to the concentration in plots unaffected by the shrub.

C) Nitrate

The concentrations of nitrate varied significantly by sampling date for each collected soil water sample. The averages of each cluster were determined, and these results plotted in a bar chart for better visual comparison. This can be seen in Figure 2.

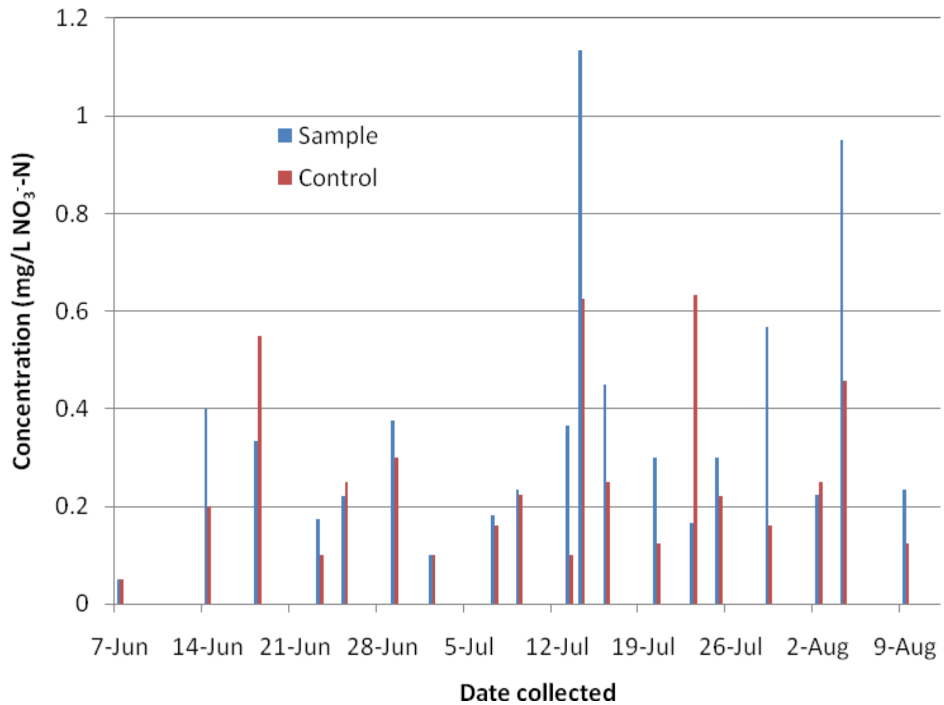

Figure 2. Concentrations of nitrate at each plot per sample round.

A statistical analysis of the nitrate concentrations indicated that … the concentrations of nitrate at the sample plots were insignificant (p=0.072), however, there was a trend indicating the potential of a relationship.

D) Ammonia

Similar to total nitrogen and nitrate concentrations, the concentrations of ammonia varied significantly by sampling date for each collected soil water sample. The averages of each cluster were determined, and these results plotted in a bar chart for better visual comparison. This can be seen in Figure 3.

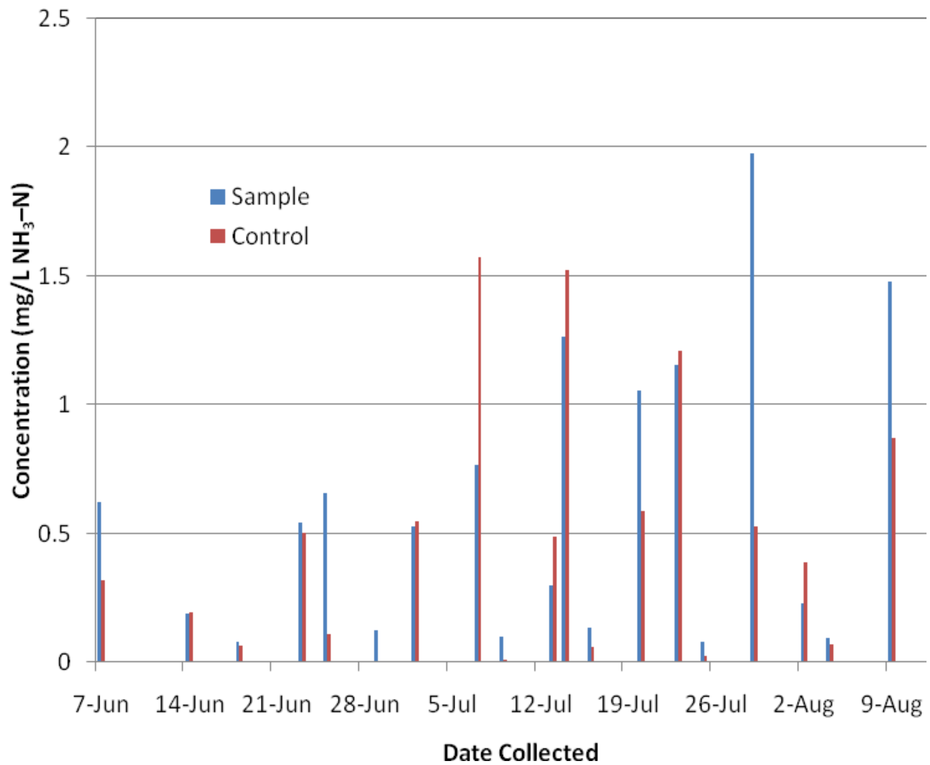

Figure 3. Concentrations of ammonia at each plot per sample round.

A statistical analysis of the nitrate concentrations indicated that the concentrations of nitrate at the sample plots were insignificant (p=0.074), however, there was a trend indicating the potential of a relationship

E) Potassium

Figure 4 shows the average potassium concentrations for the sampling sites and their paired controls for the seven rounds of sampling.

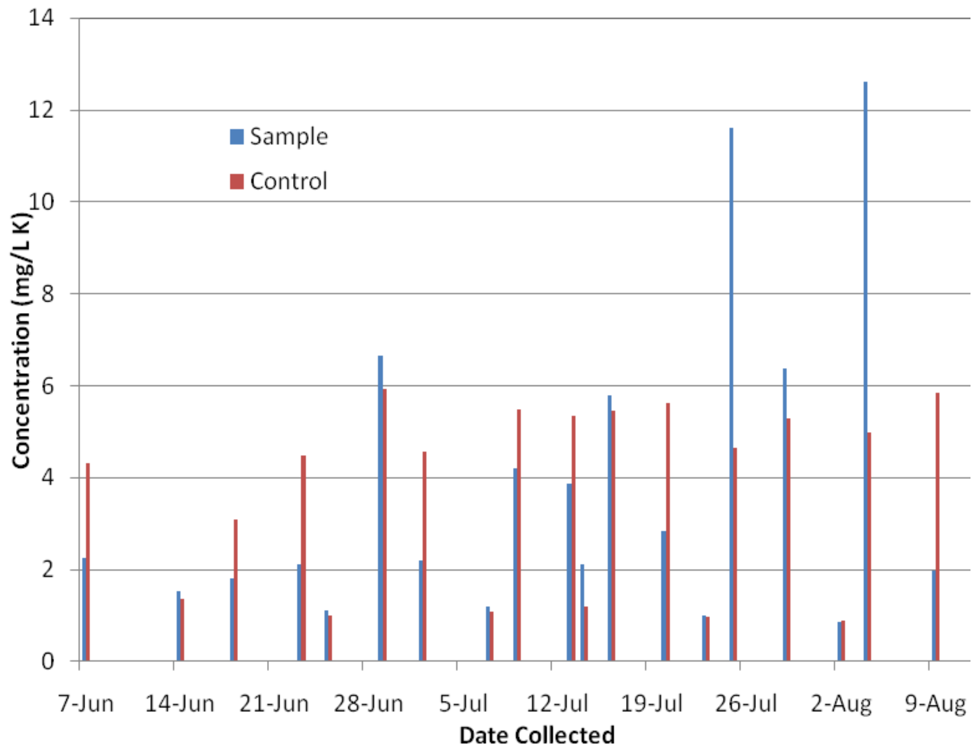

Figure 4. Concentrations of potassium at each plot per sample round.

The results of the statistical analysis resulted in a p-value of 0.480, which is much greater than the standard α of 0.05indicating that there is no significant difference in concentration of potassium in samples collected from the sampling sites samplers relative to the samples collected from the control samplers.

F) Hardness (Calcium and Magnesium)

The Hach procedure for hardness does not result in only one value, but can provide the the concentrations of both calcium and magnesium. Similar to the potassium test, the Hach procedure for determining hardness requires a substantial sample size. Due to this fact, all of the samples were diluted to create enough solution to be analyzed. The resulting data, then, is adjusted, taking into consideration the dilution factor. Figures 5 and 6 show the average calcium and magnesium concentrations for the sampling sites and their paired controls for the seven rounds of sampling.

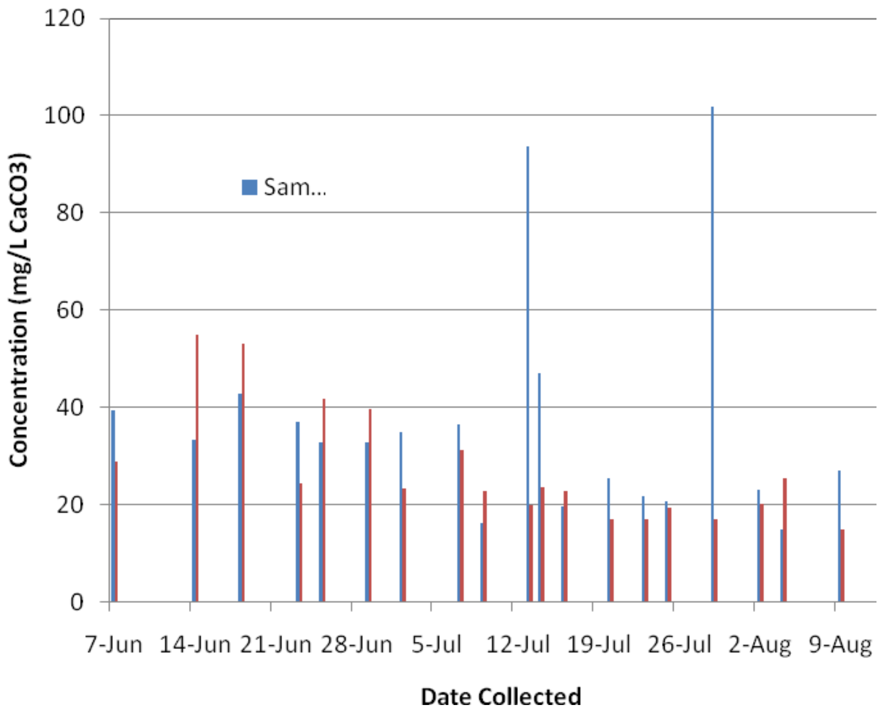

Figure 5. Concentrations of calcium at each plot per sample round.

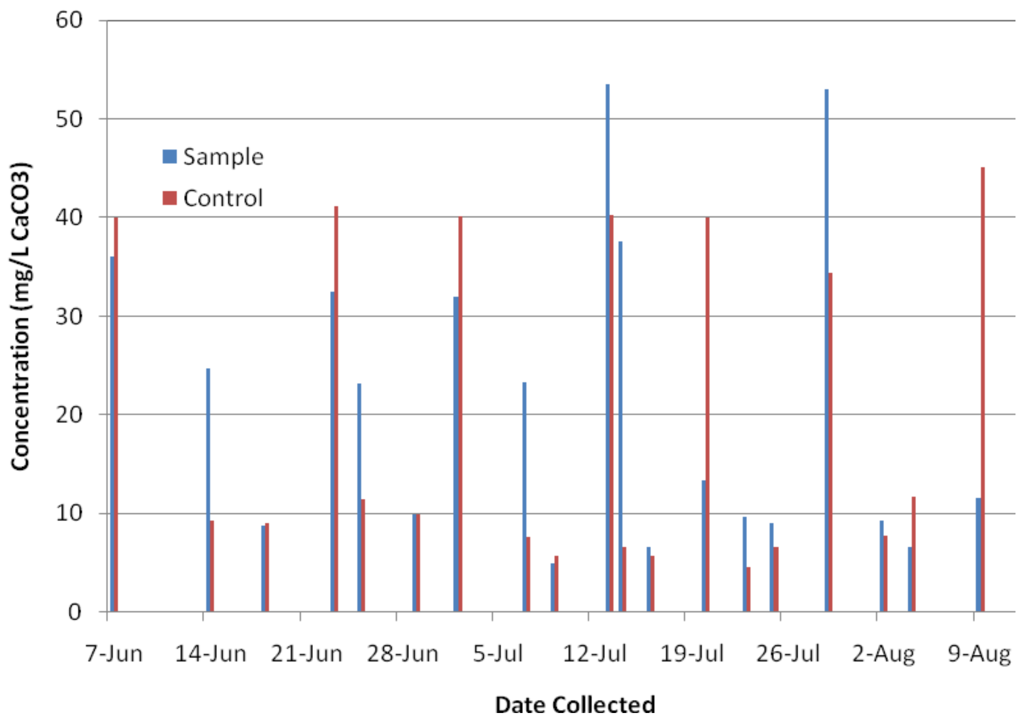

Figure 6. Concentrations of magnesium at each plot per sample round.

The hypotheses for both the calcium and magnesium concentrations follow the same theory as the potassium concentration: a lesser concentration on average would be found in the sample plots than in the control plots. As calcium and magnesium together are the major constituents of the hardness of water and act in the same manner, these individual concentrations were added together for each plot every sample round to find the concentration as the total hardness of the sample in mg/L as $CaCO_3$. Our hypothesis is that the concentration of the total hardness in the plots affected by the *E. umbellate* spelling would be lower than that of the plots unaffected by Autumn olive The t-test resulted in a p-value of 0.079, indicating that there is no significant change in total hardness between the sampling sites and the control sites.

Discussion of Results

Our results indicate that there is not a significant difference between the sample and control plots at a confidence level of 95%. However, there are many other factors which should be taken into account before this conclusion is reached.

A significant limiting factor was the weather. This past summer was hotter and wetter on average than usual. At the beginning of the summer there was an increase in the amount of rain, but the heat caused a great deal of that water to exist in the air as humidity and not stay within the soil as moisture content. The heat continued into the second half of the summer, but the rain did not. On the rare occasion that it did rain, the water would be quickly absorbed by the surrounding vegetation, leaving very little within the ground. Because of this, it was much more difficult to collect samples in the second half of the summer, cumulating in a cluster where no samplers collected water in Round 7. In addition, many of the samplers that did collect water required dilution to obtain enough water to work with. This lowered the concentration of the sample contained within the water sample, and while it can be brought back to the correct magnitude with the dilution factor, there will still be an added measure of error from this.

One obvious factor that the lack of rain causing fewer of the samplers to collect per round causes is the lowering of the sample size. The initial design for the study had been for seven rounds of soil water sample collection, with fifteen experimental plots, and fifteen control plots. This design would have resulted in 30 sample concentrations per plot treatment per round for each test and a total of 210 sample concentrations per plot treatment overall. This would be a large enough set of data to compute an accurate and fairly reliable statistical analysis per round if all samples were to be analyzed together. However, it was decided to analyze the samples by round, leaving only 15 samples per round. Over the course of the study, however, several issues arose, causing the total number of samples collected per round to be less than 15. Therefore, simply the collection of a greater number of samples may have resulted in different conclusions to the t-tests. All of these factors taken together support the suggestion that the data is in fact significant, and the slight distance outside of the 5% range should not eliminate the results from significance.

As previously mentioned, this research was conducted during the summer months, starting in June and continued through August. The beginning of this time fell at the end of the heavy growing season, when plants actively extract soil nutrients. Therefore, we expected and measured lower concentrations of these compounds during those first few months. Because of this, the data collected was divided into two groups: the samples collected during the first half of the summer at the end of the growing season and the data collected during the second half of the summer after the growing season ended. July 13th was decided to be the dividing point for this split. The statistics presented with the results are therefore the ones that match the second half of the summer when we expected to find relevant results. The statistical analyses on the data from the first half of the summer all show that there is not a significant difference between the two means, with p values around .45 for all tests.

The work presented within this report does support that conclusion. The sampling size was increased by a factor of three, and even though many of the same problems that hampered the previous summer's data collection occurred again, a great deal more samples were collected. The statistical analysis did also prove to be more significant.

Conclusion

The invasive shrub *Elaeagnus umbellate spelling* was hypothesized to have an impact on the water and soil quality because of its nitrogen fixing ability. This was examined by testing soil and ground water samples from plots around the Autumn Olive shrub and comparing the results to plots without Autumn Olive. Statistical analysis did provide trending evidence that the concentrations of the three ions, nitrate, total nitrogen, and ammonia were higher at the experimental Autumn Olive plots than the control plots. As a continuation of the Aljobeh-Boroski research of 2009, the addition of more plots proved to result in more significant results.

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Appendix A

Table A-1: Analysis results for all samples collected during summer 2010

	Date	Sample	Nitrate	TNT	Ammonia	Potassium	Mg	Ca
			mg/L NO_3^--N	mg/L N	mg/L NH_3–N	mg/L K	Mg/L as $CaCO_3$	Mg/L as $CaCO_3$
1	7-Jun	LC1	0.0	1.3	0.608	14.2	62.20	1.00
2	23-Jun	LC1	0.0	4.0	1.248	14.4	76.00	0.00
3	2-Jul	LC1	0.0	5.3	1.291	14.6	76.40	0.00
4	13-Jul	LC1	0.0	1.5	1.117	18.4	78.80	0.00
5	20-Jul	LC1	0.0	0.0	1.306	19.2	75.20	0.00
6	29-Jul	LC1	0.0	3.7	0.880	20.0	74.00	0.00
7	9-Aug	LC1	0.0	1.7	1.726	18.0	88.00	0.00
Average			0.0	2.5	1.168	17.0	75.80	0.14
1	7-Jun	LC2	0.0	0.8	0.237	0.8	23.80	37.20
2	23-Jun	LC2	0.0	2.3	0.363	0.6	6.20	60.40
3	2-Jul	LC2	0.2	0.6	0.464	0.6	7.80	56.00
4	13-Jul	LC2	0.2	3.8	0.374	0.5	5.60	49.60
5	20-Jul	LC2	0.1	0.0	0.617	0.4	5.20	48.20
6	29-Jul	LC2	0.1	1.7	0.564	0.5	5.20	43.20
7	9-Aug	LC2	0.0	1.3	0.889	2.0	6.80	44.20
Average			0.1	1.5	0.501	0.8	8.66	48.40
6	2-Aug	LC3	0.2	0.7	0.581	2.8	8.40	20.40
7	9-Aug	LC3	0.3	1.1	0.676	2.6	7.20	15.80
Average			0.3	0.9	0.629	2.7	7.80	18.10
1	7-Jun	LC4	0.0	0.0	0.065	0.9	63.80	0.00
2	23-	LC4	0.1	0.3	0.051	0.6	74.40	0.00

	Jun							
3	2-Jul	LC4	0.1	0.0	0.053	0.7	68.20	0.00
4	13-Jul	LC4	0.1	0.0	0.050	0.6	70.00	0.00
5	20-Jul	LC4	0.2	0.0	0.038	0.6	72.60	0.00
6	29-Jul	LC4	0.2	0.0	0.071	0.7	77.60	0.00
7	9-Aug	LC4	0.2	0.8	0.184	0.8	78.40	0.00
Average			0.1	0.2	0.073	0.7	72.14	0.00
1	7-Jun	LC5	0.2	2.0	0.363	1.4	10.20	77.40
2	23-Jun	LC5	0.3	1.9	0.351	2.3	7.80	37.00
3	2-Jul	LC5	0.1	2.3	0.379	2.4	8.00	37.00
4	13-Jul	LC5	0.1	1.4	0.402	1.9	6.80	30.40
5	20-Jul	LC5	0.2	0.0	0.395	2.3	7.20	20.40
6	29-Jul	LC5	0.3	0.6	0.536	2.5	6.60	21.00
Average			0.2	1.4	0.404	2.1	7.77	37.20
1	7-Jun	LS1	0.1	1.0	0.626	6.1	50.20	30.40
2	23-Jun	LS1	0.1	2.6	0.530	6.5	20.60	58.20
3	2-Jul	LS1	0.2	3.1	0.633	6.8	21.00	53.20
4	13-Jul	LS1	0.4	2.8	0.496	8.8	16.00	45.60
5	20-Jul	LS1	0.6	0.7	0.578	6.3	18.60	40.00
6	29-Jul	LS1	0.1	11.3	4.444	12.0	15.60	41.60
7	9-Aug	LS1	0.0	3.6	2.364	4.1	12.20	31.00
Average			0.2	3.6	1.382	7.2	22.03	42.86
1	7-Jun	LS2		0.5	0.285	1.1	21.00	41.80
5	20-Jul	LS2	0.1	0.0	1.171	0.9	5.20	15.80
6	29-Jul	LS2	0.2	1.2	0.744	0.7	5.80	18.00
7	9-Aug	LS2	0.1	0.0	0.553	0.6	10.20	18.80

Average			0.1	0.4	0.688	0.8	10.55	23.60
1	7-Jun	LS3	0.0	0.0	0.208	1.2	16.80	59.20
2	23-Jun	LS3	0.2	1.1	0.103	0.8	13.60	37.60
3	2-Jul	LS3	0.1	5.2	0.211	0.9	16.20	36.40
4	13-Jul	LS3	0.2	0.0	0.272	1.3	13.60	23.60
5	20-Jul	LS3	0.2	1.5	1.415	1.3	16.20	20.40
6	29-Jul	LS3	0.3	3.7	1.689	1.1	14.00	21.20
7	9-Aug	LS3	0.6	1.1	1.511	1.2	12.40	31.40
Average			0.2	1.8	0.773	1.1	14.69	32.83
1	7-Jun	LS4	0.1	0.4	0.116	0.7	72.40	0.00
2	23-Jun	LS4	0.4	1.4	0.065	0.6	75.80	0.00
3	2-Jul	LS4	0.1	0.3	0.056	0.5	67.20	0.00
4	13-Jul	LS4	0.5	0.0	0.125	1.5	131.00	212.00
6	29-Jul	LS4	1.7	1.7	1.017	11.7	176.67	326.67
Average			0.6	0.8	0.276	3.0	104.61	107.73
1	7-Jun	LS5	0.0	2.6	1.882	2.1	19.60	65.60
2	23-Jun	LS5	0.0	2.8	1.467	0.5	20.00	52.40
3	2-Jul	LS5	0.0	5.8	1.211	0.6	23.40	50.60
Average			0.0	3.7	1.520	1.1	21.00	56.20
1	14-Jun	OC1	0.2	0.2	0.035	1.9	6.80	46.60
2	25-Jun	OC1	0.1	3.4	0.012	1.6	11.20	58.20
3	7-Jul	OC1	0.1	1.5	0.054	1.2	8.40	37.60
4	14-Jul	OC1	0.2	1.8	0.025	1.3	6.80	24.40
5	23-Jul	OC1	0.1	0.0	0.014	1.0	4.40	19.60
6	2-Aug	OC1	0.1	0.0	0.060	1.0	9.00	23.80
Average			0.1	1.2	0.033	1.3	7.77	35.03
3	7-Jul	OC2	0.4	10.2	7.060	2.2	6.60	26.00
4	14-	OC2	2.1	9.5	5.612	2.3	5.00	24.80

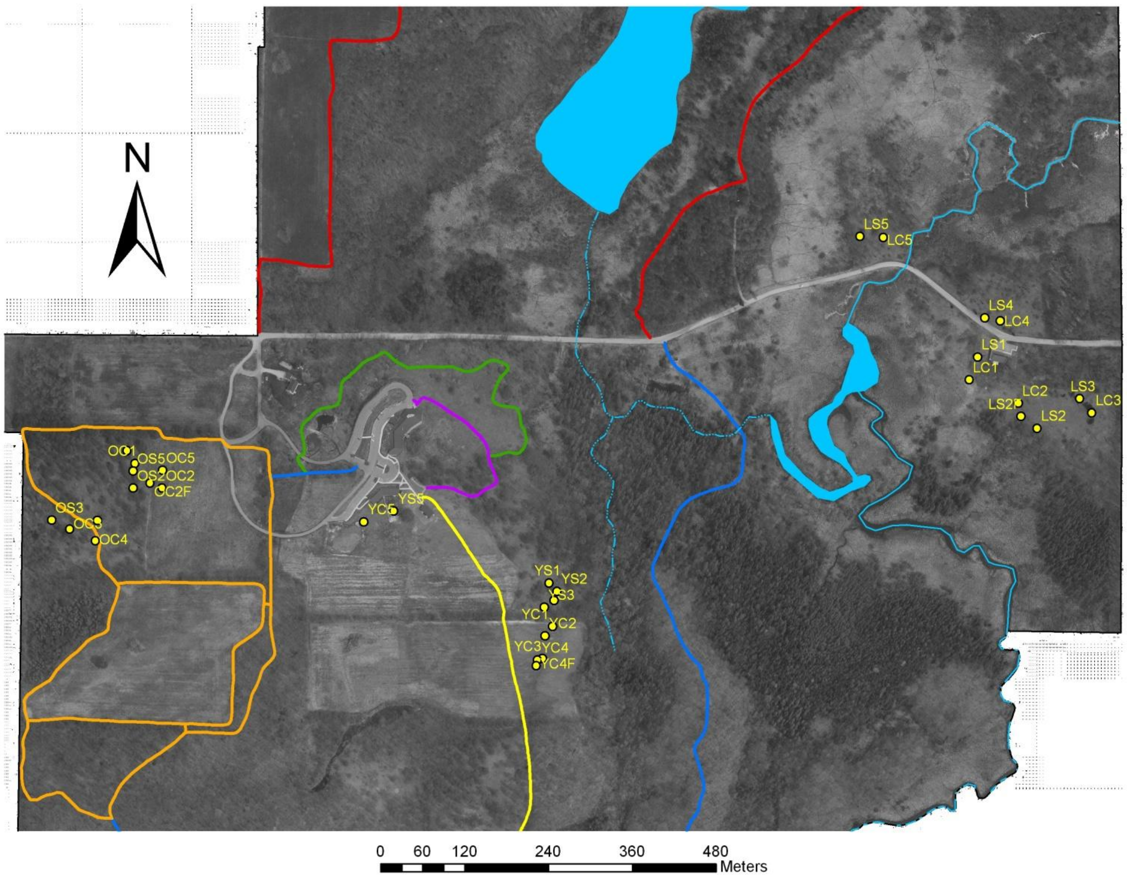
	Jul							
5	23-Jul	OC2	1.7	5.2	3.612	1.6	5.00	20.60
6	2-Aug	OC2	0.4	2.2	0.715	0.8	6.40	16.40
Average			1.2	6.8	4.250	1.7	5.75	21.95
1	14-Jun	OC3	0.1	0.5	0.065	0.9	9.00	69.20
2	25-Jun	OC3	0.1	0.0	0.261	0.8	13.60	43.60
3	7-Jul	OC3	0.1	0.6	0.326	0.5	9.40	33.80
4	14-Jul	OC3	0.1	1.1	0.374	0.7	8.40	28.60
Average			0.1	0.6	0.257	0.7	10.10	43.80
1	14-Jun	OC4	0.5	1.6	0.230	1.8	10.40	41.00
2	25-Jun	OC4	0.4	0.0	0.116	1.2	9.60	30.00
3	7-Jul	OC4	0.1	0.7	0.317	1.1	5.20	18.00
Average			0.3	0.8	0.221	1.4	8.40	29.67
1	14-Jun	OC5	0.0	0.0	0.440	0.8	10.80	63.00
2	25-Jun	OC5	0.4	0.0	0.043	0.4	11.20	35.00
3	7-Jul	OC5	0.1	0.4	0.097	0.4	8.40	40.20
4	14-Jul	OC5	0.1	0.2	0.068	0.5	6.40	16.80
5	23-Jul	OC5	0.1	0.0	0.000	0.3	4.20	10.60
Average			0.1	0.1	0.130	0.5	8.20	33.12
1	14-Jun	OS1	0.4	0.0	0.224	2.4	8.20	28.60
2	25-Jun	OS1	0.2	1.1	0.089	1.4	12.20	44.20
3	7-Jul	OS1	0.1	2.8	0.169	1.4	8.80	35.40
4	14-Jul	OS1	0.2	6.5	3.892	2.9	7.20	20.40
5	23-Jul	OS1	0.2	3.5	3.352	1.8	6.00	14.40
Average			0.2	2.8	1.545	2.0	8.48	28.60
1	14-Jun	OS2	0.9	1.4	0.213	1.9	69.00	0.00
2	25-Jun	OS2	0.2	2.6	2.900	2.1	58.20	5.00
3	7-Jul	OS2	0.3	3.9	3.318	1.5	65.80	13.80

4	14-Jul	OS2	2.8	4.6	0.958	1.8	99.60	62.80
Average			1.1	3.1	1.847	1.8	73.15	20.40
2	25-Jun	OS3	0.2	0.5	0.094	0.8	17.80	49.20
3	7-Jul	OS3	0.1	0.3	0.119	1.0	14.20	37.40
4	14-Jul	OS3	1.3	0.7	0.187	3.3	36.00	82.67
5	23-Jul	OS3	0.2	0.0	0.083	0.8	14.60	33.20
6	2-Aug	OS3	0.2	0.0	0.114	0.9	15.20	36.60
Average			0.4	0.3	0.119	1.4	19.56	47.81
1	14-Jun	OS4	0.2	0.2	0.206	0.8	13.60	46.40
2	25-Jun	OS4	0.3	0.5	0.178	0.6	16.40	39.40
3	7-Jul	OS4	0.3	4.5	0.182	1.5	20.00	61.82
Average			0.3	1.7	0.189	1.0	16.67	49.21
1	14-Jun	OS5	0.1	0.4	0.111	1.0	8.20	58.40
2	25-Jun	OS5	0.2	0.7	0.009	0.6	11.40	26.20
3	7-Jul	OS5	0.1	0.7	0.031	0.5	7.40	34.40
4	14-Jul	OS5	0.2	0.9	0.022	0.4	7.40	21.80
5	23-Jul	OS5	0.1	2.0	0.020	0.4	8.40	17.80
6	2-Aug	OS5	0.2	3.5	0.026	0.7	6.60	15.40
Average			0.2	1.4	0.037	0.6	8.23	29.00
1	18-Jun	YC1	0.2	0.8	0.045	1.6	8.80	31.80
2	29-Jun	YC1	0.2	0.0	0.000	0.7	13.20	37.20
3	9-Jul	YC1	0.1	1.1	0.006	0.8	6.40	20.20
4	16-Jul	YC1	0.2	0.0	0.055	0.8	6.00	19.80
5	25-Jul	YC1	0.2	0.0	0.007	0.8	6.60	17.40
6	4-Aug	YC1	0.1	0.2	0.012	0.8	11.20	14.80
7	13-Aug	YC1	0.2	0.7	0.294	1.0	6.40	26.40
Average			0.2	0.4	0.060	0.9	8.37	23.94

1	18-Jun	YC2	0.7	0.5	0.008	2.2	10.00	83.20
2	29-Jun	YC2	0.3	0.0	0.000	1.0	14.20	48.80
3	9-Jul	YC2	0.2	4.8	0.000	1.1	7.40	27.40
4	16-Jul	YC2	0.2	0.0	0.047	1.0	9.20	27.40
5	25-Jul	YC2	0.1	0.0	0.011	1.0	6.20	21.00
6	4-Aug	YC2	1.1	0.0	0.042	3.2	23.16	48.42
Average			0.4	0.9	0.018	1.6	11.69	42.70
1	18-Jun	YC3	0.8	1.4	0.052	0.9	7.20	55.00
2	29-Jun	YC3	0.6	0.2	0.000	0.4	6.80	44.80
3	9-Jul	YC3	0.5	1.8	0.000	0.4	5.40	29.00
4	16-Jul	YC3	0.6	0.9	0.052	0.4	4.80	29.20
5	25-Jul	YC3	0.3	0.0	0.026	1.1	7.40	27.00
6	4-Aug	YC3	0.3	6.7	0.054	0.5	8.80	20.00
Average			0.5	1.8	0.031	0.6	6.73	34.17
5	25-Jul	YC4	0.4	0.0	0.025	0.4	6.60	17.80
6	4-Aug	YC4	0.6	0.5	0.144	0.8	9.84	32.06
7	13-Aug	YC4	0.5	0.0	0.246	0.9	8.80	31.40
Average			0.5	0.2	0.138	0.7	8.41	27.09
1	18-Jun	YC5	0.5	0.2	0.152	7.7	10.00	42.40
2	29-Jun	YC5	0.1	0.0	0.020	21.6	5.40	27.40
3	9-Jul	YC5	0.1	0.0	0.038	19.6	3.60	14.40
4	16-Jul	YC5	0.0	0.0	0.081	19.6	2.60	15.00
5	25-Jul	YC5	0.1	0.0	0.055	20.0	6.40	13.80
6	4-Aug	YC5	0.2	0.2	0.084	19.6	5.20	12.40
7	13-Aug	YC5	0.2	2.2	0.208	18.4	6.20	15.80
Average			0.2	0.4	0.091	18.1	5.63	20.17

2	29-Jun	YS1	1.0	1.6	0.194	12.4	14.40	34.80
6	4-Aug	YS1	1.7	2.3	0.038	14.4	5.80	15.20
Average			1.4	2.0	0.116	13.4	10.10	25.00
2	29-Jun	YS2	0.3	0.6	0.288	11.2	13.20	37.80
3	9-Jul	YS2	0.4	1.5	0.171	9.8	6.20	19.20
4	16-Jul	YS2	0.4	0.4	0.179	10.6	7.20	16.40
5	25-Jul	YS2	0.3	0.0	0.081	11.6	9.00	20.60
6	4-Aug	YS2	0.2	0.3	0.146	10.8	7.40	14.40
7	13-Aug	YS2	0.2	0.5	0.389	11.2	10.40	23.00
Average			0.3	0.6	0.209	10.9	8.90	21.90
1	18-Jun	YS3	0.5	2.2	0.129	1.8	6.80	44.00
2	29-Jun	YS3	0.1	0.0	0.022	1.2	6.00	29.20
3	9-Jul	YS3	0.2	1.1	0.074	1.1	4.80	15.60
4	16-Jul	YS3	0.5	1.1	0.092	1.0	6.00	22.80
Average			0.3	1.1	0.079	1.3	5.90	27.90
1	18-Jun	YS4	0.3	0.5	0.049	2.1	12.20	55.20
Average			0.3	0.5	0.049	2.1	12.20	55.20
1	18-Jun	YS5	0.2	0.4	0.066	1.5	7.20	29.40
2	29-Jun	YS5	0.1	0.0	0.000	1.8	6.00	29.40
3	9-Jul	YS5	0.1	0.0	0.047	1.7	3.80	13.60
Average			0.1	0.1	0.038	1.7	5.67	24.13

Appendix BA) Pictorial view of site locations



B) Pictoral Site Comparisons

I) Yellow Trail

YS1

YC1

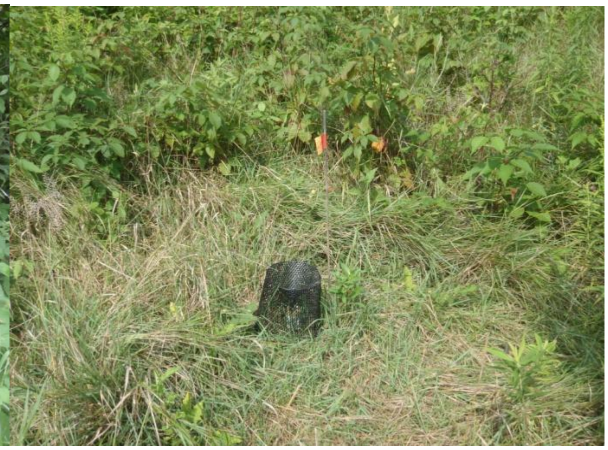
YS2

YC2

YS3

YC3

YS4 **YC4**

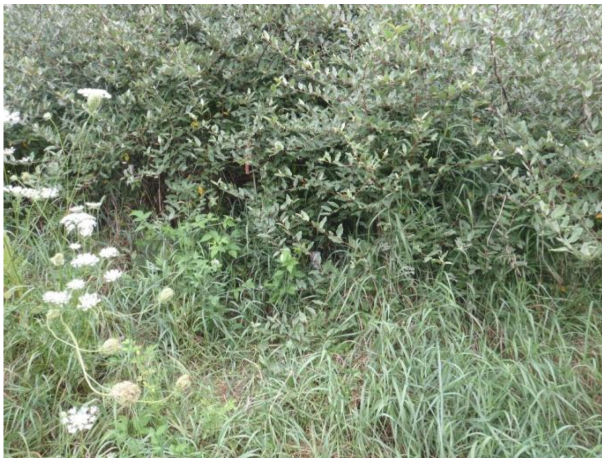


YS5 **YC5**

II) Orange Trail

OS1

OC1



OS2

OC2

OS3

OC3


OS4 **OC4**


OC5 **OC5**

III) Lab Area


LS1 **LC1**

LS2

LC2

LS3

LC3

LS4 **LC4**

LS5 **LC5**