Decay Rates of Native and Invasive Tree Species Leaves in Aquatic and Terrestrial Sites

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Abstract

In this study, we look at the decay rates of native and invasive tree species leaves in aquatic and terrestrial environments. We also determine if invasive tree species leaves influence the decay rates of native tree species leaves when they are physically near each other. We also investigate if geographical factors cause leaves to decay at different rates by examining the decay rates of similar tree species leaves in 4 different regions of the United States.

1 Introduction

Trees are essential to life as we know it. They produce oxygen and are sources of wood, paper, oils, syrups, and other products that many humans need or enjoy. Trees also have ecological impacts on the environment. In most parts of the world, leaves change color in autumn. Ironically, these leaves are most beautiful before they die. Once these leaves meet their fate, microorganisms and decomposers break down internal nutrients that can be recycled in the environment in the coming seasons.

In this study, we investigate the decay rates of native and invasive tree species leaves in terrestrial environments and in aquatic environments. Data was collected from 27 different institutions across the United States. We will analyze data from seven of these 27 samples. One of the goals of this study was to determine whether or not invasive tree species' leaves decayed faster than native tree species' leaves. This was done by collecting and weighing leaves from native trees and from invasive trees. Then we set the leaves out in terrestrial and aquatic environments and re-weighed them over several months. Doing this helped us determine whether invasive tree species had advantages over native tree species in internal components. Another goal we had was to determine whether moisture affected decomposition rates across different regions in the country.

2 Definitions and Development

Institutions were allowed to choose different types of corresponding invasive and native tree species in their particular area to study. The list is presented in **Figure 2.1**.

While it was necessary for all the institutions to measure the decay rates of invasive and native tree species leaves, the type of environment varied. Some institutions decided only to study the decay rates of leaves in aquatic environments (stream sites) while others decided only to study the decay rates of leaves in terrestrial environments (upland sites away from the stream). Some institutions chose both ecosystems.

Invasive Species	Native Species Pair
Buckthorn	Black Cherry or Gray Dogwood
Honeysuckle	Spice Bush
Norway maple	Sugar Maple, Red Maple, or Sycamore
Privet	Texas Mountain Laurel
Tree of Heaven	Smooth Sumac

Figure 2.1: A list of invasive species trees and their paired native species trees.

For all institutions, the protocols were the same. Leaves were shaken from trees in late autumn and captured in a bag. Gloves were worn to avoid contamination. Once the leaves were collected, they were weighed and put into five different litterbags. The first bag contained 100% invasive tree species leaves, the second bag contained 75% invasive tree species leaves and 25% native tree species leaves, the third bag contained 50% invasive tree species leaves and 50% native tree species leaves, the fourth bag contained 25% invasive tree species leaves and 75% native tree species leaves, and finally the fifth bag contained 100% native tree species leaves. After the bags were made, they were attached to a string of fishing line. Each string of fishing line contained five bags (one of each of the bags mentioned previously) in random order. For the institutions that chose to study decay rates of terrestrial and aquatic environments, ten strings were placed in an aquatic environment, and ten strings were placed in a terrestrial environment. Three bags served as control bags and were sent to a lab to be studied. Aquatic leaf litterbags were collected 1-2 months and 3-4 months after the initial setup, and terrestrial leaf litterbags were collected at 3-4 months and 12 months after the initial setup. The litter was allowed to dry and then was weighed.

Before we analyze our results, we define some terms.

Definition 1 **Decomposition** is when substances break down into their natural elements.

Definition 2 A **native species** is a species which belongs to a habitat or an environment and has been in that habitat or environment for a long enough time to adapt to the climate, hydrology, and geology of its region. Native species generally have a positive impact on the ecosystem [1].

Definition 3 An **invasive species** is a species which does not belong to a habitat or an environment because it was introduced on purpose or on accident. Invasive species generally have a negative impact on the ecosystem [1].

Definition 4 Mixed bags (bags that contain different ratios of invasive leaves and native leaves in the same bag) are **additive** when the decomposition rates of single samples (native only bags or invasive only bags) determine the decomposition rates of the mixed bags.

3 Results

We ran a *t-test* assuming unequal variances for two main hypotheses. We tested if (1) aquatic decay rates were higher than terrestrial decay rates, and if (2) native decay rates were higher than invasive decay rates.

The controls for the first main hypothesis were whether 100% invasive tree species leaves were used or whether 100% native tree species leaves were used. Statistics were run for 60 day time frames and 120 day time frames.[1]

The controls for the second main hypothesis were whether leaves in an aquatic environment were used or whether leaves in a terrestrial environment were used. Statistics were run for 60 day time frames and 120 day time frames.[1]

These tests were run by combining all the data from the seven different schools into one data set based on the parameter tested. We used a 5% significance level, which is common for biological studies that are not medical. We reject the null hypothesis (H_0) and accept the research hypothesis (H_1) when the *p*-value is less than .05. When the *p*-value is greater than .05, we accept the null hypothesis.

Hypothesis	***t*-critical**	***t*-statistic**	***p*-value**
H_0: 100% Invasive Aquatic 120 Day ≤ 100% Invasive Terrestrial 120 Day H_1: 100% Invasive Aquatic 120 Day > 100% Invasive Terrestrial 120 Day	1.69	4.04	.00015
H_0: 100% Native Aquatic 120 Day ≤ 100% Native Terrestrial 120 Day H_1: 100% Native Aquatic 120 Day > 100% Native Terrestrial 120 Day	1.73	5.23	.000024
H_0: 100% Invasive Aquatic 60 Day ≥ 100% Native Aquatic 60 Day H_1: 100% Invasive Aquatic 60 Day < 100% Native Aquatic 60 Day	1.71	2.46	.011
H_0: 100% Invasive Aquatic 120 Day ≥ 100% Native Aquatic 120 Day H_1: 100% Invasive Aquatic 120 Day < 100% Native Aquatic 120 Day	1.69	.017	.49
H_0: 100% Invasive Terrestrial 120 Day ≥ 100% Native Terrestrial 120 Day H_1: 100% Invasive Terrestrial 120 Day < 100% Native Terrestrial 120 Day	1.68	1.77	.04

Figure 3.1: A table showing the hypotheses, *t*-critical (one-tailed) values, *t*-statistic values, and *p*-values (one-tailed) for the combined institute data as specified in *t-tests* assuming unequal variances.

The results in **Figure 3.1** show that the decay rates of leaves in aquatic environments are higher than the decay rates of leaves in terrestrial environments for both 100% invasive tree species bags and 100% native tree species bags. This might be the case because moisture allows decomposers (bacteria and fungi) to increase their productivity rates [2]. Since organisms need water for survival, an increase in moisture may lead to an increase in decomposers, which would lead to an increase in decomposition of leaves.

The results also show that decay rates for leaves from native tree species are higher than the decay rates for leaves from invasive tree species for both aquatic 60 day and terrestrial 120 day data. This might be the case because the invasive trees were more recently introduced

[1] 60 day time frame = 59 days for Augustana, 60 days for Beloit, 60 days for Ferrum, and 43 days for Macalester (Aquatic only)
120 day time frame = 124 days for Augustana, 120 days for Beloit, 120 days for Carthage (Terrestrial only), 120 days for Ferrum, 102 days for Macalester (Aquatic only), 129 days for Rogers State (Terrestrial only), and 120 days for SUNY (Terrestrial only).

to the environment than the native trees were. Thus, the current decomposers in the environments have been adapted to break down the internal content of the native tree leaves more efficiently than the internal content of the invasive tree leaves.

Finally, the results show that after 120 days in an aquatic environment, the invasive tree species decay rates are greater than or equal to the native tree species decay rates. This is probably the case since aquatic leaves always decayed faster than terrestrial leaves according to our analysis. Therefore, after 120 days, most of the leaves—be them invasive or native—were fully decayed. That would result in invasive tree species and native tree species decay rates possibly being statistically equal if the invasive tree species decay rate was not greater than the native tree species decay rate.

Next, we ran a single factor ANOVA comparing whether the mixed bags were additive or not. In order to determine whether a mixed bag was additive, the bags containing the different ratios of native and invasive species leaves needed to be unequal to each other. In other words, the bags were additive when the research hypothesis was supported.

The ANOVA tests were run for aquatic 60 and 120 day[1] mixes as well as terrestrial 120 day[1] mixes. Like the previous test, the data set includes all corresponding institution data, and the null hypothesis is rejected when the *p*-value is less than .05. For the sake of simplicity, *75% Native* refers to the bags containing the ratio *75% Native: 25% Invasive* leaves, *50% Native* refers to the bags containing *50% Native: 50% Invasive*, and *25% Native* refers to the bags containing *25% Native: 75% Invasive* leaves.

Hypothesis	***F*-critical**	***F*-value**	***p*-value**
H_0: (Aquatic 60 Day) 75% Native = 50% Native = 25% Native H_1: (Aquatic 60 Day) 75% Native ≠ 50% Native ≠ 25% Native	3.15	.12	.89
H_0: (Aquatic 120 Day) 75% Native = 50% Native = 25% Native H_1: (Aquatic 120 Day) 75% Native ≠ 50% Native ≠ 25% Native	3.18	.11	.90
H_0: (Terrestrial 120 Day) 75% Native = 50% Native = 25% Native H_1: (Terrestrial 120 Day) 75% Native ≠ 50% Native ≠ 25% Native	3.11	1.29	.28

Figure 3.2: A table showing the hypotheses, *F*-critical values, *F*-values, and *p*-values to determine whether mixed bags are additive or not via an ANOVA test combining all institute data.

The results in **Figure 3.2** show that the mixed bags were not additive. This means that the native and invasive tree species leaves did not statistically affect each other's decay rates. This might be the case because the internal compositions of the native and invasive tree species leaves were similar enough that the decomposers were able to break them down at similar rates in this experiment. We suspect that the internal components of the invasive and native tree species leaves were similar enough to be statistically equal but not chemically equal because we saw a difference in decay rates between the native and invasive tree species leaves in **Figure 3.1.**

A third test we ran was an ANOVA comparing the decay rates of the same types of leaves between two institutions. These two institutions used the same invasive-native tree pairing when they collected data. Ferrum and Augustana both looked at decay rates of leaves from Tree of Heaven (an invasive tree) and from Smooth Sumac (a native tree). Also, both institutions placed bags in aquatic and terrestrial environments, and were the only two schools who used the same types of tree pairings to collect data from both ecosystems. We analyzed 100% invasive terrestrial 120 day data, 100% native terrestrial 120 day data, 100% invasive aquatic 60 day data, 100% invasive aquatic 120 day data, 100% native aquatic 60 day data, and 100% native aquatic 120 day data. The null hypothesis is rejected when the *p*-value is less than .05.

Hypothesis	***t*-critical**	***t*-statistic**	***p*-value**
H_0: Ferrum 100% Invasive Terrestrial 120 Day = Augustana 100% Invasive Terrestrial 120 Day H_1: Ferrum 100% Invasive Terrestrial 120 Day ≠ Augustana 100% Invasive Terrestrial 120 Day	± 2.78	-4.03	.016
H_0: Ferrum 100% Native Terrestrial 120 Day = Augustana 100% Native Terrestrial 120 Day H_1: Ferrum 100% Native Terrestrial 120 Day ≠ Augustana 100% Native Terrestrial 120 Day	± 2.57	1.04	.35
H_0: Ferrum 100% Invasive Aquatic 60 Day = Augustana 100% Invasive Aquatic 60 Day H_1: Ferrum 100% Invasive Aquatic 60 Day ≠ Augustana 100% Invasive Aquatic 60 Day	± 2.78	1.12	.33
H_0: Ferrum 100% Invasive Aquatic 120 Day = Augustana 100% Invasive Aquatic 120 Day H_1: Ferrum 100% Invasive Aquatic 120 Day ≠ Augustana 100% Invasive Aquatic 120 Day	± 2.31	-5.28	.00075
H_0: Ferrum 100% Native Aquatic 60 Day = Augustana 100% Native Aquatic 60 Day H_1: Ferrum 100% Native Aquatic 60 Day ≠ Augustana 100% Native Aquatic 60 Day	± 2.36	-.10	.92
H_0: Ferrum 100% Native Aquatic 120 Day = Augustana 100% Native Aquatic 120 Day H_1: Ferrum 100% Native Aquatic 120 Day ≠ Augustana 100% Native Aquatic 120 Day	± 2.78	-1.20	.30

Figure 3.3: A table showing the hypotheses, *t*-critical (two-tailed) values, *t*-statistic values, and *p*-values (two-tailed) for Ferrum and Augustana data as specified in *t-tests* assuming unequal variances.

The results in **Figure 3.3** show that invasive tree species decay rates between the two schools are not the same in terrestrial environments and in aquatic environments after 120 days. However, the invasive tree species decay rates were the same for both institutions in the aquatic environment after 60 days. Also, the native decay rates were the same in terrestrial environments and in aquatic environments after 60 and 120 days. This may be because of geographical factors. Augustana is in the northwestern region of Illinois, and Ferrum is in the south-central region of Virginia. In general, the Illinois college's region (Moline, Illinois) experiences cooler mean temperatures and more snowfall throughout the year than the Virginia college's region (Richmond, Virginia). Also, the average total precipitation amounts between the two regions are fairly similar but vary throughout the winter months [3], which may be due to moisture in snowfall. These variations in moisture and warmth can affect decay rates as we have seen in comparing aquatic and terrestrial rates.

A final test we ran was an ANOVA single factor, which compared the four institutions that used Tree of Heaven as an invasive tree and Smooth Sumac as a native tree. These schools were Ferrum, Augustana, Rogers State, and Carthage. Because Rogers State and Carthage only collected terrestrial data, only the terrestrial data was analyzed for all schools in these tests. The schools collected terrestrial data after 120 days.[1] The null hypothesis is rejected when the *p*-value is less than .05.

Hypothesis	*F*-critical	*F*-value	*p*-value
H_0: Ferrum 100% Invasive Terrestrial 120 Day = Augustana 100% Invasive Terrestrial 120 Day = Rogers 100% Invasive Terrestrial 120 Day = Carthage 100% Invasive Terrestrial 120 Day H_1: Ferrum 100% Invasive Terrestrial 120 Day ≠ Augustana 100% Invasive Terrestrial 120 Day ≠ Rogers 100% Invasive Terrestrial 120 Day ≠ Carthage 100% Invasive Terrestrial 120 Day	3.29	13.02	.00019
H_0: Ferrum 100% Native Terrestrial 120 Day = Augustana 100% Native Terrestrial 120 Day = Rogers 100% Native Terrestrial 120 Day = Carthage 100% Native Terrestrial 120 Day H_1: Ferrum 100% Native Terrestrial 120 Day ≠ Augustana 100% Native Terrestrial 120 Day ≠ Rogers 100% Native Terrestrial 120 Day ≠ Carthage 100% Native Terrestrial 120 Day	3.29	39.57	.00000023

Figure 3.4: A table showing the hypotheses, *F*-critical values, *F*-values, and *p*-values to determine whether leaves were similar among Ferrum, Augustana, Rogers State, and Carthage for the specific data as specified using ANOVA.

The results in **Figure 3.4** show that both the invasive and native tree species decay rates in terrestrial environments are not similar between the institutions. This means that there may be specific geographic factors that affect the decay rates of terrestrial leaves. We already know there may be geographic factors that affect the decay rates for Ferrum and Augustana. When we consider climate data for the Tulsa region (Rogers State) and the Milwaukee region (Carthage College), we find that there are differences in average precipitation, snowfall, and temperatures between the four institutions. The average precipitation amounts are roughly similar, but vary in the winter months and in the late spring. In the late spring, Tulsa has significantly higher average precipitation measurements than the other three regions. We also find that Tulsa is warmer than Richmond, which is warmer than Moline, which is warmer than Milwaukee. As can be expected, Milwaukee has higher snowfall than Moline, which has more snowfall than Richmond, which has slightly more snowfall than Tulsa January through March [4]. These variations in moisture and warmth can affect decay rates as we have seen in comparing aquatic and terrestrial rates.

4 Conclusion and Directions for Further Research

Overall, based on our results from **Figure 3.1**, we found that aquatic decay rates are higher than terrestrial decay rates. Also, for the most part, native tree species decay rates are higher than invasive tree species decay rates, except when native and invasive tree species leaves are in aquatic environments. When native and invasive tree species leaves are in aquatic environments, invasive decay rates are greater than or equal to native decay rates. Based on the pattern of native tree species rates being higher than invasive tree species rates, we conclude that the native and invasive tree species rates are equal because both the native and invasive tree species leaves probably decayed close to 100% of their original mass in the aquatic environment. Based on **Figure 3.2**, we found that the mixed bags were not additive. This means that the native and invasive tree species leaves did not statistically affect each other's decay rates. This might be the case because the internal compositions of the native and invasive tree species leaves were similar enough that the decomposers were able to break them down at similar rates in this experiment. Though, we suspect that the internal components of the invasive and native tree species leaves were similar enough to be statistically equal but not chemically equal because we saw a difference in decay rates between the native and invasive leaves. The results in **Figure 3.3** and **Figure 3.4** show that invasive tree species decay rates are not always similar in different geographical regions, and native tree species decay rates are not always similar in different geographical regions either. Factors like precipitation, temperature, and snowfall are just a few factors that can affect decay rates.

Based on the results, it seemed clearly evident that leaves in aquatic environments decay faster than leaves in terrestrial environments. In order to further explore how moisture affects the decay process, researchers should test the decay rates of leaves in dry climates, such as deserts, and in more humid climates, such as rain forests. Similarly, researchers can also test how leaves decay in differing aquatic environments such as oceans and ponds rather than stream sites. In order to compare the decay rates of invasive and native leaves, these experiments can be redone in order to see if other results are obtained. More data can also be collected. Even though the protocols mention that leaves were to be collected after 365 days, a year has not yet passed from the time of the initial setup and when the data was analyzed in this report. More data can also be collected because factors such as animals, floods, and people, have caused some bags to be lost.

References

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Appendices

Data can be provided upon request.

To learn more about EREN-DATIS (Ecological Research as Education Network-Decomposition in Aquatic and Terrestrial Invaded Systems), please visit www.erenweb.org/datis.

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