Fruit Size in Flowering Dogwood (*Cornus florida*): Effects on Avian Frugivory and Seed Dispersal

By
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April, 2018



Allegheny College
Department of Biology

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A Senior Comprehensive Project in Partial Fulfillment of the Requirements
for a Bachelor of Science Degree from Allegheny College

I hereby recognize and pledge to fulfill my responsibilities as defined in the Honor Code
and to maintain the integrity of both myself and the College community as a whole.

_____
Pledge

Approval by the Senior Thesis Committee:

_____
Dr. Mumme

_____
Dr. Wissinger

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Abstract

Recent changes in climate around the world have reinforced the importance of understanding fragile plant and animal interactions that occur in nature. Birds rely on fruiting plants as a source of food, and plants need birds to disperse their seeds so that they can reproduce. The purpose of this study was to determine how fruit size affected ingestion and subsequent seed regurgitation on germination rates of flowering dogwood, a common fruiting tree in northwest Pennsylvania. Seeds were collected directly from flowering dogwood fruits on trees, and regurgitated seeds were collected from underneath the same flowering dogwood trees. Seeds of both groups were stratified over the winter and germinated in the spring to see if regurgitated seeds had higher or lower germination success. This study also looked at whether birds showed a preference for larger or smaller fruits. This was done by measuring individual fruits and the seeds within them to see if the size of the seed could be an indicator of fruit size. Because a strong correlation was found between fruit and seed size, the size of regurgitated seeds could be compared to the average size of uneaten seeds. There was not a significant difference in seed size between regurgitated and uneaten fruits, indicating that frugivorous birds do not have a strong preference for large versus small seeds. None of the seeds collected from undigested fruits germinated, but two (3.8%) of the 52 regurgitated seeds did germinate. Although limited, this result suggests that ingestion and regurgitation is important for dispersal and germination of flowering dogwood seeds.

Introduction

In recent years, global climate change has become one of the most hotly debated topics and is a major concern of many people. Temperature fluctuation has serious consequences such as altering water levels, changing the length of seasons, as well as shifting habitats of plants and animals. This is problematic since every relationship that occurs in nature is a product of millions of years of evolution, and the climate is now changing at a much faster rate than it has before. The average global temperature has risen 2 °F in the last 150 years, but most of that change has occurred in the last 35 years (Climate change evidence 2018). Some individual species are able to adapt quickly enough to keep up, but others cannot. This can strain established relationships between species that adapt at different rates.

There are already many examples of organisms altering their behavior in response to climate change. Increasingly warm and damp winters have caused the breeding season of many species of plants, birds, and amphibians to start early (Forchhammer *et al.* 1998). Another study found that during warmer years, caterpillars grow more rapidly. This causes an early "food peak" for birds that feed off of caterpillars, such as Pied Flycatchers. Pied Flycatchers decrease the size of their clutches in years with early food peaks (Both and Visser 2005). Climate change can have serious effects on bird migration in both the spring and fall. Based on historical data, bird populations in Sweden arrive earlier in the spring than they used to in southern and central Sweden (Kullberg, *et al.* 2015). Spring arrival has generally started earlier for migrating birds, but fall migration patterns have been less consistent. Some birds are migrating earlier while others are migrating later. A study published as early as 2003 found that during fall migration, birds that migrate to locations south of the Sahara Desert have begun to migrate earlier

than they did in the past, while species whose destination was north of the Sahara Desert were delaying their migration (Jenni and Kery 2003). Because fifteen years have passed since the publication of this paper, the results would probably be slightly more exaggerated if this study were to be repeated today. This is a bad sign since all living organisms are somehow connected to each other, and behavioral changes in one species can have serious consequences for all of the organisms that it interacts with.

One crucial mutualistic relationship exists between fruiting trees or shrubs and avian frugivores that consume the fruit and distribute the seeds of that plant. Even birds that would normally prey on insects will consume fruits when they migrate in the fall (Thompson and Willson 1979). Many trees grow best in specific microhabitats, but their seeds won't normally make it to these locations without the help of specific animal dispersers. Some research has shown that seeds are more likely to germinate when they have been freed from the pulp of the fruit, which occurs when they are ingested. A study done in 1997 investigated the effects of regurgitation and defecation by several species of waxwings and thrushes (*Bombycilla cedrorum, Turdus migratorius, Hylocichla mustelina, Catharus guttatus* and *C. minimus*) on germination success of spicebush (*Lindera benzoin*), chokecherry (*Prunus virginiana*), and arrowwood (*Viburnum dentatum*). Their results suggest that defecated seeds do not necessarily experience higher germination rates, but regurgitated seeds do since they are cleaned and free of pulp. The authors also note that seeds cleaned manually by humans also germinated more successfully than those left inside fruit (Meyer and Witmer 1997). Relationships between plants and frugivores are obviously crucial for all actors. Animals have a reliable source of nutrients, while the plants are able to reproduce as successfully as possible. This

interaction is especially important during fall migration when bird mortality increases by as much as 15 times the normal rate. This is due to the high energy demands of migration, which require birds to consume fruits with high fat contents (Smith et al. 2013).

One important source of energy for migratory birds is the flowering dogwood (*Cornus florida*). Flowering dogwood is native to eastern North America and displays white flowers in the spring which yield to bright red fruit in autumn (*Cornus florida*). Flowering dogwoods improve the soil surrounding them because their leaves decompose relatively quickly which enriches the soil with nutrients (Wennerberg 2018). A senior project done in 2012 found that at least 22 different types of birds fed on flowering dogwood fruit in Greendale Cemetery of Meadville, Pennsylvania. The most common visitors to these trees included Cedar Waxwings, American Robins, Northern Cardinals, European Starlings, and White-throated Sparrows (Jacobs 2012). The eastern chipmunk, white-footed mouse, grey squirrel, black bear, and skunks are also known to rely on flowering dogwood trees for at least part of their diet (Wennerberg 2018).

Different birds have been found to show preferences for specific fruit sizes. A previous study found that birds preferred to stop at shrubs that have the most fruit, the largest fruit, and the greatest amount of fruit pulp (Sallabanks 1993). The same study found that when offered dough fruits, robins would sample the larger fake fruits before the smaller ones. One possible explanation for this is that larger fruits have larger seeds, which are regurgitated rather than defecated. Seeds take up a lot of space in a bird's digestive tract, and they are expelled more quickly when regurgitated (Levey 1986). This allows birds to consume more fruit in a shorter amount of time.

My study was designed to see if regurgitation by avian frugivores affected germination success specifically of flowering dogwood seeds. Seeds that had been swallowed and regurgitated by birds were predicted to have a higher germination rate than those gathered directly from the tree. One previous study looked at the effects of digestive processing on seed germination and did not find that regurgitation had a significant effect on germination success (Meyer and Witmer 1998). This study however, did not look specifically at *Cornus florida*, which was the main subject of my project. While gathering seeds for this experiment, I also examined the effects of seed size to see whether or not birds showed a preference for either large or small seeds. Based off of the literature, I expected birds to show a preference for larger *Cornus florida* seeds.

Methods

In order to determine if there is a difference in germination success between manually cleaned flowering dogwood seeds and those regurgitated by birds, a large sample size was collected for both groups. Four flowering dogwood trees were identified in Greendale Cemetery in Meadville, PA. Ten fruits were collected from each tree and the seeds were removed from the pulp, then laid out to dry overnight before being stored in plastic bags. Regurgitated seeds were collected from underneath the same trees that the fruit came from and were collected between September 23, 2017 and October 17, 2017. Both undigested and regurgitated seeds were stratified for three and a half months in a refrigerator at 40 °F ("How to Grow Dogwood Trees From Seed" 2018). Seeds from each tree were stored separately in plastic bags. Each bag contained the same amount of sphagnum peat moss, which was kept moist throughout stratification. Each plastic bag was placed inside of a brown paper bag to minimize light exposure of seeds (Allen and

Farmer 1977). Although these fruits and seeds were not randomly collected, they were still measured to test if there is a difference in size between seeds collected directly from the tree versus those found after being ingested.

On February 19th, the seeds were planted in individual plastic pots to avoid overcrowding (Wennerberg 2018) and monitored daily. Enough water was given to each plant to maintain moist soil without flooding. The seeds were germinated in a greenhouse and were exposed to sunlight throughout the germination process. 40 undigested and 52 digested seeds were planted for a total of 92 seeds.

Flowering dogwood fruit and seed samples were also collected from four saplings along the Ernst Trail in Meadville, PA after the fruit had been completely stripped from the trees in Greendale Cemetery. These were collected between October 21, 2017 and November 17, 2017. The length, width, and mass of these fruits were recorded, and then the seeds were removed from the pulp and the same measurements were recorded on the seeds. Regurgitated seeds were also collected from underneath of these saplings and similarly measured. These measurements were run through statistical analyses to test whether or not there is a correlation between fruit size and the size of the seed within the fruit, as well as whether or not birds show a preference for larger or smaller seeds.

Results

There was a positive correlation between the length, width, and mass of a fruit and the length, width, and mass of the seed within the fruit (Figure 1). This meant that regurgitated seeds on the ground could be compared to undigested seeds to determine if birds were selecting fruit based on size. There was not a difference in the width (Figure

3), length (Figure 4), or mass (Figure 5) between regurgitated seeds and undigested seeds (Table 1).

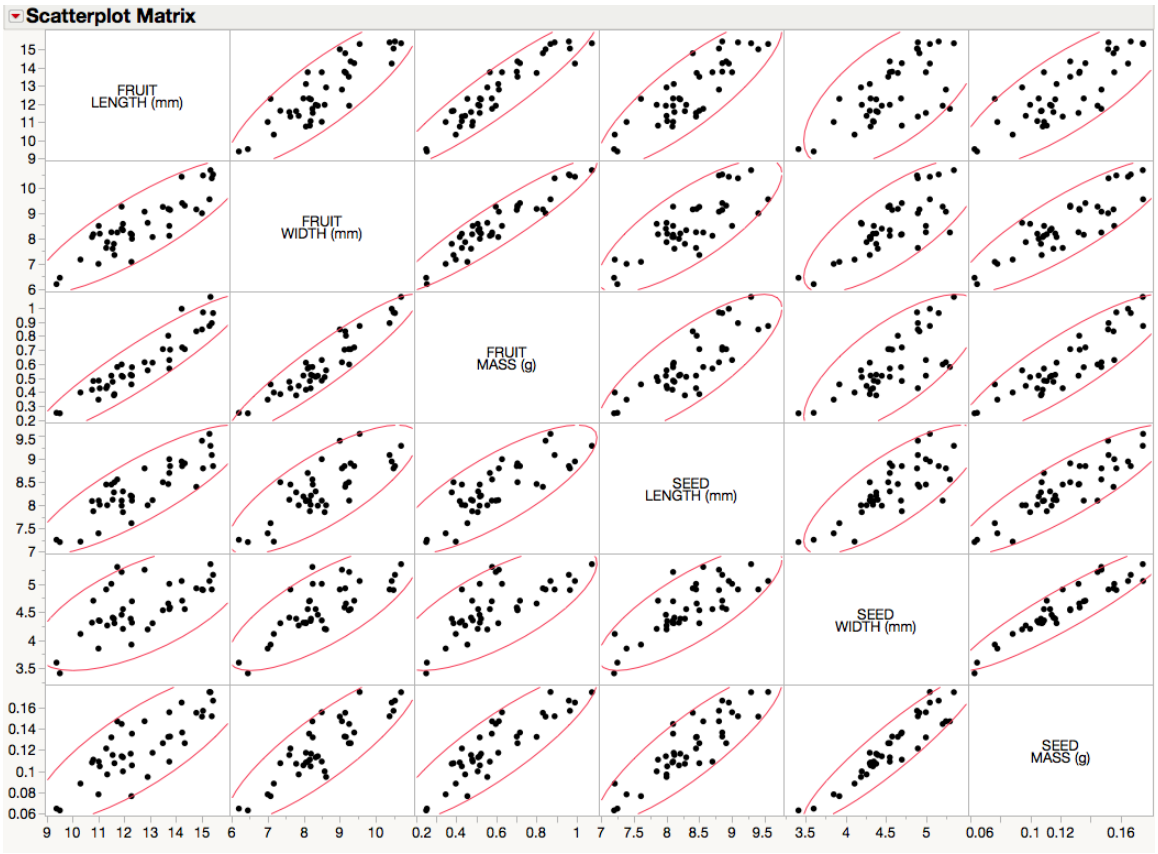


Figure 1. Positive correlations among fruit and seed length, width, and mass for flowering dogwood fruits and seeds gathered along the Ernst Trail.

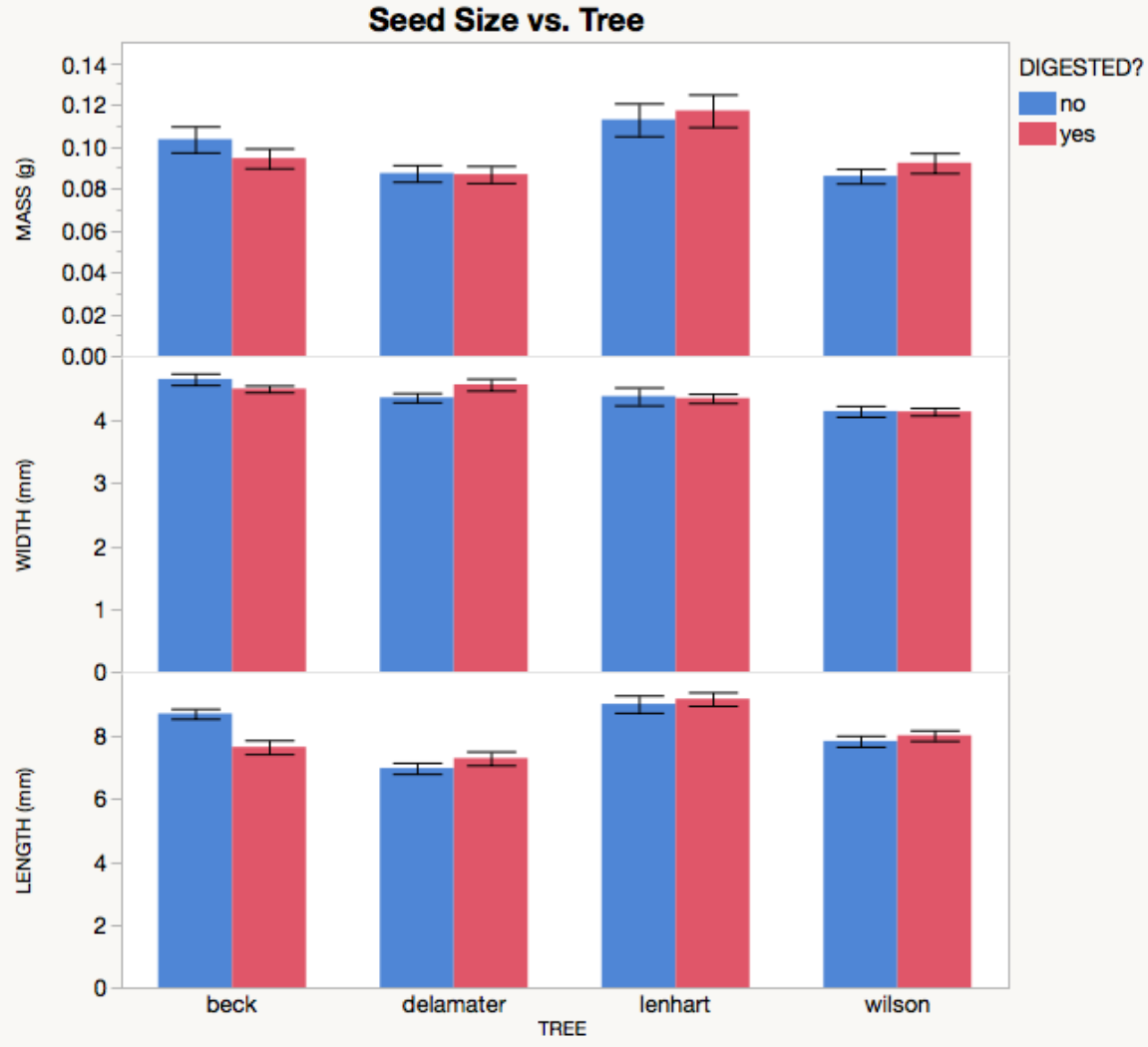


Figure 2. Relationship between size of digested and undigested *Cornus florida* seeds by the tree that they originated from in Greendale Cemetery. Error bars show 1 standard error from the mean.

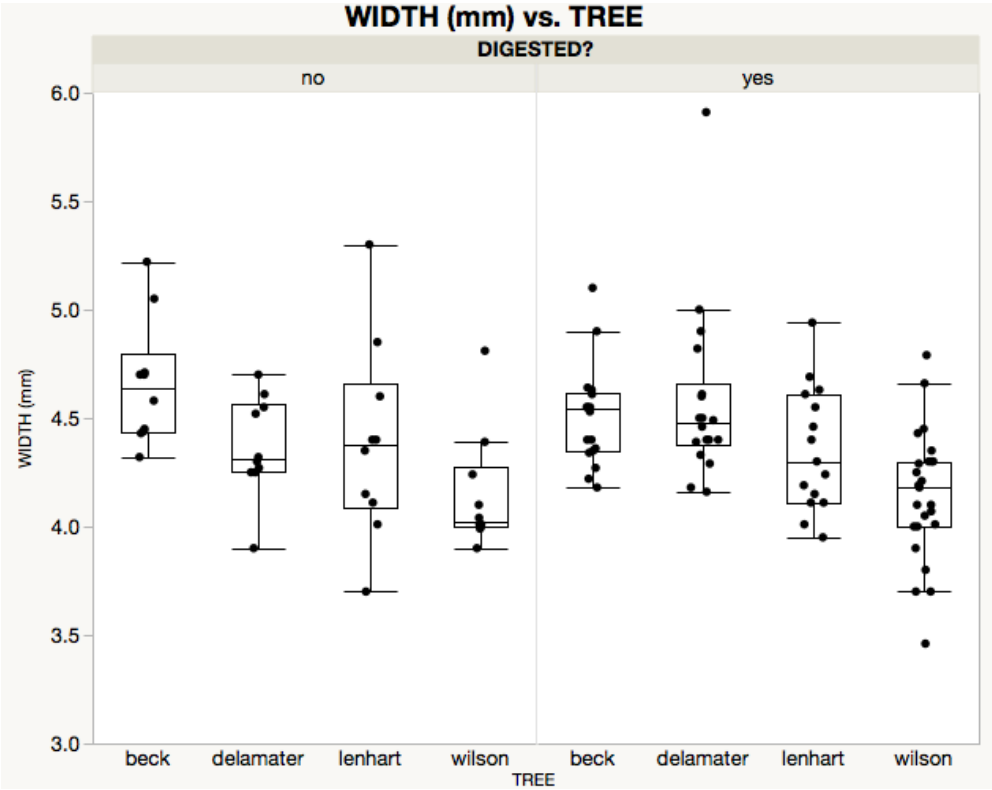


Figure 3. Differences in seed width between digested and undigested *Cornus florida* seeds by tree from Greendale Cemetery. There were no significant differences in width between digested and undigested seeds.

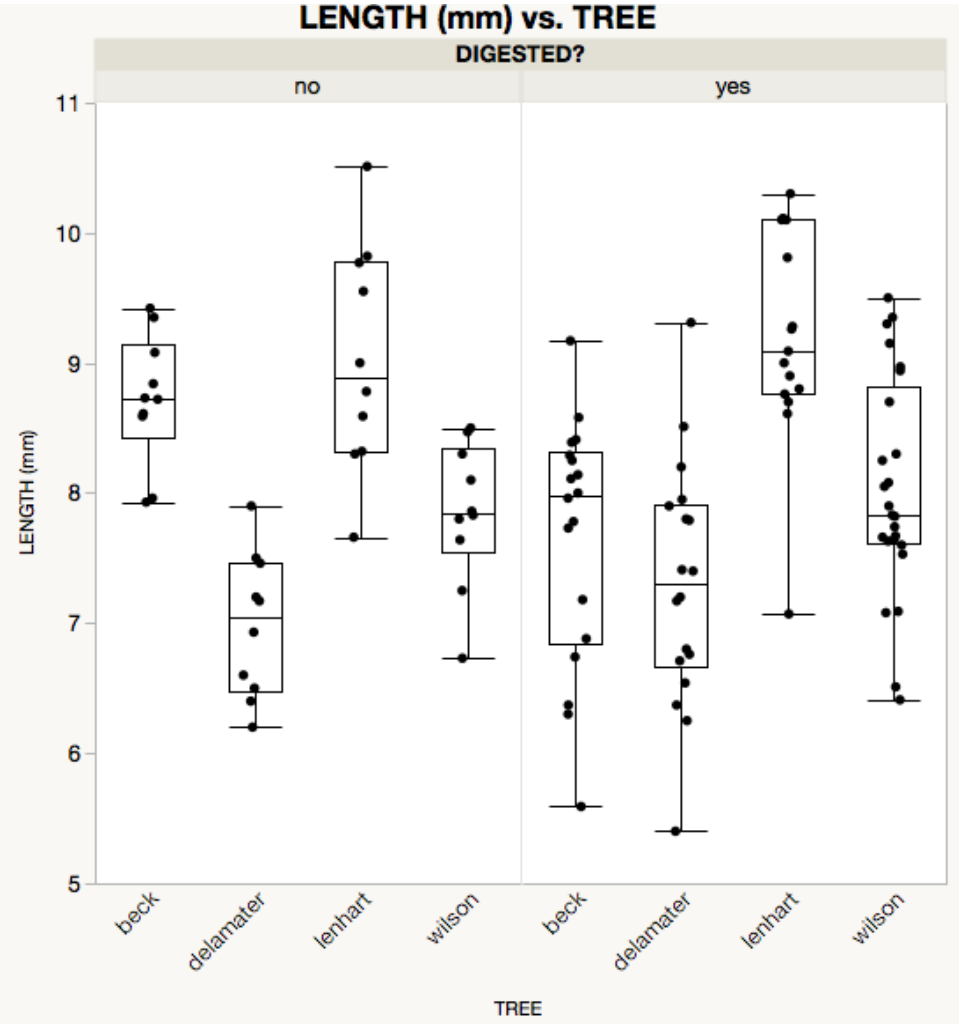


Figure 4. Relationship between tree and length of seeds from Greendale Cemetery. There was not a significant difference in length between undigested and digested seeds.

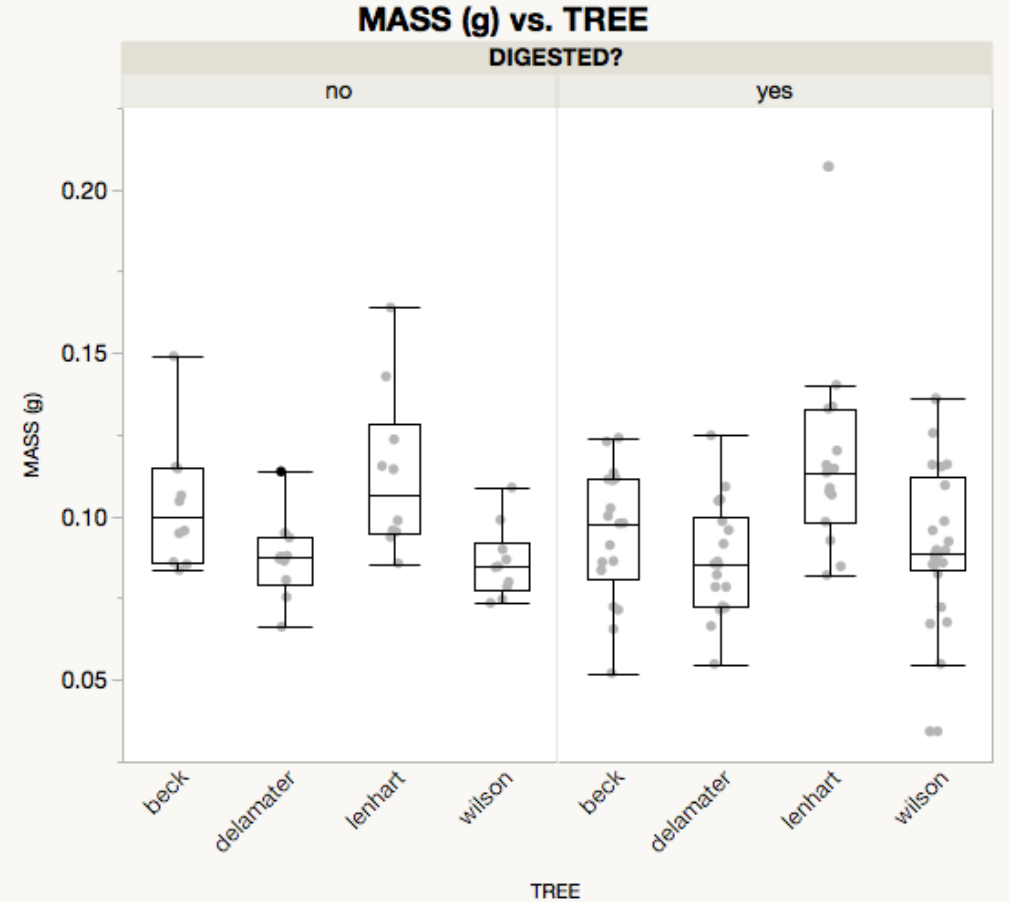


Figure 5. Relationship between tree and mass of seeds from Greendale Cemetery. The mass of the seeds varied depending on the tree, but there were not significant differences in mass between digested and undigested seeds.

Table 1. Calculated *F*(1) and *P* values for the difference in length, width, and mass of flowering dogwood seeds collected along the Ernst Trail.

Variable	*F*(1) value	*P* value
Length	0.3426	0.5575
Width	0.0062	0.9374
Mass	0.0071	0.9330

Of the 52 regurgitated *C. florida* seeds planted from Greendale Cemetery, only 2 (3.8%) germinated, both sprouting above the soils surface on day 25 after planting. However, none (0%) of the 40 undigested seeds had germinated by day 36. On day 25 of the germination trial, two seeds had sprouted above the soil. After 36 days, the

ungerminated seeds were excavated to ensure that they did not show any signs of development.

Discussion

Based on the size of regurgitated seeds, birds did not appear to show a preference for larger or smaller fruits. Although some research indicates that birds prefer shrubs with larger fruit (Sallabanks 1993), and that birds can eat relatively more fruits with larger seeds than with smaller seeds (Levey 1986), there is also research that shows some birds may actually prefer smaller fruit. Many migratory birds are limited as to which fruits they can consume by the size of their gape, which is the inside of their mouth. One study found that the size of fruit that a bird can eat is positively correlated to the size of the bird's gape (Mack 1993). This would explain the variety in sizes of seeds found regurgitated under seeds since presumably the birds stopping at these trees are not all identical sizes.

A few studies have explained the relative proportions of fruit with large seeds versus small seeds and had similar results. One study looked at 111 different species of fruit found on the Iberian Peninsula and found that when looking at increasing fruit size, the mass of the seed increases more rapidly than the mass of the pulp, so larger fruits have relatively more seed than pulp (Herrera 1987). A more recent study found that small single-seeded fruits have a higher pulp:seed ratio than large single-seeded fruits (Jordano 2000). It therefore may be more efficient for birds to eat smaller fruits than larger fruits.

There are several possible reasons why only two of the planted *C. florida* seeds germinated in this experiment. Most sources called for seeds to be stratified for 120 days at 40 °F (Wennerberg 2018), but due to time constraints, the seeds used for this project

were stratified for only 106 days. The seeds therefore may have needed more time to stratify and prepare for germination. Another issue that arose was the dampness of the soil. Several sources agree that the soil should be kept moist but should also be well-drained (Wennerberg 2018). In an effort to maintain soil moisture, water was added to the trays underneath of planting cups so that water could be absorbed through the bottom of the cups and not completely saturate the soil. Since water was constantly available to the planting pots, the soil was always damp and patches of green algae began to grow on top of the soil. At the end of the germination trial, seeds were removed from the soil and appeared to still be dormant. It is also possible that the temperature change from stratification in a refrigerator to being planted in the greenhouse was too much of a shock for the seeds since they are sensitive to rapid soil temperature fluctuations (Wennerberg 2018). Similar experiments should try to stratify seeds for the full 120 days, and carefully monitor the amount of water added to the soil to avoid oversaturation. Seeds should also be warmed up gradually after stratification to replicate the natural temperature change that occurs in spring.

Since the only two seeds that germinated during this study were digested, it is important to understand why digestion and regurgitation could have increased germination success of flowering dogwood seeds. Based on a meta-analysis of gut treatment on plant seeds, there are two mechanisms that could help explain this result. The first mechanism is scarification of the seed coat either by the food ingested with the seed, or by the chemicals found in the digestive tract of whatever animal ate the seed. The second mechanism is the removal of pulp from the seed since the presence of pulp can actually hinder germination. The meta-analysis found that responses of seeds to gut

treatment is variable depending on the species of plant, but in general these two mechanisms tend to increase germination success (Traveset and Verdu 2002).

The main result of this study was that there is a correlation between fruit and seed size in *Cornus florida*, so the size of the seed can be used to determine relative fruit size and vice versa. Based on the size of the regurgitated seeds found underneath flowering dogwood saplings along the Ernst Trail, migratory birds do not show a preference for larger or smaller fruits. Due to the small number of seeds that successfully germinated, I was not able to determine if ingestion and subsequent regurgitation has an impact on germination success of flowering dogwood seeds.

There are many directions in which future related projects could go. One follow-up study could evaluate fruit size selection by several species of birds of varying sizes. This would work best in a lab setting so that birds can be monitored more closely and the size of the fruit that the birds have access to will be more controlled. The amount of time that it takes for different migratory birds to digest the fruit and regurgitate the seed could also be studied, as well as where these birds go to digest their food. If they simply regurgitate seeds directly under the parent tree, they are not really benefiting the tree or its offspring. This could lend some insight into where different birds tend to leave regurgitated seeds, which is one factor in determining if that type of bird is a true disperser of flowering dogwoods. If birds or even other animals that most effectively disperse these seeds are identified, then coevolution between flowering dogwoods and these animals can be studied to understand exactly why the two organisms have certain specific traits. Understanding these close relationships will help deepen our

understanding of mutualistic interactions in nature and how these relationships could be affected by global climate change.

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