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Effect of habituation on seed consumption and species abundance of birds at feeders at Drew University and the Great Swamp Watershed Association–Conservation Management Area

A Thesis in Biology

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ABSTRACT

The provisioning of seed-eating birds has grown in recent years, impacting their health, reproduction, and survivability. However, since few studies have focused on the impact that habituation plays in the abundance and foraging habits of these species, I positioned feeders at two sites in Northern New Jersey. The first was the Zuck Arboretum, a broadleaf forest at Drew University (Madison, NJ), where birds are well habituated to both feeders and humans. The second location was the Great Swamp Watershed Association–Conservation Management Area (GSWA-CMA), a less habituated restoration site in Harding Township. Both sites contained two feeders, with one close to the human foot trail and the second approximately 20m away, to comprehend how distance influences foraging behavior. To achieve these goals, I refilled the feeders twice per week for 10 weeks, establishing trail cameras for continuous monitoring. I hypothesized that Zuck would possess a larger species richness and visitor count than the CMA, with CMA birds exhibiting more vigilance, a behavior correlated with lower levels of habituation. I also predicted that far feeders would have a greater number of avian species and visitors, to avoid potential risks associated with being near humans. Furthermore, I hypothesized that all of the seed would be consumed at both sites shortly after setting up my feeders. After analyzing my data, I found that site impacted both the average amount of seed removed and the number of visitors observed, while distance from the trail only affected the quantity of visitors. In particular, while the average amount of seed removed from Zuck surpassed the quantity taken from the CMA, more visitors were seen at the CMA and far feeders, potentially because of the higher quantity of cachers and small birds observed. At the CMA, species richness grew over time, as birds became habituated to the feeders, stabilizing around week 5. However, species richness each week at Zuck exceeded that of the CMA. Additionally, while some species

maintained their dominant or subordinate status, many birds' rankings fluctuated based on the identity of the other visitors. More vigilance was seen at the CMA than Zuck, supporting my hypothesis that CMA birds respond more to the presence of people. Finally, season and temperature influenced the quantity of birds visiting the CMA, but not Zuck. While CMA birds experienced a decline in the quantity of natural food sources in late autumn, many birds at Zuck may not have experienced these same constraints, as food is frequently left behind by the college community, supporting generalists, like Blue Jays (*Cyanocitta cristata*). Future scientists could utilize my research as a baseline to establish a more complete understanding of how best to support diverse, seed-eating avian populations in New Jersey and around the world.

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INTRODUCTION

Overview

Humans have engaged in the practice of feeding birds for thousands of years. This pastime has recently risen in popularity, however, due to the emergence of new technology and people's growing desire to connect with nature. Through scientific studies, we now know that many bird species become habituated to humans over time and that birds are more likely to feed nearer to cover than in the open. Surprisingly, little research has been conducted about the role of habituation on the abundance and feeding behaviors of free-living, seed-eating birds. My study aimed to examine these factors at two different sites, one situated within a college campus arboretum and the other within a low-trafficked conservation site in Northern New Jersey, to aid in best practices for supporting seed-eating bird populations, especially those at risk of extinction. Through my research, I hoped to explore the following questions: 1) Does habituation affect the quantity of seed consumed at feeder sites? 2) How does habituation, in the form of site and distance from human foot trails, impact species richness and the total number of birds visiting feeders? and 3) Are varying degrees of habituation correlated with differential behaviors at feeders?

Defining Birds

Despite the average human possessing scant knowledge of birds, this group of animals is remarkably complex, united under a single class. In fact, Aves possesses the most wide-ranging set of four-limbed species alive today (Gill & Prum, 2019). Species as dissimilar as the Ruby-throated Hummingbird (*Archilochus colubris*), Emperor Penguin (*Aptenodytes forsteri*), Great-horned Owl (*Bubo virginianus*), White-throated Sparrow (*Zonotrichia albicollis*), and Doublecrested Cormorant (*Nannopterum auritum*) all find a spot within the class's 40 orders and 247 families (Gill & Prum, 2019).

While the 10,000 bird species resemble modern-day reptiles as descendants of flighted theropod dinosaurs (Gill & Prum, 2019), birds have some important defining traits that differentiate them from all other animals on Earth. Specifically, birds are a monophyletic group that is warm-blooded, lays eggs, and possesses a backbone ("Birds," n.d.; "Aves," 2001). All birds also have feathers, wings, and a bill devoid of teeth ("Birds," n.d.; "Aves," 2001).

Within the United States, there are hundreds of species that either permanently reside in, seasonally inhabit, or travel through the country. Among these, the order Passeriformes (passerines) makes up the largest quantity (Gill & Prum, 2019). These perching species, including Northern Cardinals (*Cardinalis cardinalis*), Tufted Titmice (*Baeolophus bicolor*), and Blue Jays (*Cyanocitta cristata*), are commonly seen at supplemental feeders. Other frequent visitors come from the order Piciformes (piciforms), such as the Red-bellied Woodpecker (*Melanerpes carolinus*), Downy Woodpecker (*Dryobates pubescens*), and Hairy Woodpecker (*Dryobates villosus*).

Even though all of the aforementioned feeder birds currently have stable or increasing populations, countless other species are not as fortunate. Approximately one-third of bird species in the US are at a heightened conservation risk, with 112 classified as "Tipping Point Species," meaning that their populations have fallen by at least 50 percent in the last 50 years ("State," 2025). Some of these "Tipping Point Species" include the Wood Thrush (*Hylocichla mustelina*), Chimney Swift (*Chaetura pelagica*), Eastern Towhee (*Pipilo erythrophthalmus*), American Oystercatcher (*Haematopus palliates*), and the Black Rail (*Laterallus jamaicensis*). Legislation, like the Migratory Bird Treaty Act of 1918, has helped to control the overharvesting and trading of birds and their feathers, safeguarding more than 1,000 species (Leahy & Murphy, 2018; “Migratory,” 2020). However, more action must be taken to protect vulnerable birds from threats ranging from anthropogenic climate change and habitat fragmentation to pollution and human-caused collisions.

The field of ornithology has grown immensely since Aristotle’s account of birds in the *History of Animals* and naturalist Gilbert White’s 1789 field observations (Gill & Prum, 2019). However, even today, there are immense voids in humans’ knowledge of bird life. Through ornithologists and citizen scientists’ efforts, we will hopefully expand our understanding of this diverse class, for the continued existence of both common and threatened species.

Prevalence of Feeding Birds

Feeding wild birds has enabled humans to establish meaningful interspecific interactions. While this practice is seen throughout the globe, feeding wildlife is especially commonplace in Western nations, like the United States (Jones & Reynolds, 2008; Dayer et al., 2019). In fact, the first American to officially report feeding free-living birds was naturalist Henry David Thoreau in 1845 (Willcox et al., 2011). As this practice grew, so did commercialization, with the first bird feeder being sold in the mid-1920s for hummingbirds (Willcox et al., 2011). Although the concept of bird feeding was initially developed to help ensure the survival of birds during the winter months, this practice has now expanded to the entire year (Jones & Reynolds, 2008).

Supplemental bird feeding has persisted to this day for various reasons. One of the most promising explanations is the joy that people experience from watching birds, believing that they are contributing to species’ well-being (Dubois & Fraser, 2013; Goddard et al., 2013; Galbraith et al., 2014; Cox & Gaston, 2016). By feeding, many humans strive to counteract harmful environmental practices (Howard & Jones, 2004). These ideologies are rooted in science, since feeding is classified as a conservation practice in certain scenarios (Ewen et al., 2015). Other reasons for feeding include a desire to enhance birds' reproductive success, augment species richness, and hear new melodies (Cannon, 1998; Dunn & Tessaglia-Hymes, 2001; Howard & Jones, 2004; Horn & Johansen, 2013; Dayer et al., 2019). For some bird enthusiasts, their feeding habits are even dictated more by ambient temperature and the quantity of visitors than financial or time barriers (Dayer et al., 2019). The prevalence of disease also plays a significant role in these humans' feeding choices.

Although birds are now supplementally fed year-round, temperature change still has a profound influence on people's decision to provide feeders, with the greatest number feeding during the winter (Galbraith et al., 2014). This is due to the fact that humans associate the season with a deficit in natural resources for wildlife. Regardless of the particular motivation, the act of supplementally feeding birds is currently a bustling industry, with fifty to fifty-seven million people providing food yearly in the US ("U.S. Department," 2018).

Benefits and Consequences of Feeding Birds

Bird feeding is a common practice in today's society, with greater than 40 percent of the US population supplementing birds in winter (Smith, 2020). However, it is necessary to educate the public about both advantages and consequences of supplementation, so individuals could make an informed decision about whether or not to feed wild birds. This knowledge could also offer people guidance about how to engage in safer practices, if choosing to provide seed.

There are countless benefits to providing food to free-ranging birds. As a significant population constraint, an insufficient quantity of food directly impacts birds' health and survivability (Newton, 1998). To alleviate these pressures, seed offers undernourished birds a nutritional supply (Buczacki, 2007), fueling them with polysaccharides and lipids (Karasov, 1990; Bairlein, 2002). Feeding also enhances immunity, decreases stress levels, and promotes feather development, allowing for greater attendance to energy-demanding mechanisms, like preserving elevated lymphocytes (Wilcoxen et al., 2015). Unlike foods found in the wild that are unpredictable in time and scale, foods placed at feeders are easily accessible throughout the year (Bridge et al., 2009; Oro et al., 2013). Supplemental seed is even correlated with heightened ranges in some species (Fuller et al., 2008; Fuller et al., 2012; Fischer & Miller, 2015; Greig et al., 2017).

Along with individual assets, bird feeding garners value at the population level. In particular, supplemental feeding could improve mother birds' breeding value, raising the quantity of chicks born each year (Boutin, 1990; Schoech, 1996). Supplemented adult females have also been found to lay eggs sooner in the year, providing them with potentially heightened procreation (Robb et al., 2008; Amrhein, 2014). Even if feeding ceases in the weeks leading up to mating, advanced laying times and elevated fledgling survival persist (Robb et al., 2008). However, one should be aware that continual feeding is required to sustain many of the other advantages associated with the practice (Wilcoxen et al., 2015).

Despite the many virtues, there are some inherent risks associated with feeding. Specifically, a major concern is that feeding sometimes allows non-native species, like House Sparrows (*Passer domesticus*) to thrive over their native counterparts, reducing avian diversity at supplemented sites (Galbraith et al., 2015). This alteration in abundance is only seen while actively feeding, though (Galbraith et al., 2015).

There are also some concerns at the individual level, with heightened predation pressure (Hanmer et al., 2017; Malpass et al., 2017) and disease transmission (Lawson et al., 2012; Adelman et al., 2015; Wilcoxen et al., 2015; Galbraith et al., 2017). In fact, in one study, approximately eight percent of bird visitors displayed signs of illness (Wilcoxen et al., 2015). Similarly, supplemental food causes birds to put on unnecessary weight, impairing their overall motility when attempting to avoid predators (Lima, 1986; Rogers, 2015). Other potential downsides include more aggressive behavior, deficient seed quality, and decreased foraging ability (Jones & Reynolds, 2008).

It is possible to counteract the challenges of supplemental feeding, however. For instance, due to feeder birds' elevated immunity, enhanced feather development, and reduced stress levels, these animals are more likely to fight off illness, compared to those not supplemented (Wilcoxen et al., 2015). To reduce the likelihood of disease transmission, one could also consider regularly disinfecting feeders. Fortunately, cleaning seems to be popular among the bird feeding community, with 67 percent of participants, in one study, engaging in this procedure (Dayer et al., 2019). People could also consider ceasing seed supplementation during periods of heightened disease transmission, since feeding doesn't result in dependency (Wilcoxen et al., 2015). To address depredation, people have reported chasing away predators and establishing potential hiding areas for birds (Dayer et al., 2019).

In conclusion, feeder birds tend to be in better physical and reproductive condition than those that don't receive seed. However, even with precautionary behaviors on the part of humans, supplemented birds still face threats, including predation and disease. People must, therefore, contemplate all inherent risks and benefits before determining whether or not to feed.

Physiological Determinants of Feeding

Aves are a diverse class that possesses the greatest mass-independent metabolic rates of all backboned animals (Schmidt-Nielsen, 1997). Within the group, there are countless distinguishing characteristics that separate one species from another, including behavior, physical traits, and lifestyle choices. Arguably, one of the most significant, but oftentimes forgotten, attributes is physiological make-up. These features influence whether a particular bird is highly selective in its dietary decisions or if it is a generalist (Cruz-Neto & Bozinovic, 2004). Specifically, physiological properties impact the process of breaking down lipids and carbohydrates into usable parts, which partially explains diverse food choices among species (Dhillon, 2020).

With seed-eating birds, in particular, a species' digestive system affects the kinds of seeds that are accessible to it. One implication is that a bird could only consume those seeds that are an appropriate volume relative to its bill size (Johansen et al., 2014). For instance, by primarily eating White Proso Millet, birds like Mourning Doves (*Zenaida macroura*) could maximize their bill-to-seed volume ratio (Johansen et al., 2014). Birds also preferentially choose seeds based on how long it takes them to manipulate and consume a given variety (Johansen et al., 2014). With some common backyard visitors, like Northern Cardinals (*Cardinalis cardinalis*) and Black-capped Chickadees (*Poecile atricapillus*), fiber, fat, and protein quantities also appear to influence their decisions (Johansen et al., 2014).

Another factor that substantially affects feeding habits is a bird's neurological and genetic configuration. In particular, caching birds that store seeds for later consumption possess a larger hippocampus with more neurons, compared to those that don't cache as frequently (Freas et al., 2012; Roth et al., 2012). As a major component in spatial cognitive capacity, birds with well-developed hippocampi more readily retrieve food stored sometime in the past versus those with less sophisticated hippocampi (Branch et al., 2022). Genes also play a role in a bird's ability to successfully cache (Branch et al., 2022). Although spatial cognitive ability is not believed to improve over a bird's lifetime (Tello-Ramos et al., 2018; Sonnenberg et al., 2019; Heinen et al., 2021), an individual's likelihood to cache varies based on environmental conditions. For instance, birds that are subjected to severe winters are more likely to cache than those residing in less intense environs (Freas et al., 2012; Roth et al., 2012; Croston et al., 2016).

From studying physiological traits, scientists now hypothesize that a bird's specific mass-independent basal metabolic rate (BMR) is affected by habitat conditions. In particular, BMR is smaller for birds with an unstable source of food (McNab, 2002; Cruz-Neto & Jones, 2005). Upper trophic levels and omnivorous diets are also said to lower an animal's BMR (McNab, 2009; Bozinovic & Sabat, 2010). Our knowledge of physiological features will undoubtedly continue to evolve in the future, providing us with an even greater understanding of birds' feeding behavior.

Effect of Distance from Trail on Feeding Behavior

With the growth in human disturbance and habitat fragmentation, it is important to consider the impact that people have on wildlife. For instance, disturbance results in birds modifying their foraging habits (Skagen et al., 1991) and dispersing (Burger et al., 1995). This may be due to the fact that other species consider humans to be predators (Frid & Dill, 2002). Since adult birds have been found to interrupt nestling feeding upon hearing predators (Zanette et al., 2011), one should be mindful of their noise level when near a bird's nest. Likewise, birds' community composition is affected by human noise (Francis et al., 2009; 2011; Slabbekoorn & Halfwerk, 2009). In urban and agricultural environments, in particular, birds and other animals sometimes exhibit more aggressive behaviors, to increase their survivability and mating capacity (Evans et al., 2010; Scales et al., 2011; Foltz et al., 2015; Fossett & Hyman, 2021).

While less than five percent of urban birds worldwide are non-native (Aronson et al., 2014), these species can have a significant impact on native wildlife. For example, non-native species could spread disease to, compete with, and hybridize native birds, diminishing their numbers and abundance (MacDougall & Turkington, 2005; Martin-Albarracin et al., 2015). However, even non-native species are currently experiencing losses throughout the United States (Rosenberg et al., 2019).

To acquire a better understanding of how individual birds respond to the presence of humans, it is useful to study Flight Initiation Distance (FID), or the point at which a bird escapes an incoming threat. Studies have shown that FIDs are unique to a given species, with factors like Basal Metabolic Rate (BMR) and larger reproductive age positively affecting the distance at which a bird departs (Møller, 2009; Møller & Garamszegi, 2012; Blumstein, 2014). However, an individual's FID doesn't differ by location (Blumstein et al., 2003). It is important to study FID because both over-responding to insignificant stimuli or under-responding to potentially threatening stimuli are costly to an individual (Blumstein, 2014). This is especially applicable to birds residing within contiguous habitats. These animals were discovered to be the most sensitive to disturbance, since they responded more over time to disruptive human stimuli, rather than learning to ignore them (Blumstein, 2014).

Many people believe that public trails could help to promote positive associations between birds and human society. However, since even minor habitat fragmentation could influence bird behavior and distribution (Marcum, 2006), consulting the scientific literature could help one to better comprehend how distance from a human foot trail affects different species. Researchers found that birds preferred feeders within forests and on forest edges, versus those housed in more open environments, due to varying levels of cover (Lee et al., 2005). Both species richness and abundance may be elevated at feeders nearer to cover because of lower predatory risk, exposure to the elements, and flight expenditure (Grubb & Greenwald, 1982; Lima, 1985; Todd & Cowie, 1990; Horn et al., 2003). There is also more seed eaten at feeders closer to cover (Cowie & Simons, 1991). However, not all birds benefit equally. Instead, more dominant individuals are believed to eat from feeders closer to cover, while subordinate birds consume seed from farther feeders (Cowie & Simons, 1991).

Impact of Seed and Feeder Type on Consumption

With approximately one million tons of seed being provided to free-ranging birds each year (Greig, 2017), it is apparent that the practice of feeding birds is not disappearing in the foreseeable future. It is, therefore, essential for the public to be knowledgeable about the most desirable feeders and seeds to invest in. While all seeds appear to be the same at first glance, in reality, some are preferentially chosen over others. In particular, Black Oil Sunflower and White Proso Millet are chosen over hemp and peanuts, with peanuts being the least desirable and sunflowers the most (Dhillon, 2020). Contrary to popular belief, these differences are not due to the quantity of carbohydrates, lipids, proteins, or energy stored in a given seed (Dhillon, 2020). Instead, sunflowers may appeal to birds because of the seed's ability to be easily manipulated by a variety of species while foraging (Willcox et al., 2011).

It is still important to provide birds with an assortment of seeds, however. Studies have shown that switching from an exclusively sunflower feeder to one also with millet, tree nuts, and peanuts elevated the overall quantity of species and birds utilizing a given feeder (Horn, 1999). Specifically, a larger number of birds, including Blue Jays (*Cyanocitta cristata*), Northern Cardinals (*Cardinalis cardinalis*), and Red-bellied Woodpeckers (*Melanerpes carolinus*) visited the assorted seed feeder (Horn, 1999).

Along with seeds, it is also essential to consider the kind of feeder, since this factor also affects the quantity of visitors (Horn, 1995). There are several different types of feeders available, but some of the most popular ones include hopper, tube, and platform. A hopper feeder is a V-shaped chamber that appeals to a variety of birds (Fig. 1; Willcox et al., 2011). This feeder also stores an ample quantity of seeds, minimizing refills. Tube feeders, which primarily attract smaller species, are cylindrical with several perches for the birds to land on (Fig. 2; Willcox et al., 2011). Finally, with the platform feeder, seed is stored on a smooth, open tray (Fig. 3; Willcox et al., 2011). If interested in the platform feeder, one should consider purchasing a brand with a mesh screen, to reduce the likelihood of disease spreading among visitors (Willcox et al., 2011). The presence of small pores, in particular, enables seeds to dry faster than those on a solid platform, curbing the probability of illness. Being mindful of these factors when choosing to feed birds maximizes visitations, while keeping bird visitors healthy.

Figure 1. Hopper feeder with landing perches. Photo courtesy of “All Living” (2025).

Figure 2. Tube feeder with landing perches.

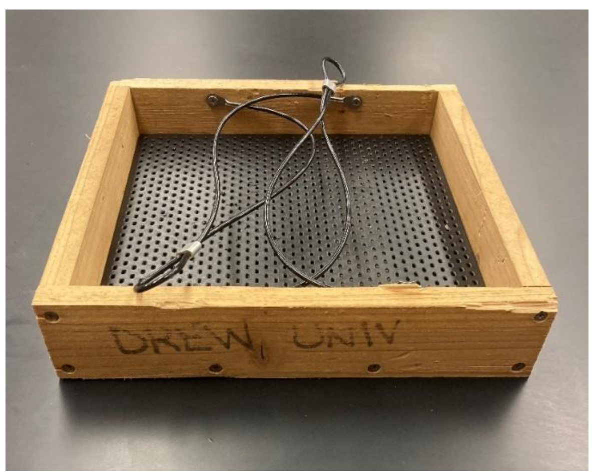

Figure 3. Platform feeder with mesh screen, where seeds are placed.

Dominance at Feeders

From watching birds outside one's window, it is clear that certain species, as well as individuals, exhibit greater dominance than others. However, it is important to contextualize these observations to acquire a better understanding of the dynamic relationships inherent in a given avian community. Dominance hierarchies describe the ranked position of different animals, which is determined by how one organism interacts with others (Drews, 1993). There are many different types of dominance hierarchies in non-human societies. For instance, scientists have observed despotic (one dominant member with control over conspecifics), linear, and even corporative (certain individuals possess the same ranking) hierarchies (Perrin, 1955; Fushing et al., 2011).

Dominance hierarchies are advantageous in that they could potentially reduce the quantity of aggressive encounters between two animals (Smith, 1974). However, supplemental feeding has been shown to elevate competition between species (Francis et al., 2018). For example, in one study, a species that weighed more occupied the feeder for a longer period of time, while the subordinate, lighter individual ate from a less desirable feeder (Francis et al., 2018). These differences were not influenced by evolutionary relationships (Francis et al., 2018). A species' rank in the dominance hierarchy was not dictated by its biological family, but rather by its body weight (Francis et al., 2018).

Aggression is also occasionally seen at feeders, such as defensive displays and even physical attacks (Francis et al., 2018). This behavior is costly, as hostility could lead to long-term injuries to all individuals (Rosenbaum et al., 2016), especially subordinate conspecifics. Although there are many risks associated with being a subordinate bird, there are also inherent advantages. For instance, lower-ranking birds could travel close behind dominant conspecifics, to locate the most valuable foodstuffs (Hogstad, 1989). The ranking for interspecific organisms is built upon characteristics, such as age, weight, and prior encounters (Haley et al., 1994; Zucker & Murray, 1996). Regardless of a bird's position in the dominance hierarchy, these pre-determined rankings have substantial impacts on an individual's daily experiences.

Effect of Vigilance on Feeding

Vigilance is a crucial strategy, where an animal scans an area to identify potential predators or members of its own species. As an antipredator mechanism, vigilance enables prey to avoid being noticed and subsequently eaten by a predator (Caro, 2005). It is also performed when foraging and locating mates (Marcum, 2006).

While vigilance could potentially be disadvantageous or even deadly if an animal decreases its foraging time to scan (Burger et al., 1995; Baker et al., 2010), many animals are capable of foraging and scanning simultaneously (Whittingham & Evans, 2004; Jones et al., 2006; Beauchamp, 2009). A bird's decision to scan is context-dependent, with longer periods equating to elevated risk (Mettke-Hofmann, 2022). To test vigilance, one typically monitors how often an animal extends its head past the horizontal axis (Cimprich & Grubb, 1994; Pravosudov & Grubb, 1995).

Scanning could be performed both individually and as a group. Group vigilance generally reduces predatory risk, along with the amount of time that an animal needs to scan (Elgar, 1989; Delm, 1990; Roberts, 1996; Bednekoff & Lima, 1998; Morelli et al., 2019). Subordinate individuals, however, don't always obtain the same advantages as dominant ones (Pravosudov & Grubb, 1999). While dominant members keep subordinates physically safe, the lower-ranking bird may need to sustain heightened vigilance (Pulliam, 1984; Elgar, 1989).

Many other factors besides group size impact vigilance rate. For instance, elevated competition for food and consistent environmental patterns both lead to lower degrees of vigilance (Siddle, 1972; Carbone et al., 2003; Melrose et al., 2019). On the other hand, enhanced physical condition, exploratory behavior, and concurrent excessive heat and human-produced noise all strengthen scanning responses (Beale & Monaghan, 2004; Mettke-Hofmann, 2022; Blackburn et al., 2024).

In areas with growing human disturbance, vigilance is frequently directed towards humans, as other species view people as predators (Marcum, 2006). Disturbance has even contributed to species making dramatic lifestyle changes, including evading human-dominated locations and switching their circadian rhythm (Griffiths, 1993). Researchers have found that both residents and migrants, as well as edge and interior species, are approximately equally affected by human fragmentation (Marcum, 2006). Some potential solutions include establishing a restoration agenda for at-risk species, preserving interior wooded sites, and even hosting educational campaigns (Marcum, 2006).

Impact of Season on Feeding

In the Northeast, many people start feeding birds as ambient temperatures drop. This practice likely stems from a fear that birds receive an inadequate quantity of natural foodstuffs in winter. Individuals also readily believe that more birds visit the feeders during these colder months. It is crucial to contemplate the validity of these claims to understand how best to assist our avian community. Through research, scientists have found that birds, indeed, have fewer resources to rely on in winter, while requiring a greater supply of energy for their daily processes (Dhillon, 2020). Additionally, more food is eaten from the feeders in the fall and winter versus in the spring (Brittingham & Temple, 1992). However, the quantity of birds at the feeders is not influenced, on a daily basis, by temperature or seasonal factors (Brittingham & Temple, 1992). Scientists believe that this could be explained by winter birds prioritizing the most desirable foods shortly before roosting and resting at other times of day (e.g., McNab, 1974; Brittingham & Temple, 1988; Olsson et al., 2000). Despite these findings, it is nevertheless important to provide seed to ensure that these animals are constantly receiving enough resources to survive the coldest days of winter.

Effects of Climate Change on Feeding

With the ever-growing effects of anthropogenic climate change, it is apparent that countless wildlife, including birds, are negatively impacted. Climate change is unfortunately wreaking havoc on a menagerie of organisms, including species that used to be prevalent (Johnson et al., 2017). For instance, climate change has already altered the distribution of many species and has increased the number of extinctions per year (Easterling et al., 2000; Hughes, 2000; McCarty, 2001; Carpenter et al., 2008; Keith et al., 2008). With a narrower lens, one could consider how climate change has hindered animals' offspring rearing and territoriality (Santee & Bakken, 1987; Wiley & Ridley, 2016; Mason et al., 2017). Elevated temperatures from climate change could even cause chicks to be more vulnerable to predation, impacting future breeding (Cunningham et al., 2013; van de Ven et al., 2020).

An oftentimes overlooked consequence of climate change is its influence on foraging, particularly caching. For example, rising temperatures and humidity have resulted in the destruction of seed through germination and microbial propagation (Kimball et al., 1997; Sutton et al., 2016). Many species may also not be able to store their cache for very long, due to a shorter, milder winter season (Makoto et al., 2014). This reduced ability to cache could potentially impair birds' breeding efficacy (Waite & Strickland, 2006).

It is valuable to recognize that not all cached seed is affected equally. For instance, caching is especially compromised in low latitude locations, due to dramatic changes in precipitation and humidity (Sutton et al., 2016). The specific commodity being cached and the length of time since collecting further determine the severity of impact (Sutton et al., 2016).

As climate change continues to worsen, some cachers have begun to adapt, relying on natural chemical agents and adjusting the methods in which they handle food (e.g., Martin, 1981; Rich & Trentlage, 1983; Jenkins & Devenport, 2014). However, not all species have the means to transform their behaviors in response to climate change. We are at a pivotal moment in our society – to either continue to ignore the ever-intensifying ramifications of climate change or to engage in meaningful practices to sustain lives, now and into the future. The choice is ours.

Habituation and Birds

An essential feature of learning in the animal kingdom is the concept of habituation. Originally studied more than 2,000 years ago, habituation describes a reduction in an animal's behavioral response to a stimulus over time (Blumstein, 2016). Rather than being impacted by neuronal or muscular exhaustion, habituation relies on the strength and regularity of a particular stimulus (Dissegna et al., 2021). It is oftentimes essential for an animal to dismiss insignificant stimuli, so that they could focus their attention on more pressing matters, such as mating and anti-predator avoidance.

Researchers need to consider an animal's degree of habituation when developing a wildlife conservation plan. Specifically, scientists have discovered that certain species become more, as opposed to less, responsive to humans over time (Blumstein, 2014). This is especially consequential for some at-risk species, since sensitized animals are all too often forced to abandon their habitat due to ever-increasing disturbance (Blumstein, 2016). Even animals that do habituate may have a more challenging time ignoring stimuli that are not generally found in their environment (Blumstein, 2016). Other factors that impact an animal's ability to habituate include its specific life cycle, natural history, and location (Blumstein, 2016; Sutton et al., 2021). In fact, previous research shows that highly traversed areas possess more habituated birds than sites with fewer humans (Sutton et al., 2021).

Despite habituation originally being classified as a form of “single-stimulus” learning (Rankin et al., 2009), newer models have begun to refute this categorization. Instead, scientists like Wagner believe that habituation is oftentimes situation-dependent (Dissegna et al., 2021). Specifically, Wagner’s model implies that an animal’s response is not based on how sophisticated an organism’s nervous system is, but instead operates separately (Dissegna et al., 2021).

It is important to study habituation on a more local level with birds, so that the scientific community could have a better understanding of how best to support different species. While many birds are highly habituated, some like the Carolina Wren (*Thryothorus ludovicianus*) and Downy Woodpecker (*Dryobates pubescens*) don’t habituate as readily (Marcum, 2006). To ensure that all species, including sensitized birds, receive an opportunity to forage, the public’s current supplemental feeding practices must be examined.

My Scientific Study and Hypotheses

My research focused on examining the impact of habituation on species abundance and feeding behaviors of wild, seed-eating birds in Northern New Jersey. To achieve this goal, I established feeders at two different sites. The first was the Zuck Arboretum, a mature temperate deciduous forest situated at Drew University, a small liberal arts institution. The second was the Great Swamp Watershed Association–Conservation Management Area (GSWA-CMA), a restoration site with fewer human trail users. Zuck represented an area with more habituated birds, while the CMA served as a less habituated site, due to the differing quantity of people occupying the two trails. Within each site, I established two feeders, one near the human foot trail and another farther away, to understand how distance affects feeding choices. I hypothesized that all of the seed would be consumed at both sites shortly after my feeder set-up, with the quantity of birds at any given feeder decreasing after the peak of migration. I also hypothesized that I would observe both a larger species richness and total bird count at Zuck, since habituated birds may be more accustomed to eating at feeders, compared to those less habituated. Additionally, I predicted that there would be more species and a larger quantity of birds at feeders further from the trail at both sites. Even though Zuck birds are hypothetically more habituated than CMA birds, there will likely still be more visitors at the Zuck Far feeder, since birds tend to avoid unnecessary risk. Lastly, I hypothesized that Zuck birds would display more behaviors commonly associated with habituation, such as decreased scanning rates, versus those at the CMA.

METHODS

Site Location

Drew University's Zuck Arboretum. The first site where I conducted my research was the Zuck Arboretum, a mature temperate deciduous forest with a 0.8mi (1.29 km) loop nature trail located at Drew University in Madison, New Jersey. This site first became accessible to students following an 1867 land sale to Founder Daniel Drew ("Frequently," 2024). Today, both the university and neighboring properties benefit from hiking, bird watching, and passive nature studies.

There are numerous restoration actions being employed to limit invasive plants and maintain the area's immense biodiversity. Specifically, the presence of deer exclosure fencing, established in 2011 ("Biodiversity," 2024), provides small mammals and birds with a healthy understory for nesting and evading predators. Likewise, the removal of invasive plants and the establishment of native wildflowers help to sustain the local ecosystem ("Biodiversity," 2024).

The arboretum's mature broadleaf forest, shrubs, vernal pools, and two ponds offer numerous species, both common and at-risk, with sufficient habitat to find food, mate, and raise young. Some of the many species on-site include Eastern Gray Squirrels (*Sciurus carolinensis*), Zigzag Goldenrods (*Solidago flexicaulis*), and Red-backed Salamanders (*Plethodon cinereus*). Zuck also houses the New Jersey-threatened Barred Owl (*Strix varia*) and the federally-endangered Indiana Bat (*Myotis sodalist*). The arboretum is further advantageous as an aquifer recharge site, flood mitigator, and carbon sequester for Morris County, with Drew possessing some of the longest-standing trees in the area ("Frequently," 2024).

I decided to complete my study near the Zuck Arboretum gateway (Fig. 4, 5, & 6), as this area is heavily trafficked. The particular site possesses ample shrubs and trees for wildlife, especially birds, as a closed understory.

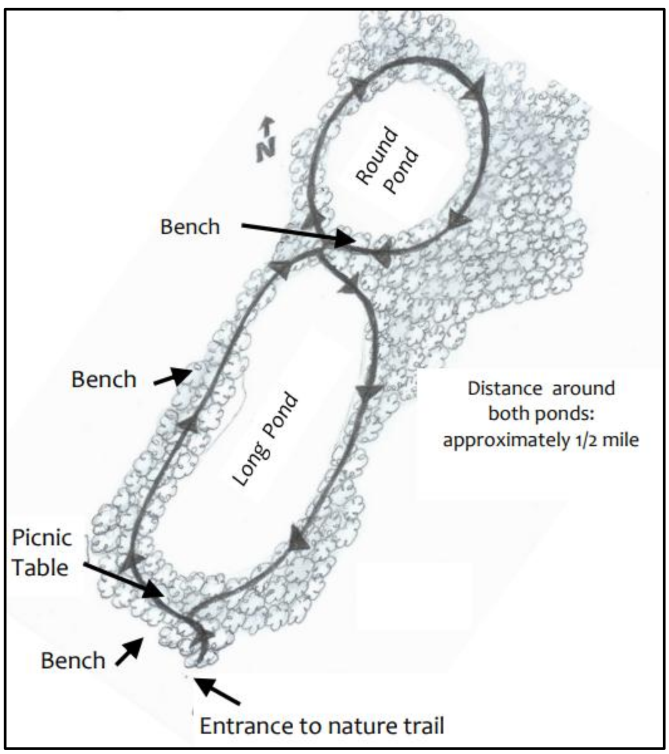

Figure 4. Map of the Zuck Arboretum. Photo courtesy of Sara Webb (2024).

Figure 5. Standing next to Zuck Arboretum sign. Photo courtesy of Rosemary Rogers.

Figure 6. Zuck Arboretum trail with adjacent close feeder.

Great Swamp Watershed Association–Conservation Management Area (CMA). My second site was the CMA, a 73-acre restoration area situated in Harding Township, New Jersey (Fig. 7). Once an agricultural farm for sheep and horses (England, 2021), this location is now a floodplain forest, open to the public throughout the year, offering walking trails, guided tours, and scenic spots to observe wildlife. The CMA possesses numerous ecological functions, ranging from carbon sequestration and flood reduction to minimizing noise from neighboring Interstate 287 and controlling excessive temperatures.

The CMA's lush forest, brook, and vernal pools provide habitat for plant and animal species, ranging from the abundant Canada Goldenrod (*Solidago canadensis*) and Tufted Titmouse (*Baeolophus bicolor*) to the elusive Carolina Wren (*Thryothorus ludovicianus*) and Milksnake (*Lampropeltis triangulum*). The area also supports at-risk species, such as the federally-threatened Swamp-pink (*Helonias bullata*) and the state-threatened wood turtle (*Glyptemys insculpta*).

To maintain its rich biodiversity, the CMA engages in a range of restoration efforts. For instance, the property utilizes best management practices to remove invasive species, such as Garlic Mustard *(Alliaria petiolata)*, Multiflora Rose (*Rosa multiflora*), and Japanese Barberry (*Berberis thunbergii*) ("Stewardship," 2022). The CMA has also established bat boxes, brush piles, and bird houses as shelter for species ("Stewardship," 2022). Other measures include planting native vegetation and installing deer exclosure fencing ("Stewardship," 2022). The Wetlands Reserve Program and the Partners for Wildlife Program have helped fund some of the CMA's restoration initiatives, including the establishment of vernal pools and the utilization of tree trunks to establish a meandering stream (England, 2021).

I chose to conduct my study along the CMA's Orange Trail (Fig. 8, 9, & 10), since this fenced-in site most closely resembles the Zuck Arboretum. Land within the Orange Trail is generally drier than many other locations at the CMA, providing a more desirable habitat for species of interest. In addition to geographic conditions, microhabitat along the Orange Trail is also appropriate. These conditions ensured that habitat type was not a contributing factor in potential differences across sites. The Orange Trail is a low-traversed area, offering a lens into how birds less habituated to humans respond to the presence of feeders.

Figure 7. Standing next to CMA sign. Photo courtesy of Rosemary Rogers.

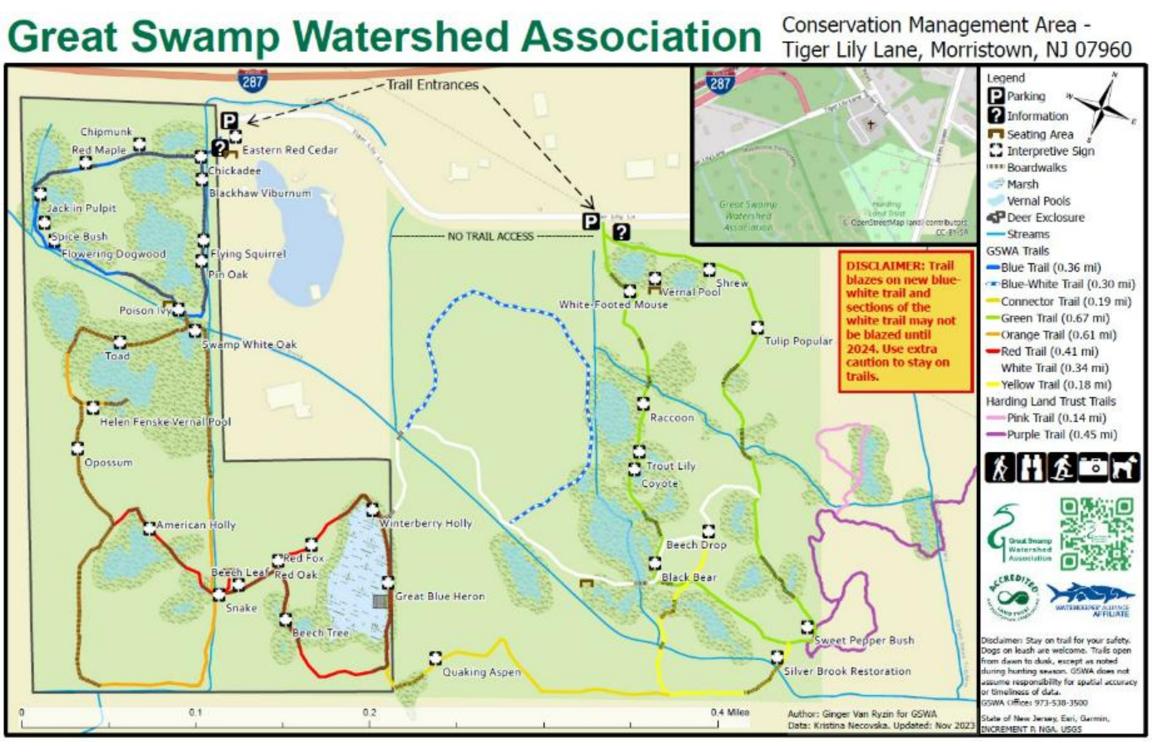

Figure 8. Map of the CMA, including Orange Trail. Photo courtesy of Ginger Van Ryzin (2023).

Figure 9. View of the CMA Orange Trail.

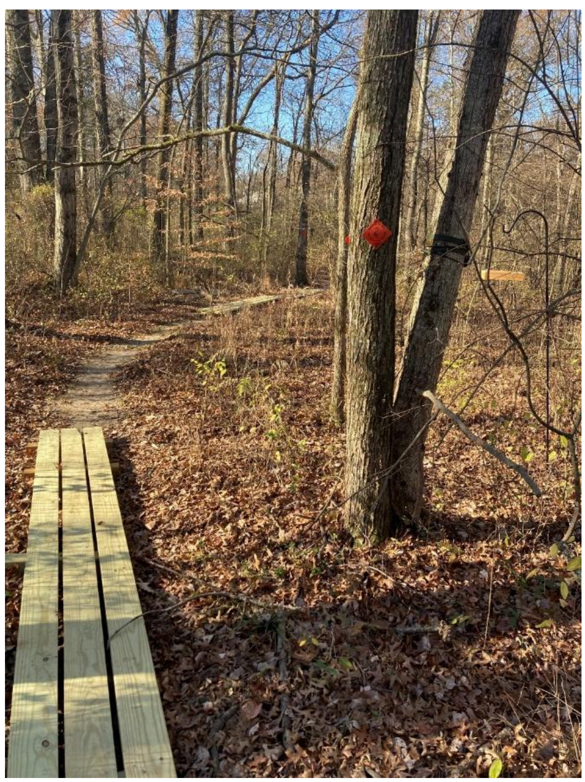

Figure 10. CMA Orange Trail with adjacent close feeder.

Feeder Set-up

Locations. At both Zuck and the CMA, I established a transect with 2 Nature's Way Cedar Tray Wild Bird Feeders (5.08cm x 25.4cm x 25.4cm). One feeder was situated near the walking trail and the second was located approximately 20m away. In particular, the far feeder at Zuck was 19.5m from the trail (Fig. 11), while the distance at the CMA was 21.5m (Fig. 12). I chose to use two feeders at both sites (Fig. 13, 14, 15, & 16), rather than only one, since I wanted to determine whether there were any differences in the number of visitors or the type of species visiting based on proximity to humans. The feeders at the CMA represent a low-trafficked area, while Zuck is highly traversed.

Figure 11. Distance between Zuck Close and Zuck Far feeders from the trail.

Figure 12. Distance between CMA Close and CMA Far feeders from the trail.

Figure 13. View of Zuck Close feeder.

Figure 14. View of Zuck Far feeder.

Figure 15. View of CMA Close feeder.

Figure 16. View of CMA Far feeder.

I decided to use platform feeders due to their appeal to a diverse selection of seed-eating birds. These feeders are ideal for field studies, as they contain removable trays for easy cleaning purposes. They specifically hung from Shepherds Hooks that were 7ft in height. After positioning the feeders, I set up a total of four Browning Strike Force trail cameras (one per feeder; Fig. 17 & 18). These cameras were level with the feeders and faced away from the trails, in order to continuously monitor bird activity.

Figure 17. Exterior features of the Browning Strike Force trail camera.

Figure 18. Interior features of the Browning Strike Force trail camera, including SD card storage capacity, delay time, and model number.

Seed Type. I provided my feeder visitors with 0.3kg (approximately two cups) of Kaytee Birders' Blend (or Birders' Paradise Blend) Wild Bird Food (Fig. 19 & 20). The mix possessed the following: sunflower seed, millet, milo, safflower seed, cracked corn, and peanuts. I chose a mix with a variety of nuts and seeds to attract a greater diversity of species.

Figure 19. Measured seed for Zuck feeders.

Figure 20. Measured seed for CMA feeders.

Feeding Frequency. I traveled to the CMA and Zuck three times per week for a total of 10 weeks (September 16-November 22, 2024). Each Monday morning, I would fill the feeders with bird seed and turn on the trail cameras for continuous monitoring. On Wednesdays, I poured any leftover seeds into labeled reusable bags, so that I could later remove spent seeds and weigh the remaining contents with a calibratable, analog scale. I then cleaned the feeders with disinfecting wipes, prior to refilling. The SD cards were also switched out at this time. Fridays involved transferring the leftover seeds to my labeled reusable bags for future weighing, cleaning the feeders, and placing new SD cards into the trail cameras. I decided not to refill the feeders nor turn on the trail cameras on Fridays, as I wanted an equal number of days per session (i.e., Mondays-Wednesdays and Wednesdays-Fridays) for my data collection. All three days, I also recorded metadata at the start and conclusion of my feeder preparation, including the date, time, general weather patterns, temperature, and any other pertinent notes.

Camera Trapping

Camera trapping was employed throughout my 10-week study, as the primary means to determine the types of species and number of visitors at my feeders. I decided to employ this method, rather than relying on visual observations, to avoid potential bias in my study results.

My trail cameras were programmed to produce 30s videos with a one-minute delay during daylight and 20s videos with a one-minute delay during the night.

When analyzing my video clips, I counted visitors that were either actively feeding, caching, or directly interacting with the feeder through another means, like roosting. Based on Wein and Stephens' 2011 study, I defined caching as a bird that leaves the feeder with one or more seeds in its bill. Caching birds store seeds at a nearby location for later consumption, rather than eating at the feeder. Likewise, I referred to a few publications when recording vigilant/scanning behavior. I considered a bird to be vigilant if was moving its head from side-to-side or if its head surpassed the horizontal axis (Cimprich & Grubb, 1994; Pravosudov & Grubb, 1995; Beauchamp, 2015). Scanning behavior is performed for predator detection, as well as for spotting conspecifics.

Since some species fly back and forth from a nearby tree or shrub to bird feeders, I only tallied birds with a different directional pattern, to reduce tallying an excessive number of repeat visitors during any given video. However, if a bird was seen feeding or roosting for more than one video, I counted this as distinct visitations, due to the animal's extended interaction with the feeder.

I established a separate tally for non-avian species, such as Eastern Gray Squirrels (*Sciurus carolinensis*), Eastern Chipmunks (*Tamias striatus*), and mice, since these non-target visitors could potentially impact my study results.

Data Compilation

I relied on the software program, Google Sheets, when compiling my feeder data. I established two different spreadsheets, one with all of my raw data and another that served as a subsample. The raw data spreadsheet contained the following information related to my camera trapping videos: date, time, week #, session identification (Monday-Wednesday or Wednesday-Friday), video #, site (Zuck or CMA), feeder (Close or Far), species (Alpha Codes – *refer to Table 4 in Appendix*), and number of visitors. I also included the amount of seed removed (kg) per session.

For my subsampling spreadsheet, I recorded information for every fifth video clip featuring one or more bird visitors. In addition to recording the date, time, week #, session identification, video #, site, feeder, and species, I also noted the current temperature, as well as behavioral observations and the presence/absence of vigilance and caching.

Statistical Analysis

Following my data collection, I performed statistical tests using the software SPSS to better understand the impact of site and distance from the trail on both the average amount of seed removed from each feeder and the average number of avian visitors per session. I also conducted statistical analyses for the number of avian visitors per species, the percentage of vigilant birds per species, the percentage of caching birds per species, and the number of avian visitors by average temperature. Specifically, I performed a Two-Way ANOVA for the average quantity of seed removed from each feeder, as well as the average number of avian visitors per session, based on both site and distance. A Two-Way ANOVA was also performed for the number of avian visitors by average temperature and date. Finally, I employed a Pearson Chi-Square test for the number of avian visitors per species, the percentage of birds vigilant per species, and the percentage of birds caching per species as a function of site and distance from trail.

RESULTS AND DISCUSSION

Seed Consumption

Following the completion of the study, I examined the quantity of seed taken from each of the four feeders over a 10-week period (Fig. 21). I found that the amount removed from the Zuck

Arboretum increased during the first two weeks, prior to stabilizing. However, contrary to Zuck, the quantity taken from the CMA gradually grew over time, following an initial three weeks of scant seed removal.

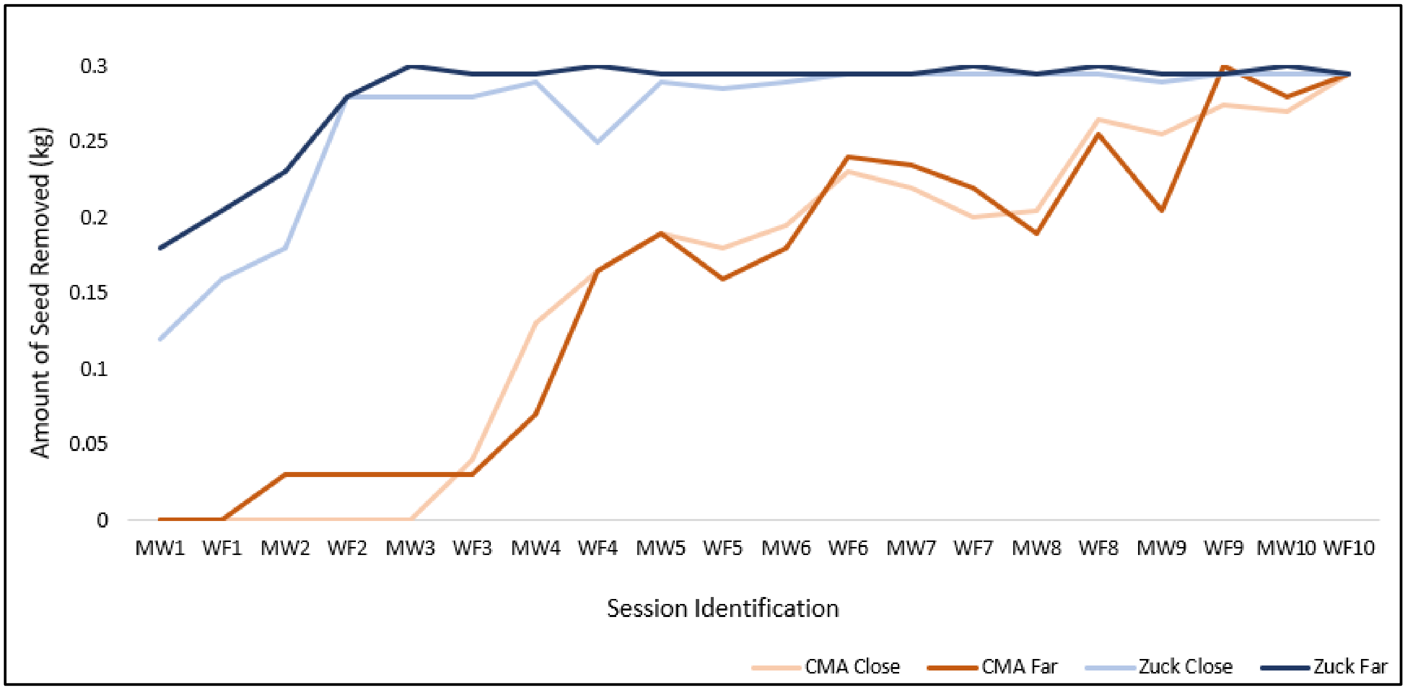

Figure 21. Total amount of seed (kg) removed from CMA and Zuck Arboretum feeders over time. "MW" indicates Monday-Wednesday session and "WF" Wednesday-Friday. Associated numerical identification symbolizes week #, where 1=Mid-September, 3=Late-September/ Beginning of October, 5=Mid-October, 7=Late-October, and 9=Mid-November.

Dissimilarities in the quantity of seed taken from the two sites may have been due to differing levels of habituation to the feeders. In particular, at Zuck, the initial growth in the amount removed may represent the amount of time that it took birds to first discover the feeders. Similar to other studies' findings that it takes roughly four weeks for feeders to become readily utilized by urban birds (Galbraith et al., 2015), I discovered that my visitors consumed a relatively equal quantity from Zuck, beginning in week three. Since Zuck birds were already accustomed to using other supplemental feeders on-site, birds may have more readily incorporated two additional feeders into their diets, explaining why there was a roughly stable amount of seed removed in the last seven weeks of the study.

On the other hand, seed removal from the two CMA feeders was negligible in the first few weeks, but then gradually increased until the end of the study. Early on, CMA birds were unhabituated to the feeders, with mice primarily visiting. However, following the initial three weeks, birds became accustomed to the feeders. Another reason why more birds began to visit could have been be due to an overall reduction in the quantity of natural food sources. As food resource availability is considered to be a consequential variable for population size (Lack, 1954; Martin, 1987; Newton, 1998), birds' foraging behavior at the CMA feeders could represent a more pressing need to locate food later in the fall. Some of the smaller, permanent birds may be especially vulnerable, due to their elevated energy needs (Dhillon, 2020).

Additionally, there was a statistically significant difference in the average quantity of seed removed from the two sites (Fig. 22; Two-Way ANOVA: $F_{1,79} = 43.198$, $P < 0.001$), with more seed being taken from Zuck ($M = 0.27$, $SE = 0.01$) than the CMA ($M = 0.16$, $SE = 0.02$). However, distance from the trail didn't impact the amount of seed removed from either site (Two-Way ANOVA: $F_{1,79} = 0.143$, $P = 0.706$). There was also no interaction between site and distance from the trail (Two-Way ANOVA: $F_{1,79} = 0.165$, $P = 0.686$). It should be noted that the data set was skewed, with unequal variances across groups. These unequal variances remained even after performing multiple transformations (log, square root, and Box-Cox).

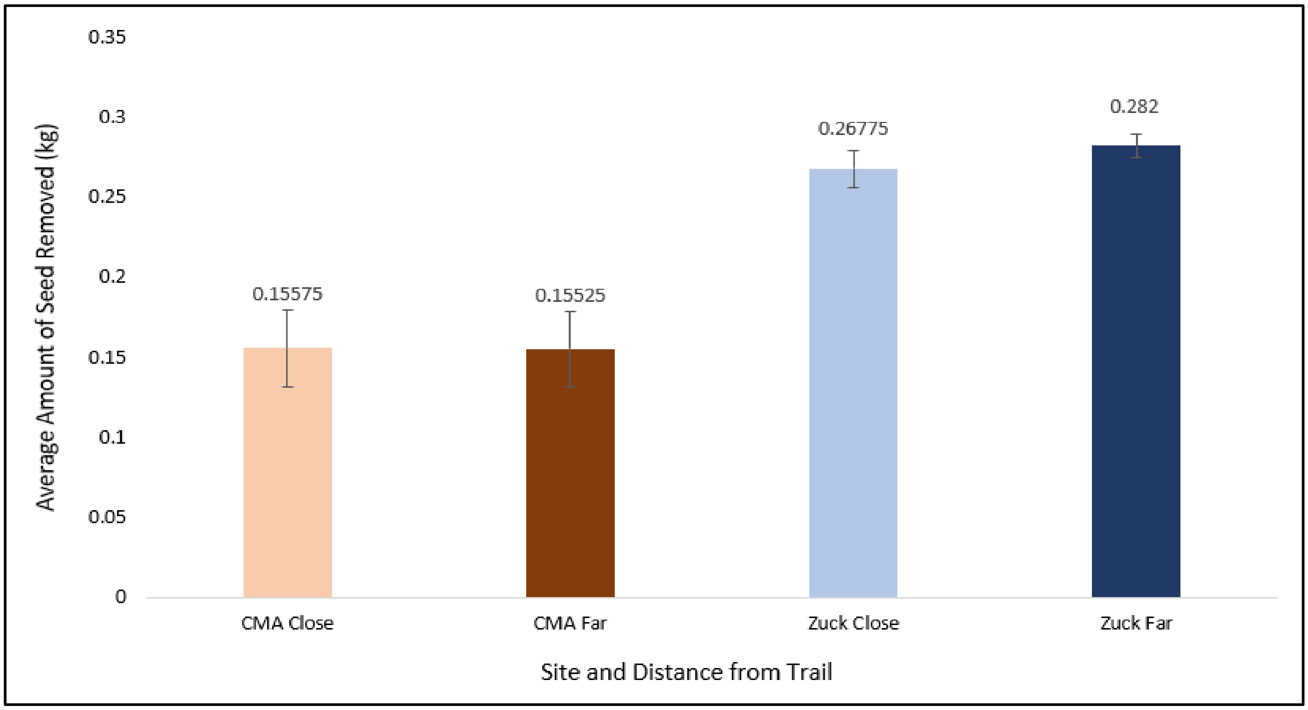

Figure 22. Average amount of seed removed (kg) from CMA and Zuck Arboretum feeders, of varying distance from human foot trails.

From these data, one could surmise that Zuck birds are more habituated to humans and the presence of seed than CMA birds. Since animals learn to not overly respond to insignificant stimuli over time (Rankin et al., 2009), the fact that feeders were previously present at Zuck and that humans more readily utilize this site's trails could explain differences observed in the amount of seed removed between sites. Another plausible reason could be that less tolerant birds left Zuck, as people began to occupy the site more (Samia et al., 2015). Differences could also stem from the types of species visiting the two sites. For instance, larger birds, like Mourning Doves, remove more seed during any given visitation than smaller species, such as Tufted Titmice and White-breasted Nuthatches (*Sitta carolinensis*). Mourning Doves were only witnessed at Zuck, while Tufted Titmice and White-breasted Nuthatches (*Sitta carolinensis*) were seen more at the CMA. Less feeding, and more caching, involving the removal of one or a few seeds, could also contribute to the lower amount removed from the CMA.

It is important to note that my findings contradict the scholarly literature about the impact of distance from cover on the amount of seed removed. Specifically, prior research has shown that amount of seed removed declines as one moves farther away from cover (Cowie & Simons, 1991). In fact, the amount eaten next to cover was two times that of feeders 7.5m away in one study (Cowie & Simons, 1991). However, I found that the distance from the trail didn't matter, since there was an approximately equal amount of seed removed from Zuck Close and Far feeders and from CMA Close and Far feeders.

Quantifying Bird Visitors

After analyzing the number of birds visiting each feeder over the course of the study, I discovered that there were 15,640 individuals. The quantity of Zuck visitors was relatively stable at both the close and far feeders, while there was a negligible amount at the two CMA feeders for the first three weeks (Fig. 23). In the remaining seven weeks, there were two peaks in CMA visitations – one during weeks 4-5 and another during week 9.

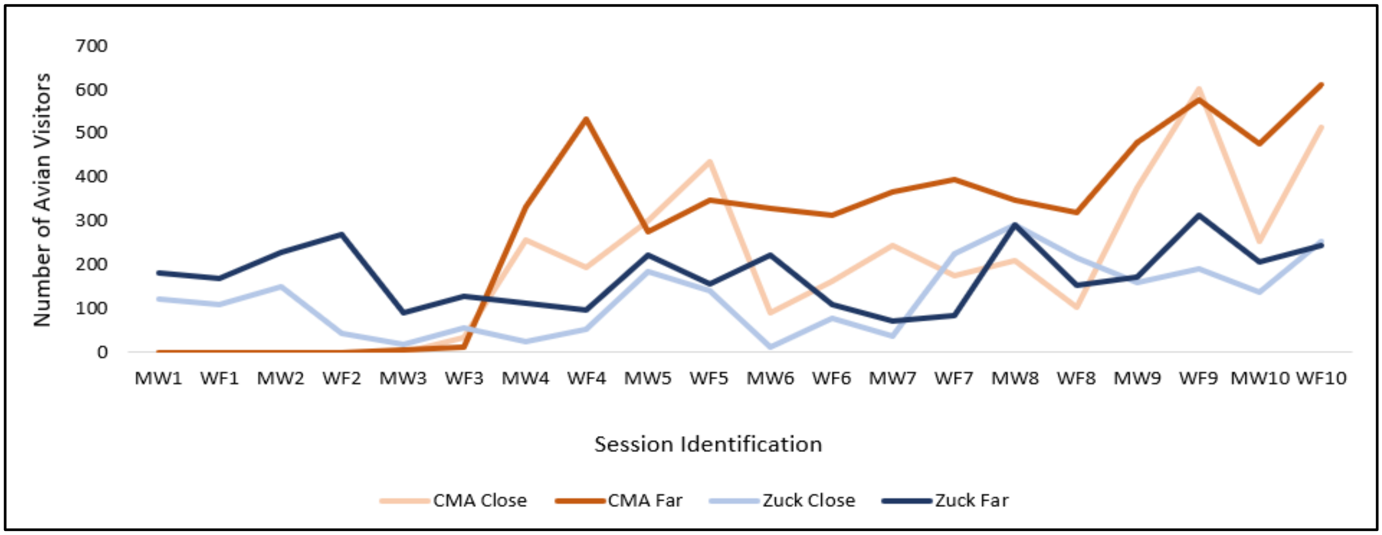

Figure 23. Total number of avian visitors at the CMA and Zuck Arboretum feeders, by session identification. "MW" indicates Monday-Wednesday session and "WF" Wednesday-Friday. Associated numerical identification symbolizes week #, where 1=Mid-September, 3=Late-September/Beginning of October, 5=Mid-October, 7=Late-October, and 9=Mid-November.

The number of visitors at Zuck may have been consistent across the 10 weeks because the site frequently provides supplemental seed for local wildlife. Zuck birds were likely already accustomed to visiting other feeders within the arboretum, so they simply extended their consumption to my novel feeders. Those birds that previously fed from supplemental feeders probably utilized the experimental platform feeders, while those that didn't regularly consume seed unlikely visited. At the CMA, I initially didn't observe many birds, but following the first few weeks, the number visiting noticeably increased. My findings resemble other studies, where it took birds two weeks to find supplemental seed in one area, while they found food in a matter of days at other sites (Galbraith et al., 2015). At Zuck, bird visitors were present on the first day, but at the CMA feeders, they didn't come until week 3.

When analyzing bird visitors to the CMA, I found that Tufted Titmice and Blue Jays came first (Fig. 24 & 25). For Blue Jays, this likely had to do with the species' elevated ranking in the dominance hierarchy as a larger, more aggressive species. However, with Tufted Titmice, the opposite may actually be true. Studies have found that subordinate conspecifics visit a feeder first following the appearance of a fictious predator and the playback alarm call of a Tufted Titmouse (Waite & Grubb, 1987). Researchers believe that dominant Tufted Titmice wait longer before moving to ensure that the predator actually left (Waite & Grubb, 1987). While my study didn't involve playback calls, it is probable that a similar pattern occurred at my feeders with the subordinate Tufted Titmice. However, further studies would need to be conducted to confirm or refute this.

Figure 24. First Tufted Titmouse at the CMA Close feeder.

Figure 25. First Blue Jay at the CMA Far feeder.

Peaks in visitations were apparent at the CMA towards the middle and end of the study. Specifically, the first peak occurred during weeks 4-5 and was likely caused by migration. Because energy in the form of lipids is especially pertinent for long-distance migrants (Bairlein, 2002), it is probable that some migratory birds stopped at my feeders during their journey. As far as the second peak, this observation may be due to changes in ambient temperature, paired with a decline in the number of natural foodstuffs and birds' heightened need for energy (Dhillon, 2020).

After compiling data based on the number of avian visitors observed throughout the 10-week study, I found that there was a statistically significant difference in the average number of visitors per session, when independently examining site (Two-Way ANOVA: $F_{1,79} = 7.529$, $P = 0.008$) and distance from the trail (Fig. 26; Two-Way ANOVA: $F_{1,79} = 4.375$, $P = 0.04$). Specifically, more birds visited the CMA ($M = 241.15$, $SE = 31.30$) than Zuck ($M = 149.85$, $SE = 12.86$) and there were also more visitors at the far feeders ($M = 230.30$, $SE = 26.01$) than at the close feeders ($M = 160.70$, $SE = 22.67$). However, there was no statistically significant interaction between site and distance (Two-Way ANOVA: $F_{1,79} = 0.312$, $P = 0.578$). It should be noted that the data set was skewed, with unequal variances across groups. These unequal variances remained even after performing log, square root, and Box-Cox transformations.

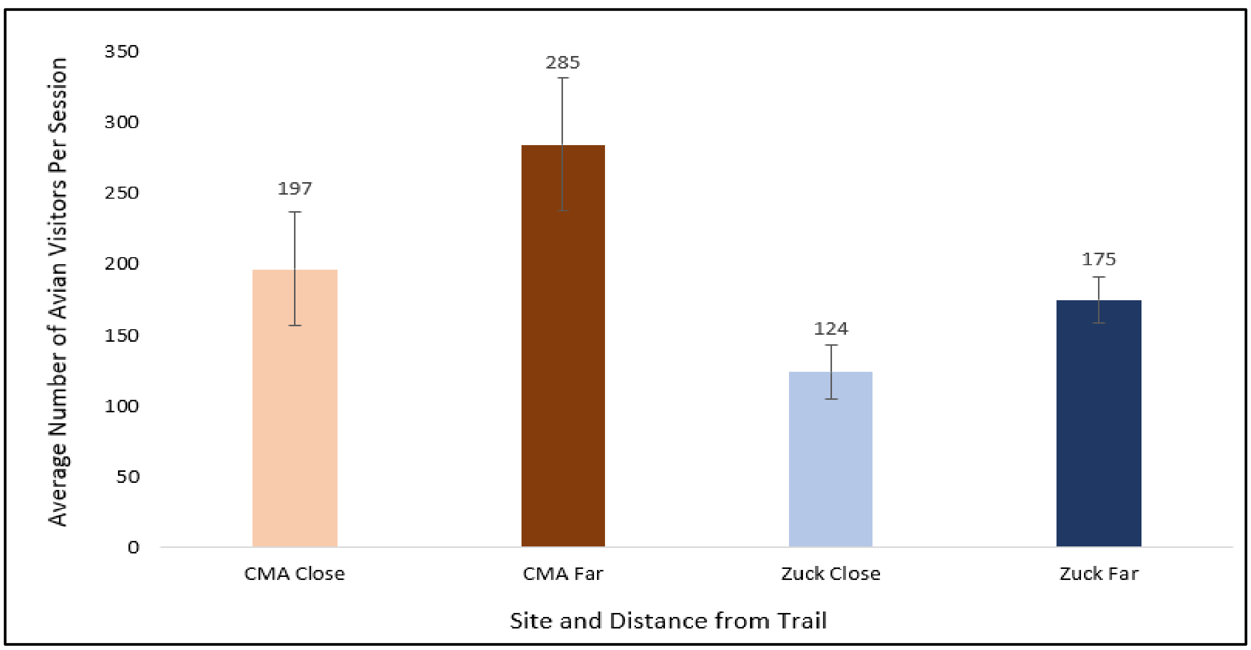

Figure 26. Average number of birds, per session, visiting the CMA and Zuck Arboretum feeders, based on site and distance from the trail.

One probable reason for differences in the average number of visitors observed at the two sites is that more birds reside in or migrate through the CMA. As a larger site with low human interference, the CMA may be perceived as a safer habitat for less habituated birds, compared to Zuck, which is situated on a college campus. Another potential explanation for this finding is that more birds may have visited the CMA feeders as a novel site. Since the CMA didn't previously possess supplemental feeders, birds residing in this forest may have sought out the feeders more, as it was unclear how long this food supply would last.

Along with site, distance also impacted the quantity of visitors, with more birds interacting with feeders farther from the human foot trail, compared to those closer to the trail. Specifically, less habituated birds may have been hesitant to visit the feeders nearer to the trail due to their close proximity to humans. This supports past findings, which show that birds, when presented with an option, choose to utilize feeders nearer to cover versus those at a greater distance (Horn et al., 2003). Scientists believe that several factors, including lower energetic demands, reduced predatory threats, and diminished contact with the elements may elucidate birds' feeding decisions (Grubb & Greenwald, 1982; Lima, 1985; Todd & Cowie, 1990).

Tracking Species

By examining the number of species observed during any given week of my study, I learned that Zuck had a larger species richness than the CMA (Fig. 27). Analyzing fluctuations over time, I found that the quantity of species at Zuck was initially relatively stable, decreased during weeks 6-7, and finally surpassed the number previously seen towards the end of the study. On the other hand, at the CMA, the number of species gradually increased over time, prior to stabilizing around week 5.

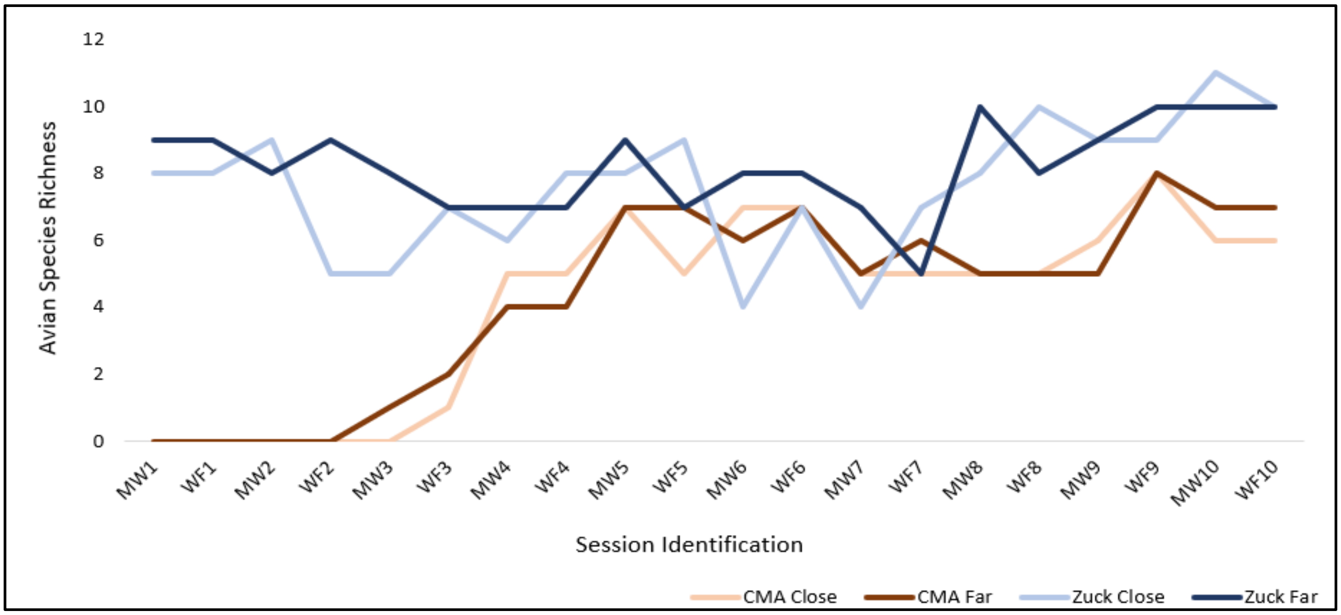

Figure 27. Total number of bird species at the CMA and Zuck Arboretum feeders, by session identification. "MW" indicates Monday-Wednesday session and "WF" Wednesday-Friday. Associated numerical identification symbolizes week #, where 1=Mid-September, 3=Late-September/Beginning of October, 5=Mid-October, 7=Late-October, and 9=Mid-November.

Contrary to previous research, where a larger variety of species was recorded closer to cover than farther away (Horn et al., 2003), in my study, distance from the trail had less of an impact on species richness than site location. I found that Zuck possessed a greater diversity of species than the CMA during any given session. Specifically, I learned that Zuck Close and Far feeders had a maximum of 11 and 10 species, respectively, while CMA Close and Far feeders both had only eight species. However, when examining the number of unique species observed over the course of the 10 weeks, Zuck and the CMA had roughly the same quantity (13 and 12), not considering count or frequency.

Migratory patterns may be the reason for the fluctuating number of species observed at Zuck. In particular, weeks six and seven likely represented a period of time when species living in New Jersey in summer already migrated, while those residing in the state in winter didn't complete their journey yet. Likewise, the quantity seen during weeks 8-10 may have been greater than weeks one through five, since some species, like Dark-eyed Juncos (*Junco hyemalis*), that only reside in New Jersey in winter, arrived.

Within the CMA, the initial growth in species was likely caused by increased habituation to the supplemental feeders. Once the birds became accustomed to foraging at the feeders, the number of species was able to stabilize for the duration of the study. It may have taken several weeks for the number of visitors to become roughly constant, since the CMA birds were not habituated to the presence of supplemental seed. Likewise, some species are more prone to visit novel feeders than others. Certain species never habituate, while others are capable of exhibiting this behavior in as short as 2-17 days (Conomy et al., 1998; Blumstein, 2016).

Furthermore, I found that there was a statistically significant difference in the number of visitors per species, based on both site (Chi-Square test: $X^2_7 = 881.179$, $P < 0.001$) and distance from the trail (Fig. 28; Chi-Square test: $X^2_7 = 25.663$, $P < 0.001$). Specifically, for the majority of species, I observed the greatest number of visitors at both CMA feeders and those farther from the trail.

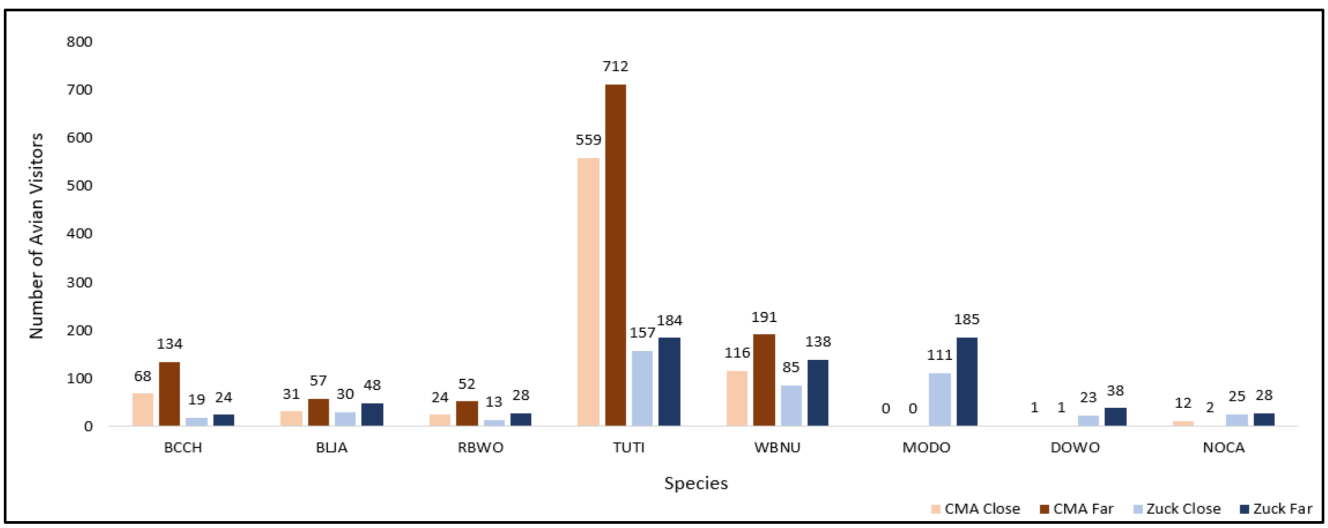

Figure 28. Total number of visitors, per species, at the CMA and Zuck Arboretum feeders for a subsample of videos.

While I generally observed more visitors at the CMA than Zuck, it is important to note that for a few species, including Mourning Doves, Downy Woodpeckers, and Northern Cardinals, more birds were recorded at Zuck. With Mourning Doves, in particular, this is likely the result of differential habitat conditions. Specifically, the CMA is a 78-acre floodplain forest with ample trees throughout. On the other hand, despite being a mature forest, Zuck is surrounded by a baseball field and a small condominium with a more open understory. As Mourning Doves are widely seen in more suburban communities, they may prefer edge sites, as opposed to dense forests.

When comparing the number of visitors, per species, at close versus far feeders, more were observed at a greater distance from the trail. This conclusion was supported by the literature, which found that for eight different species, including Black-capped Chickadees and Mourning Doves, there was a larger number of visitors at feeders nearer to cover (Horn et al., 2003). In my study, the only exception was the Northern Cardinal, that had an approximately equal quantity at both feeders (37 visitors at the close feeders versus 30 at the far feeders).

At the two CMA feeders, noticeably more Tufted Titmice visited than other species. This may be because Tufted Titmice respond less to noise than visual cues, compared to other birds (Hetrick & Sieving, 2011). While human voices are occasionally heard at the CMA, few people traverse through the section of the trail where my feeders were positioned. However, Tufted Titmice also comprised the greatest number of birds at the Zuck Close feeder, an area that is heavily trafficked. Therefore, one could argue that this species likely habituates to humans more quickly than other species in this area.

Vigilance and Dominance

Following data collection, I analyzed percentages of birds engaging in vigilant behavior for the most commonly-occurring species. I found that there was more vigilance at the CMA than Zuck (Fig. 29; Chi-Square test: $X^2_4 = 90.635$, $P < 0.001$). I also discovered that species scanned more farther from the trail versus closer (Chi-Square test: $X^2_4 = 22.011$, $P < 0.001$). In fact, there were significantly fewer vigilant birds at the Zuck Close feeder than the other three.

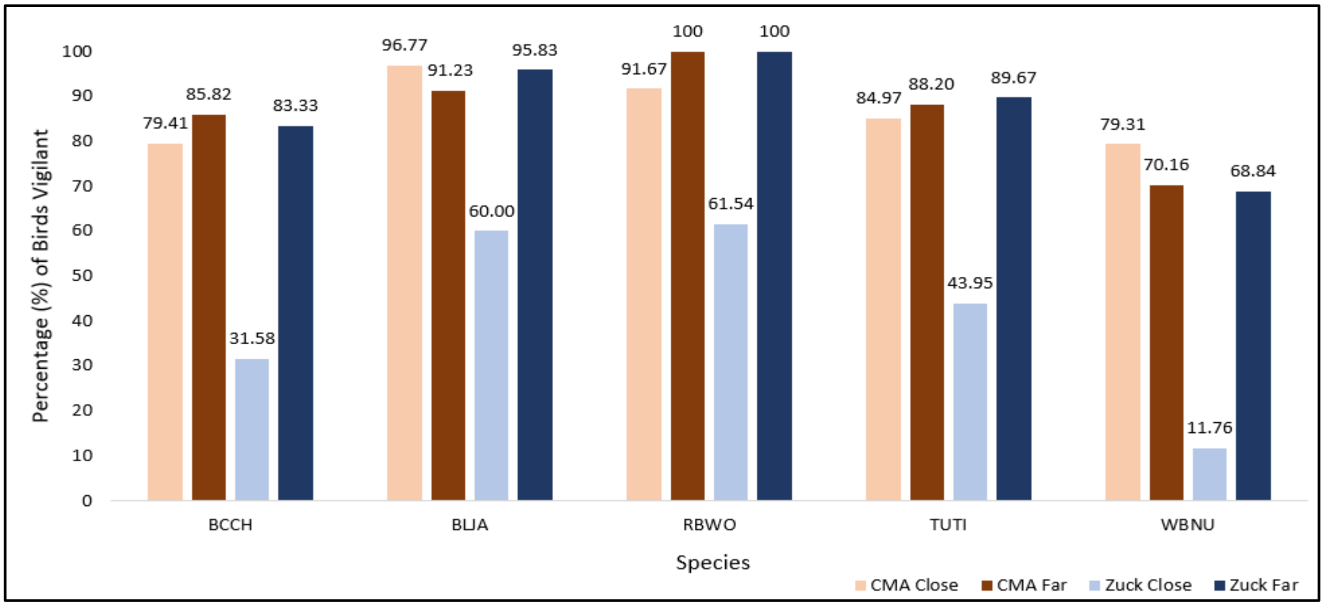

Figure 29. Percentage (%) of birds vigilant for the most frequent species at the CMA and Zuck Arboretum feeders, within a subsample of videos.

My data suggest that birds from more habituated sites, like Zuck, are not as vigilant as those residing in less habituated locations, such as the CMA. This supports the scientific literature, which states that scanning behavior is abbreviated in more disturbed areas (Vallino et al., 2019). However, my study contradicts the previous finding that vigilant behavior is performed more in areas with less cover (Barnard, 1980; Lendrem, 1983), since birds farther from the trail actually exhibited heightened scanning. Across species, birds at the Zuck Close feeder were the least vigilant, which opposes past studies' findings.

By examining the data with a narrower lens, it is apparent that certain species are more likely to scan than others. For instance, the White-Breasted Nuthatch was consistently less vigilant than the Red-bellied Woodpecker and the Blue Jay. The White-breasted Nuthatch was even observed preening in one of the videos, paying little attention to potential predators (Fig. 30). Rationale for these data likely stems from numerous factors, including vision, sociality, and habituation.

Figure 30. White-breasted Nuthatch preening at Zuck Far feeder.

In particular, vision plays a role in vigilance, since birds with larger blind spots have a harder time detecting predators while their heads are down (Lima & Bednekoff, 1999; Guillemain et al., 2002; Kaby & Lind, 2003; Devereux et al., 2006). These birds' heads need to be oriented above the horizontal plane, in order to see advancing predators, compared to those with smaller blind spots that can partially scan with their heads down (Lima & Bednekoff, 1999; Guillemain et al., 2002; Kaby & Lind, 2003; Devereux et al., 2006).

Sociality is another characteristic used to understand vigilant behavior. While Blumstein (2006) was specifically focusing on cooperative breeding, one could argue that Blue Jays, that don't cooperatively breed but call other conspecifics to the feeder, are more social than White-breasted Nuthatches that typically forage independently. This may partially explain why vigilance rates of Blue Jays are higher, since they scan more often for conspecifics than White-breasted Nuthatches.

Lastly, habituation is a significant element for vigilance. For instance, one study found that some species habituated more to human disturbance than others (Marcum, 2006). These habituated species have a greater probability of dismissing irrelevant, expected stimuli in the environment (Hockin et al., 1992). This would elucidate why certain species that are clearly habituated scan less at the feeder.

Dominance relationships are an integral component of avian communities around the world. While I focused on species visiting feeders in New Jersey, dominance could be studied in a wide array of settings. From my observations of dominance relationships, it is apparent that specific behavioral patterns exist. For instance, Mourning Doves primarily relied on physical responses, like ptiloerection, head bobbing, and feather plucking, to scare away other birds (Table 1). Similarly, Red-bellied Woodpeckers tended to use aggression more often than other species. However, while certain species were consistently dominant, the dynamics of others' relationships depended more on the identity of the second bird.

Table 1. Common dominance relationships for inter- and intraspecific birds at each feeder. Examples are not unique to individual feeders. Similar behaviors were seen at the other three.

CMA Close	BCCH	Changes location when TUTI chases it
	COGR	Ptiloerection, intraspecific wing spreading and chasing
	NOCA	Lowers head and chases TUTI
	TUTI	Intraspecific chasing, beak opening, and head lowering
CMA Far	BCCH	Changes location when RBWO lands
	BLJA	Flies away when RBWO lands
	TUTI	Flies away when WBNU chases it
	WBNU	Intraspecific chasing
Zuck Close	MODO	Intraspecific feather plucking, wing flapping, and head bobbing
	NOCA	Spreads tail feathers and lowers head towards WBNU
	RBWO	Lowers head and opens beak towards BLJA
	WBNU	Extends wings when flying in to scare TUTI
Zuck Far	BCCH	Flies away when TUTI lands
	MODO	Ptiloerection, bobbing head towards DOWO
	RBWO	Lowers head towards TUTI
	WBNU	Flies away when DOWO lands

The behavioral patterns observed throughout the study are a product of the individual species and their overall ranking in the dominance hierarchy. Since dominant birds are known to supplant lower-ranking animals (Pravosudov & Grubb, 1999), agonistic behaviors taken by Red-bellied Woodpeckers at the feeder, such as head lowering and beak opening, exemplify their elevated position in the hierarchy. Likewise, when a subordinate bird comes into contact with a dominant animal, the subordinate individual will leave the vicinity without prompting from the higher-ranking member (Pravosudov & Grubb, 1999). For instance, this behavior was observed with the Black-capped Chickadee departing when the Tufted Titmouse arrived. Subordinate birds also perform more scanning behavior when with a dominant bird from another species versus when accompanied by a lower-ranking conspecific (Pravosudov & Grubb, 1999).

Upon analyzing my data, it is clear that particular species were consistently dominant, while other species' rankings were more context-dependent. Specifically, Red-bellied Woodpeckers were dominant throughout the study. On the other hand, with species like the White-breasted Nuthatch and the Tufted Titmouse, their dominance status depended on which other bird was at the feeder (Fig. 31). For instance, White-breasted Nuthatches acted aggressively towards Tufted Titmice, but were subordinate to Downy Woodpeckers. Similarly, Tufted Titmice were subordinate to White-breasted Nuthatches, but were dominant to Black-capped Chickadees.

Figure 31. White-breasted Nuthatch unsuccessfully attempting to scare Northern Cardinal at Zuck Close feeder.

There are numerous components that one needs to consider when studying dominance hierarchies, including weight and physical attributes, among others. In particular, weight is believed to be one of the most significant characteristics shaping dominance. In these scenarios, larger birds tend to dominate the feeders (Francis et al., 2018). This finding was supported by my research, where larger birds, like Red-bellied Woodpeckers and Mourning Doves scared away smaller visitors (Fig. 32 & 33).

Figure 32. Black-capped Chickadee moving to the Shepherd Hook pole, as a Red-bellied Woodpecker arrives at the CMA Far feeder.

Figure 33. Moments before Mourning Dove bobbed head towards Downy Woodpecker, scaring it, at Zuck Far feeder.

With Red-bellied Woodpeckers, in particular, they also utilize physical make-up to establish dominance. This species regularly employed its large beak to its advantage, to acquire the greatest number of seeds from my feeders. Past studies have found that when taking weight into account, species with larger beaks assumed an elevated position in the hierarchy (Leighton et al., 2023). This was true of my study, as the Red-bellied Woodpecker not only scared away smaller birds, like the Tufted Titmouse, but also caused relatively equally-sized species, such as the Blue Jay, to fly away (Fig. 34). A probable reason for this increased flightiness is the potential risk associated with a lengthier beak. A woodpecker's large beak could contribute to physical harm in aggressive encounters, so other birds avoid this risk by adopting a subordinate position (Leighton et al., 2023).

Figure 34. Red-bellied Woodpecker using beak to scare Blue Jay at the Zuck Close feeder.

Characteristics that impact dominance among conspecifics include weight, as previously discussed, along with age, sex, past experience, and overall level of aggression (Haley et al., 1994; Zucker & Murray, 1996). These factors may partially explain why certain conspecifics displaced others. For instance, particular Mourning Doves prevented others from consuming seed at the feeder through behaviors, like targeted head bobbing and feather plucking (Fig. 35). Similar behaviors were exhibited by different species and their conspecifics, including White-breasted Nuthatches and Tufted Titmice. Another instance of aggression in conspecifics is evident through ptiloerection, where an individual puffs out its feathers, in an attempt to scare another into fleeing (Fig. 36).

Figure 35. Intraspecific feather plucking at Zuck Close feeder.

Figure 36. Ptiloerection (puffed out feathers) in a Common Grackle at CMA Close feeder.

By mapping out the "winners" and "losers" of each dyad, I discovered that certain species were consistently dominant (Ex: Red-bellied Woodpeckers), while others were subordinate (Ex: Black-capped Chickadees) (Table 2). However, some species, like the Tufted Titmouse, only won during particular encounters. Lastly, dominance was rare among specific dyads, such as the Downy Woodpecker and the Mourning Dove or the Black-capped Chickadee and the Red-bellied Woodpecker.

Table 2. Dyads representing the total number of "wins" for each species within a subsample of videos. "Wins" are defined as the more dominant or aggressive species in a given video.

Dyad	Number of Dominance "Wins" Per Species
BCCH/RBWO	0/1
BCCH/TUTI	0/18
BCCH/WBNU	0/2
BLJA/MODO	1/4
BLJA/RBWO	0/3
BLJA/TUTI	2/0
BLJA/WBNU	2/0
DEJU/MODO	0/1
DEJU/TUTI	1/0
DEJU/WBNU	0/2
DOWO/MODO	0/1
DOWO/TUTI	3/2
DOWO/WBNU	2/0
MODO/TUTI	4/0
MODO/WBNU	3/0
NOCA/TUTI	12/0
NOCA/WBNU	4/2
TUTI/RBWO	0/6
TUTI/WBNU	4/57

If one is unable to establish a complete dominance hierarchy for a given bird, studying dyads could provide useful information. Within these dyads, a researcher identifies a “winner” and a “loser.” The “winner” either supplants the “loser” through agonistic behavior or the “loser” simply flies away when the “winner” arrives (Francis et al., 2018). While some “winners” relied on chasing, feather plucking, and beak opening to scare away visitors in my study, other “winners,” like the Red-bellied Woodpecker and the Tufted Titmouse, simply needed to land on the feeder to send the other bird flying.

“Winners” acquire resources at the feeder, likely enhancing their overall level of fitness (Fellers, 1987; Leighton et al., 2023). On the other hand, “losers” decrease the quantity of time foraging to prevent negative encounters with dominant birds (Francis et al., 2018). My data contradict Leighton et al. (2023)’s finding that species with more conspecific fights are typically lower-ranking in the interspecific hierarchy. For instance, in my study, Mourning Doves regularly engaged in feather plucking, wing flapping, and head bobbing with conspecifics, but still won the majority of interactions with other species.

At my feeders, some species were consistently “winners.” For instance, the Tufted Titmouse was always dominant over the Black-capped Chickadee, the Northern Cardinal over the Tufted Titmouse, and the White-breasted Nuthatch over the Tufted Titmouse (Fig. 37, 38, & 39). My findings were supported by prior research, showing that Tufted Titmice are dominant over Carolina Chickadees (Pravosudov & Grubb, 1999; *Poecile carolinensis*), a species closely related to the Black-capped Chickadee. It is probable that the Northern Cardinal won over the Tufted Titmouse based on size, since larger species cause smaller ones to maintain their subordinate ranking through interference competition (Morse, 1974). Other studies supported my data that Tufted Titmice oust Black-capped Chickadees (Miller et al., 2017).

Figure 37. Black-capped Chickadee moving towards Shepherd Hook pole, as Tufted Titmouse arrives at CMA Far feeder.

Figure 38. Northern Cardinal defending seed against Tufted Titmouse at Zuck Close feeder.

Figure 39. White-breasted Nuthatch flies towards Zuck Far feeder, scaring Tufted Titmouse.

My result that White-breasted Nuthatches are dominant over Tufted Titmice contradicts previous studies, which found that there is usually a tie between these two birds because of sex-based behavioral differences (Waite & Grubb, 1988; Miller et al., 2017). Further studies would need to be conducted to support or refute these conclusions, however, since my study didn't address the sex of individual visitors, including White-breasted Nuthatches. When Red-bellied Woodpeckers made an appearance, they were almost always dominant, a result shown in other studies (Miller et al., 2017).

It is also important to question why dominance was uncommon among some dyads. One potential reason could be that any given two species possessed different foraging preferences. For instance, Mourning Doves prioritize White Proso Millet (Johansen et al., 2014), while Dark-eyed Juncos and Downy Woodpeckers consume a wider variety of seeds. Additionally, since Black-capped Chickadees didn't win any dominance encounters with other species, they may have been viewed as non-competitors by Red-bellied Woodpeckers.

Caching

By examining the percentage of birds caching, I discovered that certain species cached more often than others (Fig. 40). Specifically, Blue Jays were seen caching the least out of the five most frequently occurring species.

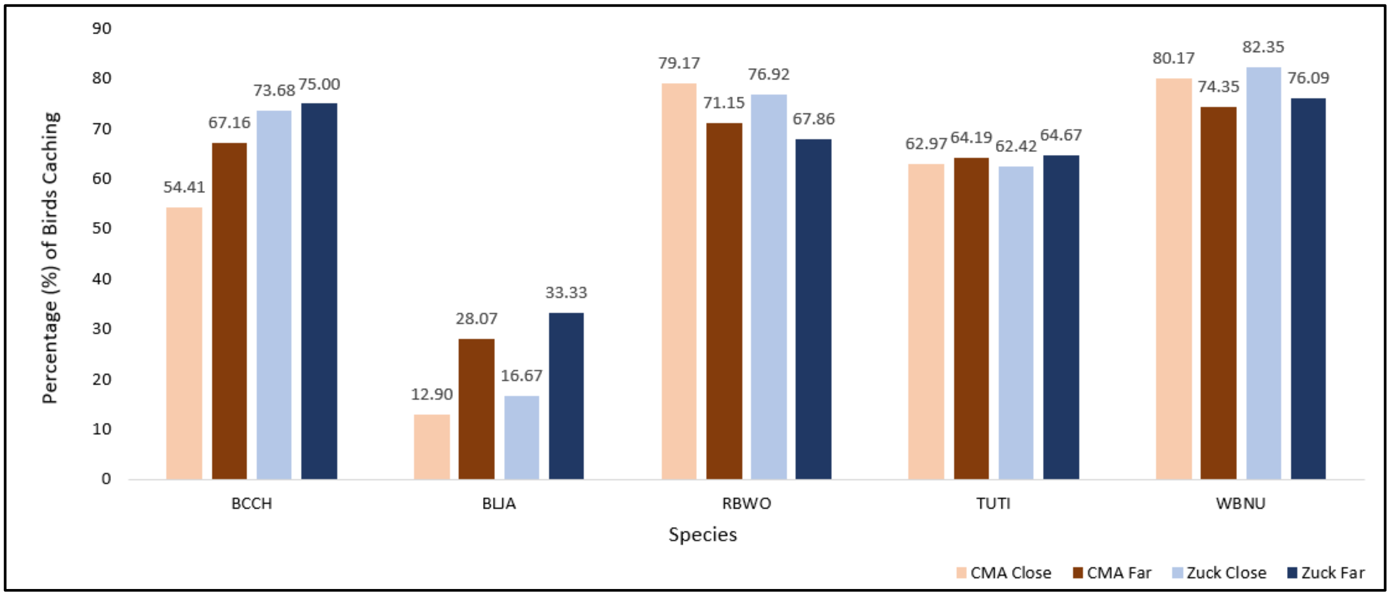

Figure 40. Percentage (%) of birds caching for the most frequent species at the CMA and Zuck Arboretum feeders, within a subsample of videos.

It is apparent that certain species cached more than others at the four feeders. Upon first glance, the reasons for these differences are not obvious. However, scientists now believe that variation in caching may be related to genetics and evolutionary history. Evolution may partially explain why Black-capped Chickadees and Tufted Titmice, both members of the Paridae family, cache, while Blue Jays from the Corvidae family don't frequently cache. In particular, the Corvidae family possesses specialized cachers, non-cachers, and intermediate cachers due to multiple evolutionary paths (de Kort & Clayton, 2006). The shared ancestor of Blue Jays and all other corvids, including American Crows (*Corvus brachyrhynchos*), Fish Crows (*Corvus ossifragus*), and Common Ravens (*Corvus corax*), was an intermediate cacher. However, some species have since diverged to become non-cachers and specialized cachers (de Kort & Clayton, 2006). For instance, Blue Jays became specialized cachers, which means that they prioritize one food group for caching (de Kort & Clayton, 2006). This may justify why Blue Jays in my study cached less often than other species because small or medium-sized nuts, especially acorns, are their caching food of interest, rather than seeds (Darley-Hill & Johnson, 1981).

In another study, researchers found that more caching occurred if the time it took Blue Jays to handle food was abbreviated and habitats were inferior (Wein & Stephens, 2011). It is sensible that Blue Jays didn't cache from the CMA or Zuck feeders because habitat conditions were favorable, with an abundance of natural foodstuffs, including acorns. However, one should recognize that the impact of handling time on caching is species-specific (Wein & Stephens, 2011). Some species, like American Crows, cache more for foods with extensive handling times, rather than for those with abbreviated times (Cristol, 2001).

Another crucial factor impacting caching is an animal's genetic make-up. In particular, certain genes influence a bird's degree of spatial awareness (Branch et al., 2022), which is important for caching. This is why White-breasted Nuthatches are able to cache food in the bark of trees, as opposed to primarily eating at the feeder (Kilham, 1974; Petit et al., 1989; Woodrey, 1991). Disparity in birds' spatial awareness and memory is related to top outlier genes, which impact the quantity and size of neurons in the hippocampus (Branch et al., 2022). In one study, focusing on *GRM3* and *ELMO1* top outlier genes, scientists identified varying levels of hippocampal expression for Black-capped Chickadees at changing latitudes (Pravosudov et al., 2013), exemplifying the significance of these genes for behavior. While genes play a vital role in caching ability, it is nevertheless important to recognize that other factors, such as handling times and habitat quality, as previously discussed, also influence this behavior.

Through a Chi-Square test, I determined that there was a statistically significant difference in the number of caching birds, by species, based on site (Fig. 41; Chi-Square test: $X^2{}_4 = 85.845$, $P < 0.001$). In particular, more birds cached at the CMA than at the arboretum. Since the CMA doesn't typically provide bird seed, these unpredictable conditions could potentially explain why CMA birds cache more often than Zuck birds, which have a frequent supply of seed available to them. With Blue Jays, however, they were seen caching roughly equally at both locations.

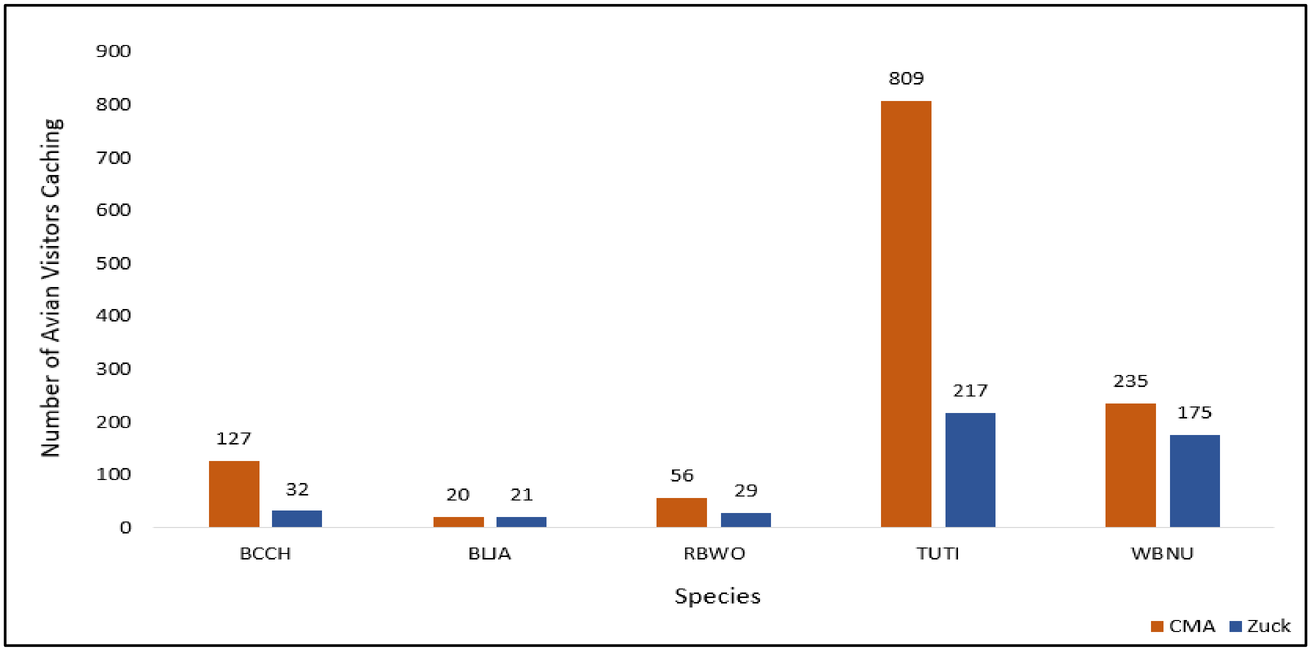

Figure 41. Total number of birds caching for the most frequent species, by site, within a subsample of videos.

Lastly, there was also a significant influence of distance from the trail on the quantity of caching avian visitors, by species (Fig. 42; Chi-Square test: $X^2{}_4 = 16.776$, $P < 0.05$). More caching birds were observed at the far feeders than at the close feeders, possibly because the close feeders were nearer to their food reserves, making it easier for the birds to deposit a seed and come back for more.

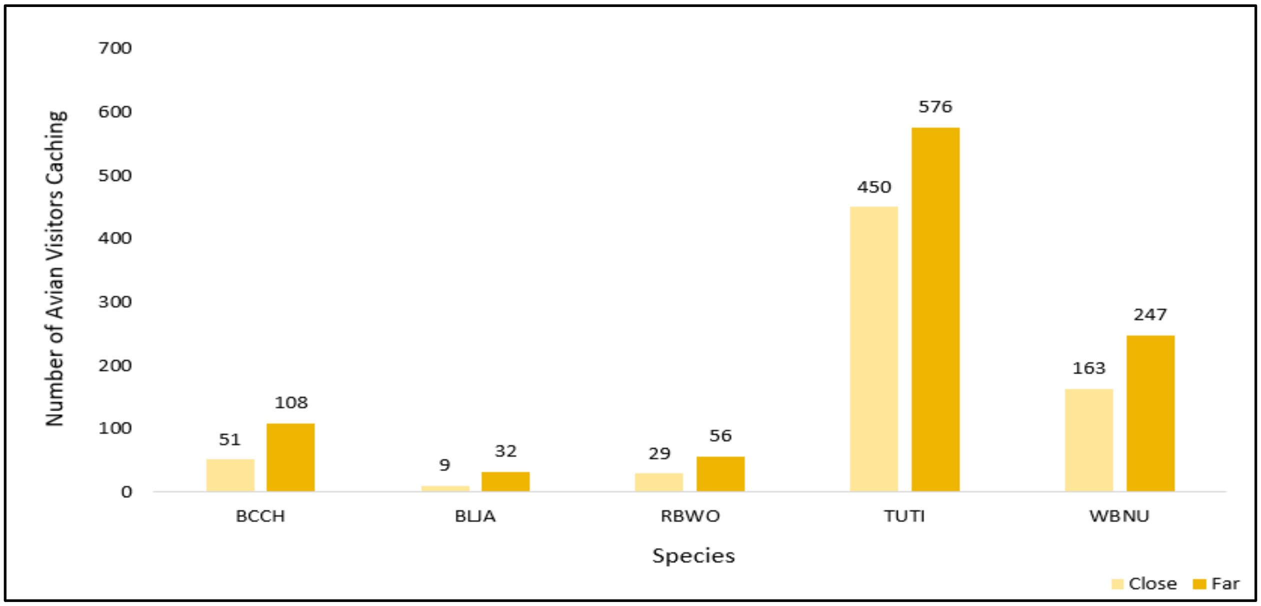

Figure 42. Total number of birds caching for the most frequent species, by distance, within a subsample of videos.

Temperature

Throughout the course of the study, there was a gradual decline in the average ambient temperature, with the highest overall temperatures being observed in the middle of September and the lowest temperatures towards the end of November (Fig. 43).

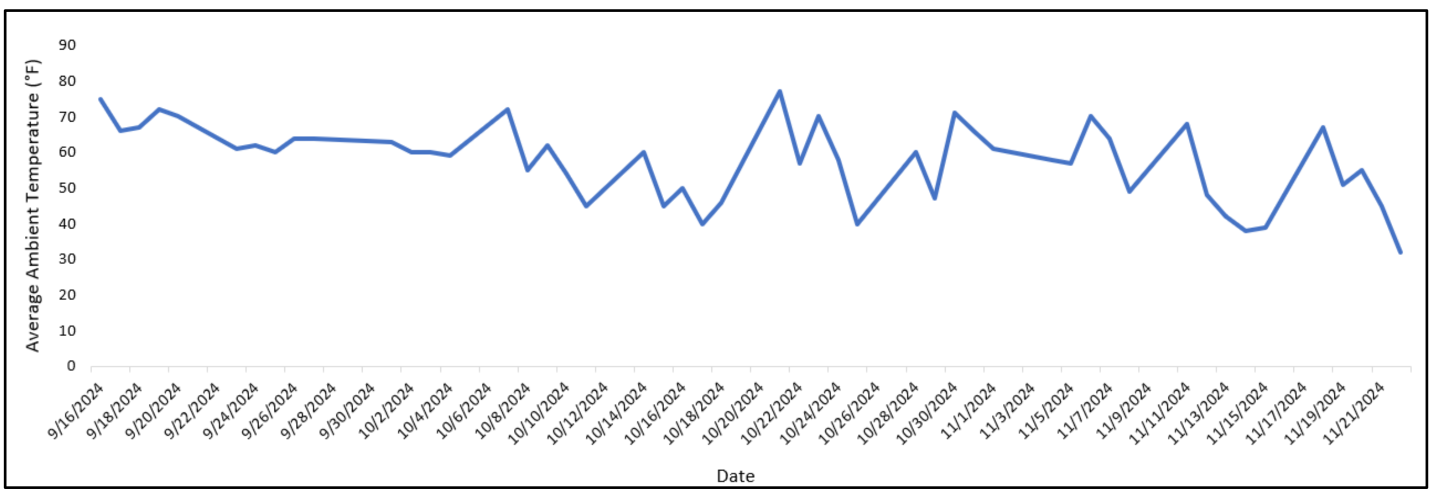

Figure 43. Average ambient temperature (°F), per date, at the CMA and Zuck Arboretum feeders. Data were obtained from a subsample of videos.

Upon analyzing the average ambient temperature at the CMA and Zuck, it is apparent that temperatures steadily decreased over time. Seasonal fluctuation is readily seen in the Northeast, where my study was conducted. Historically, winters were frigid and snow-filled, while summers were humid with elevated temperatures ("USGCRP," 1970). However, due to anthropogenic climate change, ambient temperatures have become warmer in recent years.

With 2024 being hotter than average in the Northeast, yearly temperatures were up to 6°F higher than average in some locations, with northern and central areas most affected ("An Unsettled," 2025). In fact, 2024 was classified as/tied for being the hottest recorded year in this area ("An Unsettled," 2025). It is also important to note that the state experienced a severe drought during the duration of my study. Autumn 2024 was identified as the driest period since the year 1895 (Robinson, 2024). As temperatures are expected to increase by 4.5-10°F as early as the 2080s ("USGCRP," 2014) and as the probability of more intense droughts is predicted to rise (Cawdrey, 2023), it is apparent that climate change is an existential threat that must be addressed.

Specifically, climate change impacts the health and behavior of wildlife, including birds. For instance, heat stress forces birds to engage in heat dissipation, taking away time for foraging (Cunningham et al., 2013; Edwards et al., 2015; Evans et al., 2018; Merrall & Evans, 2020). Furthermore, fluctuations in average temperature and precipitation caused by climate change may be detrimental to caching birds. This is due to changes in the amount of time it takes for seeds to germinate and take on a non-consumptive state (Sutton et al., 2016). Cached food is also more likely to rot with elevated temperatures in autumn, affecting the viability of breeding (Waite & Strickland, 2006). On a larger scale, climate change could even alter the population size and placement of species (Easterling et al., 2000; Hughes, 2000; McCarty, 2001; Grøtan et al., 2009) or contribute to heightened extinction (Carpenter et al., 2008; Keith et al., 2008). It is, therefore, imperative for scientists and the general public to engage in more climate-friendly practices, such as switching to renewable energy, eating less red meat, and relying on public transit whenever possible, for the betterment of wildlife and human societies.

After performing a Two-Way ANOVA ($F_{2,79} = 23.627$, $P < 0.001$), I found that both date (season) and average temperature impacted the number of visitors at the CMA, but not at Zuck (Fig. 44). At the CMA, the number of birds observed increased with cooler temperatures. However, at Zuck, birds were approximately equally likely to visit, regardless of temperature.

While date was the most important factor impacting the number of visitors, temperature resulted in approximately 38 percent of the variation observed. Even when controlling for date, average temperature was still found to affect the quantity of visitors seen. As temperature decreased by 1°F, feeders saw an increase of roughly one visitor. Likewise, as date progressed by one, about three more birds were observed at the feeders.

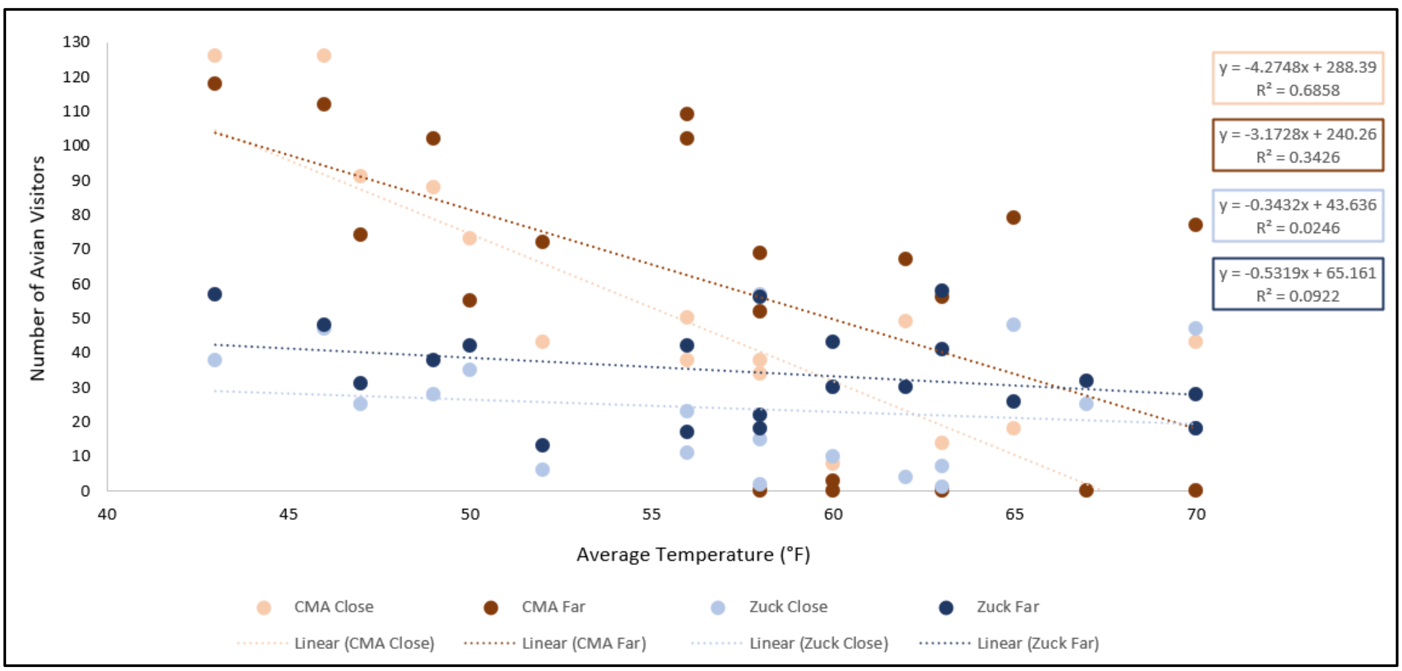

Figure 44. Number of birds visiting the CMA and Zuck Arboretum feeders, by temperature. Temperatures were derived from the average per session (MW1, WF1, etc.) for all four feeders.

CMA birds were potentially more likely to visit in later autumn, when temperatures were beginning to drop, due to an overall reduction in the availability of natural foods, like seeds and berries. Previous research has shown that birds become constrained by the number of resources present in their environment, while simultaneously necessitating more energy for travel and to survive intense winters (Dhillon, 2020). Since supplemental seed was briefly offered during the course of the study, these birds may have taken advantage of the surplus for their health.

On the other hand, Zuck birds may not have visited the feeders more often when temperatures became colder, since there were more resources for these animals to rely on. For instance, generalists, like Blue Jays, are able to consume anthropogenic foodstuffs that the college community discards throughout the year. However, CMA birds didn’t receive this opportunity, since fewer people visit the swamp and trash is rarely left on-site. Other studies support my Zuck conclusion that temperature doesn’t impact the likelihood of feeder use. For instance, Brittingham and Temple (1992) discovered that feeders may not be a primary component of their diet, but rather only a supplemental source. Nevertheless, due to inconclusive results regarding temperature, it is advantageous to provide birds with a continuous, reliable source of food, whenever possible, especially in the colder months of the year.

Infrequent Visitors

It is apparent that certain species visited the feeders more frequently than others, depending on both site and distance from the trail. For instance, Mourning Doves were common at Zuck, but were not present at either CMA feeder (Table 3). Likewise, Common Grackles (*Quiscalus quiscula*) were not observed at the arboretum, while they were seen at the CMA. The frequency of these CMA visitations depended on distance from the trail, since Common Grackles were infrequent at the close feeder, but were common at the far feeder within the subsample of videos. Noteworthy rare visitors included the Carolina Wren, Eastern Screech-Owl (*Megascops asio*), and Gray Catbird (*Dumetella carolinensis*).

Table 3. Commonality of species at the CMA and Zuck feeders, based on a subsample of videos.

Common – 11 or more birds seen.

Uncommon – 4-10 birds seen.

Rare – 3 or fewer birds seen.

Not present – 0 birds seen.

Species	CMA Close	CMA Far	Zuck Close	Zuck Far
BCCH				
BLJA				
CARW				
COGR				
DEJU				
DOWO				
EASO				
GRCA				
HAWO				
MODO				
NOCA				
RBWO				
TUTI				
WBNU				

Through my study, I learned more about the foraging behaviors of both common and rare visitors. While the Carolina Wren was observed at multiple feeders, other rare visitors, such as the Eastern Screech-Owl and Gray Catbird, were only seen at one feeder when examining the subsample of videos (Fig. 45, 46, & 47). With the Eastern Screech-Owl, in particular, it may have been exclusively recorded at the CMA Far feeder because the species doesn't consume seeds. It could have been temporarily resting or preparing to hunt. Likewise, since Gray Catbirds and Carolina Wrens are primarily insectivores, feeding from the ground ("Carolina," 2024; "Gray," 2024), they were not readily seen on my camera traps.

Figure 45. Carolina Wren sitting on CMA Far Shepherd Hook pole.

Figure 46. Eastern Screech-Owl sitting at CMA Far feeder.

Figure 47. Gray Catbird sitting at Zuck Far feeder.

Within the two sites, I observed the White-throated Sparrow (*Zonotrichia albicollis*) foraging from the ground. However, since my recordings didn't capture this species, I didn't include it as part of my study. To fully account for the species richness of seed-eating birds at the CMA and Zuck, additional feeders would need to be established at varying heights with accompanying trail cameras.

Furthermore, it is important to acknowledge that certain species don't habituate to people (Blumstein, 2016). In particular, one could study species' natural environment and life history to help estimate a particular animal's ability to habituate (Blumstein, 2016). Researchers have found that larger animals are typically more responsive to human disturbance than smaller species, but could habituate more readily (Blumstein, 2016). However, larger species, like Blue Jays, appeared to be more vigilant than some of the smaller birds in my study.

Non-Avian Visitors

Along with 15,640 avian visitors, I also observed many other animals at my four feeders, including mice, Eastern Chipmunks, and Eastern Gray Squirrels (Fig. 48, 49, & 50). In fact, mice were my first visitors at the CMA, prior to any birds arriving. Since many humans perceive non-avian visitors to be a nuisance, it is important to acknowledge the advantages that these mammals provide, so some may alter their preconceived notions.

Specifically, with mice, many people consider these small mammals to be disease-harboring and property-damaging pests. While it is true that mice transmit certain illnesses, one must also recognize their ecological benefits. For instance, mouse species are a major source of food for other animals, including snakes, Red-tailed Hawks (*Buteo jamaicensis*), and Red Foxes (*Vulpes vulpes*). Mice also aerate the soil through burrowing behavior. Researchers even found that mice influence forest composition through seed dispersion, providing a healthy ecosystem (Suzuki & Kajimura, 2023), necessary for countless animals, including birds.

Other animal species that people tend to dislike include the Eastern Chipmunk and the Eastern Gray Squirrel, possibly due to their oftentimes generous consumption from supplemental feeders. However, chipmunks have been found to provide crucial ecosystem services, such as spreading fungal spores and aerating the soil (Kroll, 2013; Warren, 2016). Likewise, squirrels influence which nut-producing trees will be present in the future through scatter hoarding behavior (Chambers & MacMahon, 1994; Sundarum et al., 2018). In particular, the germination of unconsumed nuts promotes the development of mature trees (Chambers & MacMahon, 1994). Finally, both squirrels and chipmunks act as prey for native species.

I would advise the bird-feeding community to refrain from chasing these non-avian visitors from the supplemental feeders, instead permitting these rodents to consume seed. Despite negative societal perceptions, these species are oftentimes beneficial members of ecological communities and must be treated with respect, rather than scorn.

Figure 48. Mouse at CMA Close feeder.

Figure 49. Eastern Chipmunk consuming seeds from Zuck Close feeder.

Figure 50. Eastern Gray Squirrel consuming seeds from Zuck Far feeder.

Key Takeaways

This observational study aimed to explore the influence of habituation on the quantity of seed-eating avian visitors, as well as their feeding behaviors. I chose to conduct my research at the CMA and Zuck Arboretum, two restoration sites with nature trails in Southern Morris County, New Jersey, due to potentially differing levels of habituation. While CMA birds were never supplementally fed and had limited encounters with humans, birds at Zuck had been provided with seed for years and had frequent interactions with people, as the site is situated at Drew University, a college campus. In addition to site differences, I also wanted to determine if distance from the trail affected visitors, so I set up two feeders at both the CMA and the arboretum, one close to the human foot trail and one roughly 20m away.

Prior to conducting the study, I hypothesized that there would be a heightened level of scanning at the CMA, which would signify a reduced degree of habituation. I also believed that Zuck would have a higher species richness and visitor count, due to these birds' familiarity with supplemental feeders and the presence of humans. Furthermore, I predicted that the farther feeders would experience a greater species richness and overall number of birds, since animals preferentially choose areas that are less risky, if given an option. Lastly, I hypothesized that birds from both sites would deplete the seeds shortly after establishing the feeders.

While some of my hypotheses were supported by my data, others were not. Specifically, my prediction that there would be more vigilance at the CMA was seen at my feeders, with some species scanning more than others. However, more birds scanned farther from the trail than closer, which was unexpected. While species richness per week at Zuck was indeed higher than the CMA, the overall number of species seen at the two sites was approximately equal. Contrary to my hypotheses, I found that distance from the trail didn't affect species richness, as the far feeders had the same species richness as the close feeders. However, species abundance was elevated at both the CMA and far feeders, possibly because they appeal to less habituated birds.

Additionally, site impacted both the number of avian visitors and the amount of seed removed, while distance from the trail only affected the quantity of visitors. More seed was taken from the two Zuck feeders, while there were more visitors at the CMA and far feeders. There may have been more visitors at the CMA, despite fewer seeds being removed, because of the types of birds observed. Specifically, the CMA possessed more cachers, which typically remove only one or a few seeds at a given time, compared to birds that eat copious amounts directly from the feeder. The CMA also saw a greater number of small species, such as Tufted Titmice and Black-capped Chickadees, which don't remove as many seeds as the larger birds.

Finally, while the quantity of birds visiting was relatively stable at Zuck, the CMA experienced peaks in visitations. This was likely due to migration, as well as fluctuations in ambient temperature and a decline in the number of natural foodstuffs later in autumn. Zuck birds have anthropogenic foods available to them all year round, a resource that is unavailable to the CMA birds.

My research hopefully provided the bird feeding community, as well as the general public, with useful information about the many factors contributing to birds' diverse feeding behaviors and interactions. It is, nevertheless, important for future researchers to conduct additional studies on habituation and seed-eating birds, possibly focusing on select species, in order to better understand apparently conflicting results observed in this study.

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APPENDIX

Table 4. Four-Letter Alpha Code for bird species observed at the feeders, along with accompanying common and scientific name.

Four-Letter Alpha Code	Common and Scientific Name
AGOL	American Goldfinch (*Spinus tristis*)
BCCH	Black-capped Chickadee (*Poecile atricapillus*)
BLJA	Blue Jay (*Cyanocitta cristata*)
CARW	Carolina Wren (*Thryothorus ludovicianus*)
COGR	Common Grackle (*Quiscalus quiscula*)
DEJU	Dark-eyed Junco (*Junco hyemalis*)
DOWO	Downy Woodpecker (*Dryobates pubescens*)
EASO	Eastern Screech-Owl (*Megascops asio*)
GRCA	Gray Catbird (*Dumetella carolinensis*)
HAWO	Hairy Woodpecker (*Dryobates villosus*)
MODO	Mourning Dove (*Zenaida macroura*)
NOCA	Northern Cardinal (*Cardinalis cardinalis*)
RBWO	Red-bellied Woodpecker (*Melanerpes carolinus*)
TUTI	Tufted Titmouse (*Baeolophus bicolor*)
WBNU	White-breasted Nuthatch (*Sitta carolinensis*)

Figure 51. Zuck Arboretum trail from gateway.

Figure 52. Zuck Arboretum trail at a distance from feeders.

Figure 53. Habitat adjacent to Zuck Arboretum feeders.

Figure 54. Standing next to Zuck Close feeder. Photo courtesy of Rosemary Rogers.

Figure 55. Standing next to CMA Close feeder. Photo courtesy of Rosemary Rogers.

Figure 56. American Goldfinch sitting at CMA Far feeder.

Figure 57. Black-capped Chickadee sitting at CMA Close feeder.

Figure 58. Blue Jay sitting on Zuck Close Shepherd Hook pole.

Figure 59. Carolina Wren eating at Zuck Far feeder.

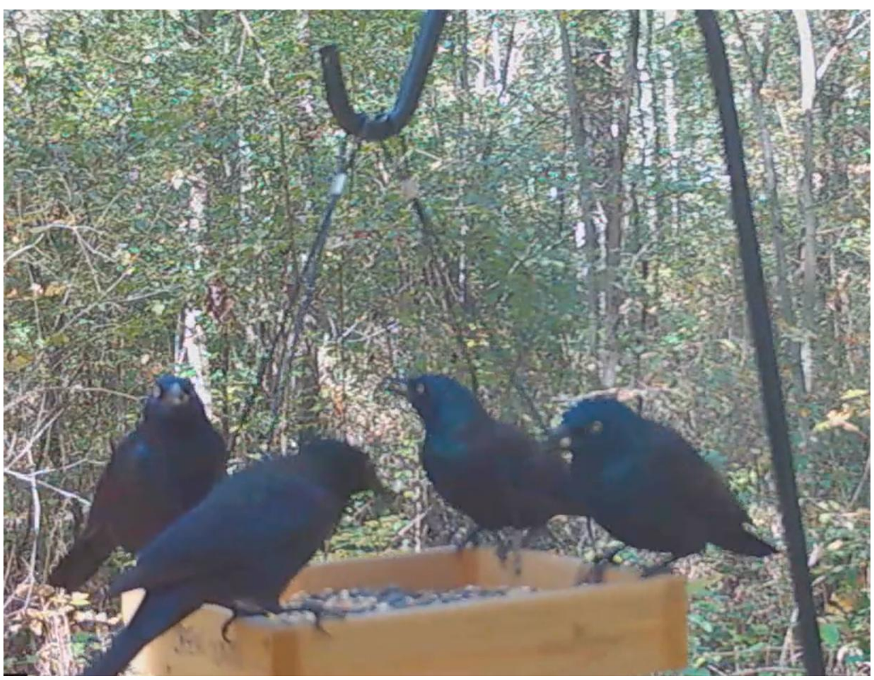

Figure 60. Common Grackles eating at CMA Close feeder.

Figure 61. Dark-eyed Junco sitting at Zuck Close feeder.

Figure 62. Downy Woodpecker eating at Zuck Close feeder.

Figure 63. Eastern Screech-Owl sitting at CMA Far feeder.

Figure 64. Gray Catbird sitting on Zuck Close Shepherd Hook pole.

Figure 65. Hairy Woodpecker sitting at Zuck Far feeder.

Figure 66. Mourning Dove sitting at Zuck Far feeder.

Figure 67. Northern Cardinal sitting at CMA Close feeder.

Figure 68. Red-bellied Woodpecker consuming seed at CMA Close feeder.

Figure 69. Tufted Titmouse eating at CMA Far feeder.

Figure 70. White-breasted Nuthatch eating at CMA Far feeder.