Arthropod Abundance in Bolton Flats Wildlife Management Area

A Major Qualifying Project

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Chapter 1

Literature Review

The focus of this project is to observe the arthropods present in the grassland area of Bolton Flats Wildlife Management Area (WMA). In particular, a focus was made made to compare the arthropods present in unburned sections of the grasslands with areas burned from a fire months prior. To gain insight on arthropods, we researched typical species found in New England grasslands, along with the vegetation they feed on. Additional research was conducted to understand how vegetation and wildlife respond to the changes a fire brings to grasslands. This research is important in order to further understand the ever decreasing population of Whip-poor-wills, who call Bolton Flats home during the Spring and Summer seasons.

Whip-poor-wills

Whip-poor-wills are a type of bird the breed in several regions across North and Central America. Their habitats consist of open woodlands adjacents to grasslands and meadows. They use the open woodland for nesting and forage in the adjacent grasslands and meadows. In Massachusetts, particularly, there are very few areas that support this type of habitat. Therefore, whip-poor-wills can only be found in a handful of sites, including Bolton Flats. Whip-poor-wills typically arrive in Massachusetts by May and leave for their wintering grounds by September. Moths, found in the adjacents grasslands, make up the main source of the whip-poor-wills diet, in addition to flying beetles. Whip-poor-wills forage for food during the evening and nighttime hours. Due to the sparse amounts of grasslands left, whip-poor-wills are struggling to find suitable habitat and their numbers have steadily declined in Massachusetts since the 1970s (Massachusetts 2015).

Bolton Flats WMA

The Bolton Flats Wildlife Management Area located in Lancaster, MA is the survey site for arthropod observation and data collection. Bolton Flats WMA is a 923 acre flood plain that is settled between the Nashua and Still rivers. It contains agricultural fields, grasslands, woodlands and shrublands. The wildlife in this area includes a variety of birds (*Rufous-Sided Towhee, Pine Warbler, Ruffed Grouse, Prairie Warbler, Whip-poor-will,* *Common Nighthawk, American Woodcock*), vegetation (*Populus tremuloides, Comptonia peregrina, Quercus ilicifolia, Pinus rigida*) and insects (*arachnids, coleoptera, diptera, formicidae, lepidoptera, aphidoidea*) (Harvard 2017) (National Heritage 2016). It is one of the few habitats in Massachusetts that Whip-poor-wills species use as breeding grounds. A portion of this area is pitch pine- scrub oak barrens, where this avian species resides (MassWildlife 2018). Pitch pine-scrub oak is a habitat of dense shrubs and trees that are typically maintained by human intervention (National Heritage 2016).

Pitch Pine- Scrub Oak Community

Pitch Pine- Scrub Oak barrens contain scattered pitch pine *(Pinus rigida*) trees and patches of scrub oak (*Quercus ilicifolia).* They also contain a variety of other shrubs, bushes, and small trees. Pitch pine- scrub oak communities are important and necessary habitats for a variety of wildlife. Habit management is necessary to contain these early forests, through burning, moving, and herbicide treatments. Prescribed fires are beneficial as they remove dead leaves and vegetation, while keeping the shrubs short. Additionally, most species that call these habitats home are resilient and recover well from fire (Akresh 2016). However, pitch pine- scrub oaks are not very diverse in wildlife, yet many species of Lepidoptera are restricted to these communities.

Grasslands

Grasslands are a part of nature with key components, which distinguishes them from forests and other habitats. Grasslands contain grasses, shrubs, woody plants and trees. Grasslands are maintained, as overgrowth and expansion of trees leads them to turn into forests (Dougherty 2006). Grasslands can be maintained by human intervention such as burning and mowing. However, many grasslands are sustained by natural occurrences such as grazing and wildfires. These disturbances are necessary in order to prevent the intrusion of woody plants and trees (Zuckerberg 2006). In many areas of the United States, grasslands are a threatened habitat, endangering many plants and animals that rely on them. In particular, there has been a decline in grassland bird species.

Grasslands throughout the United States vary due to different climates and geographical features. Some grasslands thrive with more precipitation and cooler weather, such as the Pacific Northwest, while other grasslands are adapted to the hot and dry climate of the Southwest. Grasslands in the Northeast are adapted to the hot summers and moderate amounts of precipitation. Each grassland grows vegetation native to that area. Overgrowth of the vegetation allows the grasslands to develop into forests. Continued maintenance is crucial to keeping grasslands as grasslands. However, the greatest threat to grasslands in New England is the continuous residential expansions, that ultimately result in the loss of this ecosystem (Foster 2002).

Grassland Fires

Fires play a crucial role in grassland management, regardless of it being planned or an act of nature. Fires that occur in grasslands have a great effect on the organic carbon reservoirs in the soil (Zuckerberg 2006). Carbon is a necessary component for the proper nourishment and growth of vegetation. While fire is able to restore soil fertility and regenerate nutrients, it can also degrade the soil and strip it of all of it nourishing capabilities. The effect of fire, beneficial or detrimental, is related to the fire length, fire intensity, the type of vegetation burned, the type of soil present, and the type and amount of ash produced, In many cases, however, fire leads to enhanced regrowth and a restock of carbon resources. There is often a rapid overturn, as vegetation quickly adapts to the upset created by the fire (Zuckerberg 2006).

Burned Vegetation and Regrowth

After a fire while much of the vegetation is destroyed, however it is a useful tool in wildlife management and plant regrowth. For grasslands in particular this is important as many plants will overgrow and invasive species can move in, transforming the area into a forest over time. With fire, however, plants such as pitch pine, scrub oak and other overstory species can thrive. These types of plants have fire-activated seeds where heat is needed to melt off the waxy surface to release the seed and allow the plant to germinate (Fire Management in the Northeast Keeping Fire on Our Side, 2008). Since the post-fire landscape is mostly ash and charcoal this gives the fire-tolerant plants more space to grow without interference from other plants. Other plants are known as fire-resistant, meaning that they have adapted features that allows the plant to survive through a fire. For example, ponderosa pine sheds its lower limbs to avoid fire on the ground and protecting its flammable crown. Other adaptations can range from thick bark to a strong moisture barrier to protect the plants from the heat (Pyne 2006). Other plants, however are fire-intolerant and cannot survive after a fire. These plants are known as obligate seeders and they have adapted to be reproductively mature early before they can be destroyed by fire (Knox 2005). These types of plants tend to grow quickly in order to reach reproduction early to allow their seeds to form, though this is only applied to species who do so only after a fire and not under other conditions (Pausas 2014).

Arthropods

Arthropods are invertebrates characterized by their exoskeleton, paired jointed appendages, and their segmented body. Arthropods are a moulting species, shedding their rigid exoskeleton to make room for growth. The arthropod phylum contains a variety of organisms including arachnids and insects, as well as crustaceans and myriapods (Ortega-Hernández, 2016). Of the subphylums, insects and arachnids are of particular interest as they have been found to reside in the Bolton Flats.

Insects are a subphylum of the arthropod, defined mainly by their exoskeleton, three-segmented body, three pairs of jointed legs, and antennae (Chapman, 2006). Insects are a highly diverse, ranging from moths and flies to wasps and beetles. Moths and beetles are especially of interest as they are the main diet of Whip-poor-wills.

Arachnids are another subphylum of arthropods generally known as eight-legged invertebrate. Species within this subphylum include spiders, scorpions, mites, harvestmen, ticks and solifugae (Cracraft, Donoghue, 2004). Of these species spiders and ticks are of special interest as they have been observed in the Bolton Flats.

Lepidoptera

Lepidoptera is an order of insects that includes moths and butterflies. Among them are 180,000 different types of species. In southern New England, shrublands are crucial habitats for moths and butterflies. Bolton Flats is an area of shrubland/grassland that contains lepidoptera. Lepidoptera are the main focus of the arthropod collection study, as moths are the main food source for Whip-poor-wills. Species of lepidoptera typically found in Massachusetts grasslands include gypsy moths *(Lymantria dispar),* eastern tent caterpillar *(Malacosoma americanum),* Isabella tiger moth (*Pyrrharctia isabella).* However, there are thousands and thousands of known species of lepidoptera in New England (Wagner 2012).

Caterpillars are the larva stage of the lepidoptera. They are herbivorous and are found living in various trees, bushes, or shrubs. Many moth species in their caterpillar stages are known for the great damage they can cause to leaves and plants as a whole Caterpillars feed on leaves and because of this, some are invasive species, such as the gypsy moth. By observing the caterpillars present in Bolton Flats, we can document their presence and further learn of the specific moths that inhabit this grassland (Wagner 2003). In our observations, caterpillars found are classified by characteristics, either hairy, leaf roll, or silk tent.

Moths are insects that belong to the Lepidoptera order and are characterized by their scale-covered wings and feathery antennae. These insects are also divided into five major groups which share the same characteristics: Arctiidae, Geometridae, Noctuidae, Saturniidae, and Sphingidae[1]. Within the United States there are 11,000 known species of moths, and around 160,000 species world wide (Smithsonian, "Moths"). Many species of moths are nocturnal, however some species can be diurnal. Many moths are also known to be migratory, much like their butterfly counterparts.

In New England, the Gypsy moth has been of particular interest as it is an invasive species. The Gypsy moth, normally native to England, first arrived in North America in the 1800's. Since then, there have been continuous efforts to minimize the insets population but has largely unsuccessful (Spear, 2005). As the Gypsy moths habitat of choice is oak, a late successional-species, there have been studies to determine the effects of the defoliation. As of present there have been no significant impact on these trees, however there is no data on long-term effects on these trees (Barron, 2008). This lack of information is important as we do not know if there are long term effects of these moths on the environment.

While the Gypsy moth population increases, other native species are on the decline, specifically the Giant Silk moths (*Saturniidae*) (Wagner 2012). These are one of the largest moth species with a wingspan of about 10 cm, making it an ideal prey for the whip-poor-will. As larvae they tend to eat woody vegetation and will grow until its legs can no longer support their body weight (Wagner 2005). The population of this species has been declining mainly due to the introduction of the parasitoid fly Compsilura concinnata (Boettner 2008). This fly was introduced as a way to control the Gypsy moth population, but as it is a generalist it targeted other moths as well greatly affecting the silk moths. While the Gypsy moth may not be the direct cause of silk moth decline, their presence affects silk moth populations.

Data Analysis

To interpret our data we calculated the averages of observed arthropods of both the burned and unburned sections. The average, or mean, of a data set is a measure of central tendency that expresses the typical value of that data set. The mean is useful to compare the averages of multiple data sets, yet it is heavily skewed by outliers (Gupta 2011). The mean was calculated by arthropod type and overall number of observed arthropods. These averages were then compared as burned vs unburned to see if there were any differences between the two sections. We also compared the modes of the two sections by arthropod type and overall abundance. The mode of a data set is the number that appears most often, so it is the value most likely to be sampled (Gupta 2011). By using these two methods we were able to visualize the differences between the two sections via bar graph. This allowed us to interpret our data with consideration to other external factors.

Chapter 2

Abstract

The population of Eastern Whip-poor-wills have been on the decline due to loss of habitat and, as a result, food abundance. In the Pine Hill section of the Bolton Flats WMA much of the vegetation that Whip-poor-wills live in was burned. The goal of this project is to identify, characterize, and compare arthropod abundance between the burned and unburned sections as such a study has never been done before. We designated 5 sections in the burned section and 5 sections in the unburned area to be surveyed for arthropod abundance. We surveyed each site 6-7 times during various times and weather conditions. We then categorized each arthropod seen and compared the two sections. Our results demonstrated that the unburned sections of Bolton Flats WMA have a larger abundance of arthropods. Additionally, the unburned sections contain a greater number of caterpillars, beetles, and moths; which make up the Whip-poor-will diet.

Introduction

The population of Eastern Whip-poor-wills (*Antrostomus vociferus)* have seen a significant decline in Massachusetts since the 1970s (Massachusetts 2015). The Bolton

Flats Wildlife Management Area (WMA) is one of a handful of areas in Massachusetts that Whip-poor-wills use for breeding grounds during the late spring and summer months. A loss of habit is a cause for their decline, as they prefer pitch-pine scrub oak communities, which have been increasingly hard to come by (Akresh 2016). These habitats must be maintained through burning, mowing, or thinning, yet are often lost to housing developments (Zuckerberg 2006). In addition, the success of the Whip-poor-wills survival relies on their ability to forage for moths and insects during the night hours (Massachusetts 2015). However, research on this species is still sparse and, in addition, there has not been previously recorded information on the lepidoptera present in Bolton Flats WMA. Therefore, this project will provide much needed information on this area, which will contribute to determining the cause of the Whip-poor-will decline in the long run.

A goal of this study was to become familiar with the arthropods present in Bolton Flats WMA, as no prior information exits. In addition, this project focused on the characterization and comparison of arthropod abundance between the burned and unburned sections of Bolton Flats WMA. This project expanded its research by relating the information found on arthropod abundance to the presence of Whip-poor-wills in this area. This information was used to examine if the type and quantity of arthropods distinguish this area as breeding grounds for the Eastern Whip-poor-wills. As arthropods are the main source of food for this rapidly declining bird species, gaining insight on one of their only habitats in Massachusetts is crucial (Massachusetts 2015). It is intended that this project will build upon what is already known about the Whip-poor-wills species, and provide insight on what may be contributing to their decline. For this project, particular focus was placed on observing caterpillars, as moths make up the primary diet of Whip-poor-wills

(Wagner 2005). In addition, it will be noted if the previous fire and burned areas have had any effect on the population of Whip-poor-wills compared to years past.

It was hypothesized that the unburned sections of Bolton Flats WMA will have a greater abundance of arthropods than the burned sections. Additionally, we hypothesized that the burned sections will have a greater variety of arthropods compared to the unburned sections, as a result of the new growth in the burned section. It is known that fire promotes biodiversity, with one study stating that the burned plots produced twice the number of plant species compared to native species (Ecological 2010). Because of this, we predicted the diversity in the burned plots would be greater. In addition, we predicted that there will be an increase in the number of Whip-poor-wills, as the regrowth of the burned section will lead to a greater diversity of lepidoptera. Therefore, the changes in biodiversity provide Whip-poor-wills with more moths, beetles, and caterpillars to sustain their diet.

Methods

Bolton Flats WMA

The Bolton Flats Wildlife Management Area (WMA), specifically the Pine Hill section in Lancaster, MA, is the survey site for arthropod observation and data collection. Bolton Flats WMA is a state owned and managed property containing agricultural fields, grasslands, woodlands and shrublands. (Harvard 2017). A portion of this area is pitch pine- scrub oak barrens, which is maintained through human intervention (MassWildlife 2018).

Survey Sites

The proper protocol for setting up survey sites for this study were adapted from the CatepillarsCount! survey guidelines. The grassland area of Bolton Flats was divided in one hectare quadrants, 1-71, including burned and unburned sections. Five quadrants were chosen in the burned sections and five in the unburned section. Within each quadrant picked, five trees were selected in each section. A center tree was picked, and designated with the letter A next to its quadrant number for identification purposes. A point north, east, south, and west were picked surrounding the center survey point, and designated with the letters B, C, D, and E, respectively.

In order for a tree or shrub to qualify as a survey site, it must be a tree with a woody stem and not a forb or grass. The center tree chosen to survey should be easy to find and have at least 50 leaves that measure 5 cm or greater in length. Once the center tree is chosen, the other four satellite trees (N, S, E, W) are chosen from this point, being sure to stay within the boundaries of the quadrant. Each satellite tree should be 5-6 steps from the center tree, with the same leaf qualifications. If a tree with these qualifications are not found within 5-6 steps of the center tree, continue until a tree is found, trying to stay within 10ft of the center survey point. On the other hand, if nothing is found to survey 5-6 steps away, it is okay to choose survey points close to the center survey point. Once a tree is found and determined to be a viable survey point, it should be marked with a flag containing its survey code on it (quadrant number followed by corresponding letter).

Survey Collection

A protocol for surveying each tree was adapted from the method suggested on the CatepillarsCount! Website. Using the Foliage Survey Datasheet and the Visual Survey method, the arthropods observed on each survey tree were recorded. On each sheet the date, time, survey code, observer, and temperature, along with any other notable information about the day is recoded. The survey plant is observed as a whole for herbivory, number of leaves (only when first picked to make sure there is 50+ leaves), and leaf length. Herbivory, the overall amount of leaf eaten by predators, are defined by a scale of 0-4. The number 0 for herbivory observed refers to the leaves being fully intact, without traces of being chewed on. A herbivory level of 4 indicates that more than 25% of the leaves are eaten, with many plants falling in between these parameters.

When looking for arthropods on the tree, only 50 leaves must be observed from a particular branch or part of the tree. If an arthropod is found, the arthropod group is identified, along with its length in millimeters, the quantity and any special characteristics. When a caterpillar is found, it must be identified by its features; for example hairy, leaf roll, or silk tent. The arthropod group should be classified by the lowest order possible and a dichotomous key, provided on *caterpillarscount.unc.edu*, is used as an aid for identification.. If the order of the arthropod is not known, unidentified may be written and a picture can be taken in order to identify the arthropod after consulting resources.

Results

We conducted arthropod observations at Bolton Flats WMA from 8 June - 5 August, 2018. A map shown in Appendix X, shows the ten quadrants where the data were collected. We surveyed each marked site once every week for a total of 6-7 times. We collected from the survey points at different times in the morning, afternoon, and evening. They were also observed during various temperatures and weather conditions. The length of time spent observing each site varied, yet a minimum of three minutes was spent making sure all leaves were looked at before declaring that site to have no observable arthropods.

Plant Identity

Over the course of 8 weeks we surveyed 10 survey sites, each containing 5 survey points. A total of 50 plants were surveyed, which can be seen in Appendix X. The majority of the plants consisted of sweet fern (22%), oak trees (26%), birch (33%), and aspen (27%). Of the plants observed, the section with the most herbivory was at site 16 (mean =2.69± 0.82)(Appendix X). This is consistent with our observations as this site has the second largest abundance of arthropods, and there were more large arthropods (greater than 5mm), such as beetles and caterpillars, observed.[X]

Over the course of this study oak plants tended to have a higher herbivory score than the others plants surveyed. Oak trees had the highest average herbivory (mean= 4.1± 0.12), while sweet ferns had the lowest (mean= 1.5 ± 0.27). The remaining plants, aspen and birch, fell in the middle of the range (aspen mean= 3.1±0.23, birch mean= 3.0±0.34). Overall, there are not statistical differences in the plant species and its herbivory ($P > 0.05$). It is also noted that some plants appeared to be dead, particularly during the last day of observation. Approximately one third of the aspen plants have exhibited signs of leaf miner damage, as shown in Appendix X.

Arthropod Observations

The most abundant types of arthropods found were ants (62.3%), flies (16.5%), aphids (3.2%), beetles (11.0%) and caterpillars (2.1%). Ants were the most abundant arthropod found by far, particularly in the burned area (Table 1). A total of 866 ants were observed, as they were typically found in clusters on the leaves, which can be seen in Appendix X. Following ants, flies and beetles were the next abundant arthropod groups. Additionally, caterpillars and aphids made up the last of the top five most abundant arthropods observed. The remaining arthropods found were classified under “other,” as a handful of each type were found. The “other” category consists of spiders, leafhoppers, grasshoppers, moths, ladybugs, true bugs, crane flies, lightning bugs, dragonflies and mosquitoes.

Table 1. Total arthropods counts from 8 June- 5 August 2018

TOTAL	Caterpillar	Ant	Fly	Beetle	Aphid	Other
Unburned	29	71	140	122	35	52
Burned	0	795	89	31	10	17
Entire Site	29	866	229	153	45	69

We tracked abundance of the four most abundant arthropod groups over time (Figure 1).During the beginning of the study, a small number of each of these groups were found. However, by the beginning of July, caterpillars were no long observed, as they had turned into moths by this time in the summer. Additionally, the number of ants observed increased dramatically during the month of July. At the beginning of the data collection, a handful of larger ants were observed, but as the summer progressed clusters of small ants were seen instead. By the last survey date, 5 August 2018, a minimal amount of arthropods were observed. During this day, two flies and one beetle were seen in all of the vegetation surveyed.Throughout the eight weeks of observation the number of flies and beetles observed stayed fairly consistent, which the expectation of the last survey date. A peak number of beetles, 47, were found on 26 June 2018.

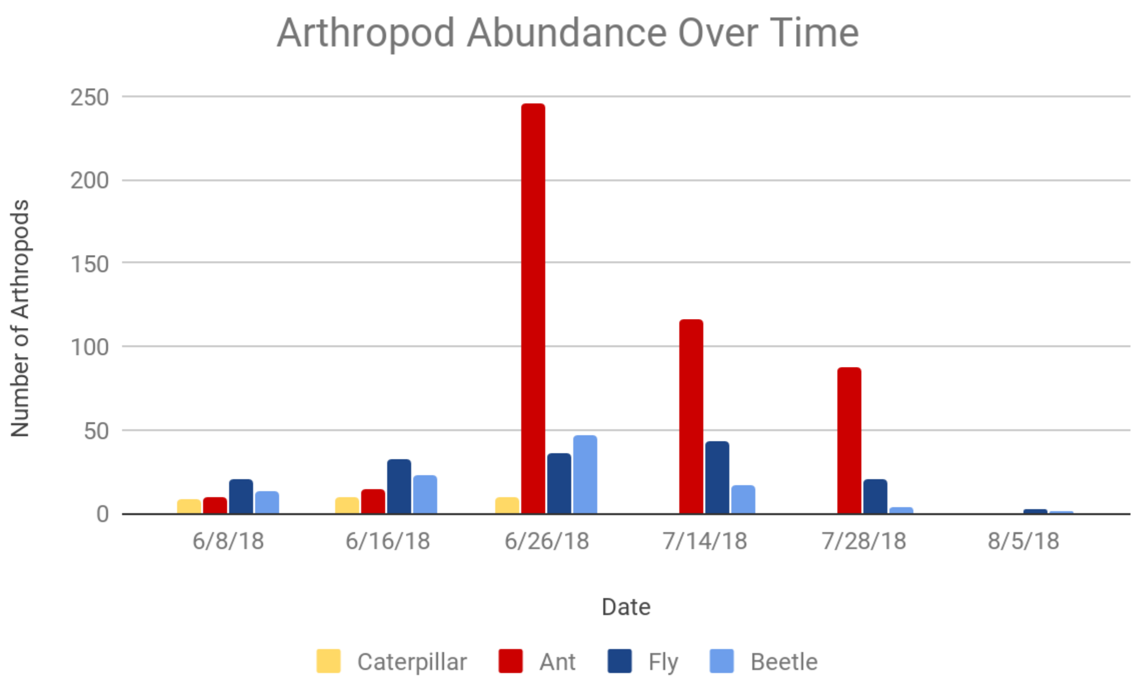


Figure 1. Arthropod abundance of the most populous groups from 8 June- 5 June 2018

Burned vs. Unburned

The burned section has shown to have the greater abundance, while the greater diversity was seen in the unburned sections (Figure 2).

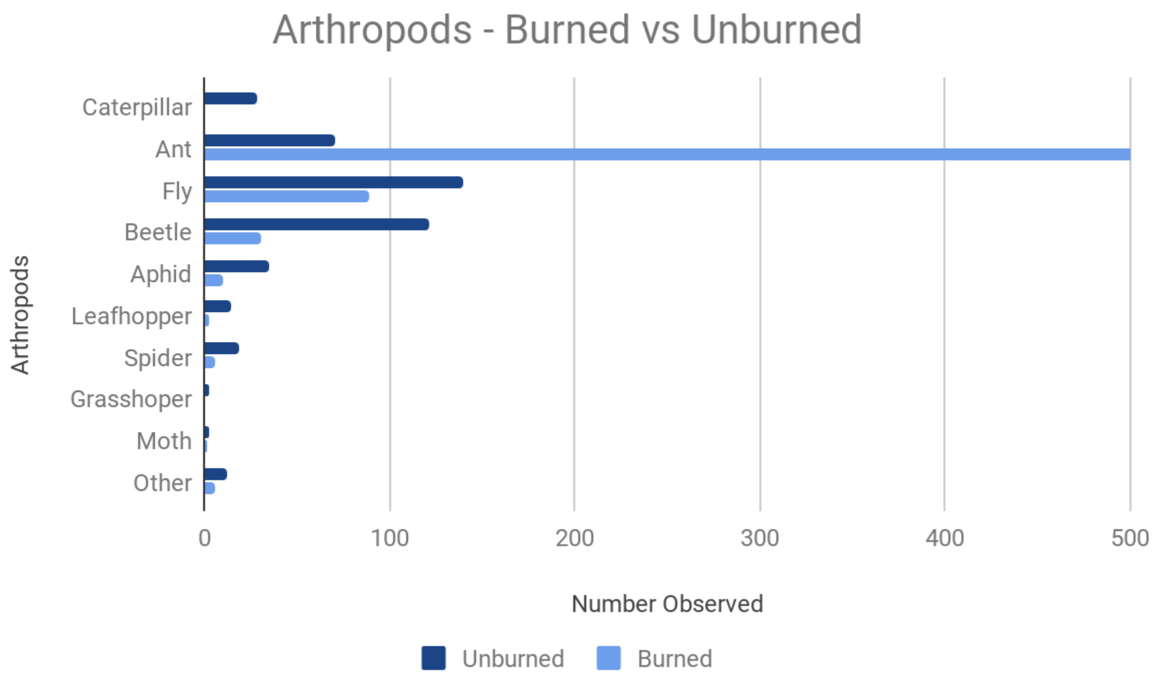


Figure 2. Arthropod abundance in the burned and unburned sections of Bolton WMA 8 June- 5 June 2018

In the burned section there is a large abundance of ants and flies. In the unburned section there were caterpillars, grasshoppers, and moths observed, which were not seen in the burned section. While the total number of arthropods observed is greater in the burned section, the largest contributors were ants, a communal arthropod group where they are seen in large groups. Due to this the data is a bit skewed, however the difference is not statistically significant (P> 0.05). Therefore, the data shows that there is not a significant difference in the abundance of arthropods in the unburned sections compared to the burned section.

Another major difference between the two sections is the plant variety. As seen in Appendix X at the beginning of the study the burned section had some grass growth but was mostly burned land. At the end of the study tall grass and flowering plants. This is in contrast with the unburned section which contained mostly pine trees, sweet fern, and aspen trees. For overall herbivory the unburned section had a higher score (mean=2.1 ±0.35.), with the burned section having a slight lower score (mean= 1.9 ± 0.32, P> 0.05). Therefore, the difference in herbivory between the burned and unburned sections is not statistically significant.

Caterpillars, Moths and Beetles

Particular attention was given to the observation of caterpillars, moths, and beetles, as they are the main diet of whip-poor-wills. A total of 29 caterpillars were found in the unburned section during the entire duration of the study, while zero caterpillars were found in the burned section. A total of 122 beetles were found in the unburned section and 31 beetles were found in the burned sections, totaling 153 all together. In the unburned section 3 moths were found, while 2 were found in the burned section. It is also important to note that on 19 July 2018, more than 15 monarch butterflies were seen flying around in the unburned sections. In addition several caterpillars webs/tents were found among the vegetation.

The caterpillars found where identified as European gypsy moth caterpillars *(Lymantria dispar dispar)*. One can be seen in Appendix X. All of the caterpillars observed were found at one survey site, the survey point 16A. This plant was identified as an oak tree. After 26 June 2018, caterpillars were no longer observed, as they had metamorphosed.

When looking at the arthropods that make up the Whip-poor-will diet, more caterpillars, beetles and moths were observed in the unburned sections. Figure 3, below, shows the number of these particular arthropods in the burned compared to the unburned section. The majority, 84%, of these arthropods were found in the unburned area. This includes 100% of the caterpillars and 80% of the beetles observed. When looking at the arthropods that make up the Whip-poor-will diet, beetles were the most abundant.

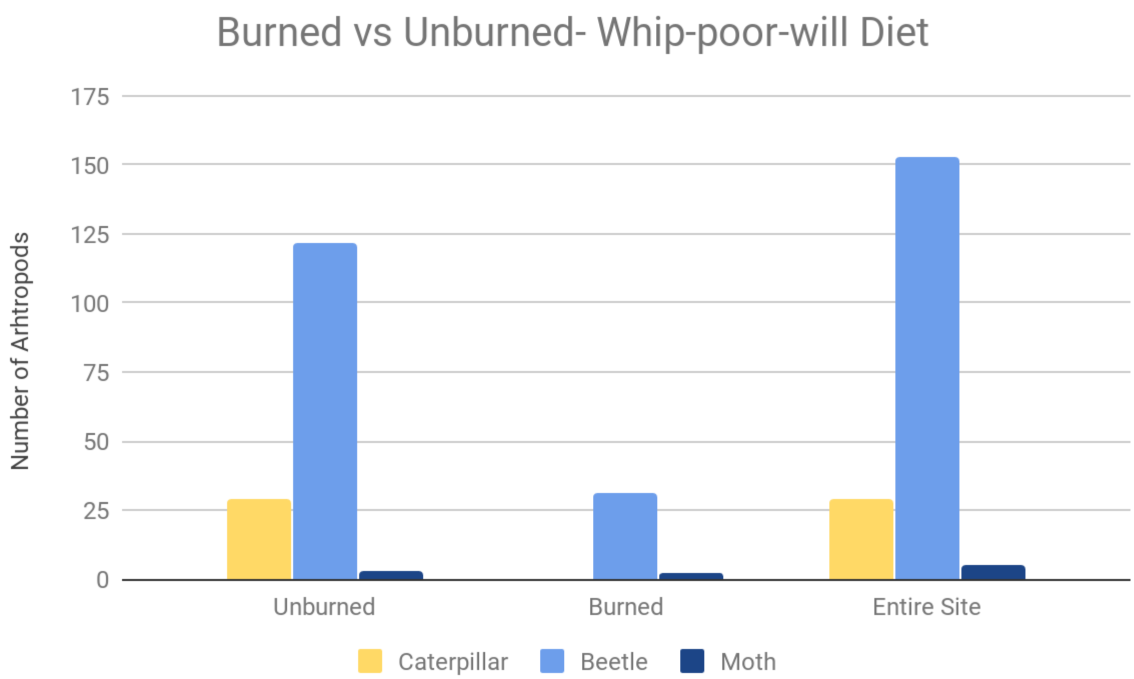


Figure 3. Number of caterpillars, beetles, and moths found in the burned and unburned sections of Bolton WMA, Summer 2018

Figure 4A shows the breakdown of arthropods found that make up the Whip-poor-will diet. It shows that 81.8% of this observed group was beetles, 15.5% was caterpillars, and 2.7% was moths. This can be compared to the data in Figure 4B, which looks at all the total arthropods found. When looking at the total number of arthropods compared to the arthropods that make up the whip-poor-will diet, 13.3% of all of the arthropods found are either caterpillars, beetles, or moths. The remaining 86.7% makes up the rest of the arthropods that had been observed, excluding those three groups.

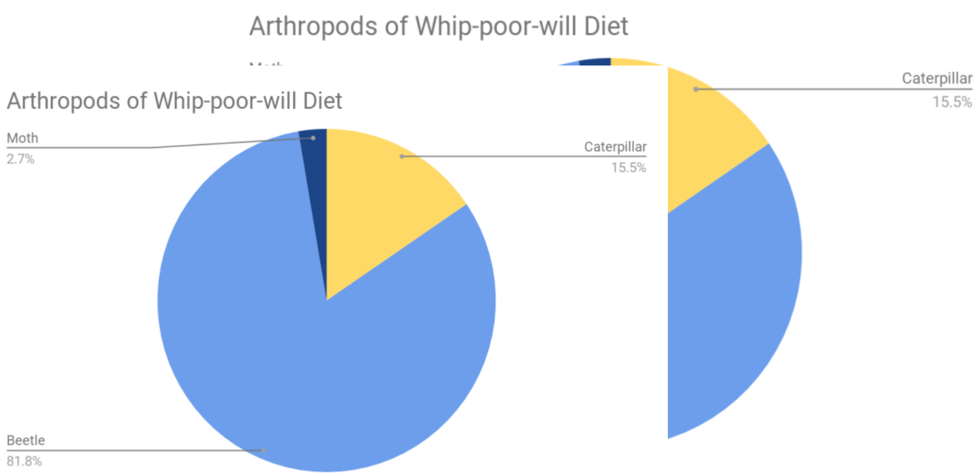
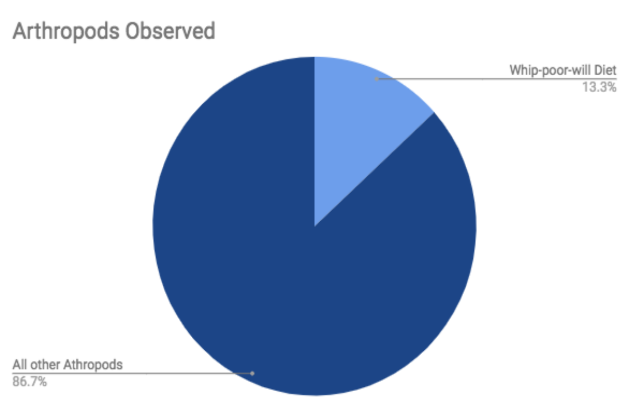


Figure 4. Comparison of arthropods making up Whip-poor-will diet with all other arthropods observed at Bolton Flats WMA, Summer 2018



Discussion

The goal of this study was to compare arthropod abundance and diversity between the burned and unburned section of Bolton Flats WMA. Previous studies have looked at these variables, including one on Nantucket Island , which looks at arthropod communities after mowing and burning (Dunwiddie 1991). When starting out on this study we expected to see more arthropod abundance and variety in the burned section as we assumed that the new growth in the burned section would allow for a greater variety of arthropods. By the end of the study, however, it was apparent that the unburned section had a much larger variety despite having lower abundance. This is similar to a study conducted by Benson, as they found that there was no difference in arthropod abundance in comparison of burned and unburned section, concluding that arthropod taxa are unaffected by fire (Benson, 2007). Because the data is the first of its kind collected, we are unable to make definitive conclusions on the influence of fire on the biodiversity. We suggest that vegetation and arthropods need to be studied for a long period of time, in order for any significant conclusions to be made. Therefore, our study was the first step in determining the influence of fire on arthropod abundance and diversity, and its relationship with the Whip-poor-wills in Bolton Flats WMA.

An interesting finding of our study was the large number of ants in the burned section, which made it overall more abundant with arthropods than the unburned section. However, if we eliminate the ants found, in both sections, the unburned section has a much greater abundance. In either case, the unburned section is more diverse. In the unburned section there were more flies, beetles, and caterpillars than in the burned section. What was most interesting was the lack of caterpillars observed in the burned section as while there were less available trees, we had expected to see some and instead saw none.

Another interesting piece of data we collected surrounded the herbivory of the vegetation we surveyed. Our observations showed that the oak plants had the greatest amount of herbivory, however, the correlation between herbivory and plant species is statistically insignificant. It is important to note that the richness of vegetation is known to influence arthropod abundance (Dunwiddie). Burning causes significant changes, such as increased soil pH and increased plant species richness (Siemann et. al). Because of this, arthropod abundance is typically greater after a burning, due the the richness in the vegetation. In our study, this could be seen with ants, as the new vegetation in the burned section appeared to generate large colonies of ants. However, many of the other types of arthropods, including beetles and caterpillars were sparse in the burned sections. Therefore, the fire appeared to beneficial to the ants in the grassland, but the new vegetation did not support other types of arthropods.

The lack of arthropods found, particularly towards the end of the survey collection period, could be due to a variety of reasons. For one, an extended heat wave that lasted for weeks at a time lead to high temperatures that are not typically seen. The majority of the observations took place during 80 degree days with clear skies. Because the survey collection took place in a grassland/shrublands area, the vegetation is in constant presence of the sun, which gave the plants more sun than necessary. Additionally, in between these periods of extreme heat were days of constant heavy rain, which lead to flash floods in the surrounding areas. The juxtaposing conditions of hot and dry, and wet and humid are not the ideal conditions for the vegetation. These extreme weather conditions may be an explanation for the patterns we saw in the data. During the last couple of surveys days much of the vegetation appeared to be dead and dried up, particularly in the unburned section. Without healthy vegetation to feed off of, the arthropods cannot thrive. This is why a steady number of arthropods were observed during the beginning of the study, before the extreme heat and rain were present.

In regards to Whip-poor-wills, we had hoped to look at the differences in densities of this species in the unburned and burned sections and compare this to the arthropod abundance. However, the density of whip-poor-wills appeared to be similar in both sections this year. Additionally, whip-poor-will caught in both sections, suggesting they had been moving around and using the entire site during this breeding season. Looking at the relationship between whip-poor-wills and arthropod abundance would be interesting to look at in the years to come.

We ran into several challenges throughout the course of the study. For one, many of the site markers placed on the survey vegetation could not be located as the weeks passed by. Some appeared to be eaten by animals, while others may have been removed. Because of this, some of the original survey sites were not able to be observed throughout the entire eight week period. Instead, similar vegetation within the same plot were surveyed in place of the sites we could no longer locate. Additionally, it should be noted that it was difficult to initially find vegetation in the burned areas that qualified to be surveyed. Because of this, many of the survey points are close together and are the same species. This could have influenced the data collected in the unburned section, as there was fewer diversity to begin with, thus resulting in a less diverse arthropod population.

Another challenge was that the observations began shortly after habitat manipulation. The burned section had been altered due to the previous fires and the unburned sections had also been recently manipulated. The unburned section was manually treated by mowing, in order to reduce the trees and shrubs and to maintain its qualities of a grassland. Habitat manipulation affects the patterns of data observed, as it disrupts the entire grasslands.

Because of the multitude of variables at play, we are unable to determine which factors play the greatest role in influencing arthropod abundance and diversity. Therefore, multiple years of data will need to be collected. With years of data, conditions will vary and the factors with the greatest influence can be narrowed down. It would be interesting to look at the arthropods found in the weeks before and the weeks following the mowing of the grasslands. It would also beneficial to see if the disparity between the burned and unburned section grows as the burned sections begins to flourish again. We could also expand our study by including herbaceous plants. By looking at the herbaceous plants, new types of arthropods would be introduced. Therefore, a more widespread and comprehensive database could be created for Bolton Flats WMA.

If this study was to be repeated, there are several things that could be improved upon. For one, data collection should begin earlier, ideally the first week of May. We observed the greatest number of arthropods at the beginning of the survey period and they decreased over time. If the data collection started earlier caterpillars could be observed for a longer period of time. We only saw caterpillars for three weeks before they had metamorphosed.

Our study was an important step in learning more about Bolton Flats WMA . By determining the arthropods present in Bolton Flats WMA, it can help others determine how this ecosystem is functioning as a whole. Arthropods effect many aspects of an ecosystem including herbivory, pest-control, and parasitism.

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Appendices

Appendix I. Unburned and Burned Survey Site Vegetation

Figure 1. Survey Plot 12 (UNBURNED)

a. Plot 8A (aspen)	*b. Plot 8B (oak)*

c. Plot 8C	d. Plot 8D (aspen)	e. Plot E (aspen)
		

Figure 2. Survey Plot 12 (UNBURNED)

b. Plot 12A(aspen)	b. Plot 12B (oak)

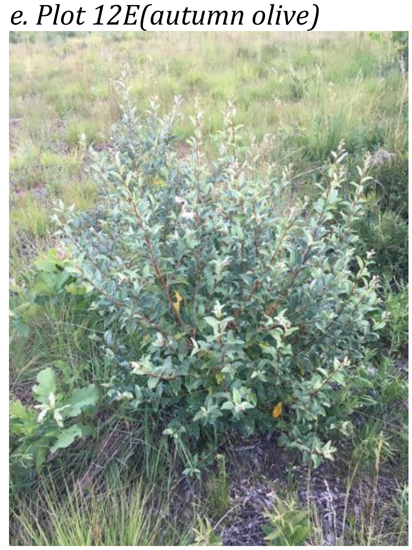
c. Plot 12C (sweet fern)	d. Plot 12D (sweet fern)	e. Plot 12E(autumn olive)
		

Figure 3. Survey Plot 16 (UNBURNED)

a. Plot 16A (oak)	b. Plot 16B

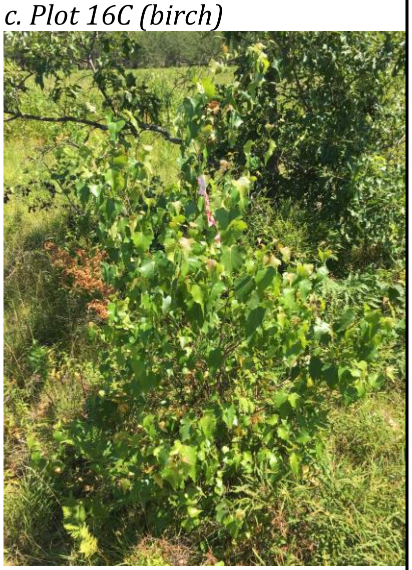
c. Plot 16C (birch)	d. Plot 16D (birch)	e. Plot 16E
		

Figure 4. Survey Plot 29 (UNBURNED)

a. Plot 29A	b. Plot 29B (sweet fern)

c. Plot 29C	d. Plot 29D (birch)	e. Plot 29E
		

Figure 5. Survey Plot 46 (UNBURNED)

a. Plot 46A	b. Plot 46B

c. Plot 46C	d. Plot 46D (birch)	e. Plot 46E (autumn olive)
		

Figure 6. Survey Plot 55 (BURNED)

a. Plot 55A (sweet fern)	b. Plot 55B (aspen)

c. Plot 55C (aspen)

d. Plot 55D (aspen)

e. Plot 55E

Figure 7. Survey Plot 62
Figure 8. Survey Plot 65

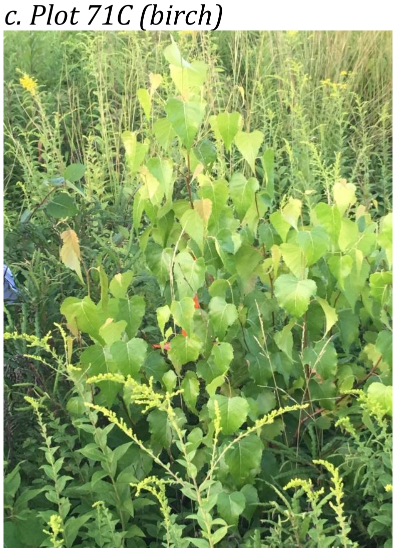
Figure 9 **Survey Plot 68**

Figure 10. **Survey Plot 71 (BURNED)**

a. Plot 71A (birch)

b. Plot 71B (aspen)

c. Plot 71C (birch)



d. Plot 71D

e. Plot 71E

Appendix II. Vegetation and Arthropods at Bolton Flats WMA

Figure 1. **Leaf miner damage found on aspen plant in survey site 71B, 5 August 2018**


Figure 2. **A cluster of ants found on aspen plant in survey site 62A, 20 July 2018**


Figure 3. **Gypsy moth caterpillar found on oak tree in survey sit 16A, 8 June 2018**

Appendix III. Maps of Bolton Flats WMA with marked survey sites

Figure 1. Map of northern section of Bolton Flats WMA with marked burned and unburned plots

Figure 2. Map of southern section of Bolton Flats WMA with marked unburned plots