Creating a "Living Laboratory" for Deadmans Head Forest During the Age of Climate Change

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Abstract

Ernie and Judy Edwards wish to create a "living laboratory" on their land in the future. The Edwards own a peninsula (45 ha) in the Southern region of New Brunswick (adjacent to the Bay of Fundy) called the Deadmans Head Forest. To commence the development of a "living laboratory" on their land, a group of four University of New Brunswick graduate students studied possible approaches for establishing a laboratory of this kind. Key characteristics of Deadmans Head Forest were investigated. As well, the future status of the forest was explored.

Several on-site visits occurred to collect base-line data for the "living laboratory" and to determine key characteristics of Deadmans Head Forest. Furthermore, this data was analysed to determine the health of the forest. Finally, future predictions for Deadmans Head Forest were made through literature research and model building.

Through literature research, several predictions were made for the species observed on-site, as well as potential pests that may seek habitat in this forest. As well, literature research was conducted to predict the future climate and its implications on the forest. A NDVI map of Deadmans Head Forest was created to determine the overall health of the forest vegetation. Finally, a LanDSET Model was created to determine soil moisture for the site.

Overall, the health of Deadmans Head Forest is in good condition. However, the Edwards will most likely note changes to their forest in the future due to the impacts of global warming. The Edwards should follow through with the creation of a "living laboratory" on their property, especially during the age of climate change. Potential items to study include future pests, future diseases, tracking change of the forest composition overtime, and population sizes of species overtime.

Acknowledgements

We would like to thank Ernie and Judy Edwards for providing their property for us to study. Their welcoming hospitality when we visited their property was greatly appreciated, as well as their interest in our project as it developed.

We express our gratitude to the Department of Forestry & Environmental Management at the University of New Brunswick for continued support throughout the project. We would like to thank Dr. Charles Bourque for his expertise on several topics, which guided us through the creation of this report. As well, we would like to thank Dr. Fan–Rui Meng for providing us with his drone to capture aerial imagery of the property.

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1 Introduction

Deadmans Head Forest is in the town of Blacks Harbor, in Southwestern New Brunswick. This forest can be characterized as a typical New England Acadian Forest with a hilly terrain. The forest is a peninsula surrounded by water on three sides and is located on the Bay of Fundy. Being a New England Acadian Forest, Deadmans Head has both coniferous and deciduous trees and hosts a whole variety of flora and fauna. The East side of the property is lined by cliff beaches and the West side is lined with sandy beaches and cliff beaches closer to the point.

The owners of Deadmans Head Forest, Ernie and Judy Edwards, aspire to create a "living laboratory" on their property, which would be led by the Nature Trust of New Brunswick. The Edwards' main goal for Deadmans Head Forest is that is be preserved and protected, so that future generations can enjoy it. As a first step in the creation of this "living laboratory", Deadmans Head Forest was studied by four University of New Brunswick graduate students.

Baseline data for the forest was collected during several site visits to determine key characteristics of this forest. Furthermore, literature research was conducted to determine predictions for the future of this forest. An NDVI (Normalized Difference Vegetation Index) map was created for the property to determine the overall health of the forest. As well, a LanDSET model was created to determine soil moisture.

Through this data collection, literature, mapping, and model building, a baseline for this "living laboratory" was created. Special emphasis was placed on the impacts of climate change on Deadmans Head Forest throughout this study.

2 Background

The landowners of Deadmans Head Forest, Ernie and Judy Edwards, are originally from Massachusetts, United States. They became landowners of Deadmans Head Forest, a 45 hectare peninsula, approximately two decades ago. Where this property is located in New Brunswick can be viewed in Figure 1. As well, a satellite image of their property can be viewed in Figure 2. Since becoming owners of this forest, they have been responsible stewards of the property adopting a minimalistic approach to disrupt as little of the forest as possible. One way they accomplish this is by living off-grid in a small house. An aerial view of their home can be viewed in Figure 3. They also engage with The Nature Trust of New Brunswick for responsible stewardship of Deadmans Head Forest. The Edwards wish for research and educational activities to take place on their property in the future without any major disruptions to the land. Ernie and Judy Edwards have an intrinsic interest in how climate change will be affecting Deadmans Head Forest in the future.

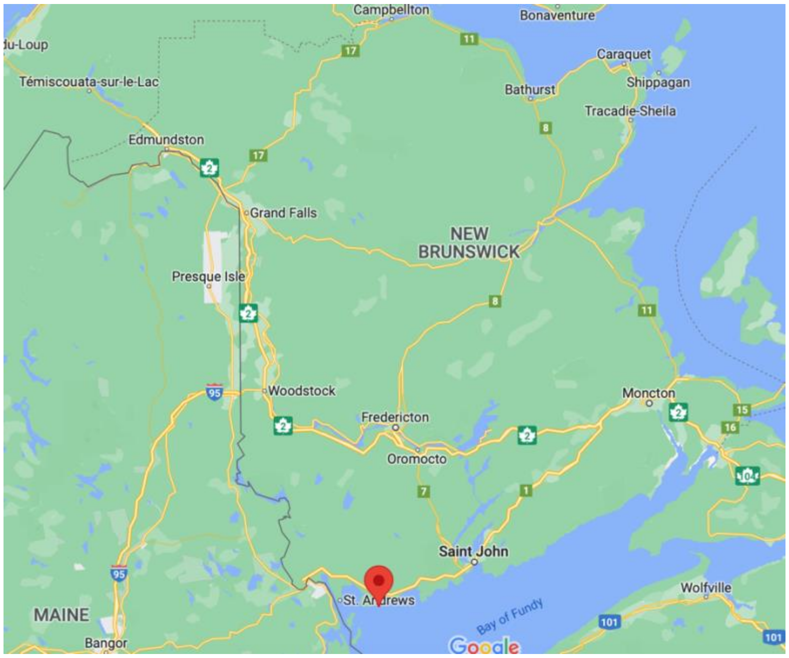

Figure 1 - Location of Deadman's Head Forest in New Brunswick, Canada

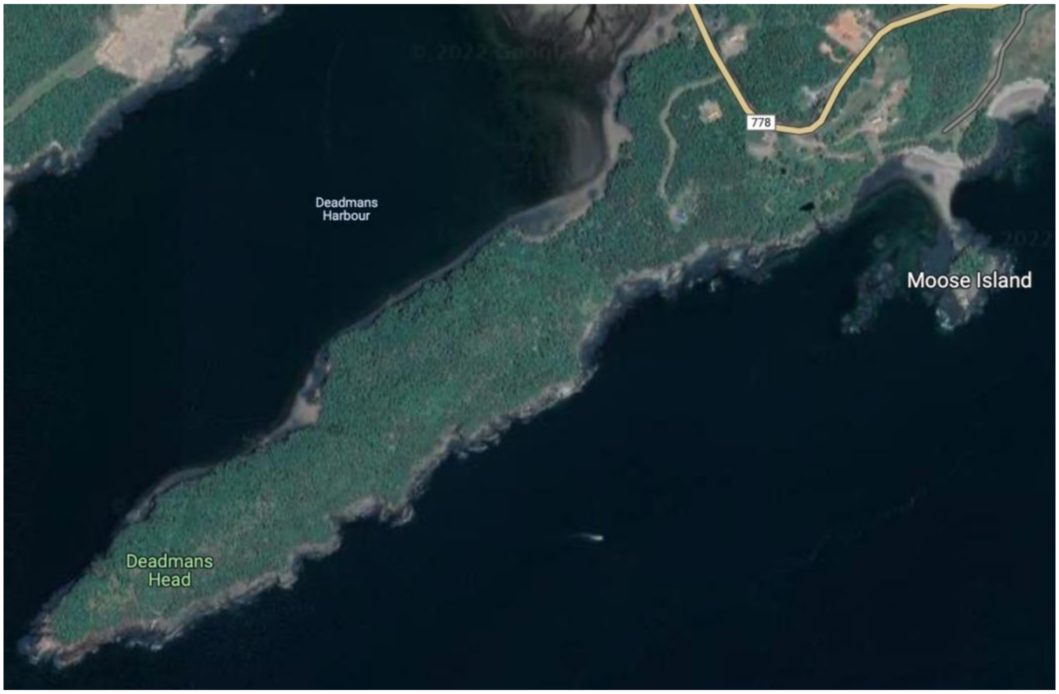

Figure 2 - Satellite Imager from Google Maps of Deadman's Forest Head in New Brunswick

Figure 3 - Aerial Imagery of Ernie and Judy Edwards' Property

3 Study Site

Deadmans Head Forest is 3 kilometers in length and covers approximately 45 hectares. Deadmans Head Forest is a New England Acadian Forest located on the Bay of Fundy and is surrounded by water on three sides. Furthermore, Deadmans Head is a mid to late successional forest suitable for shade tolerant species (Yorke, 1995). The forest has a hilly terrain, and large cliffs on the East and West side. Near the middle of the peninsula a bog is present, which is the moistest region on the property. There are some anthropogenic disturbances throughout the property (e.g., fish equipment from the neighbouring town). There is also a site that was disturbed through anthropogenic activities many years ago by previous landowners. Thistle, which is a type of invasive species, can be found on this site. There are several dead, fallen trees throughout this forest (likely caused by severe weather events coming into the coast and shallow bedrock). To get a better understanding of the site's characteristics, Figures 4 to 8 show photos that were taken during site visits, and Appendix C shows drone imagery of the site.

Figure 4 - Deadman's Head Forest

Figure 5 - West Side of Deadman's Head Forest

Figure 6 - East Side of Deadman's Head Forest

Figure 7 - Anthropogenic Disturbance and Thistle

Figure 8 - Exposed Roots due to Bedrock

4 Methods

A baseline dataset was established for Deadmans Head Forest. This was done by collecting field samples and capturing aerial images and video footage. Observations were collected at different perspectives related to tree species, wildlife, and other species observed in the forest.

4.1 Sampling Locations

Sample locations were systematically chosen to ensure that data was collected across the entire forest. To determine these sample locations, the Fishnet tool on ArcGIS was used with a 100-meter spacing between the points. This tool created 57 total points to be sampled in Deadmans Head Forest. The point feature class, on ArcGIS, was converted to a GPS Exchange format, so that the map could be uploaded to an app called Avenza. Avenza allows the user to track their location on site to each of the sampling points. Out of the 57 sites that were created, 10 sites were inaccessible as they were located on cliffs overlooking the ocean. Figure 9 shows a map of these sampling locations (An X denotes a site that could not be sampled).

Figure 9 - Sampling Locations of Deadman's Head Forest

4.2 Establishing Study Area

At each of the sample locations, an area of 80 meters squared was studied. A tree at the center of the sample location was chosen and a circular site, 5 meters in every direction from the centre tree, was established. Figure 10 shows a diagram of how each of the study areas were established.

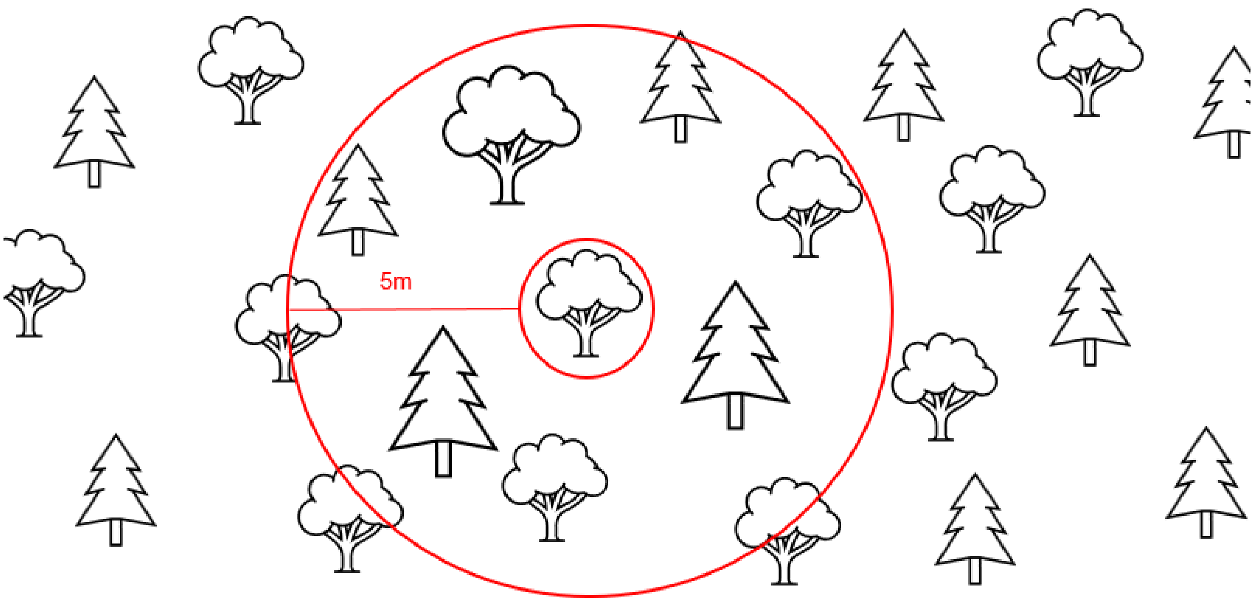

Figure 10 - Diagram of Study Area

4.3 Species Identification and General Observations

Each species noted on site was recorded. If a species was unknown, the app iNaturalist was used.

4.4 Collecting Tree Data

All tree data that was collected on site can be viewed in Appendix A.

4.4.1 Determining Canopy Coverage

The canopy coverage at each of the 47 sites was recorded. The canopy coverage was noted at each site by standing in the middle of the site and looking directly up towards the sky to determine what percentage of the sky was being covered by the overhead canopy. Many of the sites' canopy coverages had to be approximated, as much of the data was recorded when the leaves had already began falling from the trees. Figures 11 and 12 display the canopy coverage of 2 of the sites to show the variation in canopy coverage. Figure 11 displays site #3, which was given a canopy coverage of 5% and Figure 12 displays site #35, which was given a canopy coverage of 85%.

Figure 11 - Canopy Coverage of Site #3

Figure 12 - Canopy Coverage of Site #35

4.4.2 Tree Circumference

To measure tree circumference, a measuring tape was used at height of 4.5 feet, which is the average height to calculate tree diameter at breast height. Figure 13 shows how tree circumference was measured on site.

Figure 13 - Measuring Tree Circumference

4.4.3 Tree Age

Tree age was determined using dendrochronology methods. An increment borer was used at breast height (~4.5 feet). Using the extracted tree cores, rings were counted to estimate the tree age. Figure 14 shows how tree age was measured on site.

Figure 14 - Measuring Tree Age

4.4.4 Tree Height

Tree height was measured using a clinometer at a distance of 15 meters away from the tree in question. The bottom and top of the tree is measured using the clinometer and then the bottom value is then subtracted from the top value. The resulting value is an estimate of the height of the tree. Figure 15 shows a diagram of how the tree height was measured.

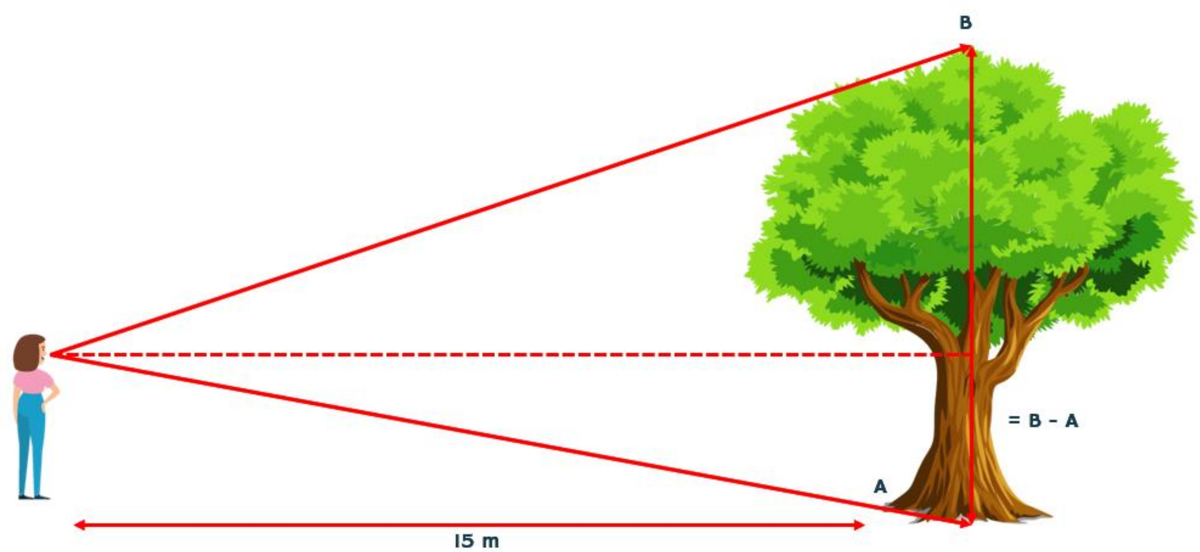

Figure 15 - Measuring Tree Height on Site

4.4.2 Dead Trees

For each site, the number of dead trees (standing and falling) was recorded.

4.5 Time Spent on Site

Table 1 summarizes the amount of time spent collecting data in Deadmans Head Forest. A total of 31.5 hours were spent on site with a total of 7 visits.

Table 1 - Time Spent on Site

Date	Time	Number of Hours
Friday September 15th	10:30 am – 3:30 pm	5
Friday September 30th	10:30 am – 6:00 pm	7.5
Wednesday October 5th	10:30 am – 2:30 pm	4
Friday October 7th	10:30 am – 2:30 pm	4
Friday October 14th	10:30 am – 4:00 pm	5.5
Friday October 21st	10:45 am – 1:15 pm	2.5
Friday November 18th	12:00 pm – 3:00 pm	3
	Total:	**31.5**

5 Tree Data

5.1 Species of Trees Found Throughout the Site

A total of 7 distinct tree species were found at the site. The tree species include:

I. Balsam Fir: A tall evergreen tree that can grow up to 30 meters tall with an average lifespan of 80 years (Coniferous Forest, 2022). Balsam fir have shallow roots and are prone to falling over during high winds (GoO, 2022b).

II. Yellow Birch: A mid to large hardwood tree with slivery-gray, paper-like bark. Yellow Birch grow to a height of 25 to 30 metres with a lifespan of over 150 years (University of Guelph, n.d).

III. Paper Birch: A hardwood tree with an average height of 25 metres with white, paper-like bark. Paper Birch has a lifespan of 80 years (Powell et al., 2011).

IV. White Pine: An evergreen tree with an average lifespan of 200-450 years and can grow between 30 to 67 meters tall (Palchaudhuri, 2022).

V. Red Spruce: Have a lifespan of 250 to 450 years and can grow up to 40 meters tall (Chakrabarti, 2022).

VI. Mountain Ash: A small deciduous tree that can grow up to 10 meters tall. Mountain Ash has a lifespan of 400-500 years (GoO, 2022a).

VII. Douglas Fir: Can reach a height of 100 meters and has an average lifespan of 400 years (Flora Newfoundland and Labrador, 2022). A single, possibly planted, Douglas fir was found on site

Figure 16

Figure 16 shows the total amount of trees sampled for each species and Figure 17 shows the distribution of tree species for Deadmans Head Forest.

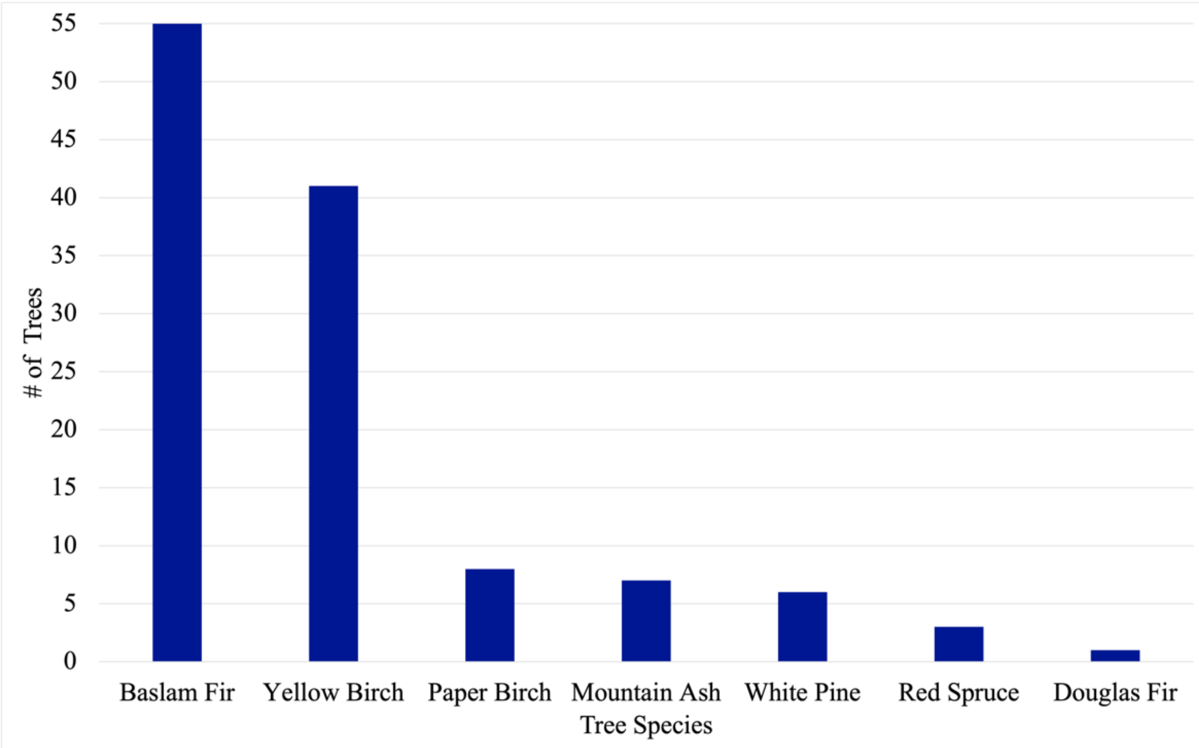

Figure 1616 - Total Number of Trees Surveyed by Species

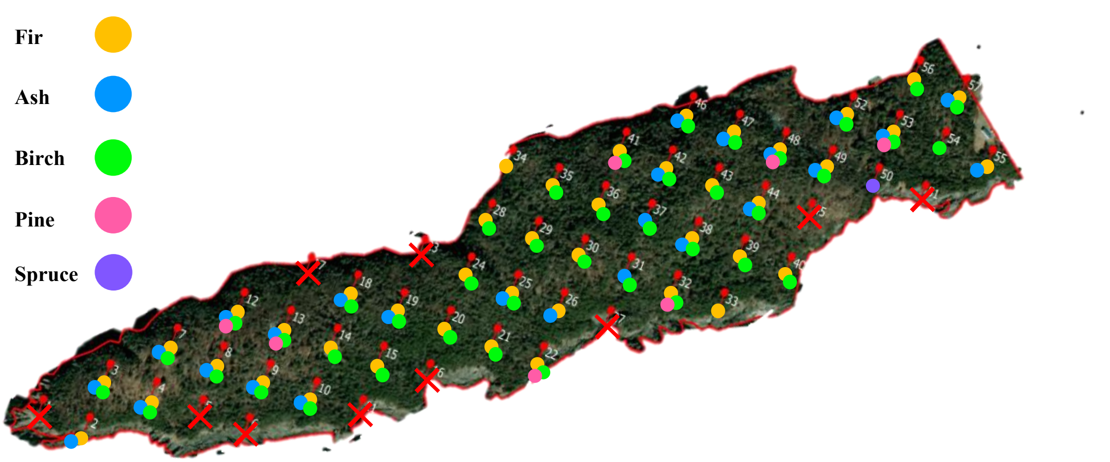

Figure 1717 - Distribution of Tree Species Across the Site

5.2 Average Old Growth Tree Age

The oldest of the old-growth trees at the site was White Pine with an average age of 103 years. Balsam Fir was the youngest with an average age of 49 years. Overall, the old-growth trees are of a similar age. Most of the trees relative to their lifespan are still young except Paper Birch and Balsam Fir which are more than half their average lifespans. Figure 18 below is a graphical representation of the average old growth age for all sampled species.

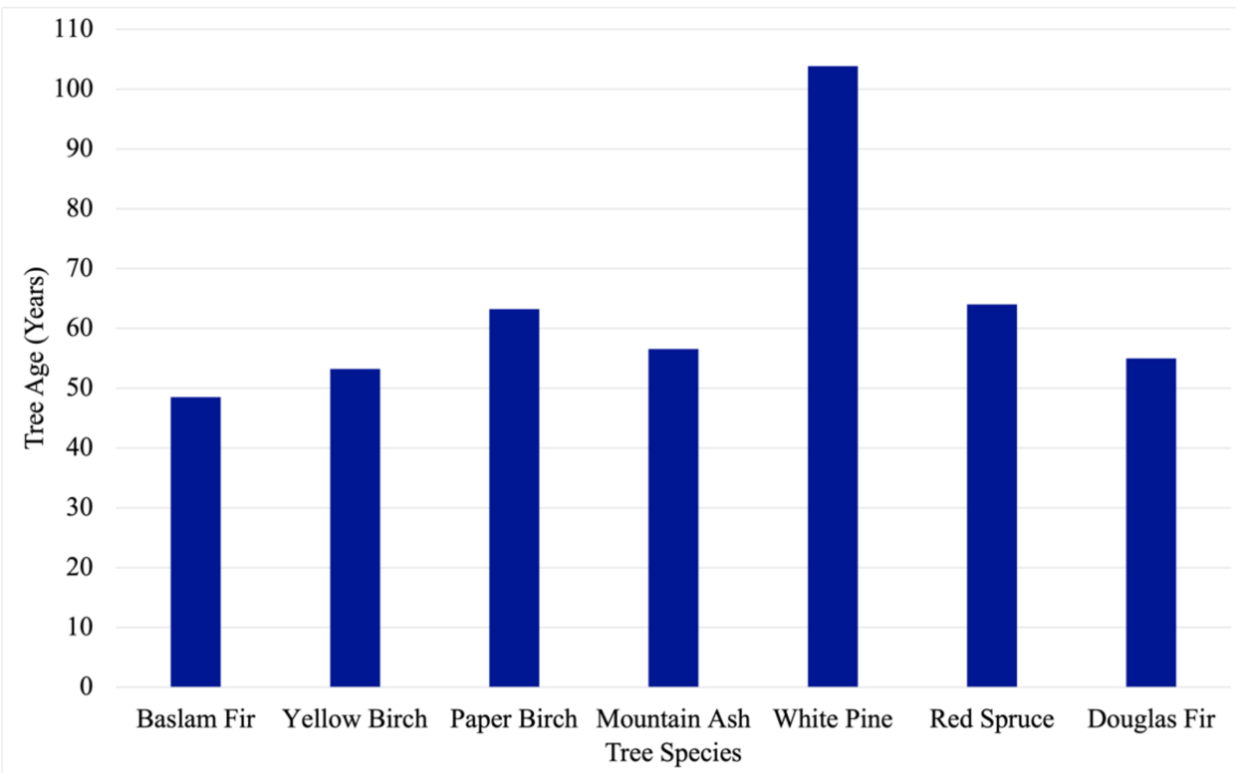

Figure 1818 – Average Old Growth Tree Age

5.3 Average Old Growth Tree Height

On average, the tallest trees were Red Spruce and the shortest was a single, possibly planted, Douglas Fir. Overall, the trees were similar in height. Figure 19 below is a graphical representation of the average old growth tree height for all sampled species.

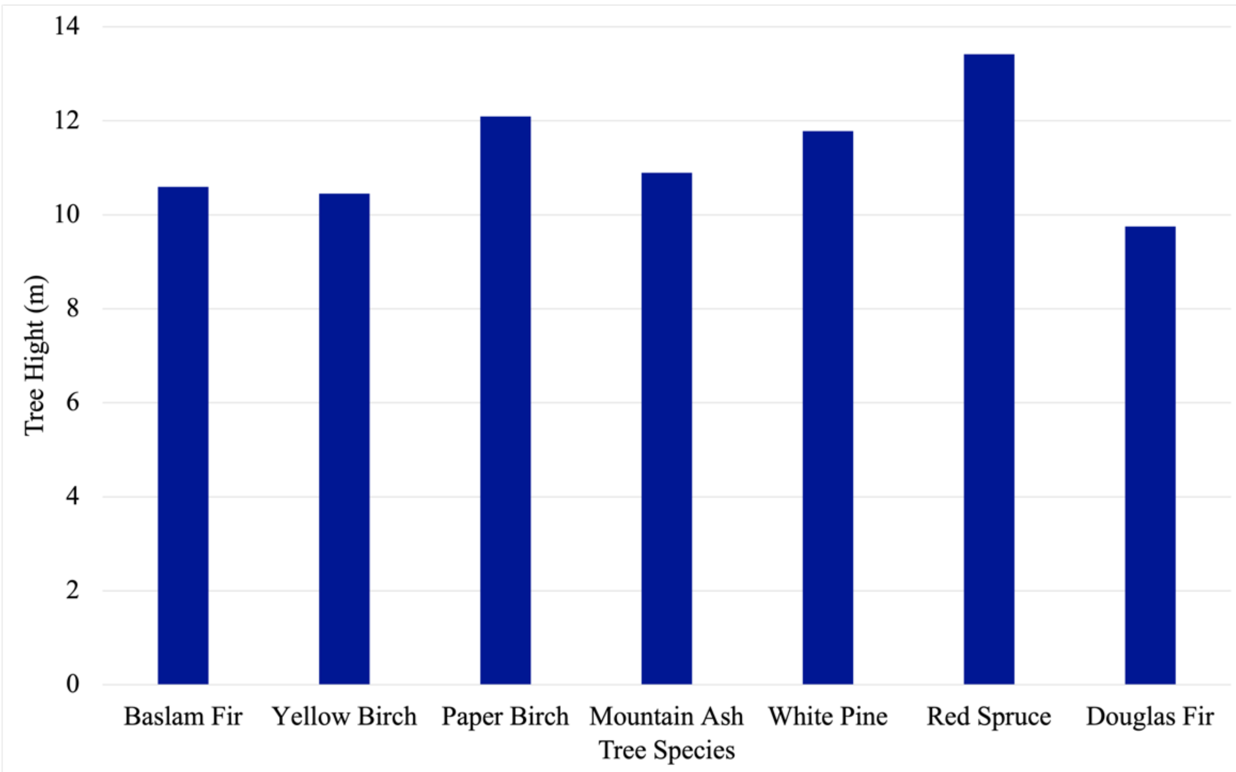

Figure 19 19 – Average Old Growth Tree Height

5.4 Average Old Growth Tree Circumference

On average the widest trees at the site were White Pine and the thinnest were Yellow Birch with Mountain Ash. Figure 20 below is a graphical representation of the average old growth tree circumference for all sampled species.

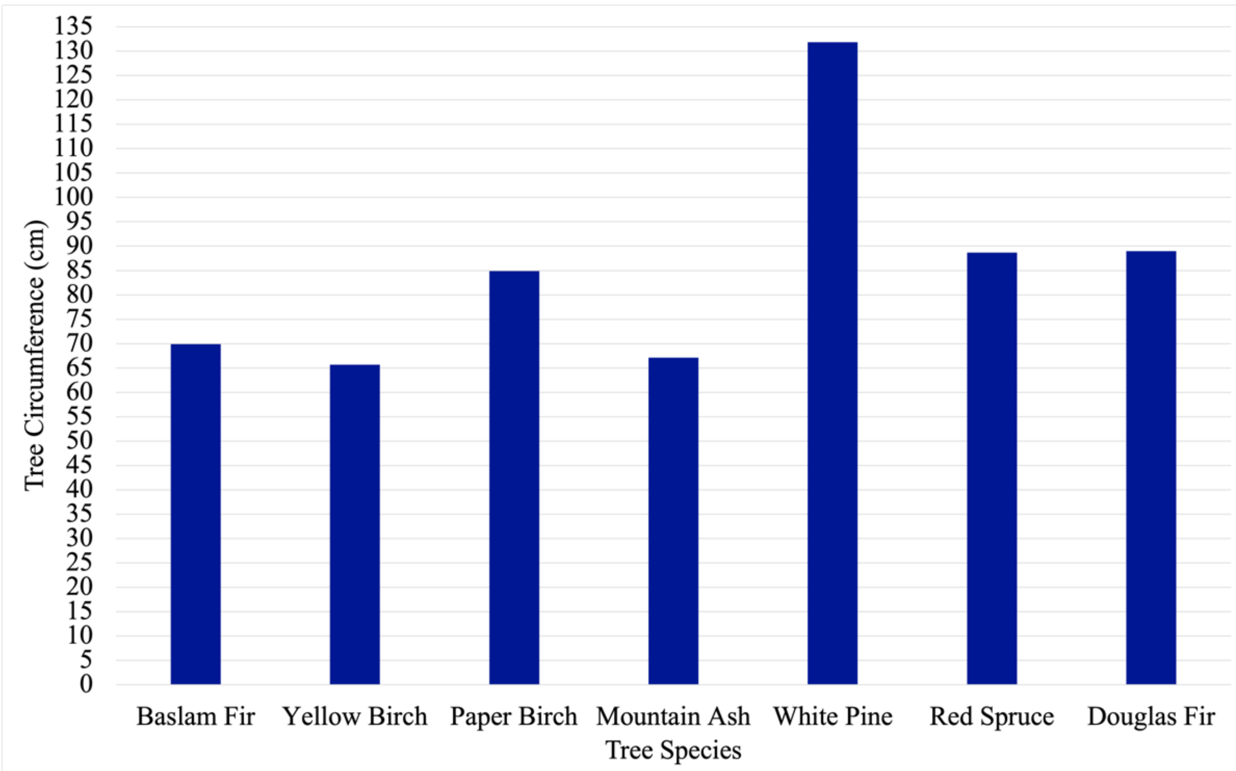

Figure 20 20 – Average Old Growth Tree Circumference

5.5 Canopy Coverage

Each of the site's canopy coverage was determined as a percentage. From this, the number of sites corresponding to a certain canopy percentage was graphed, which can be viewed in Figure 21. The median canopy coverage value across the 47 sites was 75%. As well, 30% of the sites had 50% canopy coverage or below and 70% of the sites had over 50% canopy coverage.

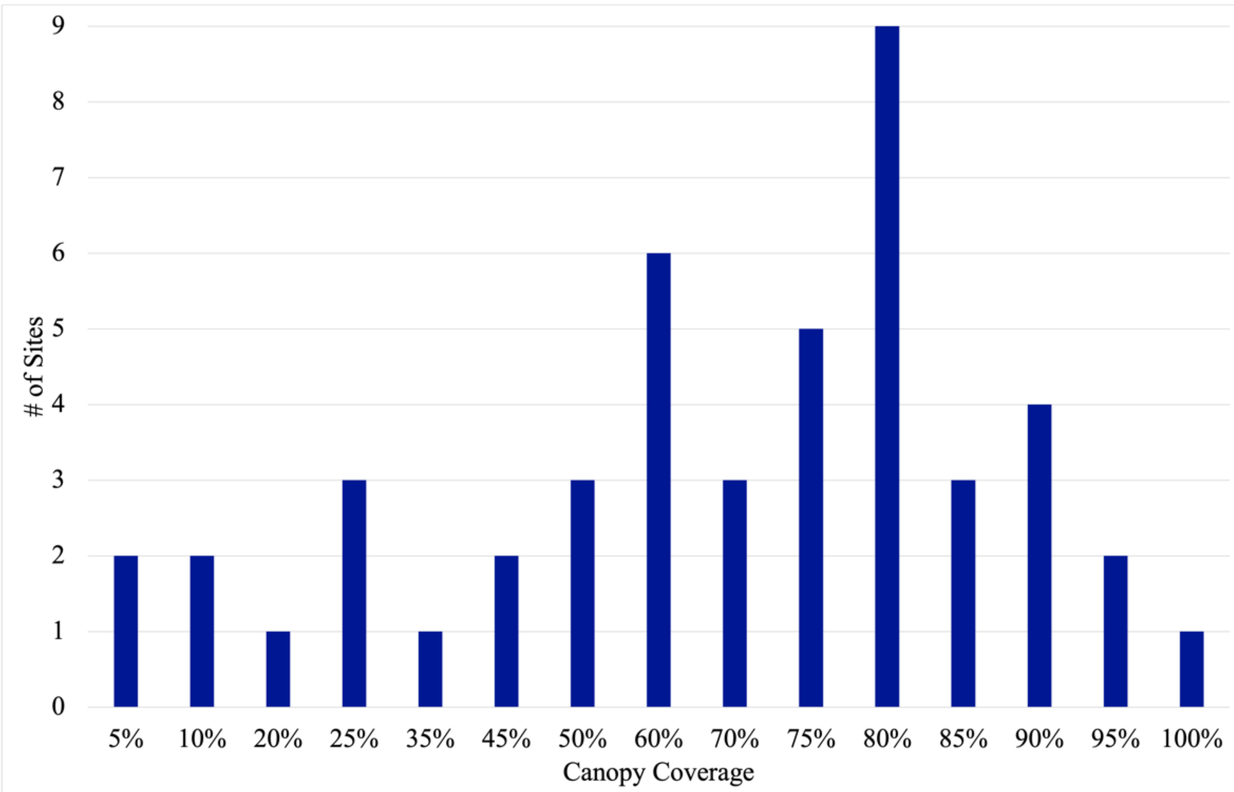

Figure 2121 - Number of Sites Corresponding to a Certain Canopy Coverage

5.6 Dead Trees

The number of dead trees (fallen or standing) on each site was determined. From this, the number of sites corresponding to range of numbers of dead trees was graphed, which can be viewed in Figure 22. The median number of dead trees across the 47 sites was 3 to 5 dead trees.

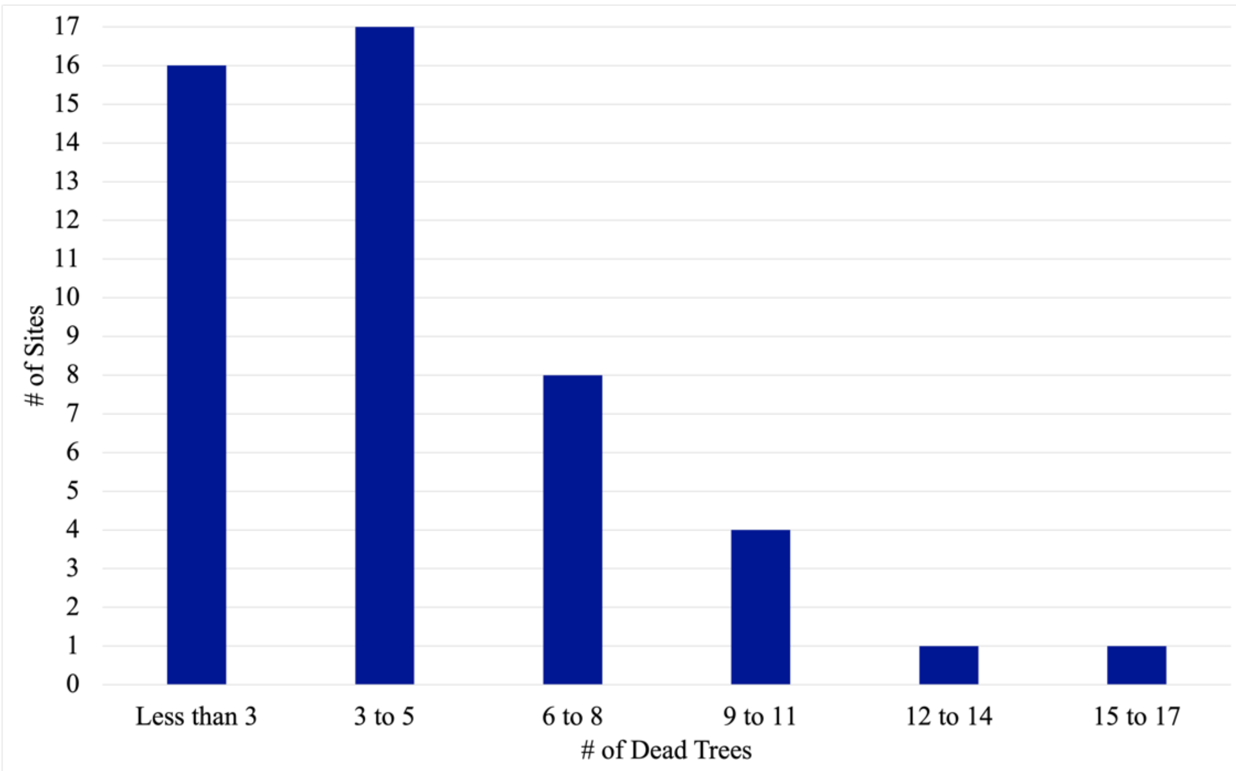

Figure 2222 - Number of Sites Corresponding to a Range of Numbers of Dead Trees

6 Tree Data Analysis

6.1 Future Predictions of Tree Species

6.1.1 Balsam Fir

Balsam Fir trees prefer cool weather and do not handle heat and humidity well (Puisis, 2022). As a result, they are projected to decline in New Brunswick due to climate change. Natural Resources Canada has climate change models that project how different species distribution will be affected by climate change. Figure 23 below depicts how Balsam Fir would be affected by climate change under the Representative Concentration Pathway (RCP) 8.5 scenario throughout the century. RCP 8.5 refers to the concentration of carbon that delivers global warming at an average of 8.5 watts per square meter across the planet. The RCP 8.5 pathway delivers a temperature increase of about 4.3˚C by 2100, relative to pre-industrial temperatures (Climate Nexus, 2019). In Figure 2323 the green zones are areas of the highest species density. They can be seen as zones for optimum growth. The blue zones are less optimal for growth with lower population density. According to the climate models, Balsam Fir is expected to migrate Northwards.

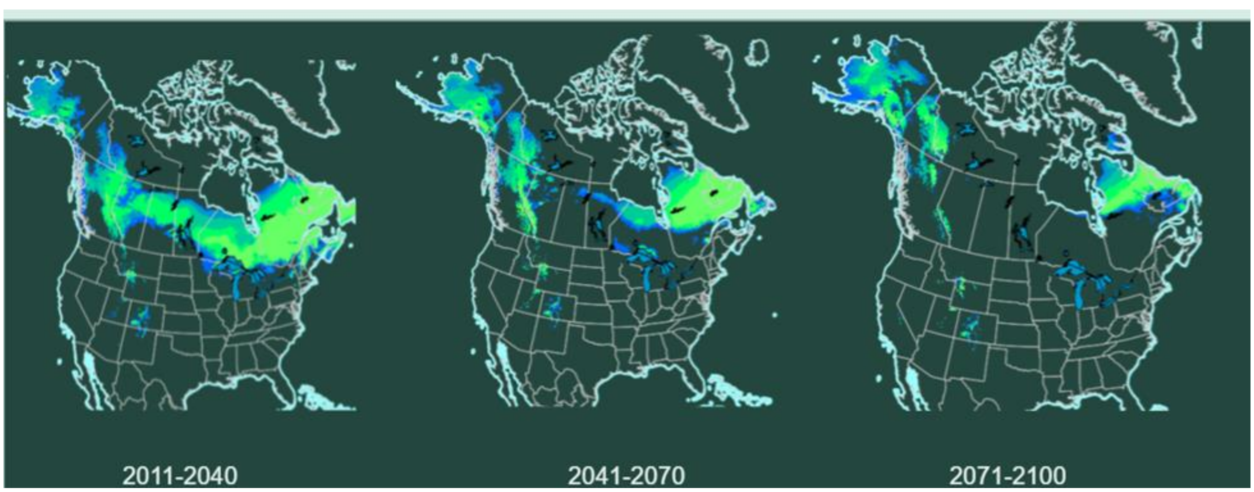

Figure 2323 - Climate Model for Balsam Fir Distribution through the 21st century (RCP 8.5; GoC, 2022)

6.1.2 Yellow and Paper Birch

Birches are vulnerable to climate change as these trees are sensitive to increased temperatures and summer droughts (Rojo et al., 2021). Figure 24 below depicts how Yellow Birch would be affected by climate change under the RCP 8.5 scenario throughout the century. Based on the climatic model Yellow Birch is expected to migrate Northwards.

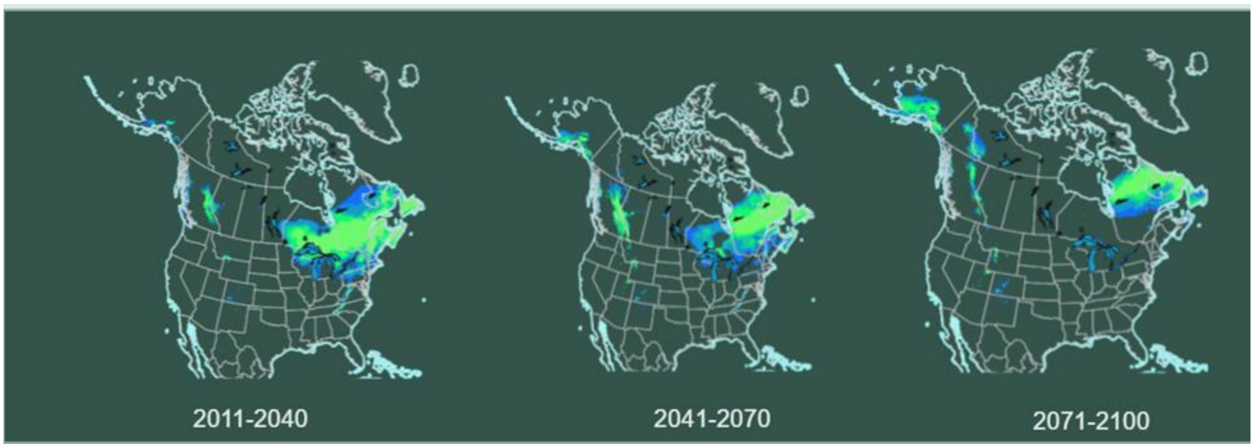

Figure 24 24 - Climate Model for Yellow Birch Distribution through the 21st century (RCP 8.5; GoC, 2022)

6.1.3 White Pine

White pine is expected to increase and prosper in the Acadian Forest throughout the century. (Bourque et. al). Figure 25 below depicts how White Pine would be affected by climate change under the RCP 8.5 scenario throughout the century. Even in the worst-case scenario of RCP 8.5 white pine is still present in the Acadian region although the optimal zones have migrated northwards.

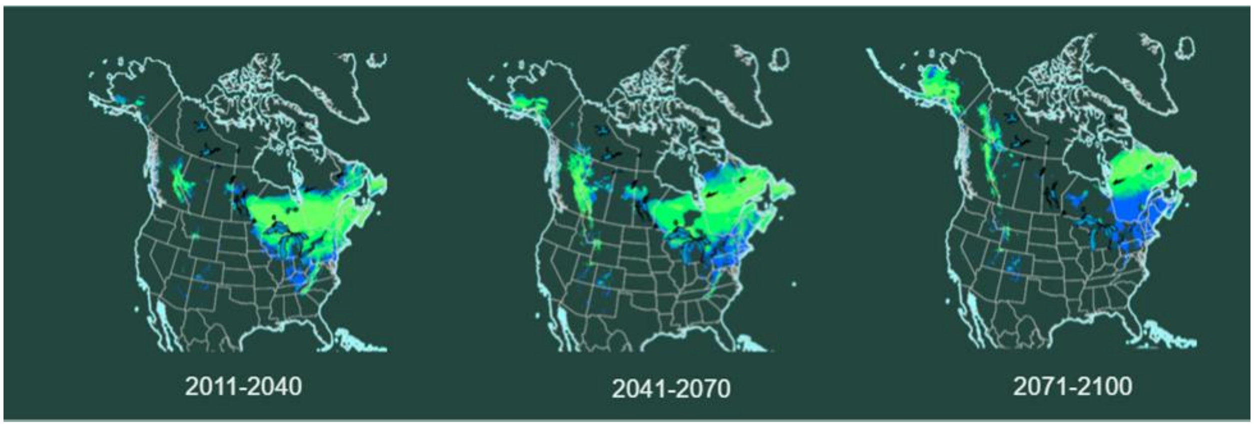

Figure 25 25 - Climate Model for White Pine Distribution through the 21st century (RCP 8.5; GoC, 2022)

6.1.4 Red Spruce

Red Spruce are sensitive to high temperatures and drought, so they are projected to decline (Bourque et al., 2008) in the future. Figure 26 below depicts how Red Spruce would be affected by climate change under the RCP 8.5 scenario throughout the century. Red Spruce is projected to migrate northwards with a reduction in habitat size.

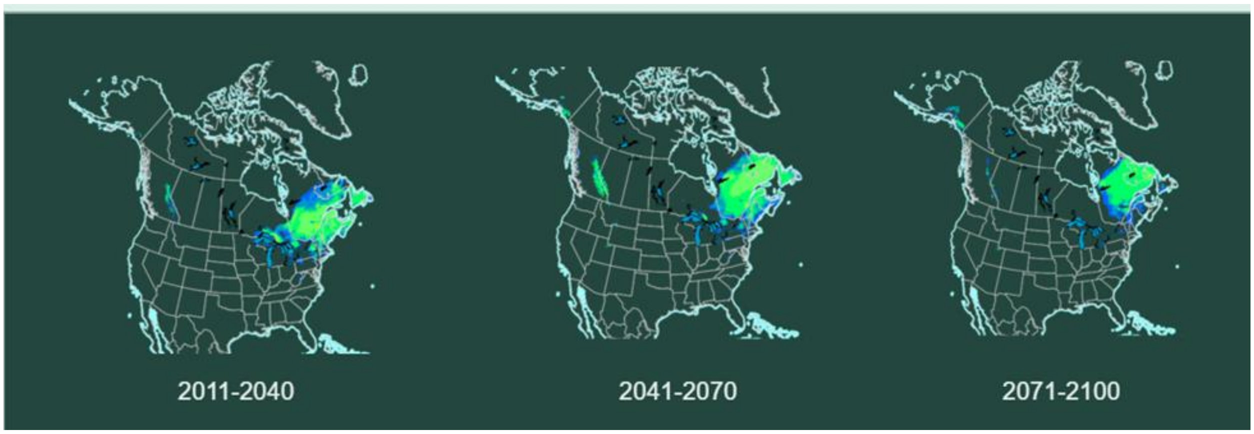

Figure 26 26 - Climate Model for Red Spruce Distribution through the 21st century (RCP 8.5; GoC, 2022)

6.1.5 Mountain Ash

Based on climate models, Mountain Ash is projected to be severely affected by climate change. Figure 27 below shows a significant decrease in Mountain Ash habitat and a Northward migration due to climate change.

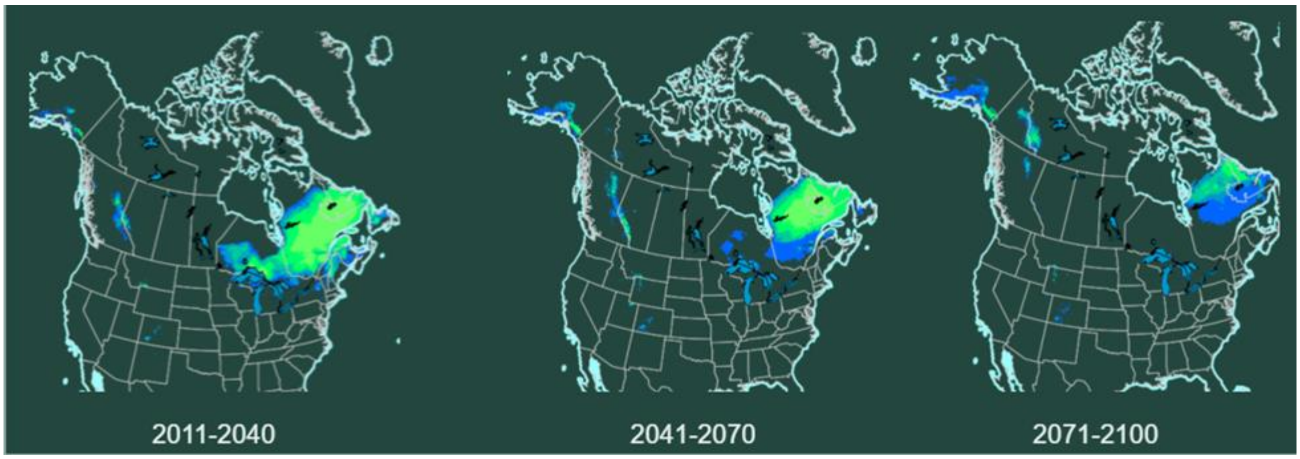

Figure 27 27 - Climate Model for Mountain Ash Distribution Through the 21st century (RCP 8.5; GoC, 2022)

6.2 Analysis of Old Growth Forest

The Forest composition is dominated by softwoods such as Spruce, Pine, and Balsam Fir which prefer cooler climates. As such, they are projected to migrate Northwards due to climate change. The site in the future would be taken over by species that prefer a more temperate climate. There are 8 species native to New Brunswick that are most likely to prosper as the climate changes: Black Cherry, White Pine, Sugar Maple, Red Maple, American Beech, Red Oak, Eastern Hemlock, and Ironwood (de Graaf, 2019).

White Pine is the only species of the 8 species present in New Brunswick that can be found on the site. In the future, it would be beneficial to fill in potential gaps in the forest with these other 7 species as the non-resilient species begin to decline.

6.3 Analysis of Canopy Coverage

The canopy coverage of the 47 sites were categorized into 4 different classes, which can be viewed in Table 2, as well, as the percentage of sites that fell into each class. Furthermore, the distribution of these canopy coverage classes across Deadmans Head Forest can be viewed in Figure 28. Most sites in Deadmans Head Forest were classified as very dense forest. The classification of these sites is as follows: ~57% of sites were classified as very dense forests, ~23% of sites were classified as moderately dense forests, ~15% of sites were classified as open forests, and ~4% of sites were classified as shrubland.

Table 2 2 - Sites by Canopy Classes (Gov of India, 2011)

Class	Canopy Coverage	Number of Sites with the Corresponding Canopy Coverage
Very Dense Forest	>70%	27
Moderately Dense Forest	40% to 65%	11
Open Forest	10% to 35%	7
Shrubland	<10%	2

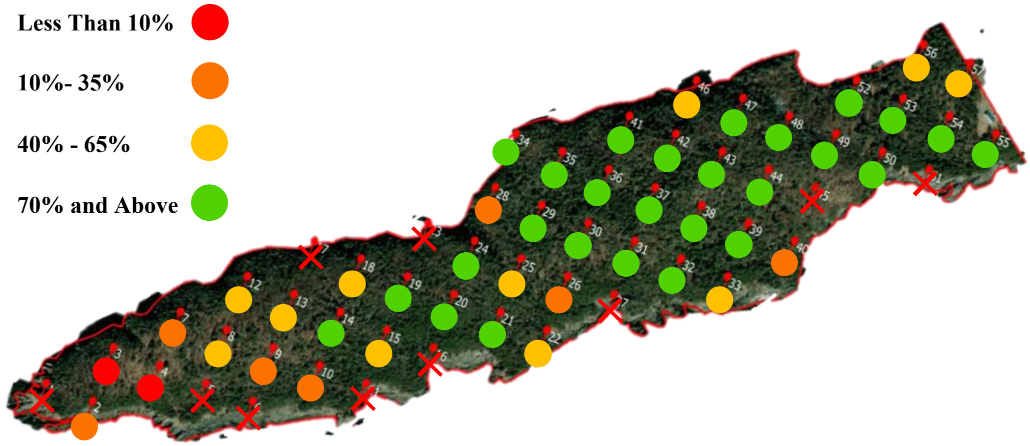

Figure 28 28 - Distribution of the Canopy Classes Across Deadmans Head Forest

Overall, the canopy coverage for Deadmans Head Forest is high, which is an indicator that the forest's ecosystem is in good health. The canopy coverage plays a very key role in the health of the forest ground, as well as the habitat for numerous species. Sites with high canopy coverage tend to be protected from external environmental forces at the base of the site compared to low canopy coverage sites. High canopy sites offer protection from sunlight, wind, precipitation, and generally these sites are cooler on the ground level. Low canopy sites tend to have more sunlight, higher winds, more precipitation, and higher temperatures on the ground level. Therefore, many species (mammals, shrubs, birds, etc.) prefer sites with higher canopy coverage, as these habitats are more protected from harsh conditions (Trimble, 2020).

Furthermore, low canopy coverage sites can signify that there are factors affecting the health of the forest at that site. For example, low canopy coverage sites can signify that pollutants, diseases, stresses, or pest may be declining the health of the trees at the site. Generally, high canopy sites have healthy trees, a good microclimate, and healthy nutrition (Trimble, 2020). It should be noted; however, that low canopy coverage sites can be very useful for new forest growth. Low canopy coverage sites have more sunlight reaching the ground, which is vital for the growth of young trees and shrubs (Simpson, 2003).

It was also noted that Deadmans Head Forest had a multi-layer canopy structure. This means that the trees making up the canopy coverage of the forest had varying degrees of height. This forest characteristic is good for two main reasons: soil health and habitat. Animals whose habitats tend to be in the canopy of the forest (e.g., squirrels, birds, etc.) prefer a multi-canopy structure as it creates a web of layers to allow them to move easily from one area to the next (Trimble, 2020). As well, multi-layer canopy structures ensure good soil health and prevent soil degradation. The main reason for this, is because less precipitation is directly hitting the forest ground. Multi-layer canopy structures cause precipitation to trickle down to the ground level at a slower rate and some of the precipitation gets absorbed by the trees as well. Generally, the soil of multi-layer canopy structure sites is richer, has a higher infiltrability, has less erosion, and less soil-loss (Trimble, 2021).

For these reasons, it can be concluded that the health of Deadmans Head Forest is very good, as many of the sites had high canopy coverage. As well, many of the sites would provide a sound habitat for many species due to their high canopy coverage. Many of the sites with low canopy coverage (as can be viewed in Figure 28 above) are located at the tip of Deadmans Head Forest. The most likely explanation for this is because these sites would be subjected to more weather stresses compared to the sites more inland. These sites would be subjected to higher winds and rains from storms coming into the coast.

6.4 Analysis of Dead Trees

Deadmans Head Forest had sites with no dead trees, as well as sites with numerous dead trees (15 and above). Sites that were near the tip of Deadmans Head Forest generally had more dead standing and fallen trees, which is most likely due to the severe weather events coming into the coast. The average of dead trees per site was determined, and from this, it was estimated that the Deadmans Head Forest has 500 dead trees/hectare. Post literature research, it is inconclusive on whether this number of dead trees is concerning. However, results from Deadmans Head Forest were compared to a study done for various forests throughout Newfoundland of snags/hectare. Compared to this study, Deadmans Head Forest had a moderate to low number of dead trees per hectare (Moroni & Harris, 2010).

Tree mortality in Canadian forests is on the rise, which is mainly caused by increasingly warm climates. It is speculated that the main cause of premature tree death in Canada is increased periods of drought. Furthermore, increased temperatures are linked to increases in tree diseases and pest outbreaks (Government of Canada, 2021). It should be noted, however, that dead trees play a vital role in a forest ecosystem. Decomposing trees (standing or fallen) provide rich nutrients for the forest ecosystem. Furthermore, dead trees can provide animals unique habitats and food (Parks Canada Agency, 2017).

7 Species Analysis

7.1 Species Found Throughout the Site

Various species were found throughout Deadmans Head Forest, and included 8 species of birds, 13 species of insects, 6 species of mammals, 7 species of trees, and 13 species in the understory (shrubs, mushrooms, etc.). A complete list of these species can be found in Appendix B. This section will focus on birds, mammals, insects, and species found in the understory. Section 6 has a comprehensive analysis of the tree species found on site. Nearly all species spotted at the study site are of the secure status (lowest level on extinction scale; GNB, 2022a; GNB, 2022b).

7.2 Climate Change Analysis of Species

This section covers how climate change will impact 3 of the species that were found on the site: Bald Eagle, Monarch Butterfly, and Aster. A climate change analysis was done on these three species, as they are sensitive to the effects of climate change, and they were spotted numerous times throughout Deadmans Head Forest.

7.2.1 Bald Eagle

Bald Eagles were spotted flying above the study site numerous times. Due to increasing climate, many Bald Eagles are moving North to avoid the warm temperatures South, which could be the reason these birds were spotted numerous times on Deadmans Head Forest. Specifically, climate change is causing stress on young Bald Eagles who still spend most of their time in the nest. Warm temperatures are causing heat related illnesses in the young, which has caused many young offspring to die (Audubon, 2014).

By 2080, it is expected that 84% of Bald Eagle's current habitat will no longer be habitable for them. One main reason for the loss of their current habitats are forest fires and severe weather events damaging forests in the United States. As well, many of their current habitats will no longer be suitable for these birds as temperature rise. However, Bald Eagles can recover 74% of this lost habitat by moving North, specifically into Canada (Audubon, 2014).

7.2.1 Monarch Butterfly

Monarch Butterflies are extremely sensitive to changes in temperature; therefore, they are greatly affected by the impacts of climate change. A large amount of Monarch Butterflies migrate to Deadmans Head Forest and the surrounding areas each year (Ernie & Judy, 2022). Monarch butterflies are an extremely important species in an ecosystem as they pollinate plants and facilitate seed distribution throughout the ecosystem (The Monarch Joint Venture, 2020). As well, the plant that Monarch Butterfly caterpillars feed on, Milkweed, are being affected by climate change. Their populations are declining throughout much of North America, as temperatures are rising. This plant species will have to begin moving North at a faster rate or they will face extinction in the future (UN, 2020).

Climate change is also affecting Monarch Butterflies' migration pattern, as they are leaving Canada later and leaving Mexico earlier. Severe weather events and warm temperatures are greatly affecting Monarch Butterfly populations and habitat (UN, 2020). In 2022, 80% of the overwintering population in Mexico was killed due to a severe weather event. As well, due to a combination of severe storms and heat, Monarch Butterflies have lost 38% of their habitat in the South (GNB, 2022). The situation for these butterflies is not much better in the North. Forest degradation in Canada is causing a decline in Monarch Butterfly populations. As well, less eggs are being laid in the spring due to severe rain events in Canada (UN, 2020).

There is an 11% to 57% chance that the Eastern population of Monarch Butterflies will be extinct by the year 2036 (GNB, 2022). Landowner's can encourage Monarch Butterflies to migrate to their property by planting Milkweeds for caterpillars. As well, planting flower gardens and not removing wildflowers can increase the Monarch butterfly population (The Monarch Joint Venture, 2020).

7.2.1 Aster

Asters generally populate near rivers, as the soil near rivers tends to be very rich. However, several patches of Asters were spotted on Deadmans Head Forest even though there is no river on, or near the property. This signifies that the site's soil is rich in nutrients. Aster is a species at risk in New Brunswick, and certain types of Asters are only found in Quebec, Maine, and New Brunswick. Therefore, it is very important that humans do not destroy this plant if they come across it (GNB, 2012). Furthermore, Asters play a significant role in the life cycle of Monarch Butterflies. Monarch Butterflies begin their migration South when Asters first start to bloom (late August). As well, these butterflies require nutrition from Asters for their long journey South (Woodbury, 2017).

7.3 Key Stone Species

A keystone species is a species of which the whole ecosystem function relies on (Mills et al., 1993). If a keystone species were to be removed from the ecosystem, other species would suffer (Mills et al., 1993). One example of keystone species in Deadmans Head Forest are Monarch Butterflies. If Monarch Butterflies were not to return to Deadmans Head Forest one year it could signify that other pollinators in this forest are in danger. Monarch Butterflies increase the biodiversity and population of plants in forests; therefore, if they were no longer present it could have major impacts on the forest. Furthermore, no Monarch Butterflies could signify that there is insufficient amount and diversity of plants in the forest for prey species (Monarch Joint Venture, 2022). Another keystone species of Deadmans Head Forest are bees, as they are Earth's primary pollinator. A complete loss or decline in the population of bees in Deadmans Head Forest would be detrimental to the forest's ecosystem. If there were no longer bees in the forest, several species would suffer greatly, as flowering plant populations would decline rapidly due to no means of fertilization. Therefore, prey species would loose essential food resources (CPAWS, n.d.).

7.4 Future Species and Their Impacts

Various types of species are migrating North in North America to avoid the impacts of climate change. 2000 species are migrating away from the equator at an alarming rate of 5 meters each day, and numerous species (fish, shrubs, insects, etc.) have moved into the Maritimes in search of a cooler climate (CBC News, 2011).

However, species moving North into Canada can be a cause for concern. Introducing new species into an ecosystem can disturb the delicate balance of the ecosystem. Species moving North can cause (and have caused) stresses on species population in Canada. Some of these species are invasive, which can cause native species to lose their habitat. Furthermore, some of these species carry diseases. This can decline native populations, as they are not immune to this disease (Mazerolle, 2018). Sections 7.4.1 to 7.4.4 discuss four insects that could cause problems in Deadmans Head Forest in future years. As the climate warms it is expected that pest infestations in the Acadian Forest will increase (Nova Scotia Department of Natural Resources, n.d.).

7.4.1 Emerald Ash Borer

The Emerald Ash Borer is a wood-boring beetle that has travelled into New Brunswick in recent years from the United States. Emerald Ash Borers populate in Ash trees. If an Ash tree is infested with Emerald Ash Borers, it only has a 1% survival rate 8 to 10 years post infestation (NB ISC, n.d.). Emerald Ash Borers can infest all species of Ash in New Brunswick. If the Emerald Ash Borer population continues to rise in New Brunswick, all Ash populations in the province could be wiped out entirely (Mazerolle, 2018). Between 2018 and 2021, Emerald Ash Borers have populated in Edmundston, Oromocto, Fredericton, and Moncton (NB ISC, 2022). While these beetles have not yet been spotted in the Black's Harbour region, they could pose a threat to Deadmans Head Forest, as it is heavy populated with Mountain Ash.

7.4.2 Balsam Fir Sawfly

Balsam Fir Sawflies are a native species to Canada; however, outbreaks of these insects can occur at random and at large. In Eastern Canada, Balsam Fir Sawflies, almost exclusively, feed on the needles of Balsam Firs. Balsam Fir flies feed on the needles of Balsam Firs during their larvae stage, which can stunt the growth and cause negative health impacts on Balsam Firs (Natural Resources Canada, 2015). In 2010, there was an outbreak of Balsam Fir Sawflies in Southern New Brunswick which caused irreversible damage on many Balsam Firs in the region (GNB, 2012). A Balsam Fir Sawfly infestation on Deadmans Head Forest could be a cause for concern as much of the forest is composed of Balsam Firs. Furthermore, there are numerous young Balsam Firs throughout Deadmans Head Forest, so a Balsam Fir Sawfly outbreak in this forest could have severe consequences on the growth of these young Balsam Firs.

7.4.3 White Pine Weevil

White Pine Weevils are a wood-boring beetle that feed and lay eggs in the trunks of White Pines in Eastern Canada. White Pine Weevils can cause severe damage to White Pines, which can cause irreversible damage and death to this species of tree (Government of Canada, 2013). An outbreak of White Pine Weevils occurred in New Brunswick in 2013 (GNB, 2014). An infestation of White Pine Weevils in the future could be detrimental to Deadmans Head Forest's White Pine Population.

7.4.3 European Gypsy Moth

European Gypsy Moth caterpillars feed on the leaves of many plants in Canada during the month of May. If an infestation occurs, these caterpillars will consume and kill most of the foliage on trees. These insects do not kill tree species; however, they can severely stunt the growth of trees (Government of Canada, 2015). Since they are an invasive, exotic species their populations are monitored throughout New Brunswick, including the Blacks Harbour region. In New Brunswick, one of the species of trees they prefer to feed on is Birch. A small outbreak of these pests occurred in 2013 in the Saint John area (GNB, 2014). A European Gypsy Moth infestation on Deadmans Head Forest could be a cause for concern as there are many Birch trees throughout this forest. Furthermore, there are numerous young Birch trees throughout Deadmans Head Forest, so a European Gypsy Moth outbreak in this forest could have severe consequences on the growth of these young Birch.

8 NDVI Map

8.1 What is NDVI Mapping?

NDVI is the Normalized Difference Vegetation Index, which is a classification system that categorizes the health of vegetation. The formula for NDVI is shown in Equation 1. This equation equates the amount of near-infrared light vegetation reflects and the amount of red-light vegetation absorbs (GISGeography, 2022).

Equation 1 - Equation for NDVI Values

$$NDVI = \frac{(NIR - Red)}{(NIR + Red)}$$

Unhealthy trees absorb more red-light and reflect less near-infrared light. On the contrary, healthy trees absorb less red-light and reflect more near-fared light. Therefore, healthier trees have a larger NDVI value compared to unhealthy trees. Satellite imagery has near infrared and red bands of light embedded in the imagery. Therefore, NDVI values can be mapped by applying Equation 1 to these bands in software, such as Arc GIS Pro. The NDVI ranges from values of -1 (dead vegetation or non-living objects) to +1 (very healthy vegetation). Table 3 shoes the classification of NDVI values (EOS, 2022).

Table 3 - NDVI Classification (EOS, 2022)

NDVI Value	Classification
-1 to 0	Dead Vegetation or Inanimate Object
0 to 0.33	Unhealthy Vegetation
0.33 to 0.66	Moderately Healthy Vegetation
0.66 to 1	Very Healthy Vegetation

8.2 NDVI Map of Deadmans Head Forest

An NDVI map of Deadmans Head Forest was created using satellite imagery from GeoNB. This imagery has embedded near-infrared and red-light band values, which were inputted into Equation 1 using Arc GIS Pro software to determine the NDVI values across Deadmans Head Forest. Figure 29 displays the NDVI map of Deadmans Head Forest.

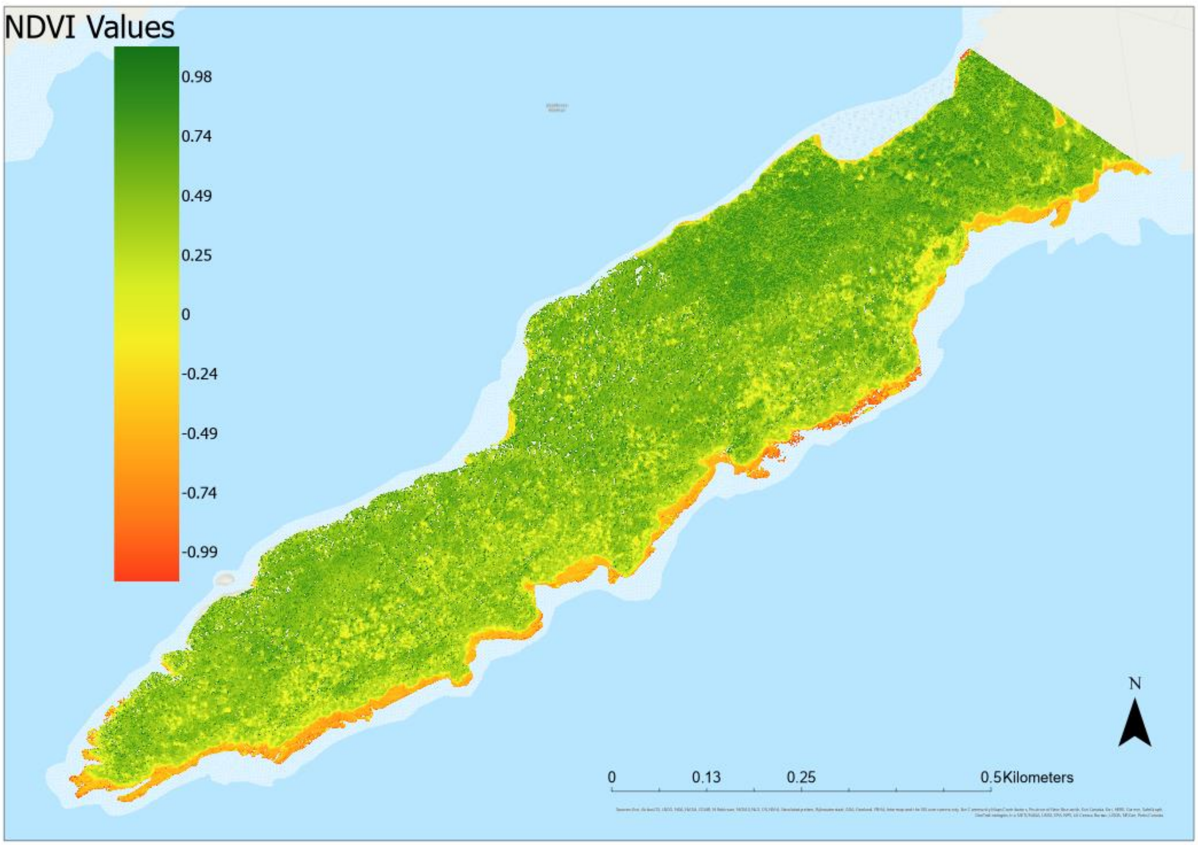

Figure 29 29 - NDVI Map of Deadman's Head Forest (1)

8.3 Analysis of NDVI Map of Deadmans Head Forest

Two regions of the NDVI Map of Deadmans Head Forest were of interest. These two regions can be viewed in Figure 30 (denoted as region A and B).

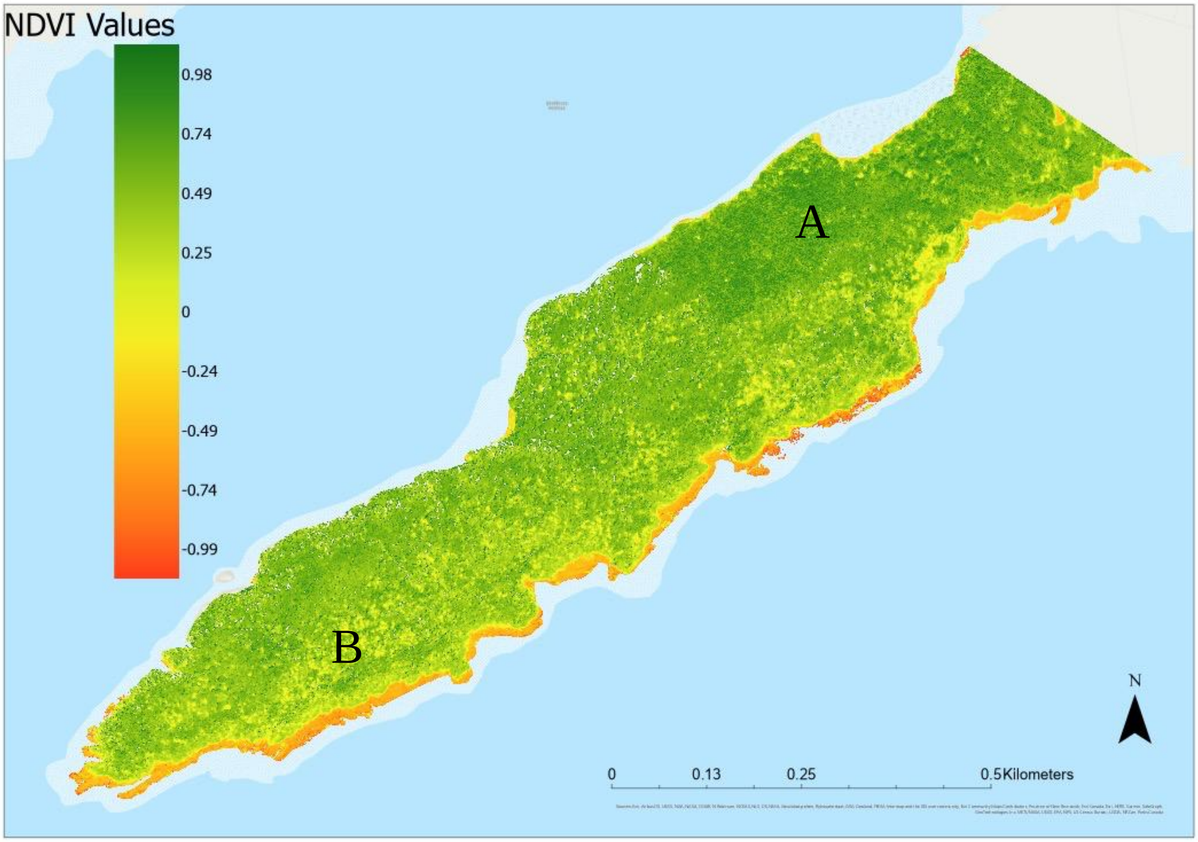

Figure30 30 - NDVI Map of Deadman's Head Forest (2)

Region A had very high NDVI values (0.7 to 1), which signifies that the vegetation in this region have very good health. However, region B had very low NDVI values (0 to -0.3), which signifies that the vegetation in this region is dead or dying. It was concluded that the vegetation in region B would be exposed to more weather stresses compared to region A. Region B is located near the tip of Deadmans Head Forest, therefore, the vegetation in this region would be heavily exposed to severe weather events coming into the coast compared to region A, which is more inland.

The overall statistics (distribution of NDVI values) for the NDVI map of Deadmans Head Forest can be viewed in Figure 31.

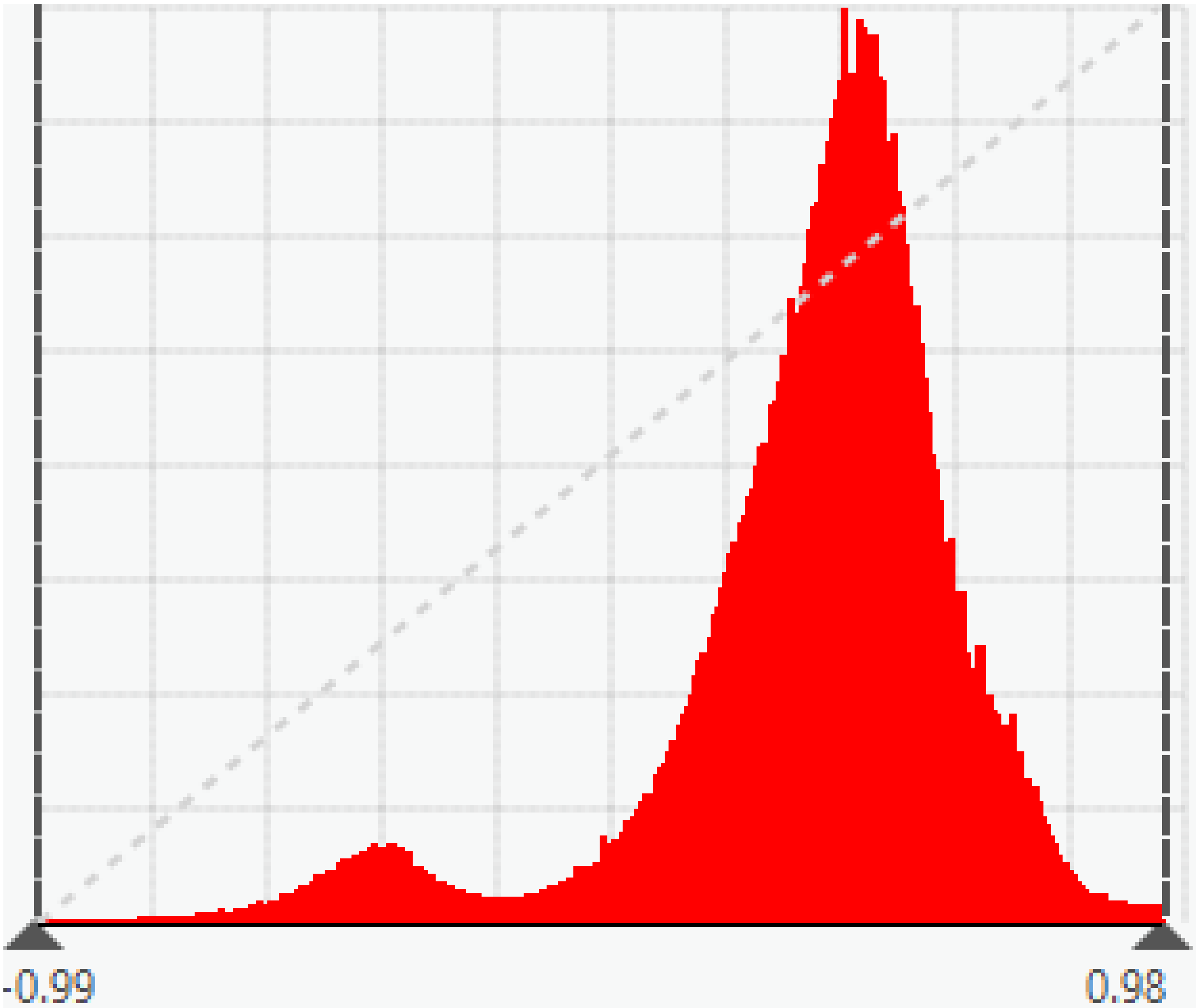

Figure 31 31- Overall Statistics of the NDVI Map for Deadman's Head Forest

As can be viewed in Figure 31, there are several points on the map that correspond to an NDVI value of -0.39 (left most bump in the figure). This means, that several points on the map have dead vegetation. However, some of these points could signify inanimate objects, such as, rocks. As can be viewed in Figure 30, regions near the point of Deadmans Head Forest tend to have NDVI values around -0.39. As can be viewed in Figure 31, the majority of points on the map correspond to an NDVI value of 0.46 (right most bump in the figure). This means, that overall, Deadmans Head Forest has moderately healthy vegetation.

9 Climate Predictions of the Study Site

Climate change is expected to change the future climate of Deadmans Head Forest. Specifically, the forest is predicted to have an increased amount of annual precipitation and an increase in annual temperature.

9.1 Precipitation Predictions of the Study Site

Increased annual precipitation has been observed in Eastern North America and is expected to increase in the future (Table 4; IPCC, 2022). Heavy precipitation and a decline in snowpack are expected as a result of climate change (IPCC, 2022; Romero-Lankao et al., 2014). Warm temperatures and mild winter conditions will decrease the amount of snowfall and increase the amount of rainfall (IPCC, 2022). The amount of snowpack will decrease due to a shorter winter period to accumulate mass. This will then affect the soil moisture content causing a "snow drought" event since most of the vegetation depends on the spring snowmelt to start their growing season (Cooper et al., 2016; Harpold et al., 2017). Hurricanes are expected to become stronger due to climate change and this could lead Deadmans Head Forest vulnerable to strong wind and rain that could damage the current forest condition (IPCC, 2022).

Table 4 - Annual Precipitation for Past, Present, and Future in the Region of Saint John, NB (data from table from Climateatlas.ca, 2022)

Year	Annual precipitation (mm)
1980	1215
2020	1279
2080	1377

9.2 Temperature Predictions of the Study Site

Rising temperatures are linked to anthropogenic activities. Unless there is a decrease in greenhouse gas emissions, temperatures will continue to increase (IPCC, 2022). Increased mean annual temperature and high temperature day frequency (heatwaves) are to be expected (Table 5; IPCC, 2022; Romero-Lankao et al., 2014). Increasing temperatures have the possibility of increasing evaporation, which could dry out the soils faster (IPCC, 2022). This could lead to droughts in the future.

Table 5 - Mean Annual Temperature for Past, Present, and Future in the Region of Saint John, NB (data from table from Climateatlas.ca, 2022).

Year	Mean Annual temperature (°C)
1980	5.9
2020	7.1
2080	11.0

10 LanDSET Model

10.1 What is a LanDSET Model?

Modeling the spatial distribution of various environmental factors allows a better understanding of different relationships over a landscape with predicted climate change events. A LanDSET model projects the distribution of soil moisture over a landscape (Bourque and Hassan, 2008). This model is built from different layer attributes including soil moisture, hydrological processes, evapotranspiration, digital elevation models (DEM), and solar radiation (Bourque and Hassan, 2008; Bourque et al., 2000). Once built, the model demonstrates hydrological outputs, evapotranspiration, and surface runoff (Bourque and Hassan, 2008).

10.2 LanDSET Model of Deadmans Head Forest

The LanDSET model built for Deadmans Head was created to view soil moisture (Figure 32). Areas coloured in blue indicate high soil moisture. The soil then looses moisture as the color turns yellow/green. A red colour represents areas with very low soil moisture content. The South-East edge of the peninsula is comprised of bedrock, which would explain the low soil moisture content.

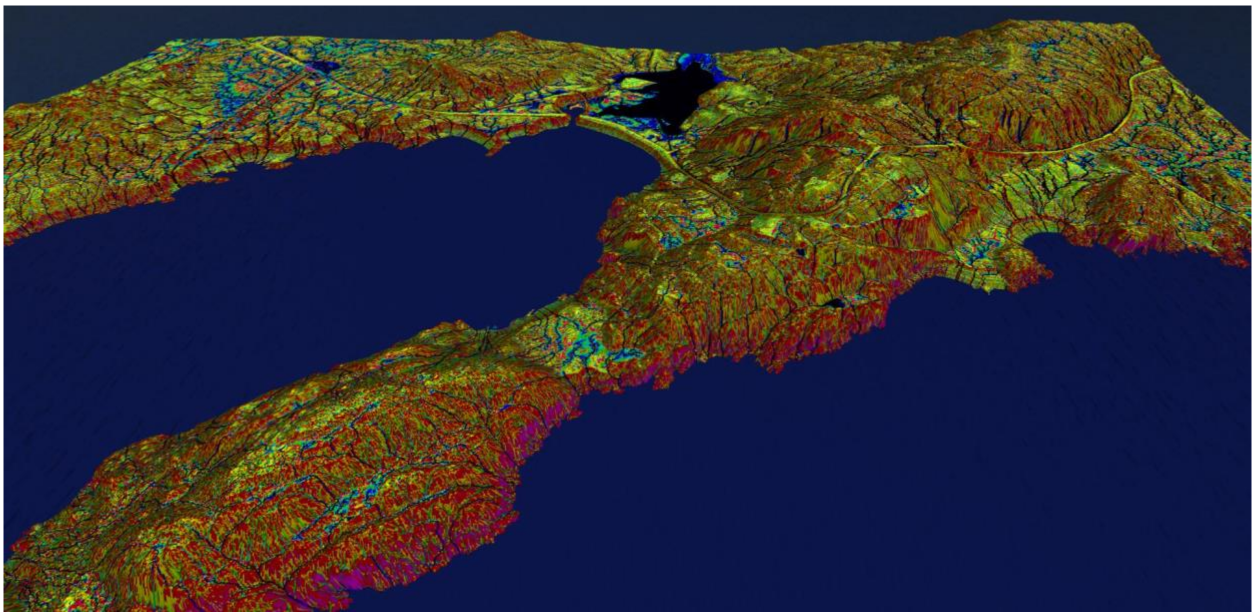

Figure 32 32 - LanDSET Model for Deadmans Head Forest Showing Soil Moisture Distribution (Blue wet, Red dry)

With a closer look into the LanDSET model, we can see the elevation changes across the landscape (Figure 33). The lower elevation area is found in the center of the peninsula and has the highest soil moisture content. The blue lines across the model indicate the hydrological flow of excess water/runoff. The LanDSET model also captures the neighboring wetland nearby, which will be discussed in the next section.

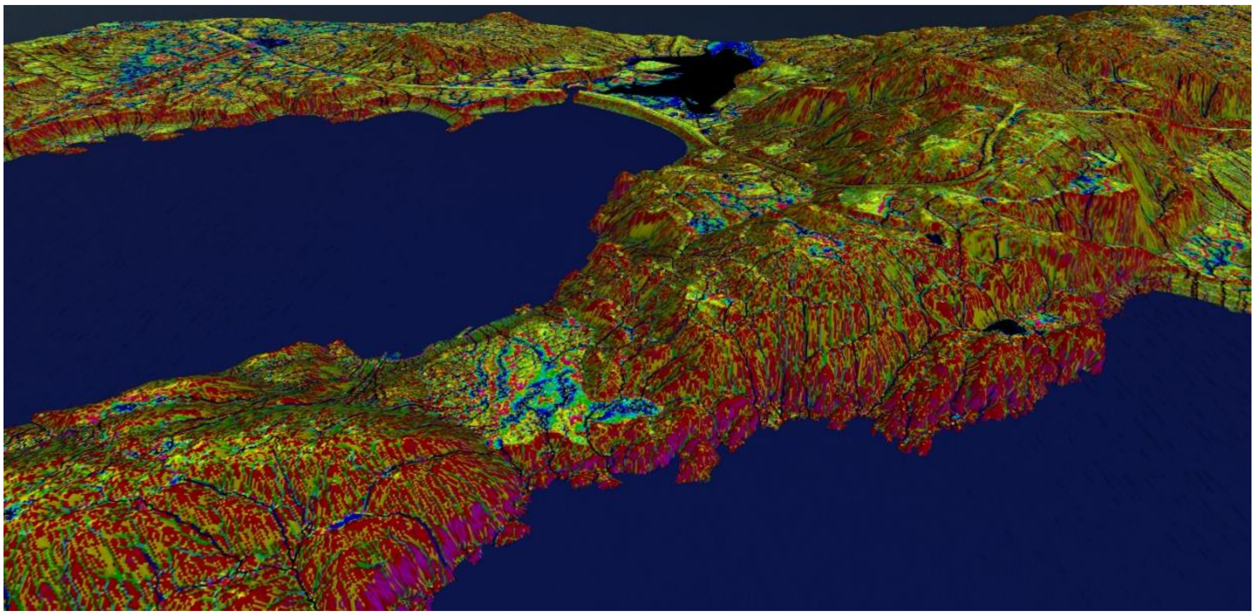

Figure 33 - Zoomed in LanDSET Model for Deadmans Head Forest Showing Soil Moisture Distribution (Blue Wet, Red Dry). Water Flow Represented With Dark Blue Channels

10.3 Analysis of LanDSET Model of Deadmans Head Forest

Tree species productivity can be influenced by multiple dynamics in a system, including soil moisture, interspecies and intraspecies competition, and natural disturbances (Bourque and Hassan, 2008). Areas that have a higher soil moisture content are preferred, providing water to root dynamics and increasing vegetation productivity (McCollum and Ibanez, 2020; Olesinski et al., 2011). Soil moisture is highest in the spring and dries out over the course of the summer (Olesinski et al., 2011). Areas with lower soil moisture can be impacted by drought, which is a stressor to the vegetation in the forest and could cause a decline in tree production (McCollum and Ibanez, 2020; Olesinski et al., 2011). With unexpected climate change events, moisture content will be a very important factor to consider for the future health of Deadmans Head Forest (McCollum and Ibanez, 2020).

11 Other Future Impacts on Deadmans' Head Forest

Erosion and flooding events are associated with climate change. Deadman Head's Peninsula is located by the Bay of Fundy, which could have some potential influence over these climate change impacts.

11.1 Erosion

Since Deadmans Head is a coastal site, it could have the potential to be affected by coastal erosion overtime due to climate change. Coastal erosion poses a risk of loosing land mass from severe storms, such as hurricanes (Sano et al., 2011). Deadmans Head Forest is currently protected from erosion due to the bedrock surrounding the peninsula which acts as a natural retaining wall. Personal communication with the landowners also indicated that they had experienced very little erosion over the past 20 years they have owned the property.

11.2 Flooding

Flooding is becoming more common as sea levels rise due to climate change. Fortunately, Deadmans Head is found at a high elevation, and is not expected to be vulnerable to future flooding events. Using the LandSET model, a flood simulation was conducted to test possible flooding events. For Deadmans Head to be affected by flooding, there would have to be a sea level rise of 12 meters. However, adjacent properties and roads would be impacted with a much lower sea level rise. A wetland next to the Edwards' property would be affected by sea level rise increase of 1 meter (Figure 34).

Figure 33 - Neighboring wetland property that will be impacted by future flooding events (photo taken by Ernie and Judy Edwards in October 2022)

If a flood event were to occur, this wetland would slowly expand in size along the harbor, and flood over the properties of the neighbors surrounding the wetland. The road (Route 778) on the west side to access the Edwards' property would also be affected by a flooding event (Figure 35).

Figure 34 - Aerial View of the Neighboring Wetland (Top Left) That will be Affected by Future Flooding Events

12 Future Plan

Continuous monitoring for future climate change and extreme weather events on the Deadman Head's property is recommended. Since climate change can impact whole ecosystems, and individual species differently, continuous monitoring is needed to build climate adaptation strategies (Mawdsley, 2011).

Now that a baseline data set has been created, future ENVS 6007 students could revisit the site in future years to monitor any changes in the forest. Species composition and distribution should be monitored with future climate (temperature, precipitation, extreme weather events, etc.) conditions. There are a variety of sensitivity analyses that could be done for the forest to dive deeper into conservation goals and strategies (Mawdsley, 2011).

Additionally, the landowners are working alongside Nature Trust NB, who is a conservation group that helps private woodlot landowners manage and conserve their land from teachings of natural heritage and biodiversity (Nature Trust NB, 2022). Our findings combined with Nature Trust NB's resources; the future of Deadman Head's Forest is in good hands.

13 Limitations

The distance to the site location was a limitation of the project, as it limited the number of site visits possible. Fieldwork was limited to weekly Friday visits due to the 127 km journey required to get there. The limited access to the site added a layer of complication due to the project's time constraints, as all fieldwork had to be done within a few weeks.

The time of year was another limitation. The project began in early fall, with only a short time to get relevant data before the leaves changed color and fell. The acquisition of a drone took longer than expected. This prevented the use of aerial photographs taken from a drone flown over the site to calculate the NDVI, as the leaves changed colors before the drone was acquired. Therefore, GeoNB Satellite Imagery was used to map the NDVI values.

An additional limitation of the project was our bias toward old-growth trees in our sampling methods. Only the three largest trees in each sampling area were measured. In the future, all further studies carried out at the site need to carry out sampling methods that provide a more accurate depiction of the forest composition.

14 Conclusion

To conclude, Ernie and Judy Edwards' property, Deadman Head's Forest, was studied to create a baseline dataset to establish a possible "living laboratory". Field surveys and spatial models were conducted to assess their current forest health and conditions. Overall, the forest is considered moderately healthy (NDVI) and hosted a variety of species. Future climate change on the property will shift the current tree species Northwards. Increased temperatures and precipitations are expected. Deadmans Head will remain resilient for the near future and is adaptable to future climate events. Continuous monitoring of the forest is recommended.

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Appendix A: Data Collected

Table 6 - Data Collected (1)

	Circumference (cm)	Tree Species	Age (years)	Bottom Reading	Top Reading	Height (m)	Fallen Trees	Overall Speicies	Coverage (%)	Notes
Point 57										
Tree #1	62	Balsam Fir	55	-2	10.5	12.5				
Tree #2	76	Balsam Fir	40	-1	7.25	8.25	7	Birch, Ash, and Fir	50	
Tree #3	58	Balsam Fir	35	-2	9	11				
Point 2										
Tree #1	58	Balsam Fir	50	-1.75	5.25	7				
Tree #2	109	Balsam Fir	60	-1	8.25	9.25	5	Ash and Fir	25	
Tree #3	69	Yellow Birch	50	-0.75	11.75	12.5				
Point 3										
Tree #1	-	Balsam Fir	-	-	-	-				
Tree #2	-	Balsam Fir	-	-	-	-	5	Birch, Ash, and Fir	5	Very young site (sapplings).
Tree #3	-	Balsam Fir	-	-	-	-				
Point 4										
Tree #1	89	Yellow Birch	45	-2	9.25	11.25				
Tree #2	73	Yellow Birch	43	-2.25	5.75	8	4	Birch, Ash, and Fir	5	6 standing dead trees (dry-no moss on rocks).
Tree #3	70	Yellow Birch	41	-0.5	7.75	8.25				
Point 7										
Tree #1	178	Balsam Fir	114	-4.25	12	16.25				
Tree #2	93	Yellow Birch	60	-1	8.5	9.5	6	Birch, Ash, and Fir	35	
Tree #3	85	Yellow Birch	43	-4.25	4.5	8.75				
Point 8										
Tree #1	100	White Birch	72	-5	8	13				
Tree #2	95	Balsam Fir	48	-6.25	2	8.25	5	Birch, Ash, and Fir	45	
Tree #3	69	Mountain Ash	51	0	6.25	6.25				
Point 9										
Tree #1	93	Balsam Fir	45	-7.75	6.5	14.25				
Tree #2	44	Balsam Fir	37	-3.75	2.25	6	11	Birch, Ash, and Fir	10	8 standing dead trees and young trees (bedrock).
Tree #3	-	-	-	-	-	-				
Point 12										
Tree #1	95	Balsam Fir	70	0	9.25	9.25				
Tree #2	133	White Pine	136	0.5	1.5	1	2	Birch, Ash, Fir, and Pine	60	
Tree #3	46	Mountain Ash	30	-1.75	7.25	9				
Point 13										
Tree #1	77	White Birch	40	-1.5	9.25	10.75				
Tree #2	84	White Birch	48	-0.5	13.5	14	8	Birch, Ash, Fir, and Pine	50	
Tree #3	85	Mountain Ash	58	-1	16	17				
Point 10										
Tree #1	84	Balsam Fir	48	-3.25	11	14.25				
Tree #2	85	Balsam Fir	68	-2.5	6.25	8.75	13	Birch, Ash, and Fir	25	7 dead standing trees.
Tree #3	-	-	-	-	-	-				
Point 49										
Tree #1	43	Yellow Birch	36	-6.5	3.25	9.75				
Tree #2	39	Yellow Birch	26	-4	4.75	8.75	8	Birch, Ash, and Fir	75	
Tree #3	48	Yellow Birch	38	-2.75	4.5	7.25				
Point 46										
Tree #1	77	Yellow Birch	55	-2	9	11				
Tree #2	97	Balsam Fir	63	-1.5	7	8.5	8	Birch, Ash, and Fir	45	
Tree #3	100	White Birch	67	-1.25	11.5	12.75				
Point 48										
Tree #1	103	White Pine	69	-1	14	15				
Tree #2	62	Balsam Fir	52	-0.5	8.5	9	17	Birch, Ash, Fir, and Pine	80	
Tree #3	73	Balsam Fir	40	-1.25	7.25	8.5				
Point 52										
Tree #1	80	Balsam Fir	49	-0.5	11	11.5				
Tree #2	47	Yellow Birch	50	-0.25	13	13.25	0	Birch, Ash, and Fir	90	Young trees.
Tree #3	44	Balsam Fir	38	0	6.25	6.25				
Point 53										
Tree #1	66.5	Yello Birch	90	-1.5	9	10.5				
Tree #2	76	Yellow Birch	70	-1.25	7	8.25	2	Birch, Ash, Fir, and Pine	70	
Tree #3	95	White Pine	53	-1.25	13	14.25				

Table 7 - Data Collected (2)

	Circumference (cm)	Tree Species	Age (years)	Bottom Reading	Top Reading	Height (m)	Fallen Trees	Overall Speicies	Coverage (%)	Notes
Point 50										
Tree #1	93	Red Spruce	63	-0.25	13.75	14				
Tree #2	80	Red Spruce	71	-1.25	12	13.25	1	Spruce	90	
Tree #3	93	Red Spruce	58	-1	12	13				
Point 54										
Tree #1	68	White Birch	65	-2	10	12				
Tree #2	-	-	-	-	-	-	8	Birch	75	Bare land and fallen trees.
Tree #3	-	-	-	-	-	-				
Point 56										
Tree #1	70	Balsam Fir	49	-4	9.5	13.5				
Tree #2	54	Balsam Fir	44	-4.5	9.5	14	5	Birch and Fir	60	Lots of rocks.
Tree #3	72	Balsam Fir	50	-3.5	9	12.5				
Point 14										
Tree #1	136	White Pine	78	-0.2	6.75	6.95				
Tree #2	96	Yellow Birch	75	-0.25	5.75	6	3	Birch, Fir, and Pine	90	
Tree #3	96	Yellow Birch	75	-1	12	13				
Point 18										
Tree #1	61	Paper Birch	63	-1.25	9	10.25				
Tree #2	43	Balsam Fir	24	-1.25	6	7.25	7	Birch, Fir, and Ash	60	
Tree #3	53	Yellow Birch	35	-0.5	7.25	7.75				
Point 19										
Tree #1	59	Yellow Birch	49	-1	10.75	11.75				
Tree #2	62	Yellow Birch	56	-0.75	11	11.75	5	Ash, Birch, and Fir	70	
Tree #3	66	Mountain Ash	52	-1	8.5	9.5				
Point 15										
Tree #1	89	Douglas Fir	55	-3.25	6.5	9.75				
Tree #2	48	Balsam Fir	40	-3.25	6	9.25	8	Fir, Birch, and Ash	60	
Tree #3	52	Balsam Fir	56	-3.25	5.5	8.75				
Point 20										
Tree #1	92	Balsam Fir	80	-3.25	10.5	13.75				
Tree #2	70	Balsam Fir	48	-3	10	13	2	Fir and Birch	95	
Tree #3	55	Balsam Fir	46	-2.75	8.5	11.25				
Point 24										
Tree #1	99	Balsam Fir	69	-1	10.5	11.5				
Tree #2	52	Yellow Birch	40	-1.5	10	11.5	4	Fir and Birch	80	
Tree #3	61	Yellow Birch	48	-1	8.5	9.5				
Point 21										
Tree #1	69	Balsam Fir	63	-1.25	8.25	9.5				
Tree #2	60	Yellow Birch	52	-1.25	7.75	9	6	Fir and Birch	95	
Tree #3	42	Balsam Fir	45	-1.5	5.75	7.25				
Point 22										
Tree #1	58	Balsam Fir	45	-3.5	3.75	7.25				
Tree #2	83	White Pine	70	-4.5	7.75	12.25	2	Birch, Fir, and Pine	60	
Tree #3	32	Yellow Birch	26	-3.25	7.5	10.75				
Point 25										
Tree #1	92	Balsam Fir	78	-0.75	11.35	12.1				
Tree #2	93	Yellow Birch	58	-0.75	9.75	10.5	2	Birch, Fir, and Ash	50	
Tree #3	103	White Birch	62	-0.75	10	10.75				
Point 28										
Tree #1	40	Balsam Fir	29	-1	3.75	4.75				
Tree #2	-	-	-	-	-	-	7	Birch and Fir	10	3 dead standing strees. Lots of litter (close to fishin trap).
Tree #3	-	-	-	-	-	-				
Point 34										
Tree #1	42	Balsam Fir	41	-2	7	9				
Tree #2	-	-	-	-	-	-	3	Fir	100	Young, dense stand.
Tree #3	-	-	-	-	-	-				
Point 26										
Tree #1	54	Balsam Fir	31	-2.5	5.5	8				
Tree #2	-	-	-	-	-	-	10	Ash and Fir	25	4 dead standing trees and lots of bare land.High elevation and steep.
Tree #3	-	-	-	-	-	-				
Point 29										
Tree #1	93	White Birch	96	-1.75	10.5	12.25				
Tree #2	54	White Birch	56	-2.75	8.5	11.25	2	Birch and Fir	85	
Tree #3	50	Yellow Birch	31	-2.25	11	13.25				

Table 8 - Data Collected (3)

	Circumference (cm)	Tree Species	Age (years)	Bottom Reading	Top Reading	Height (m)	Fallen Trees	Overall Speicies	Coverage (%)	Notes
Point 35										
Tree #1	75	Yellow Birch	54	-0.25	9.5	9.75				
Tree #2	51	Balsam Fir	41	-0.75	9	9.75	2	Birch and Fir	85	6 dead standing trees and young trees.
Tree #3	-	-	-	-	-	-				
Point 41										
Tree #1	48	Yellow Birch	52	-0.5	7.5	8				
Tree #2	193	White Pine	154	-0.25	17	17.25	3	Pine, Birch, and Fir	85	
Tree #3	61	Balsam Fir	38	0	13.5	13.5				
Point 36										
Tree #1	64	Balsam Fir	39	-4.25	8	12.25				
Tree #2	100	Yellow Birch	80	-3.75	6.75	10.5	3	Birch and Fir	80	
Tree #3	59	Balsam Fir	35	-2.75	6	8.75				
Point 30										
Tree #1	74	Mountain Ash	59	-3.75	10	13.75				
Tree #2	67	Yelllow Birch	45	-3.5	7.25	10.75	3	Birch and Fir	80	4 dead standing trees and bare land.
Tree #3	-	-	-	-	-	-				
Point 31										
Tree #1	39	Yellow Birch	87	-0.5	7	7.5				
Tree #2	79	Yellow Birch	38	-0.25	9	9.25	9	Birch and Ash	80	
Tree #3	63	Mountain Ash	66	-1.75	8.75	10.5				
Point 37										
Tree #1	87	Balsam Fir	51	-0.75	10	10.75				
Tree #2	80	Balsam Fir	33	-1.75	14	15.75	9	Birch and Ash	80	
Tree #3	58	Balsam Fir	29	-1.25	9	10.25				
Point 42										
Tree #1	70	Balsam Fir	46	-1.5	9	10.5				
Tree #2	48	Yelllow Birch	50	-1.5	7.5	9	2	Fir, Birch, and Ash	90	
Tree #3	67	Mountain Ash	80	-1.25	9	10.25				
Point 47										
Tree #1	61	Yellow Birch	59	-2	8.75	10.75				
Tree #2	54	Yellow Birch	64	-1.5	8	9.5	4	Birch, Fir, and Ash	75	
Tree #3	50	Yellow Birch	56	-2.25	6.5	8.75				
Point 43										
Tree #1	114	Balsam Fir	77	-0.5	15	15.5				
Tree #2	58	Balsam Fir	47	-0.25	12	12.25	1	Fir and Birch	75	
Tree #3	47	Balsam Fir	32	0.75	8.5	7.75				
Point 38										
Tree #1	63	Yellow Birch	65	-0.5	12.25	12.75				
Tree #2	76	Balsam Fir	53	0.5	11	10.5	1	Birch, Fir, and Ash	70	
Tree #3	48	Yellow Birch	62	-2	7	9				
Point 32										
Tree #1	84	Yellow Birch	56	-1.5	7.5	9				
Tree #2	81	Balsam Fir	34	-1.75	11	12.75	2	Birch, Fir, and Pine	75	Wet, grassy area.
Tree #3	180	White Pine	133	-0.75	15	15.75				
Point 33										
Tree #1	74	Balsam Fir	45	-6	7.75	13.75				
Tree #2	77	Balsam Fir	58	-5.25	5.75	11	3	Fir	60	
Tree #3	45	Balsam Fir	28	-5.5	0.75	6.25				
Point 39										
Tree #1	52	Yelllow Birch	32	-1	11.75	12.75				
Tree #2	93	Yelllow Birch	58	-1.25	17.25	18.5	3	Birch and Fir	80	
Tree #3	52	Balsam Fir	43	-1	11.5	12.5				
Point 40										
Tree #1	64	Yellow Birch	67	-10	3.5	13.5				
Tree #2	-	-	-	-	-	-	1	Birch and Fir	20	Bare land and 6 dead standing trees.
Tree #3	-	-	-	-	-	-				
Point 44										
Tree #1	81	Yelllow Birch	42	-2.5	7.75	10.25				
Tree #2	52	Balsam Fir	55	-2	6.75	8.75	5	Fir, Birch, and Ash	80	
Tree #3	64	Yelllow Birch	67	-1.25	14.25	15.5				
Point 55										
Tree #1	56	Balsam Fir	45	-3.5	10.75	14.25				
Tree #2	47	Balsam Fir	38	-3.5	6.5	10	5	Fir and Ash	80	Lots of young Balsam Fir.
Tree #3	52	Balsam Fir	40	-3.25	8	11.25				

Appendix B: Observed Species

Table 9 - Species Spotted on Site

Insects	Trees	Mammals	Birds	Understory
Wood Louse	Red Spruce	Deer	Bald Eagle	Lichen
Bee	Yellow Birch	Red Squirrel	Seagull	Fern
Moth	Paper Birch	Porcupine	Partridge	Aster
Woodchipper	Douglas Fir	Grey Squirrel	Eastern Pheobe	Golden Rod
Beetle	Mountain Ash	Black Bear	Crow	Northern Red Belt
Monarch Butterfly	White Pine	Frog	Osprey	Raspberries
Common Fly	Balsam Fir		Woodpecker	Moss
Mosquito			Heron	Thistle
Deerfly				Orange Jelly Spot
Stink Bug				Strawberries
Horsefly				Wild Mint
Hornet				Wood Sorrel
Spider				Old Man's Beard

Appendix C: Drone Imagery

Figure 35 - Drone Imagery of Ernie and Judy Edwards' House

Figure 36 - Drone Imager of Deadman's Head Forest (1)

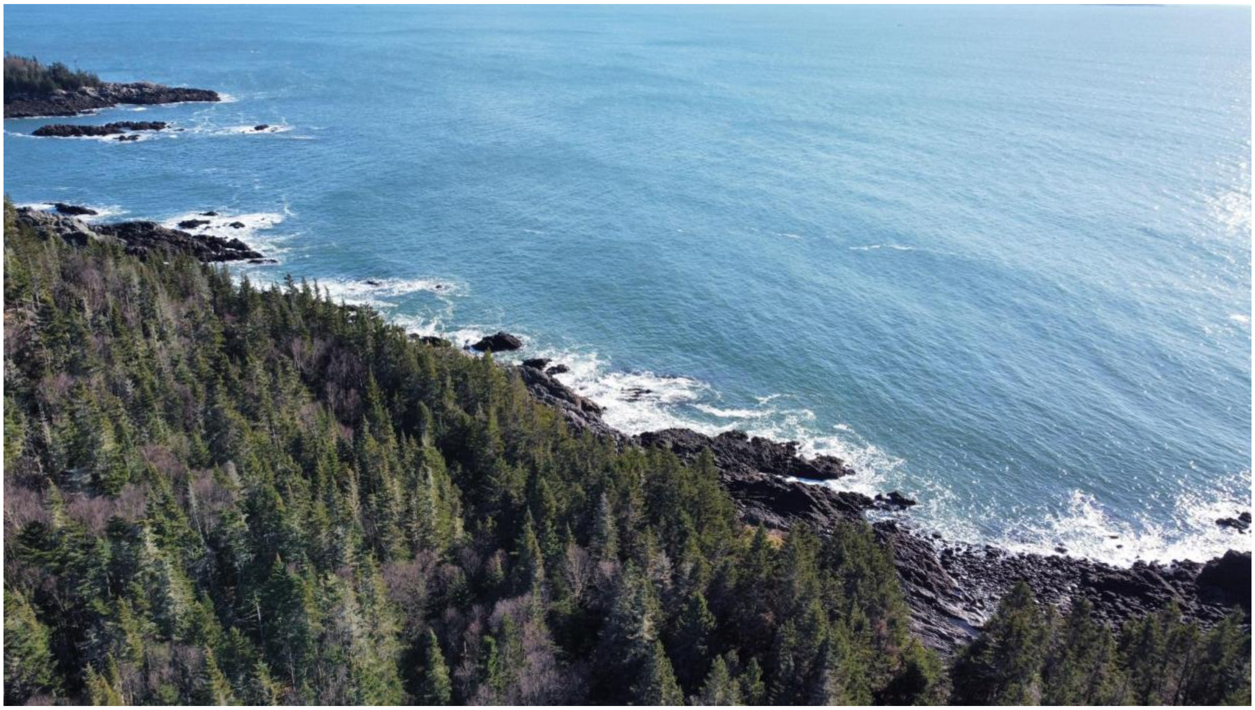

Figure 37 - Drone Imagery of Cliffs on the East Side of Deadman's Head Forest

Figure 38 - Drone Imagery of Deadman's Head Forest (2)

Figure 39 - Drone Imagery of the Tip of the Peninsula

Figure 40 - Drone Imagery of our Group