Survival and Regrowth: Assessing Red Oak Recovery After the 2023 Shelburne Wildfire

By

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A Thesis Submitted to
Saint Mary's University, Halifax, Nova Scotia
in Partial Fulfillment of the Requirements for
the Degree of Environmental Science

March 2025, Halifax Nova Scotia

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Date: April 25th, 2025

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Abstract

Wildfire disturbance events are increasing in both frequency and intensity across Canada. Historically, due to their proximity to the ocean, Maritime natural disturbances have been limited primarily to strong wind events such as hurricanes. However, climate models suggest an increased prominence in these provinces experiencing fire activity. Between May and June of 2023, three major wildfires were reported in Nova Scotia, affecting over 25,000 hectares of land. The biggest of which was located in Shelburne County. By the time this fire was completely extinguished, it had become the biggest wildfire in recorded Nova Scotian history. There is a need to understand how wildfire events affect the intricate dynamics of forest succession and forest health. Northern red oak (*Quercus rubra)* is the only native species of red oak found throughout Nova Scotia and possesses natural traits that make it more resistant to the damage caused by wildfire events. This study examined whether the natural traits of the red oak species yielded any favourable results on the survival and regrowth rates of red oak during secondary succession. Variables studied included char height, species density, and coppice regrowth. These variables were compared against red maple (*Acer rubrum*) and further towards plots of different fire intensities. The dead count for both species increased throughout the fire plots. When compared to different levels of fire intensity, greater fire intensity had a smaller effect on the dead count of red oak as compared to red maple. The fire plots not only were shown to have more coppice growth for both red oak and red maple, but also fire plots of greatest intensity were shown to have the most red oak coppice growth.

April 25th, 2025

Acknowledgements

This study would not have been possible without the help of the people from Mersey Tobeatic Research Institute (MTRI) who did the majority of the heavy lifting in the field sampling the twenty plots analysed for this study. Their high spirits in the field along with their efficiency despite difficult weather and cancellations propelled this study further. I would also like to thank Lucian Mustain and Jamie Ring from the Nova Scotia Department of Natural Resources for their continued support through the data analysis and writing process. Their dedication to the project throughout all hours of the day made me feel supported throughout this entire process. Lastly, I would like to thank and show all my appreciation to my supervisor, Dr. Peter Bush. Without him, this project would be nothing. Throughout the developmental process and well into the final stages, his time and feedback were critical to establishing a thorough research analysis that I could be proud of.

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1.0 Introduction

1.1 Climate of Nova Scotia

The forests of Nova Scotia are heavily influenced by the strong westerly winds which blow across the continent and converge with the warm North Atlantic Gulf Stream (Loo & Ives, 2003; Taylor et al., 2020). The mixing of these two currents is what creates the fluctuating weather patterns found in Nova Scotia. As compared to the centre of the country, Nova Scotia weather conditions are characterized by cool temperate summers with high levels of humidity and mild winters. The Maritime provinces as a whole, including New Brunswick, Prince Edward Island, and Nova Scotia, receive annually between 800-1500mm of precipitation each year, which is expected to increase 5%-10% over the next 50 years (Taylor & MacLean, 2025). Provincially, the average temperature is a cool 16.3°C within the summer months and -5.0°C in the winter (Steenberg et al., 2013). According to temperature records, these average temperatures have been on a steady rise since the 1960s. Between 1961 and 1990, the mean temperature was 6.0 ± 0.5 °C, whereas current data show an average temperature of 7.0 ± 0.5°C. An increase of 1.0°C across the province. Although specific regions of the province differ in their warming rates, data conclude that each region is warming in some regard between 0.5 – 1.5°C (Garbary & Hill, 2021). This trend is further observed in both New Brunswick and Prince Edward Island, where a temperature increase of 1.5°C has been documented for the 20th century (Garbary & Hill, 2021; Albert et al., 2023). Further projections for New Brunswick suggest that temperatures will increase by 4 - 6°C before the year 2100 (Albert et al., 2023).

It is worth noting that the maritime provinces are also affected by the natural long-term weather cycles known as the El Niño-Southern Oscillation (ENSO). ENSO is a long-term weather cycle occurring along the equator over the Pacific Ocean. As a result of unstable interactions between the tropical Pacific Ocean and the atmosphere, we experience two distinct weather patterns. (Fedorov & Philander, 2000). ENSO has two complementary phases, which bring about opposite weather conditions globally. Concerning Eastern North America, El Niño brings increased precipitation, increased storm activity, and milder winters. The complementary La Niña brings colder winters with more snowfall and drier summers (Fedorov & Philander, 2000). These weather patterns directly influence the year-to-year averages for both temperature and precipitation across the Maritimes.

1.2 Landforms, Topography and Soil

Nova Scotia was formed approximately 300 million to 500 million years ago as the result of the collision of the North American, African, and Eurasian tectonic plates (Loo & Ives, 2003). The collision of these three major plates created the Appalachian Mountain belt, which stretches nearly 3,200 kilometres from Alabama to the Canadian province of Newfoundland and Labrador (Britannica, 2025). The entirety of Nova Scotia falls within what was once this great mountain belt, much similar to the Rocky Mountains. However, 200 million years of erosion and successive glaciation events have significantly diminished this orogeny, reducing it to a landscape with far less pronounced topographical features (Loo & Ives, 2003). What remains is a landscape that offers only subtle traces of its long geological past. At its highest point, Nova Scotia reaches an elevation of 535 m within the Cape Breton Highlands (Taylor et al., 2020).

Glacial erosion has played a pivotal role in shaping much of Nova Scotia's landscape, giving rise to its lowland and highland regions, as well as distinctive landforms such as drumlins, terraces, and extensive till deposits (Loo & Ives, 2003). The bulk composition of Nova Scotia's parent material is derived from bedrock. Due to its coastal location, creating cool, moist soils, Nova Scotian soils are often found in podzolization. A naturally acidic soil as a result of organic acids leaching downwards and removing iron and aluminum, leaving a more acidic upper layer (Nova Scotia Museum, 1996). Moreover, leaching processes are more abundant under coniferous stands, which most of Nova Scotia soils have developed under (Nova Scotia Museum, 1996).

1.3 Forests of Nova Scotia

Local climatic and geographic variations in conjunction with vegetation groups denote nine ecoregions of Nova Scotia, shown in Figure 1. Each ecoregion is defined by its own set of unique characteristics. Notably, the coastal region, Atlantic Coastal (800), stretches up the entire Southeastern - Eastern coast of the province. This region is defined by its much cooler and moist climate and is exposed to the strongest coastal winds and windstorms (NSDNRR, 2021). The coastal region of Nova Scotia is also shown in particular to have relatively infertile and acidic soils (Taylor et al., 2020).

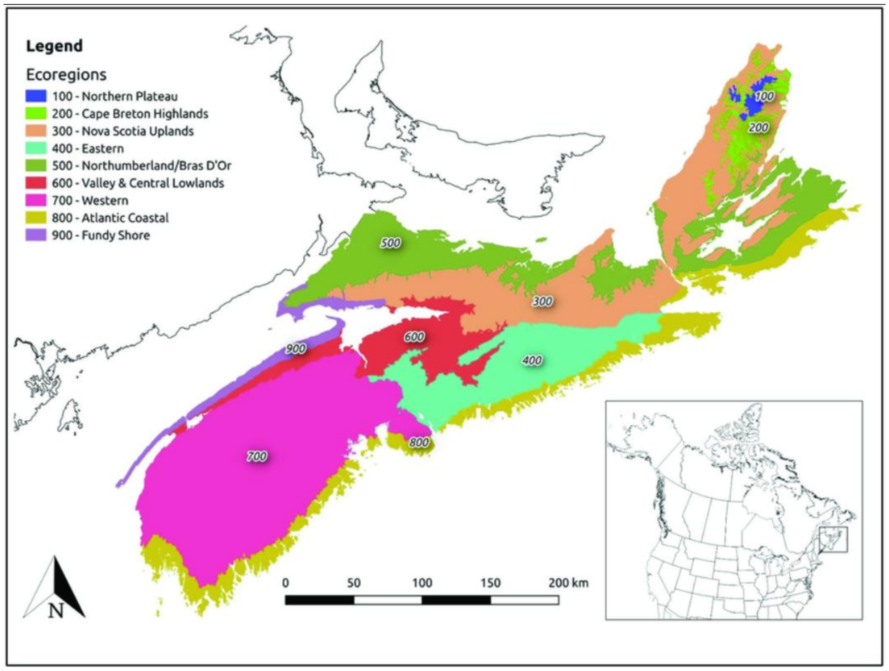

Figure 1: Map of Nova Scotia highlighting the nine ecoregions (Neily et al. 2017).

Nova Scotia contains two macroclimatic forest groups, the Acadian Forest Group and Maritime Boreal Forest Group (Neily et al., 2023). The Acadian Forest Group is a transitional zone characterized by rich biodiversity and features a strong mix of coniferous and deciduous species. Coniferous species, such as but not limited to, red spruce (*Picea ruben*), eastern hemlock (*Tsuga canadensis*), balsam fir (*Abies balsamea*), and white pine (*Pinus strobus*), account for 65% of the forest composition. Whereas deciduous species like yellow birch (*Betula alleghaniensis*) and sugar maple (*Acer saccharum*) account for 35%. Individual stands can vary in their coniferous–deciduous composition and can be found in abundance throughout all regions of the province (Loo & Ives, 2003; Albert et al., 2023). The Maritime Boreal Forest Group is primarily confined to the Atlantic Coastal and Cape Breton Highlands ecoregions, which are characterized by colder, wetter climates and, in the Cape Breton Highlands Region, higher elevations that support boreal forest stands (Taylor et al., 2020).

Nova Scotia's forests are predominantly composed of younger growth stages, reflecting a history of extensive harvesting, land clearing, and natural disturbances. In 2017, the Nova Scotian provincial government commissioned William Lahey to administer an Independent Review of Forest Practices in Nova Scotia. Results of his final report released in August of 2018 found that the province was not doing enough to protect and restore Old Growth Forests (Butt et al., 2022). His report outlined the need for forest practices to focus on including additional species, such as Northern red oak (*Quercus rubra*), in the climax species group (Butt et al., 2022; Lahey, 2018). Climax species dominate the stand composition in late succession and form what is known as climax communities. These climax communities have the longest ecological continuity, typically leading to conditions related to old-growth forests (NSDNR, 2012; Jones, 1945).

1.3.1 Red oak of Nova Scotia

Northern red oak, hereafter referred to simply as red oak, is the only species of oak native to Nova Scotia (Butt et al., 2022). Red oak plays a vital role in forest ecosystems by offering essential habitat for diverse flora and fauna, and it contributes significantly to food production through acorn yield and coppice growth. Moreover, red oak provides valuable carbon sequestration services and acts as a shelterbelt to wind and fire events (Choi et al., 2023; Nicolescu et al., 2020). Only 4% of forest stands in Nova Scotia are identified as having red oak. Of that, stands where red oak composition is greater than 50% only account for 0.25% of forested land in Nova Scotia (Butt et al., 2022). Stands of red oak can be found in each ecoregion of the province, typically in mixed stands or with other deciduous or coniferous trees (Nicolescu et al., 2020). Particularly, they are dominantly found in the Western (700) ecoregion of Nova Scotia (NSDNR, 2015; Figure 2). Red oak has been predominantly observed in areas subject to both frequent and infrequent disturbance regimes, with 82% of stands occurring within these conditions. The remaining 18% of red oak stands are associated with gap-phase disturbance dynamics (Butt et al., 2022).

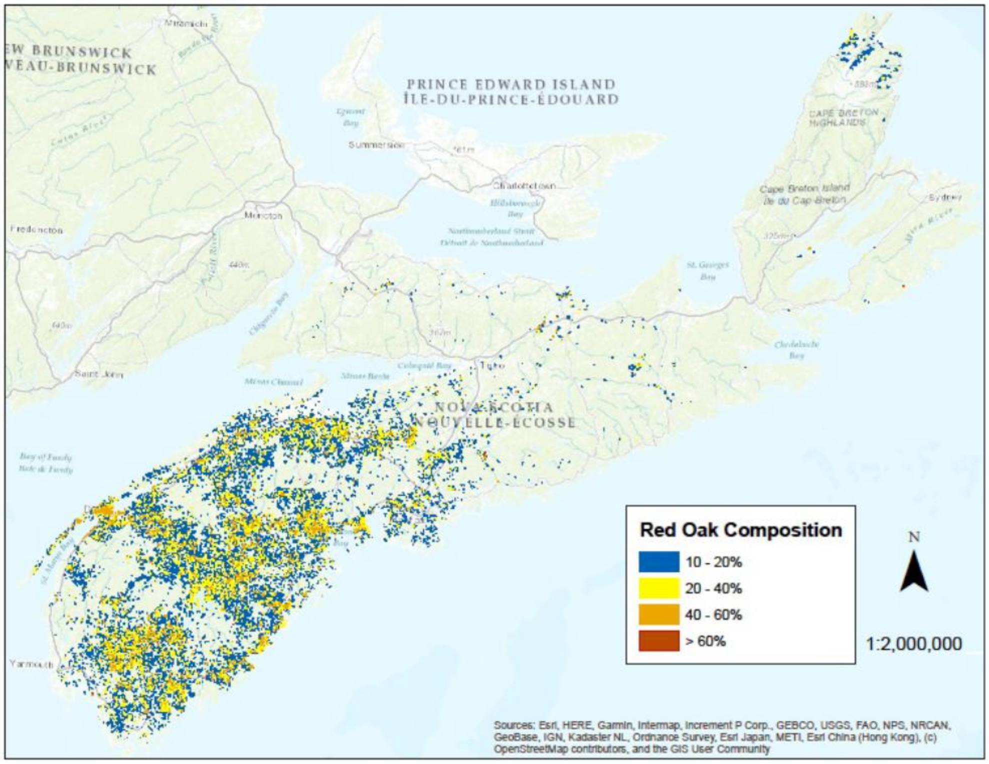

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Figure 2: Red oak distribution percentage across Nova Scotia, according to the provincial forest inventory database (NSDLF, 2020), taken from (Butt et al., 2022).

With natural disturbances becoming increasingly frequent in Nova Scotia, there is a growing need to prioritize tree species that demonstrate resilience to these changing environmental conditions. Red oak not only has established itself as resilient to natural disturbances, but it could also be a species that benefits from climate change (Steenberg et al., 2022). Compared to other tree species, red oak demonstrates a higher resilience to drought conditions and is less dependent on soils rich in nitrogen, phosphorus, and potassium, allowing it to grow on poor, sandy, and acidic soils (Nicolescu et al., 2020). As a seedling, red oak exhibits intermediate to moderate shade tolerance; however, as it matures, its ability to thrive in shaded conditions declines, making it increasingly shade-intolerant (Burns & Honkala, 1990). This poses the red oak further challenges in later maturity when trying to assert dominance in the canopy. However, during natural disturbances such as hurricanes and wildfire events, red oaks can withstand the damage inflicted by the event and in addition, gain an advantage in the subcanopy - canopy. This is due to its physiological adaptations such as a deeper tap root system which reaches 70 cm in depth. A deeper tap root system makes it resistant to both windthrow events and wildfire events (Nicolescu et al., 2020; Butt et al., 2022). In fact, wildfire events promote the advancement of red oak in ecosites. Research on prescribed burning indicates that fire can promote red oak regeneration. However, the success of this process is highly dependent on the frequency and severity of fire events (Choi et al., 2023; Knapp et al., 2015). Beyond its increased independence on water and nutrient resources relative to other species, red oak possesses notably thick bark and demonstrates superior resistance to decay following wildfire and scarring events. This process reduces canopy competition, enabling red oak to capitalize on increased light availability, promoting greater height and growth before transitioning into a more shade-intolerant species in maturity (Butt et al., 2022).

1.3.2 Intolerant Hardwoods and Red Maple

Red oak is commonly found with and shares similar characteristics with red maple (*Acer rubrum*). Both red oak and red maple are said to be early to mid-successional species (NSDNRR, 2021; Neily et al., 2022). Like red oak, as a seedling, red maple is moderately tolerant to tolerant with regard to shade conditions (Burns & Honkala, 1990). After small disturbance events, while the surrounding canopy closes and shade conditions increase around the area, red maple is unaffected and can even increase in prominence as a result of its shade tolerance (Burns & Honkala, 1990). Further, The Intolerant Hardwood (IH) forest type, particularly the IH2 forest type are understood to originate from largescale disturbance events, particularly fire (Butt et al., 2022). This forest type is abundant in both red oak and red maple.

1.4 Nova Scotia Fire History

The Maritime provinces are mistakenly overlooked for being at risk of fire activity. Despite the strong hardwood mix and naturally cool, moist environment of Nova Scotia, the province has an extensive history of wildfire. The fire regime of Nova Scotia has been significantly altered over the past centuries as

European settlers worked to establish land and railways through Canada (Taylor & MacLean, 2025). Before the arrival of European settlers in the 1600s, indigenous people had lived in the Maritime provinces for thousands of years. Historically, Indigenous people utilized fire for hunting, enhancing food resources, and warfare. Interviews with Mi'kmaq elders cite the use of fire for intentionally burning non-forested lands (Taylor & MacLean, 2025). Though the full extent of indigenous use of fire throughout Nova Scotia is substantially limited, studies conducted by Russell (1983), Parshall and Foster (2002), and Jourdy (2016) conclude that large-scale fires were primarily caused by lightning strikes and not indigenous people (Taylor & MacLean, 2025). Based on soil and charcoal samples taken from Kejimkujik National Park, only four fires of notable size have occurred over the past 6000 years, that being 250, 500, 800, and 1500 years before present (Taylor & MacLean, 2025). Annually, the percentage of forests disturbed by wildfire activity is between 0.17% and $0.4\% \cdot \text{year}^{-1}$ of forests. For a disturbance event of this size, moderate to high severity, the average return interval, the time between successive fires, in Nova Scotia ranges between 250-600 years.

Post European settlement and the establishment of agricultural practices in Nova Scotia is when changes in the forest composition can first be noticed (Wein & Moore, 1979). Several diaries from early European settlers remark on the occurrence of a large fire (>150,000 ha) in 1720, frequent fires in 1792, and another substantial fire (>175,000 ha) in 1800 (Taylor & MacLean, 2025). It was around this time that the population of Nova Scotia increased by 10,000 people, and it is best believed that wildfires were allowed to escape from land clearing operations due to a lack of fire suppression techniques at the time (Wein & Moore, 1979). Around this time, the advancement of sawmills throughout the province and the increased importance of timber as an economic resource led to the establishment of the first fire control legislation in 1761 (Wein & Moore, 1979). These were further developed in the late 1800s and early 1900s to become the Act to Prevent the Destruction of Woods, Forests, and Other Property by Fires in 1885, the Prevention of Forest Fire Act in 1913, and the Forest Fire Act in 1918 (Taylor & MacLean, 2025).

Current-day advancements in wildfire detection and suppression have greatly reduced the number of wildfires experienced by the province. From 1919 to 2018 there was an average of 330 fires each year with an average area burned of <500 ha.

1.4.1 Shelburne County Wildfire

In 2023, 15 million hectares of land in Canada were burned by wildfire activity, a new Canadian record, and a staggering increase of more than 800% from the 1.6 million hectares burned in 2022 (Government Canada, 2023; CIFFC, 2022). Projections for the coming 75 years estimate an increase in fire prominence of 25% by 2030 and a 75% increase by 2100 (Wotton et al., 2010). Further trends indicate that fire activity is no longer confined to Western provinces. Provinces less prone to fire activity, such as Ontario, Quebec, and the Maritime provinces, are experiencing increases in fire activity compared to years past**.** Nova Scotia's 2023 wildfire season was among the most catastrophic in history. Between March 15 and October 15, over 25,000 ha of land burned, surpassing the province's five-year average of 5,908 ha/year since 2019 by over fivefold (NSDNRR, 2023). The 2023 wildfire in Shelburne County is the largest wildfire reported in Nova Scotia's history. It was first reported on May 26th, 2023, and rapidly grew to over 23,000 ha by June 2nd, 2023. Fire suppression tactics were executed for more than two weeks, before the fire was called out in mid-June. Over the two-week duration, more than 25,000 hectares of land were burned, 200 homes were lost, and over 18,000 people were displaced (Calian Group, 2023). Figure 3 provides an overview of the extent of the wildfire perimeter.

In contrast, the 2024 wildfire report by the Canadian Interagency Forest Fire Centre indicates a notably subdued fire season, with only 81 fires recorded and a total of 47.7 hectares burned—the lowest wildfire activity in the past 17 years (CIFFC, 2024). However, counteracting the relieving wildfire season for Nova Scotia, there persists an ongoing drought throughout the province. As of February 28th, 2025, the majority of Nova Scotia is either abnormally dry (D0) or undergoing a moderate drought (D1), Figure 4 (Government Canada, 2024). While Nova Scotia's wildfire activity drastically declined in 2024, this reprieve is likely temporary (Wotton et al., 2003; Taylor & MacLean, 2025). Climate models conducted by Boer et al., (2000) indicate a heightened risk of extreme fire seasons in the future. Data from these models illustrate an increase in surface temperatures across the boreal forests of Canada. Shifts in temperature, precipitation patterns, and lengthened dry seasons, influenced by climate change, are expected to further intensify fire risks across Canada.

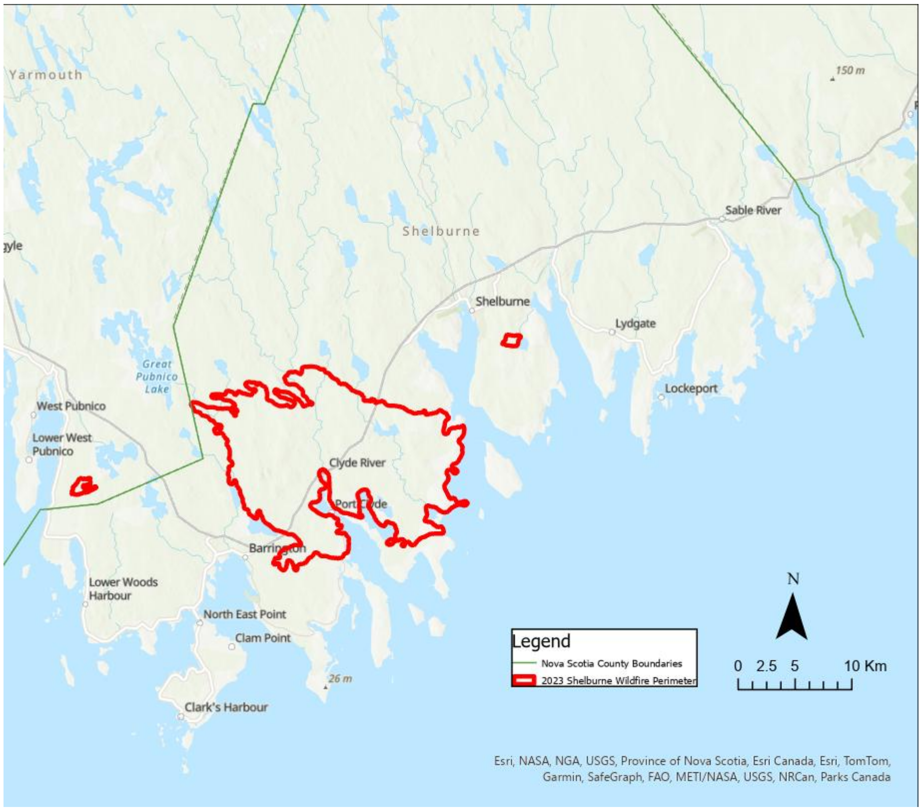

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Figure 3: Perimeter of the 2023 Shelburne Wildfire within Shelburne County

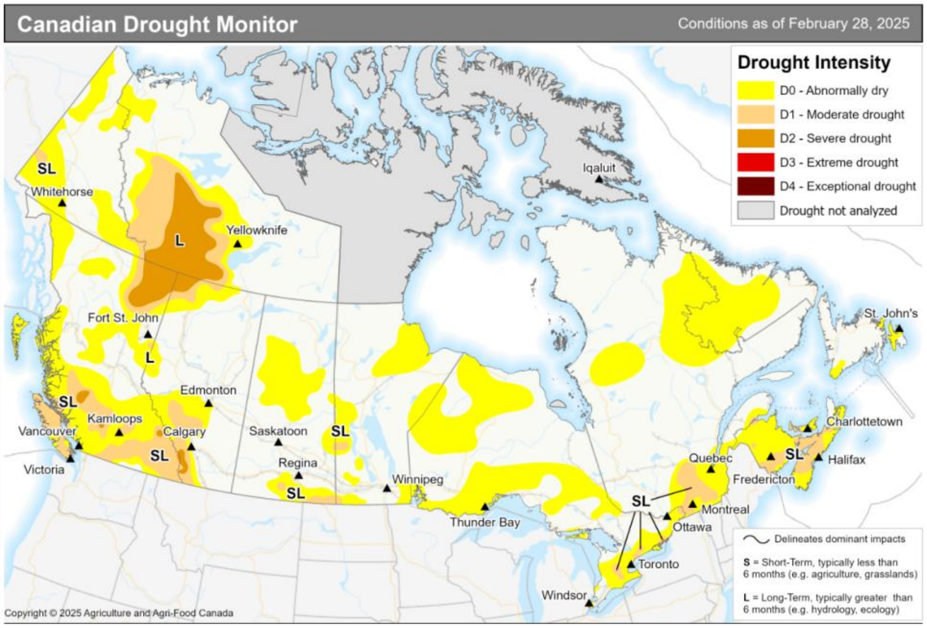

Figure 4: Canadian drought outlook as of February 28th, 2025. Taken from the Government of Canada Agriculture and Agri-Food Canada (Government of Canada, 2025)

1.5 Study Purpose and Objectives

Increases in wildfire activity across Nova Scotia will cause direct changes in the forest ecology throughout the province. This study aims to identify how the Shelburne wildfire has affected the population of red oak both within the area of the wildfire and its surrounding fire perimeter. This will be identified by comparing the impacts on red oak to a similar species, red maple. By doing so, the effects of the Shelburne wildfire can be determined through:

1. Examining how forest structure within the fire perimeter differs in stand composition, tree mortality and regeneration, compared to forest structure outside of the fire perimeter.
2. Examining how forest structure within different levels of fire intensity differs in stand composition, tree mortality and regeneration.

Conducting this research promptly is crucial to understanding the future of Nova Scotia's Forest ecology. This research will establish a fundamental knowledge base for future wildfire and forestry research as well provide insights into how specific species such as the northern red oak will respond to a changing ecosystem. Through this, a long-term framework can be established to monitor forest health and succession throughout the Shelburne area and further develop adaptive management of forestry practices and wildfire suppression techniques.

2.0 Methods

2.1 Site Descriptions

Shelburne County is located in the Western part of Nova Scotia. It exclusively falls within the Western (700) and Atlantic Coastal (800) ecoregions. Due to its proximity to their coast, this region experiences fluctuations in its day-to-day weather. Annually, it receives between 1300-1500 mm of precipitation per year (Neily et al., 2003). The Western region is a part of the Appalachian peneplain. Its geology is primarily Meguma slate and quartzite, as well as the granitic South Mountain batholith. The ecoregion has a topography that slopes gently towards the southeast coast and ranges between 25m and 289m in elevation at its maximum. The most abundant forest stands within this region are made up of red spruce (*Picea rubens*), eastern hemlock (*Tsuga canadensis*), and white pine (*Pinus strobus*). Other notable dominant trees include the fire species red oak (*Quercus rubra*) and red pine (*Pinus resinosa*). This region has been shaped by natural disturbances such as wildfire and blowdown. However, the presence of old-growth pine, hemlock, and spruce forests within this region implies the infrequency of large-scale stand disturbances (Neily et al., 2003).

The coastal region accounts for 5,532 km of the land in the province and stretches all along the Atlantic coast from Yarmouth to Scaterie Island, located just off the coast of Cape Breton. Despite the region making up 10% of the land in Nova Scotia, its width rarely exceeds 5km throughout the mainland. Black spruce (*Picea mariana*) and balsam fir (*Abies balsamea*) forests are the dominant forest stands throughout the region. Often, on nutrient-deprived soils along the eastern shore, balsam fir will form dense stands with trees of small diameter, indicating that conditions do not promote self-thinning. Within the black spruce and balsam stands, hardwoods such as red maple (*Acer rubrum*) and white birch (*Betula* *papyrifera*) play an important role in the understory. Other notable species include white spruce, which is most abundantly found in the more exposed locations of the region (Neily et al., 2003).

2.2 Experimental Design

This study utilized data from 20 distinct plots situated in Shelburne County, Nova Scotia. Of these, ten plots were positioned within the perimeter of the 2023 Shelburne wildfire, while the remaining ten were located just beyond the area affected by the wildfire (Figure 5). The FEC states that the Acadian Forest Region contains four primary vegetation types that red oak forest stands can be categorized into, as shown in Table 1. Which can be further narrowed down to being primarily found in ecosites Acadian 5 (AC5), Acadian 6 (AC6), and Acadian 7 (AC7). Due to the location of the fire, the primary vegetation type where red oaks were most abundant was Intolerant Hardwood 1a (IH1a; Large-tooth aspen / Lambkill / Bracken (Red Oak Variant)) and Intolerant Hardwood 2 (IH2; Red oak – Red maple / Which Hazel). Sites that contained these vegetation types were selected by utilizing the GIS forest inventory layer (NSDLF, 2020), predictive ecosystems mapping layer (PEM), which identifies and divides the land according to climate, physiography, surficial material, bedrock geology, soils, and vegetation (Government of British Columbia, 2011). This study also used updated satellite imagery and the previous fire history database (NSDRR, 2024; NBAC, 2024). First, Google Earth was utilized to navigate a 3D rendering of the study area to assess for the presence of red oak. To accurately isolate red oak, the imagery was set to October 2015—a period in late fall when surrounding deciduous species, such as red maple, had shed their leaves, while red oak foliage remained visible in the canopy. This approach enabled the identification of red oak stands before field assessment. Locations exhibiting a significant red oak presence were marked, and their easting and northing coordinates were recorded for further analysis. Successful points that were within ecosites AC5, AC6, or AC7 were added to a list for further selection. Lastly, sites were further selected based on accessibility. Sites chosen needed to be accessible via car or helicopter to reduce hiking time and increase efficiency within the field.

Table 1. Red oak primary ecosite locations and associated vegetation types (VT) and soil types (ST) from the Nova Scotia Forest Ecosystem Classification Guide (Neily et al. 2023)

Forest Type	Vegetation Name	Vegetation Code	Soil Type	Ecosite
Intolerant Hardwood	Large-tooth aspen/ Lambkill/ Bracken (Red oak variant)	IH1a	1, 15, 15C, 15L	5 (+/-)
			2, 2C, 2L, 5, 5C, 16, 16C, 16	6 (+/-)
			3, 3C, 3L, 6C	7 (+)
Intolerant Hardwood	Red oak – Red Maple / Witch hazel	IH2	1, 15, 15C, 15L	5 (+/-)
			2, 2C, 2L, 5, 5C, 16, 16C, 16	6 (+/-)
			3, 3C, 3L, 6C	7 (+)
Mixedwood	Red oak - White pine / Teaberry	MW11	1, 15, 15C, 15L	5
			1, 2, 2C, 2L, 5, 5C, 15L, 16, 16C, 16L	6 (+/-)
			3, 3C, 3L, 6, C, 14U, 16L	7 (-)
Tolerant Hardwood	Red oak – Yellow birch / Striped maple	TH6	1, 15, 15L, 17	9
			2C, 15L, 16, 16L, 18	10
			3C	11
			2, 2L, 5, 5C, 8, 8C, 11	13 (-)
			3, 3L, 6, 6C, 9, 9C, 12	14 (-)

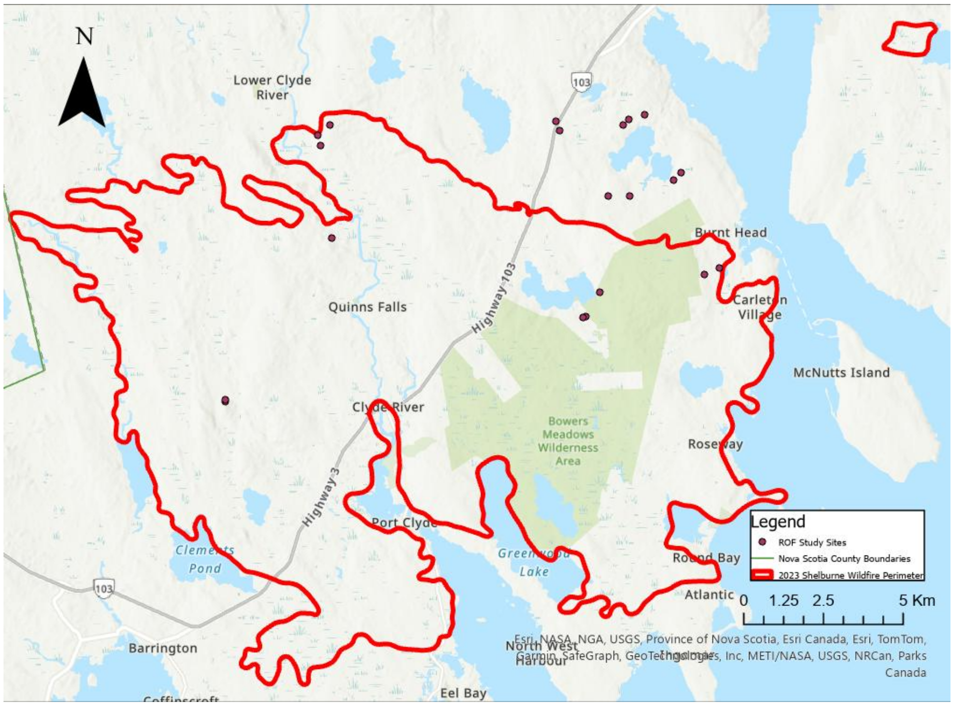

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Figure 5: 2023 Shelburne Wildfire perimeter with ROF study locations

2.3 Site Sampling

Each plot site consisted of five components: canopy tree plot, sub-canopy plot, regeneration plot, coarse woody material (CWM), and a soil sample. Each plot was sampled using the Next Generation-Canadian Forest Fire Danger Rating System (NG-CFFDRS) (Boucher et al., 2022) field sampling protocols for forest fuels (Figure 6). At each site, first, the geographic location of each site was recorded using easting and northing coordinates, and each plot was labeled with a unique Plot ID on a tally sheet. At the plot center, a wooden stake was placed and labelled with the Plot ID and the sampler's name. If the plot marker is removed or lost, four witness trees surrounding the stake were marked at their bases with orange spray paint. Site-specific conditions were documented on the tally sheet, including elevation, exposure, slope, slope length, slope position, aspect, crown closure, and drainage class.

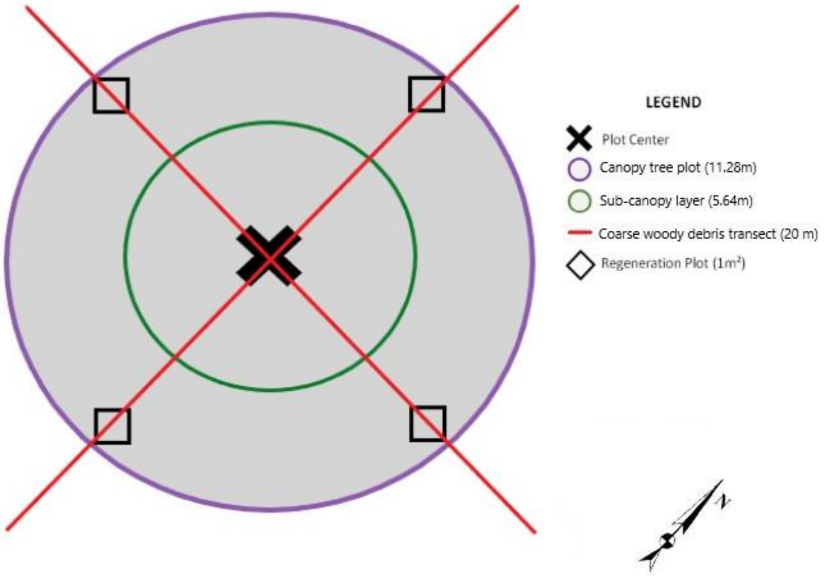

Figure 6: Outline of the nested field sampling methodology, including canopy tree plot, sub-canopy layer, coarse woody material transects, and regeneration plots. Modified based on NG-CFFDRS (Boucher et al., 2022) field sampling protocols for forest fuels.

2.3.1 Canopy Tree Plot

A circular canopy tree plot with a radius of 11.28 m^2 was created using a measuring tape. Starting at magnetic North and moving clockwise from the plot center, trees with a diameter at breast height (DBH) $\geq$ 9.1 cm were tagged with metallic nails and numbered. Data recorded for each tree included: Tree number, species, status (alive or dead), DBH, canopy position, crown density, damage code, bark char severity (if applicable), maximum bark char height (if applicable) (Figure 7), decay classification (for snags only), and coppice growth presence, which is a trees natural ability to stimulate new sprouts or stems from its base after being damaged. Additionally, two species that were dominant or co-dominant in the overstory were selected for core sampling. For these trees, their DBH and height were recorded along with their species type and tree number.

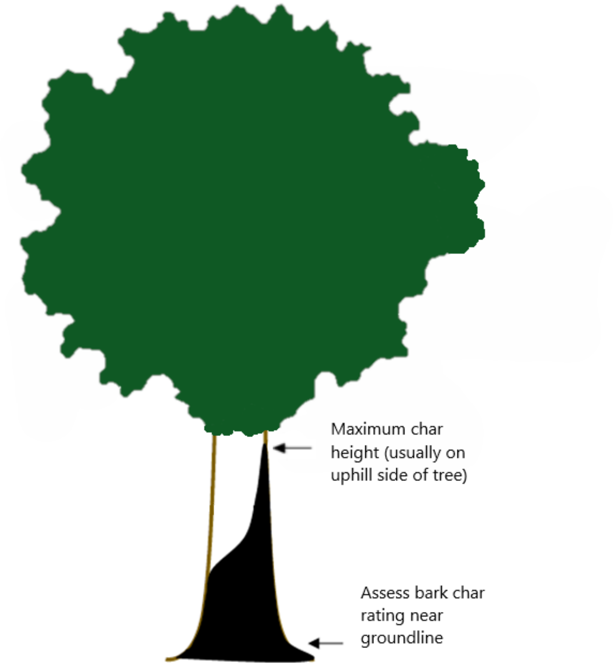

Figure 7: Example of how to assess max bark char height and bark char rating. Modified based on Hood et al., 2021 assessment of conifer trees.

2.3.2 Sub-Canopy Plot

A sub-canopy plot with a radius of 5.64 m^2 was established to assess vegetation that was greater than 31 cm in height but less than 9.0 cm DBH. Data collection followed the same methodology as the canopy plot and included: species, status (alive or dead), damage assessment, presence of coppice growth, stem count (alive or dead), and height class (31–130 cm, 131–400 cm, 401–700 cm, or ≥ 700 cm).

2.3.3 Coarse Woody Material (CWM)

To measure coarse woody material, a fixed linear intersect grid was established. Four 10-meter transects were extended in the North, South, East, and West directions from the center stake. Coarse woody material intersecting the grid or leaning ≥ 45° over the transect line with a DBH ≥ 9.0 cm was recorded. Information recorded included species, diameter at the intersection point, and decay class.

2.3.4 Regeneration Plots

Four 1 m × 1 m regeneration plots were positioned at the 5 m point along the linear grid. Within each plot, vegetation ≤ 30 cm in height was assessed. Forest debris, such as dead leaves and branches, was carefully cleared before data collection to expose any hidden vegetation. Vegetation was grouped into two height classes (1–5 cm and 6–30 cm), and tree seedlings were categorized by regeneration method (seed or coppice).

2.4 Statistical Analysis

Field results were transcribed by hand into three Excel sheets: tree data, subplot data, and regeneration data. These were later converted into CSVs for data analysis. To gain a broader understanding of how the population density of red oak and red maple varied between control and fire research plots, the total number of individual trees recorded was converted to a number of stems/ha. Because each plot accounted for 0.04 ha tree count was multiplied by 25. This way, each tree would represent 25 stems/ha. This accounted for multi-stemmed species and provided a clearer picture of species density and distribution. Similarly, coppice growth was multiplied by 100 to properly account for the density of coppice/ha. Utilizing the statistical software program R-Studio (R Core Team, 2022), Q-Q plots were constructed to visualize the relationships between red oak and red maple to the desired variable (see Appendix). Variables such as stem density, basal area, coppice growth, and char height were tested for normality to determine whether the mean was an appropriate measure of central tendency for each dataset. When Q-Q plots did not produce conclusive visual relationships, a Shapiro-Wilk test was used to assess whether each variable followed a normal distribution. While the test itself provides a statistical measure of normality, a normal distribution is generally characterized by a bell-shaped curve in which approximately 68% of values fall within one standard deviation of the mean.

Normalcy was converted into a p-value for numeric representation and later utilized for further tests. According to the P value generated from the Shapiro-Wilk test, T-tests were employed if the p-value was greater than 0.05 ($p > 0.05$) and a Mann-Whitney U test was used if the p-value was less than or equal to 0.05 ($p \leq 0.05$). After these tests were completed, relationships between variables were measured using graphing options such as scatter plots and box plots. To improve efficiency in code generation and repetition, the use of AI was emphasized.

3.0 Results

3.1 Compositional Differences Between Fire and Control Plots

A comparative analysis of forest structure between control plots and the fire plots reveals no significant compositional differences. All sites chosen for this study consisted of strong hardwood presence and can be deduced to be an Intolerant Hardwood Forest type and a variation of AC5, AC6, or AC7. Table 2 provides a summary of forest stand composition with regard to basal area. Each plot type consisted of the same tree species with only minor differences in compositional variation. One exception is the identification of Tamarack (*Larix laricina*), which had only been found in the control group. This analysis focused primarily on red oak and red maple. Table 3 summarizes the key variables analysed between red oak and red maple throughout the study area. Red maple was the most frequently occurring species across both control and fire plots, with a total of 347 occurrences. Of these, 213 were identified within the control plots, while 134 were found in the fire plots. The second most abundant tree species found throughout the study was red oak, occurring a total of 310 times, 205 times within the control plots and 105 times within the fire plots. Despite red maple being more abundant in tree count and stem count, in both the control and fire plots, red oak had a greater average basal area, leading to a greater total basal area coverage throughout the plots. Throughout the control plot, red oak had a total basal area coverage of approximately 5.43 m^2/ha, whereas red maple covered approximately 3.63 m^2 /ha. The fire plots had similar results, total red oak coverage of 5.27m^2/ha compared to 3.43m^2/ha for red maple. So, despite red maple being the most abundant throughout the study, red oak accounted for the most basal area per hectare.

Table 2. Comparison of basal area, live stem density, and dead stem density among tree species in control and fire-affected plots within the 2023 Shelburne Wildfire study area.

	CONTROL			**FIRE**		
Species	**Basal Area (m^2/ha)**	**Live Stems / ha**	**Dead stems / ha**	**Basal Area (m^2/ha)**	**Live Stems / ha**	**Dead Stems / ha**
Red Oak	135.69	3,875	1,100	131.85	1,775	700
Red Maple	90.83	5,050	250	85.80	2,150	1,175
Balsam Fir	13.30	600	250	29.82	325	1,350
Black Spruce	1.94	125	25	9.16	0	275
Tamarack	3.48	50	25	NA	NA	NA
White Birch	5.53	200	0	17.84	275	350
White Pine	9.34	525	50	0.55	0	50
Unknown	2.04	0	0	2.57	0	50
Total	**262.15**	**10,425**	**1,700**	**277.59**	**4,525**	**3,950**

Table 3: Summary statistics of red oak and red maple between stands

	Control Plots				**Fire Plots**			
	Red Oak		**Red Maple**		**Red Oak**		**Red Maple**	
	Mean	**Sd**	**Mean**	**Sd**	**Mean**	**Sd**	**Mean**	**Sd**
Basal Area / tree (m^2/ha)	0.665	0.405	0.4264	0.254	1.256	0.963	0.640	0.554
DBH (cm)	17.63	5.28	14.22	3.86	23.47	9.46	16.19	6.4
Live Stems / ha	387.5	96.64	505	204.4	253.57	151.67	268.75	249.55
Dead Stems / ha	110	84.32	50	17.67	87.5	48.18	130.5	119.75
Coppice / ha	480	1,483	1,290	1,559.5	5,850	6,430.7	5,090	6,710.8
Char Height (cm)	-	-	-	-	145.85	150.4	120.53	93.46

Sample basal area quantiles were compared to theoretical quantiles using a Q-Q plot to visually inspect for normality and are included in the appendix. A Mann-Whitney U test determined that the red oak mean basal area between plot types was significant. Comparison between the control plots and fire plots produced a p-value < 0.0001. The box plot in Figure 8 further supports this result, showing a clear separation between the median values of the two groups and minimal overlap between their interquartile ranges. This indicates a distinct difference in Red Oak basal area between the plot types. A similar result was replicated in the comparison of red maple basal area between plot types. Comparison in basal area using a Mann-Whitney U test produced a p < 0.001, shown in Figure 9. Similar to the results of red oak, the box plot for red maple had a non-overlapping median and a poor overlapping interquartile range.

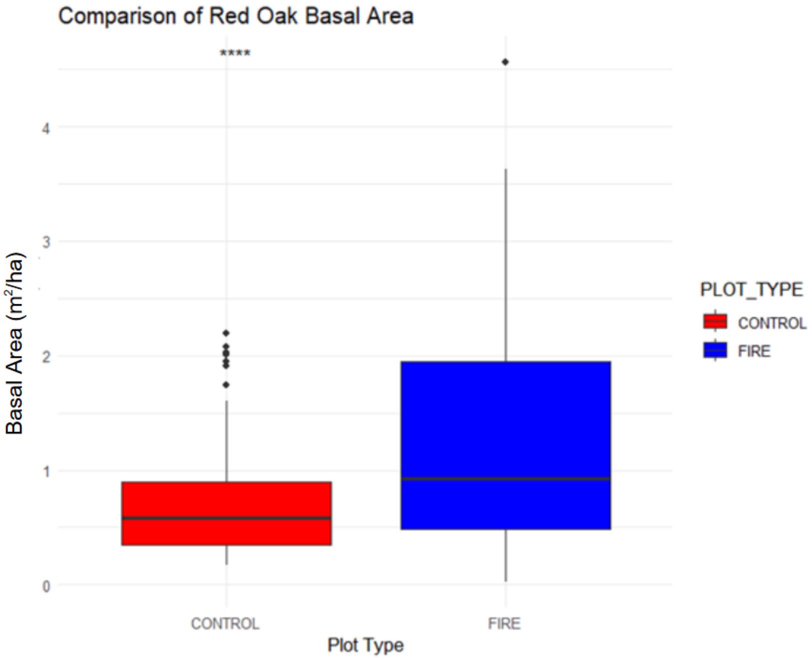

Figure 8: Variation in the basal area of red oak in control plots and fire plots across the 2023 Shelburne Wildfire study location

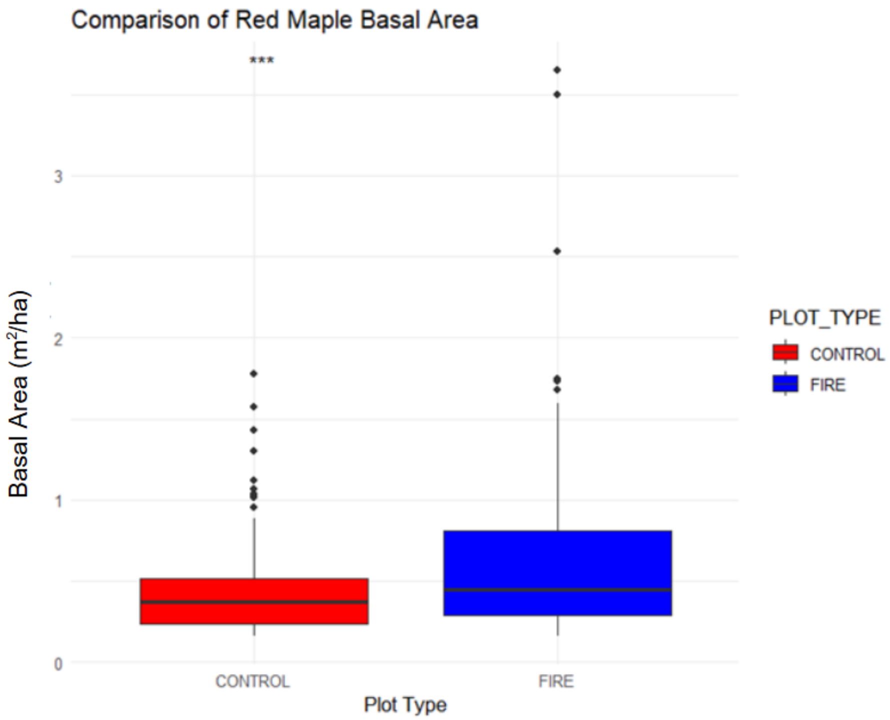

Figure 9: Variation in the basal area of red maple in control plots and fire plots across the 2023 Shelburne Wildfire study location

3.1.1 Differences in Red Oak and Red Maple Density

Since stems/ha is directly correlated with the tree count of a specific species, red maple stems were more abundant across the study area. Within both the control plots and the fire plots red maple were the most abundant tree species. Throughout the control plots, red maple ranged from 250 stems/ha at its lowest to 825 stems/ha at its greatest. On average, the density of red maple was 532.5 stems/ha. Red oak was the second most abundant tree species throughout the study area. Within the control group, red oak ranged from 350 stems/ha at its lowest to 650 stems/ha at its greatest. On average, the density of red oak was 512.5 stems/ha. With regard to the fire plots, for both red oak and red maple, there is a clear decrease in the density of each species. The density of red maple ranged from 75 stems/ha to 750 stems/ha, averaging 335 stems/ha. Whereas the density of red oak ranged from 75 stems/ha to 500 stems/ha.

Throughout the study, both living and dead red oak was recorded 310 times, while red maple was identified 347 times. Interestingly, when isolating for specific tree mortality status, living or dead, red oak has a smaller living species density and a greater dead tree density than red maple. Both dead red oak and dead red maple had a reasonably small sample size over the study area. The total sample size for dead red oak over the study area was 68 trees, of which 40 were found within the control plot. Dead red maple, on the other hand, had a sample size of 56 trees, only nine of which were found in the control plot. Converting to stem density, the average living tree density for red oak was 387.5 stems/ha, while red maple has a higher average living density of 505 stems/ha. Conversely, red oak has a greater average density of dead trees at 100 stems/ha, whereas red maple has a lower average dead tree density of 41.6 stems/ha.

However, for both tree species, the fire plots had a noticeable reduction in stems per hectare. Red maple had been reduced to an average of 335 stems/ha, and red oak 291.6 stems/ha. Fire Plot 2 was left out of this calculation as it did not have any red oak present. But in this instance, red oak had a smaller living species density and a smaller dead tree density than red maple. Red oak living density in the fire plots was 253.57 stems/ha compared to red maple living density of 268.75 stems/ha. Meanwhile, red oaks' dead density for the fire plots was 87.5 stems/ha, whereas red maple had a dead density of 130.5 stems/ha.

The difference in the live count between red oak control and fire was significant ($p = 0.03$), and the difference in live count between red maple control and fire was not significant ($p = 0.08$) (Figure 10). This process was repeated with a focus on the dead count of each species. The difference in red oak dead count remained significant ($p = 0.02$), and red maple remained insignificant ($p = 0.05$) (Figure 11).

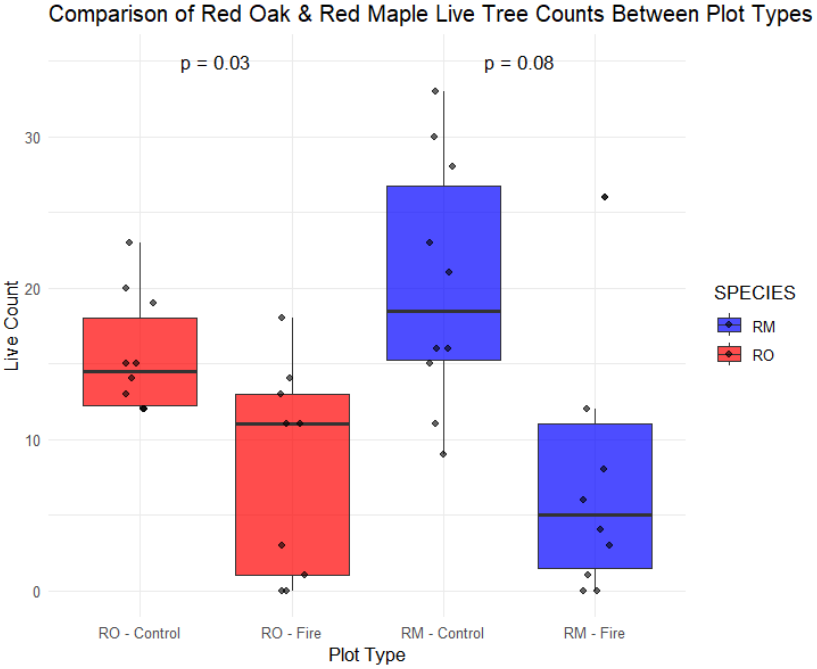

Figure 10: Box plots comparing density of living red oak and red maple between plot types

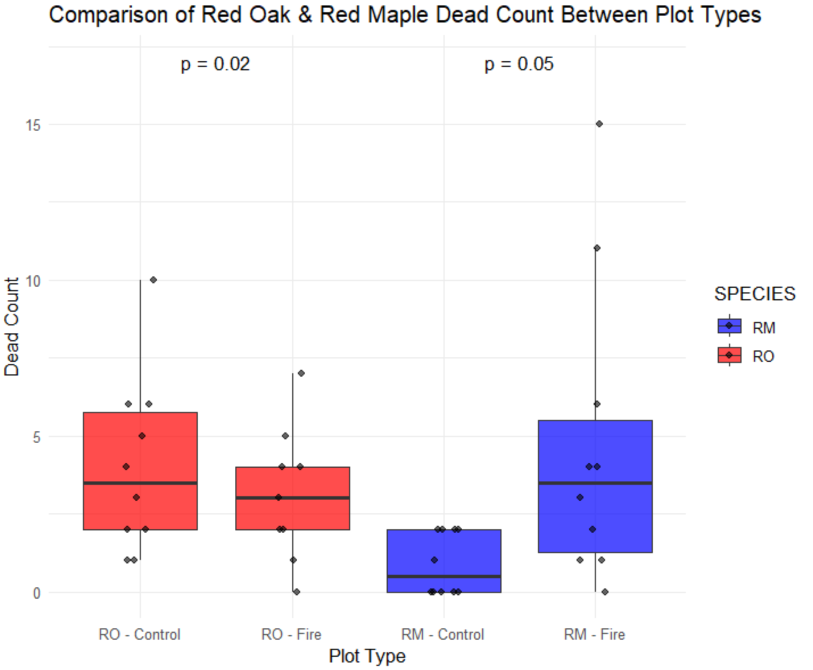

Figure 11: Variation in red oak mortality (left) and red maple mortality (right) in control plots and fire plots across the 2023 Shelburne Wildfire study location

3.2 Regeneration Differences Between Fire and Control Plots

3.2.1 Red Oak

To compare the red oak regeneration between the control plots and fire plots, coppice growth was converted to coppice stems/ha by multiplying the stems found by 100. There was a significant difference in the abundance of red oak coppice growth found between the control and fire plots. Throughout the control group, the average coppice growth was 480 stems/ha. However, only two plots, Control 7 and Control 9, were identified as having red oak coppice growth present. Between these plots, only 4800 coppice stems were identified, 4700 of which were present in Control 9. On the other hand, fire plots were shown to have more than 10 times more red oak coppice growth than control plots. In total, fire plots were shown to have an average coppice growth of 5,850 stems/ha, ranging from zero stems in Fire 2, Fire 4, and Fire 8 to a maximum of 178 stems in Fire 6 (Table 4). Because the control group only had two data points, a Q-Q plot to assess for normality would be redundant. Two data points are not enough to visualize any kind of visual pattern. This problem continues when creating a box plot to compare red oak coppice between the control and fire plots. The box representing the control plot is unable to represent the spread of the data, and the interquartile range is obsolete.

Table 4: Accumulation of red oak and red maple coppice growth throughout plot locations within the 2023 Shelburne Wildfire study location

Plot Name	Red Oak Coppice / ha	Red Maple Coppice / ha	Total Live Coppice / ha	Fire Intensity
Control 1	0	0	0	NA
Control 2	0	1,600	1600	NA
Control 3	0	0	0	NA
Control 4	0	0	0	NA
Control 5	0	0	0	NA
Control 6	0	0	0	NA
Control 7	100	3,800	3,900	NA
Control 8	0	1,200	1,200	NA
Control 9	4,700	3,500	8,200	NA
Control 10	0	2,800	2,800	NA
Total	**480**	**1,290**	**1,770**	**NA**
Fire 1	5,600	10,700	16,300	Less Intense
Fire 2	0	2,100	2,100	NA
Fire 3	2,900	1,000	3,900	Less Intense
Fire 4	0	0	0	Less Intense
Fire 5	15,200	0	15,200	More Intense
Fire 6	17,800	6,900	24,700	More Intense
Fire 7	7,400	7,200	14,600	More Intense
Fire 8	0	1,900	1,900	Less Intense
Fire 9	1,200	2,200	3,600	Less Intense
Fire 10	8,400	0	8,400	More Intense
Total	**5,850**	**3,200**	**9,070**	Less Intense

3.2.2 Red Maple

Compared to red oak, the control sites for red maple were shown to have more abundant coppice stems present. Red maple coppice was more abundant within individual plots and was also distributed across a greater number of plots. The average coppice growth for red maple across the control plots was 1,290 stems/ha. Over the control plots, five out of ten of the plots were shown to have coppice, which ranged from 120 stems in Control 8 to its maximum of 380 stems in Control 7. Fire plots were shown to have a substantial increase in red maple coppice growth. The average coppice growth for red maple across the fire plots was 3,200 stems/ha, almost 2.5 times more than the control plots. Seven out of the ten plots were shown to have coppice ranging from 100 stems in Fire Plot 3 to 1070 in Fire Plot 1. A box plot analysis shows that red maple coppice distribution was statistically not significant (p = 0.2114) (Figure 12).

3.2.3 Comparison in Red Oak Coppice Growth to Red Maple

When comparing the rates of coppice growth, the two species alternate in abundance based on plot type. Red oak has a smaller coppice density per hectare in the control plot, 480 stems/ha, compared to 1290 stems/ha red maple. Red maple has a higher coppice abundance by over 2.5 times in the control group. However, in the fire plots red oak coppice density is 1.8x greater than that of red maple. Compared to the control plots red oak coppice density grew more than 12 times greater in the fire plots. Red oak has a coppice density of 5,110 stems/ha as compared to 3,200 stems/ha of red maple.

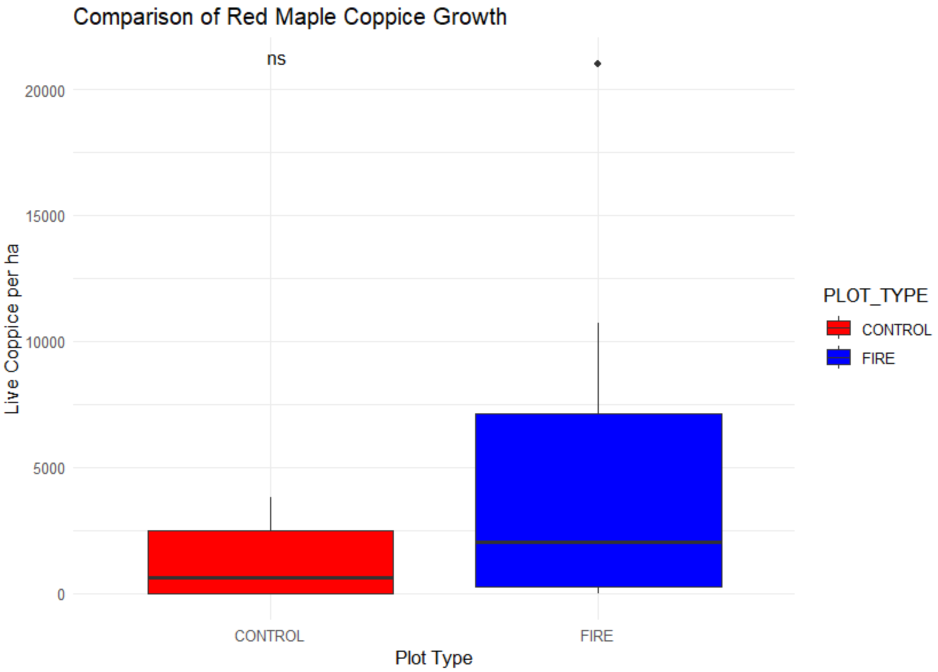

Figure 12: Variation in red maple coppice growth in control plots and fire plots across the 2023 Shelburne Wildfire study location

3.3 Differences in Fire Behaviour at Plot Level

3.3.1 Fire Intensity

Char heights for all species were graphed using a scatterplot and grouped according to plot identification and respective char heights (Figure 13). This data was later averaged to find the mean char height of a species per plot (Figure 14). When comparing the average char heights for softwood and hardwood species, softwood species had the greatest char height. Over each of the plots, each of the softwood species had a greater char height than red oak and red maple. However, the hardwood species white birch had the second highest char height, only being beaten by the unknown softwood species that was too charred to be identified (Figure 15). Because this study focuses on red oak and red maple, fire intensity categories were determined according to the mean char height for red oak across the respective plots. All fire plots were classified into two intensity levels based on average char height: (1) Less Intense, for plots with an average char height of 1 m or less, and (2) More Intense, for plots where char height exceeded 1 m (Table 5). Average char height for red oak throughout the fire plots ranged from 0m at its lowest in Fire Plot 4 to its highest of 5.43 m in Fire Plot 10; mean char height throughout the plots was 1.46m. Fire Plot 2 was excluded from this calculation as there were no red oaks present throughout the plot. Overall, a total of five plots were classified as Less Intense and had an average char height of 30.96 cm, and four plots were More Intense with an average char height of 289.46 cm (Figure 16).

Table 5: *Fire intensity categories for fire plots within the 2023 Shelburne Wildfire study location. Fire 2 did not contain any red oak and was not categorized.*

Plot Name	Average Char Height (M)	Fire Intensity
Fire 1	0.40	Less Intense
Fire 2	NA	NA
Fire 3	0.46	Less Intense
Fire 4	0	Less Intense
Fire 5	2.9	More Intense
Fire 6	2.1	More Intense
Fire 7	1.2	More Intense
Fire 8	0.23	Less Intense
Fire 9	0.46	Less Intense
Fire 10	5.43	More Intense

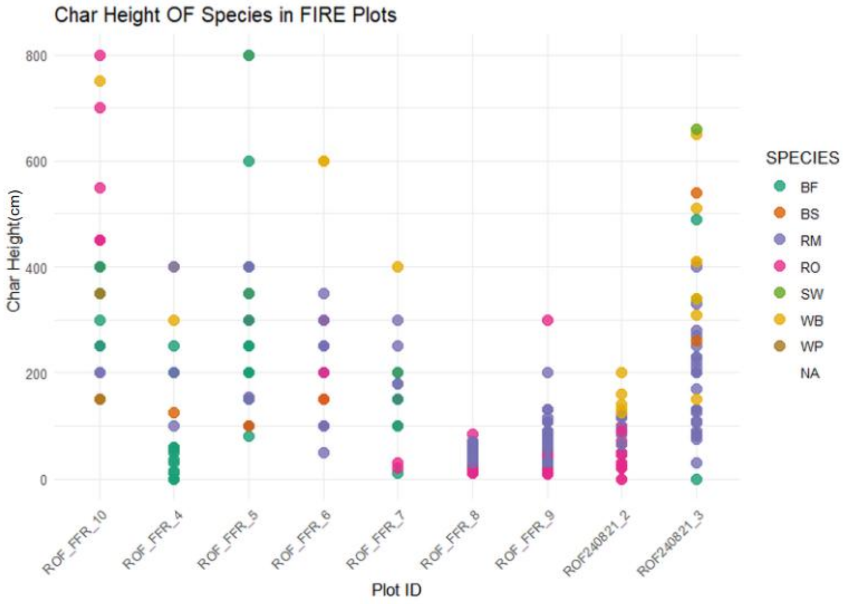

Figure 13: Char heights of species across fire plots of the 2023 Shelburne Wildfire.

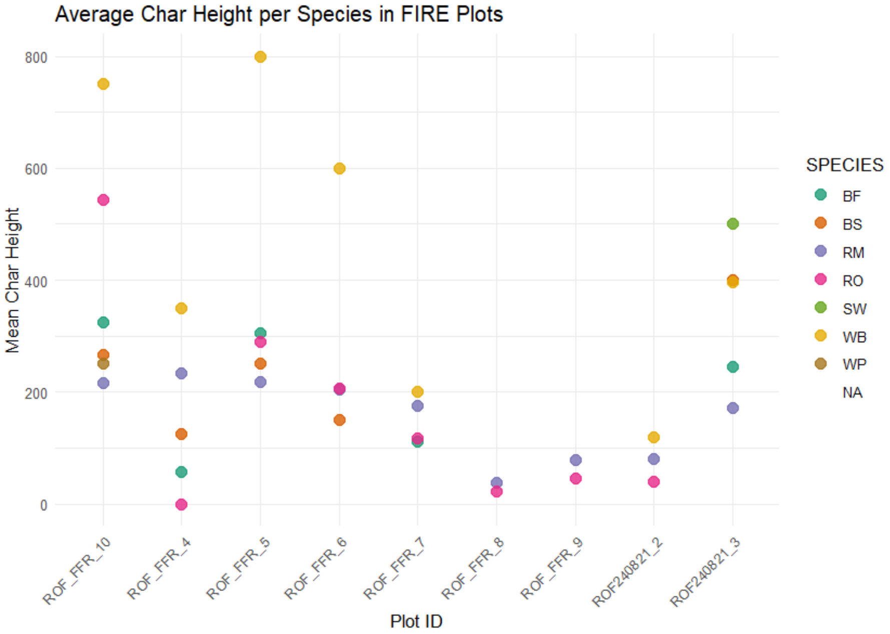

Figure 14: Average char height of species across fire plots of the 2023 Shelburne Wildfire.

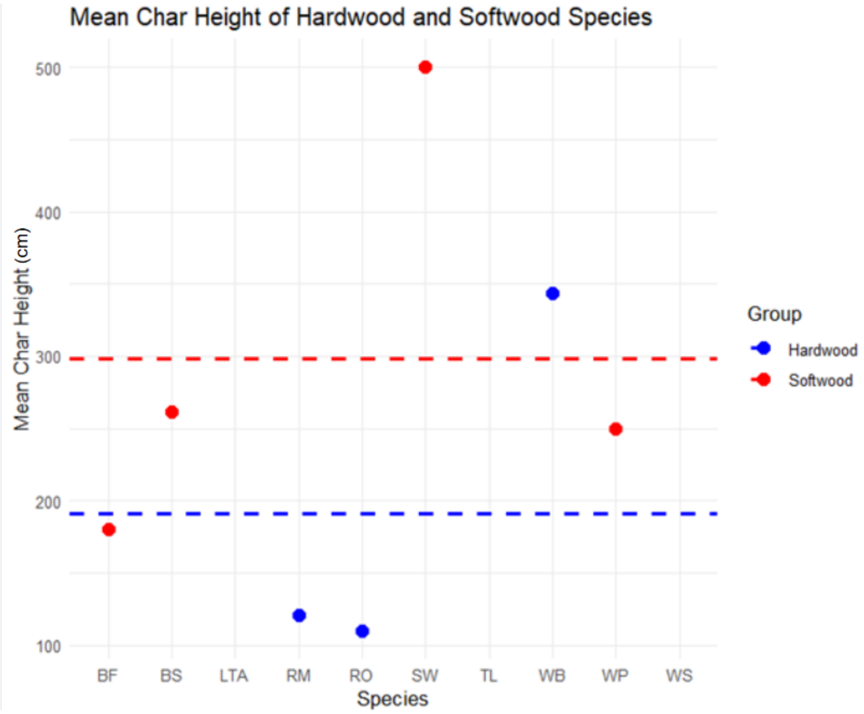

Figure 15: Average char height of hardwood and softwood species.

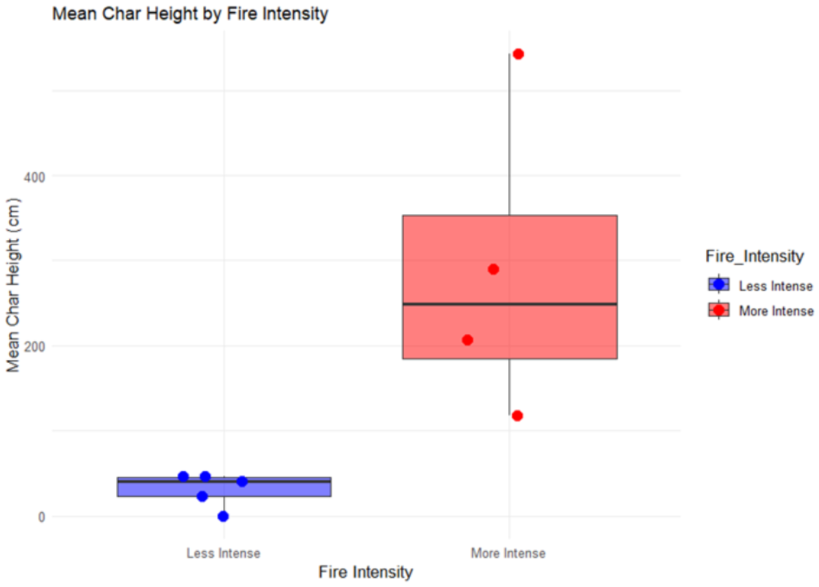

Figure 16: Box plot of mean char height between two levels of fire intensity.

3.3.2 Fire Intensity and Coppice Growth

There is an effect of fire intensity and coppice growth. When plotting the fire intensity groups to mean char height and coppice growth, plots with higher fire intensity were shown to have more coppice growth (Figure 17, Figure 18). Fire intensity had a significantly greater impact on red oak growth. All four plots categorized under More Intense fire conditions were shown to have a higher coppice growth compared to any of the plots in the Less Intense category. Additionally, red oak coppice growth in the More Intense fire plots consistently surpassed that of red maple. Within the Less Intense fire category of the plots, red maple exhibited more coppice growth per plot and was found across a higher number of plots. Red oak had only been shown to have coppice growth in three of the Less Intense plots. Red maple was found to have coppice growth in four of the five Less Intense plots. Interestingly, it was within Fire Plot 2 of the less intense category where red maple experienced the most coppice growth.

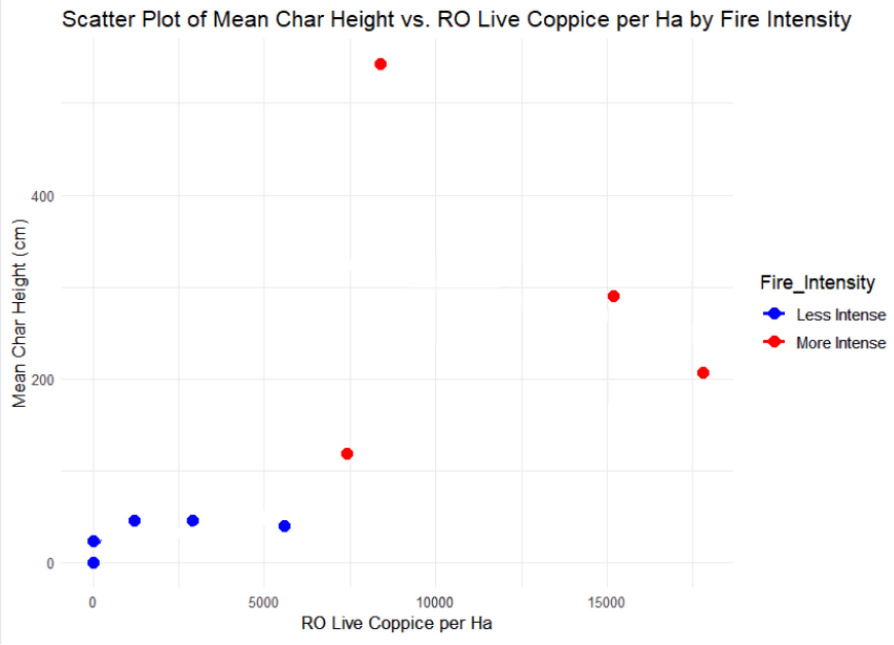

Figure 17: Scatterplot showing the amount of red oak coppice between two levels of fire intensity.

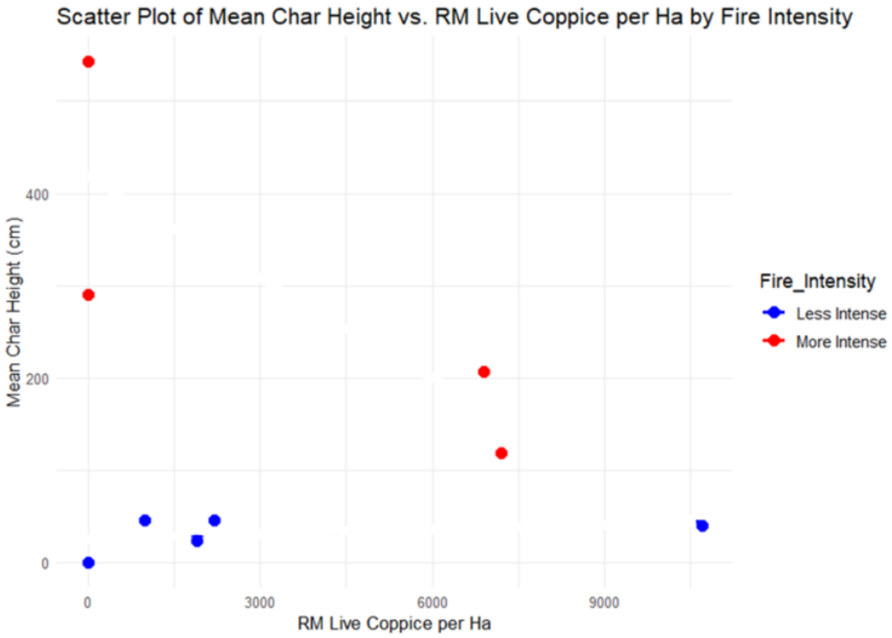

Figure 18: Scatterplot showing the amount of red maple coppice between two levels of fire intensity.

3.3.3 Difference in Dead Stem Count Between Intensities

Fire intensity directly increased the density of dead stems within the fire plot. For both species, red oak and red maple, the trees within the More Intense fire plots exhibited an increase in dead stem density and a decrease in live stem density as compared to Less Intense fire plots (Table 6). Figure 19 compares fire intensity to average char height and dead count between the two species. The More Intense fire category had a larger dead count than the Less Intense fire category. Further, red maple is shown to have the highest species dead count at a char height ranging around 2 m. Between the two intensities, red oak more than doubled in the density of dead stems from 56.25 stems/ha to 118.75 stems/ha ($p = 0.06$) (Figure 20). Red oak also experienced a decrease in live stem count from 285 stems/ha to 175 stems/ha ($p = 0.46$) (Figure 21). On the other hand, red maple dead stem density nearly tripled between Less Intense sites and More Intense sites, from 60 stems/ha to 166.7 stems/ha ($p = 0.2$) (Figure 22). It also had a reduction in live stem density by 56 %, from 315 stems/ha to 137.5 stems/ha ($p = 0.29$). From this, it is clear that the red oak mortality rate is less dependent on fire intensity.

Table 6: Summary statistics of red oak and red maple between different levels of fire intensity

	Less Intense				**More Intense**			
	Red Oak		**Red Maple**		**Red Oak**		**Red Maple**	
	Mean	**Sd**	**Mean**	**Sd**	**Mean**	**Sd**	**Mean**	**Sd**
Char Height	30.96	18.52	99.82	72.13	289.46	169.40	203.50	17.82
Coppice Growth / ha	1940	2366	3160	4301	9760	7016.27	7020	8573.91
Live Stem Density / ha	285.0	158.71	315.0	309.03	175.0	141.42	137.5	88.39
Dead Stem Density / ha	56.25	31.46	60	37.91	118.75	42.70	166.67	101.03

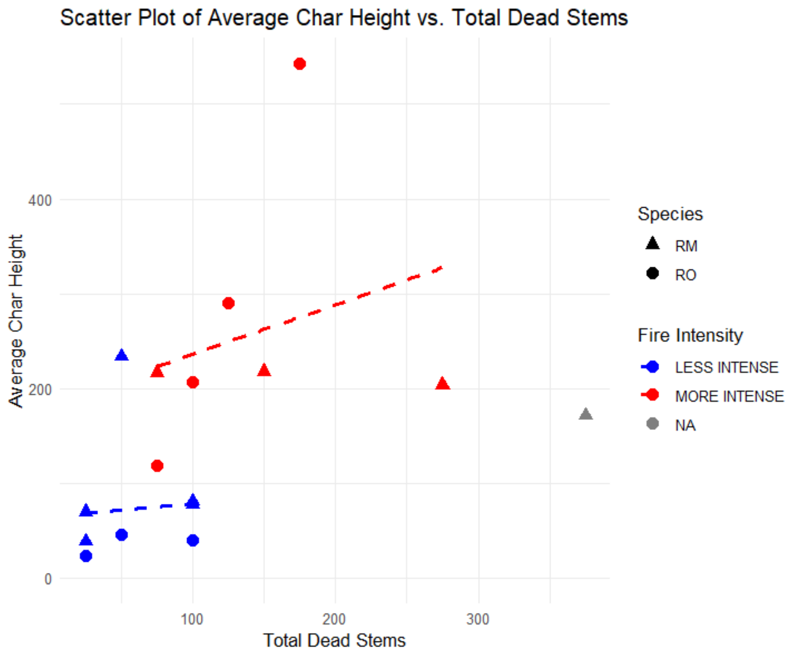

Figure 19: Scatterplot displaying the effects of fire intensity on the density of dead red oak and dead red maple.

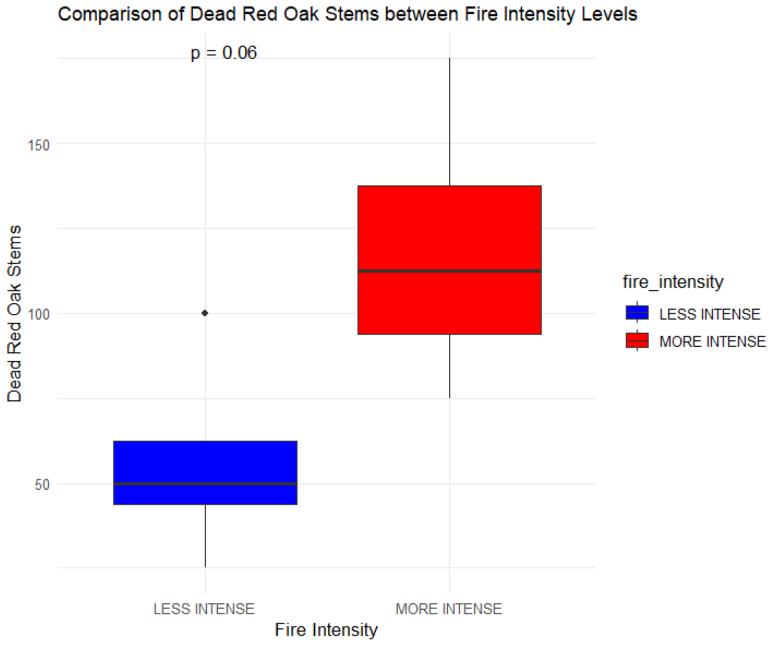

Figure 20: Box plot comparing the amount of dead red oak stems between the Less Intense Fire Category (left) and the More Intense fire category (right)

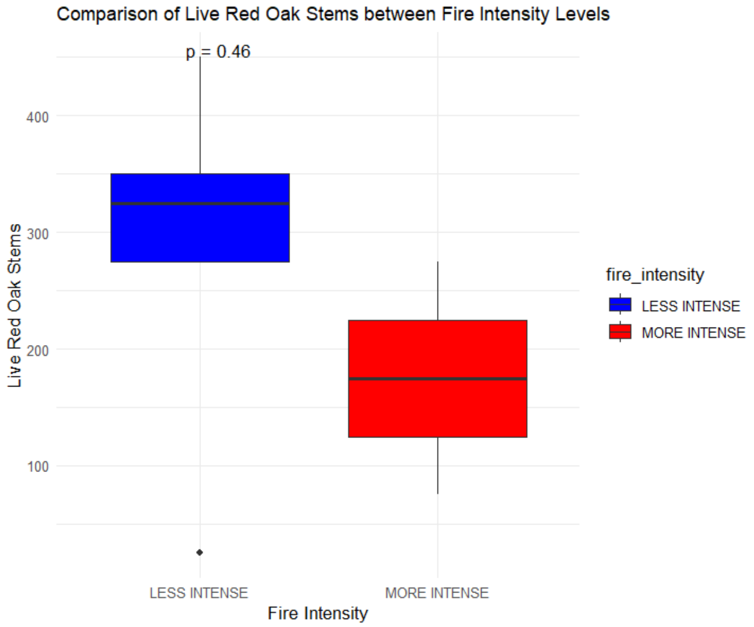

Figure 21: Box plot comparing the amount of live red oak stems between the Less Intense Fire Category (left) and the More Intense fire category (right)

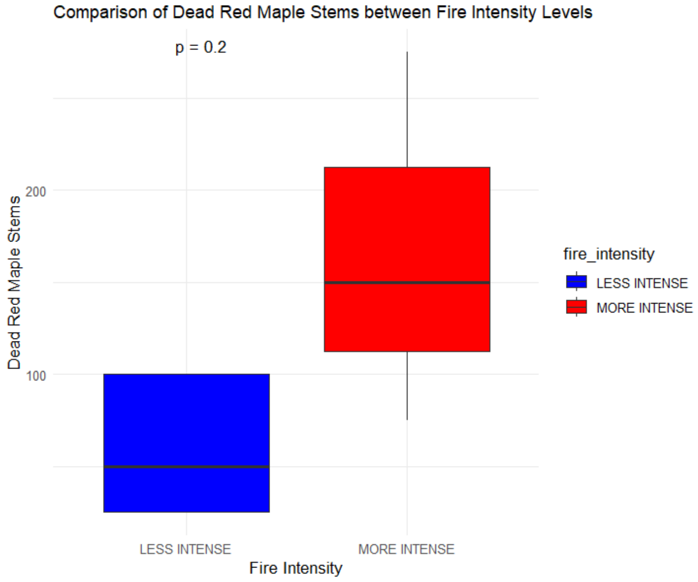

Figure 22: Box plot comparing the amount of dead red maple stems between the Less Intense Fire Category (left) and the More Intense fire category (right)

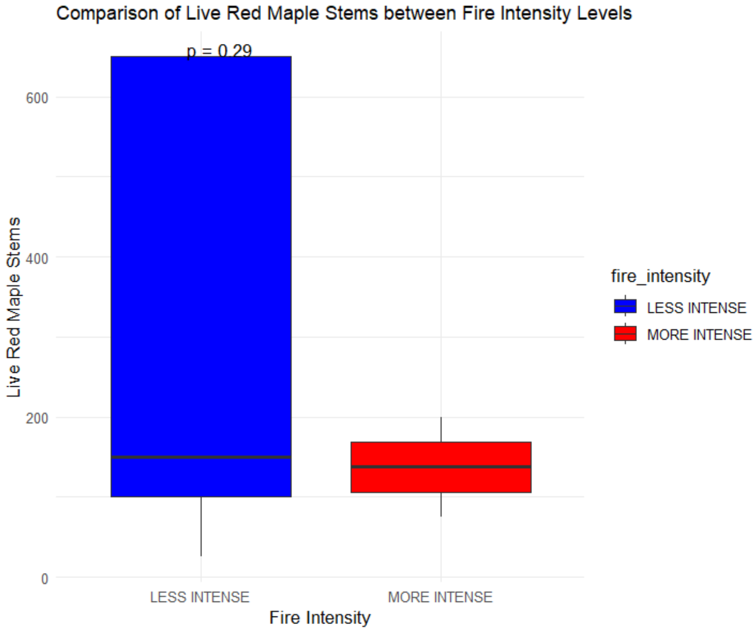

Figure 23: Box plot comparing the amount of live red maple stems between the Less Intense Fire Category (left) and the More Intense fire category (right)

4.0 Discussion

This study aimed to identify the impact of the 2023 Shelburne Wildfire on the forest ecology of burnt forest stands compared to similar forest stands outside the surrounding perimeter. This study took a particular interest in the attributes of red oak and red maple recovery; to determine if there are differences between stands in red oak mortality rates and regeneration compared to other species and to determine how various levels of fire intensity, or char height, varied between plots and affected red oak coppice growth and mortality. In summary, this study found that there were no compositional differences between plot types, and the effects of fire did not directly affect the mortality of red oak. Fire activity did, however, have a direct effect on coppice growth. Specifically, fire activity was shown to increase the amount of coppice for both red oak and red maple. This effect was primarily shown in the coppice growth of red oak.

4.1 Forest Compositional Density

This study focused on the response of red oak and red maple to the effects of wildfire. To increase the sample size of both red oak and red maple forest stands, which were composed of the intolerant hardwood forest type were targeted for the basis of this research, which were abundant in red oak and red maple. The occurrence of these two similar species allowed for a meaningful assessment of the characteristics of red oak relative to red maple. Further, the forest stand structure within the fire perimeter and the control group exhibited similar species composition, with no significant differences in population distribution or population density. The only notable difference in species composition is the presence of five tamarack trees within the control group. The similarity of each plot type gives this study a strong foundation, as any observed differences can confidently be attributed to the effects of the fire and not any pre-existing variations.

Red maple was the most abundant species within the study area. In total, red maple was recorded 213 times in control plots and 134 times within the fire plots. Red oak was the second most abundant tree species, being documented 205 times in the control group and 105 times in the fire plots. Since tree density is directly influenced by the tree count red maple was shown to have a greater population density through both the control plots and the fire plots than that of red oak. This trend repeats when isolating species status. Red maple was found to have 203 living trees and 10 dead trees within the control group and 87 living trees and 47 dead trees within the fire plots. Red oak, on the other hand, was found to have 161 living trees and 44 dead trees within the control group and 77 living trees and 28 dead trees within the fire plots. With reference to population density, red oak had a smaller living stem density and dead stem density in both the control plots and the fire plots. It was expected that red oak would have both a greater living stem density and smaller dead density than red maple. Only one of these proved correct. It is likely that due to red maple having a larger species population per plot, this expected living density trend did not occur. However, seeing that the dead count of red maple drastically increased from 10 dead trees in the control to 47 dead trees in the fire plots, and the dead count of red oak decreased from 44 dead trees in the control to 28 dead trees in the fire plots. The confidence in stating that fire activity had a greater influence on red maple mortality than red oak is quite high.

4.2 Fire Intensity

Char heights throughout the fire plots indicated that softwood species have a substantially greater average height. This result is a general occurrence within fire regimes as softwoods have weaker bark, greater lignin content, and a greater amount of ladder fuels, or branches that help carry the fire up the tree (Kurt et al., 2007; Bartlett et al., 2019). Hardwoods, on the other hand have a thicker bark and do not have ladder fuels along their base. This strongly limits the ability for fire to climb up the tree. The exception to this general immunity is white birch. White birch has paper-thin and easily flammable strips of bark that ignite when exposed to fire. This bark carries flames up the tree, it patches or lines, increasing the char height. This occurrence was documented over the 2023 Shelburne Wildfire perimeter as white birch has the greatest char height over each of the hardwoods and the second highest overall. Regardless, this outlier was kept in for average char height calculations within plots and between species. To reduce the effect this species had on calculations moving forward, fire intensity groups were set according to the char height of red oak throughout plots. This not only made the data more accurate but also more specific to the research.

Two categories of fire intensity were drafted in accordance with the average red oak char height of that plot. To avoid making too many arbitrary categories, the two categories were kept simple: Less Intense, for plots where red oak char height was below 1 m, and More Intense, for plots where red oak char height was above 1 m on average. Five plots were placed within the Less Intense category, and only four plots were categorised as more intense. As mentioned, Fire Plot 2 did not contain any red oak, so it was unable to be categorized. However, based on the average char height for red maple for that plot, it would be categorised as More Intense (mean red maple char = 1.71 m). This is a key exception, because in nearly every instance, the average char height of red maple aligned with its designated intensity category. The only exception to this is Fire Plot 4 where red oak had no char height documented on any of its trees. But red maple had an average char height of 2.33 m, the highest average char height recorded for red maple. Fire Plot 4 only consisted of one standing red oak and two red oaks classified as coarse woody material. Red maple had three standing trees and one coarse woody material. Taking this into account, Fire Plot 2 and Fire Plot 4 could arguably be placed within the More Intense fire category. This would mean that the More Intense fire conditions were more prominent throughout the fire area.

4.3 Coppice Growth

Coppicing is a trees natural ability to regenerate after being damaged. The results show that the presence of fire had a direct impact on coppice growth throughout the study area, especially red oak coppice. The density of coppice growth throughout the control groups was quite minimal. Red oak coppice in particular was only found throughout two of the control plots, Control 7 and Control 9. Between these two plots, only 4800 coppice stems were identified, leading to a red oak coppice density of only 480 stems/ha. On the other hand, red maple had a coppice density of 1,290 stems/ha. Red maple coppice was found in greater abundance and throughout more of the control plots. Since the conditions of the plots were equal between each species, the difference in coppice growth could be the result of species-specific traits. It was first thought that it could be that its red maple takes less intense levels of damage to generate coppice. But this evidence is not present when analysing the fire plots.

Both red oak and red maple showed an increase in coppice growth throughout the fire plots. Red oak coppice growth was found in seven of the fire plots and ranged from 1,200 stems/ha to 17,800 stems/ha. On average, the coppice growth of red oak throughout the fire plots was 5,110 stems/ha, an increase of more than 10 times. Red maple experienced the same effect. The density of red maple coppice growth increased by more than 2.5 times in the fire plots from 1,290 stems/ha to 3,200 stems/ha. If red maple did require less intense levels of damage to start coppicing, it was expected that red maple would have a greater amount of coppice than red maple. This concludes that the intensity of damage is not why red maple had more coppice growth in the control plots. However, data collected shows there is an effect of fire intensity and red oak coppice growth.

When looking at the two levels of intensity, plots of higher fire intensity yielded a greater amount of red oak coppice growth. Each plot located within the More Intense fire category had more coppice growth than any of those in the Less Intense fire category (Figure 17). This pattern was not shown with regard to red maple. Three fire plots were shown to have no red maple coppice growth, two of which were from the More Intense category. This left the More Intense fire category with only two plots. Further, the plot with the most red maple coppice growth, 24,700 stems/ha, was Fire Plot 6, which is categorized as Less Intense.

Taking the argument that the general fire behaviour of the 2023 Shelburne Wildfire was more intense, and the average char height throughout the fire area was greater than 1 m. The amount of red oak coppice found within the fire perimeter would be substantial. This furthers the argument that red oak plays a dominant role in post-fire forest recovery and secondary succession. That being said, coppice growth for both red oak and red maple was found in the control plots. Particularly, the amount of red maple coppice within the control plots is still an important factor to consider. Red maple does not require exposure to fire to start coppicing, though in did see an increase in coppice when exposed to fire.

4.4 Differences in Dead Species Count Between Fire Plots

Comparing the living and dead stem count between fire plots of different fire intensities shows a small correlation between char height and dead stems. In general, the plots with a higher average char height, or those categorized as More Intense fire behaviour, tend to have a larger dead stem count. For both the Less Intense and More Intense fire intensities, the trend line for each category slopes upwards. As the average char height increases, the total dead stem count increases as well (Figure 19). Plots that are categorized within the Less Intense fire activity are more tightly grouped on the scatter plot and reach a maximum of dead stem count of 100 stems/ha at a char height below 1 m. The exception to this is one red maple plot, which has a total dead stem count of 50 stems/ha at a char height of 2.3 m. This would account for Fire Plot 4, where the red oak char height was zero, so it was categorized as Less Intense. On the other hand, the More Intense fire category is loosely spaced and had its lowest dead stem count of 75 stems/ha at a char height of 1.2 m and reached its maximum at 275 dead stems/ha and a char height of around 2 m. Within this scatter plot is a NA value, which represents Fire Plot 2, which contained no red oak but had the highest dead stem count of both red oak and red maple.

More importantly, this scatter-plot displays that generally, red maple will have more dead stems at higher intensity levels than red oak. Red maple accounts for the first, second, and fourth most dead stem count with regard to fire intensity. The third highest dead stem count is red oak with 175 dead stems/ha at a char height of nearly 5.5 m. This is the highest char height of each fire plot and the highest dead stem count for red oak. This shows the resilience of red oak to fire damage, as it had the highest char height, but still less than 200 dead stems/ha.

4.5 Limitations to The Study

This study overall had a small sample size and only accounts for a small segment of the damages done by the 2023 Shelburne Wildfire. Sample sites were specifically focused on the Intolerant Hardwood Forest stand and do not account for any other ecosites that could contain red oak. Further, it was not until late data analysis that it was discovered that one of the sample sites did not contain red oak. This further reduced the sample size of the study. More importantly, the reduction in one fire plot meant that the control plots and fire plots would no longer be compared on a 10:10 scale but now on a 10:9 scale. This mistake would affect some variables of the analysis. When finding the mean and standard deviations of some values within the fire plots, some values were calculated with respect to 10 plots, and others only nine.

Further, this study specifically focused on coppice growth as the primary means of regeneration, examining how red oak and red maple respond to damage by fire and coppice. Other forms of regeneration such as seed-based from acorns were not included in the assessment of secondary succession and regrowth potential. These forms of regrowth also play an important role in forest succession and overall forest health. This will likely need to be re-examined in the coming years.

Lastly, this study only focused on the specific impact of the 2023 Shelburne Wildfire, it did not account for any other past disturbance history that may have influenced forest regeneration or composition. Additionally, plots were not analysed for the presence of charcoal, which would give insight into past fire events within the area.

4.6 Implications

This study found that there were no major differences in stand composition between the control plots and the fire plots of this study, which suggests they were similar forest ecosystems of similar origins. However, there were significant differences in the live count and dead count of red oak between plots. Both red oak and red maple experienced a reduction in the density of live stems from the control plots to the fire plots, but only red oak saw a reduction in dead stems density between the fire plot and the control. The density of dead red maple stems increased by 370% from 250 stems/ha to 1,175 stems/ha. Red oak had better resistance to the effects of the fire compared to red maple.

It is unclear if either species has a better ability to reduce char height. Within the Less Intense fire category, red oak has a smaller average char height, but in the More Intense fire category, red oak has a greater average char height. What is clear, however, is that this study found that Northern Red Oak exhibits greater resilience to fire intensity than red maple. Both species, when exposed to fire intensity that produced an average char height greater than 1 m, showed an increase in dead stem density. Within the plots of greater fire intensity, Fire Plot 5 and Fire Plot 6, red maple experienced a greater dead stem density than red oak. So, despite the overall dead count throughout the fire being equivalent between red oak and red maple, there is an increase in red maple dead count when exposed to greater fire intensity.

Additionally, this study found that red oak has a greater rate of coppicing in a post-fire regime than of its undisturbed conditions. This supports the idea that fire, even at low intensity, assists in the generation of red oak coppice growth in the intolerant hardwood forest stands. The red oak coppice found within the control plots was the lowest amount found throughout the entire study. Red maple coppice was found within the control plots over a greater number of plots and in higher abundance. However, red oak within the fire plots outperformed red maple in coppice growth throughout both control plots and the fire plots. Differences in fire intensity also played a major role in coppice growth for red oak. Red oak experienced the most coppice growth within the plots of the greatest fire intensity (Table 4).

This study has provided a strong base for further red oak succession studies. But further studies should be conducted to assess the development of red oak as a competitive canopy species. It is clear that the regeneration of red oak in this post-fire regime has taken dominance, but whether it will continue to hold its dominance into the mid to late succession still needs to be analyzed.

5.0 Appendix:

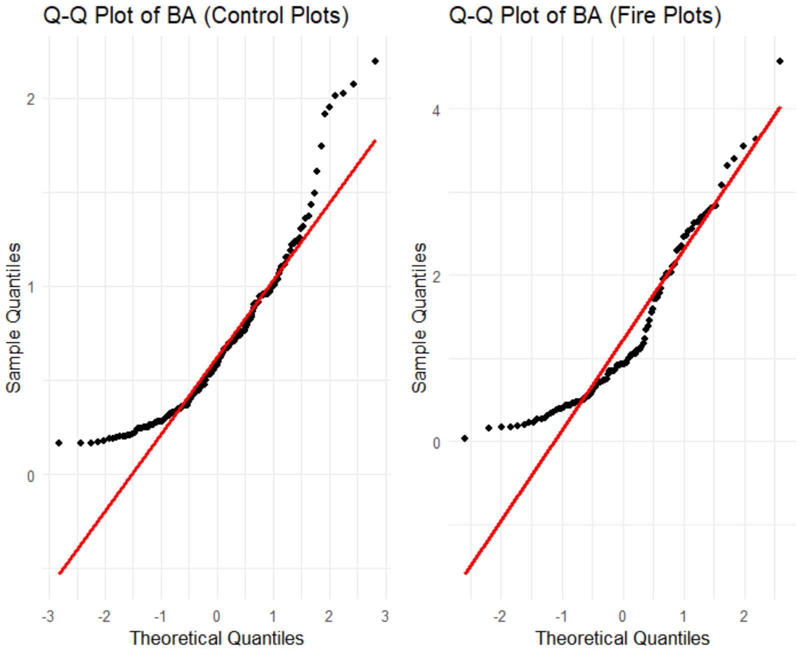

Figure 24: Q-Q plot analysis of red oak basal area across plot locations in the 2023 Shelburne Wildfire

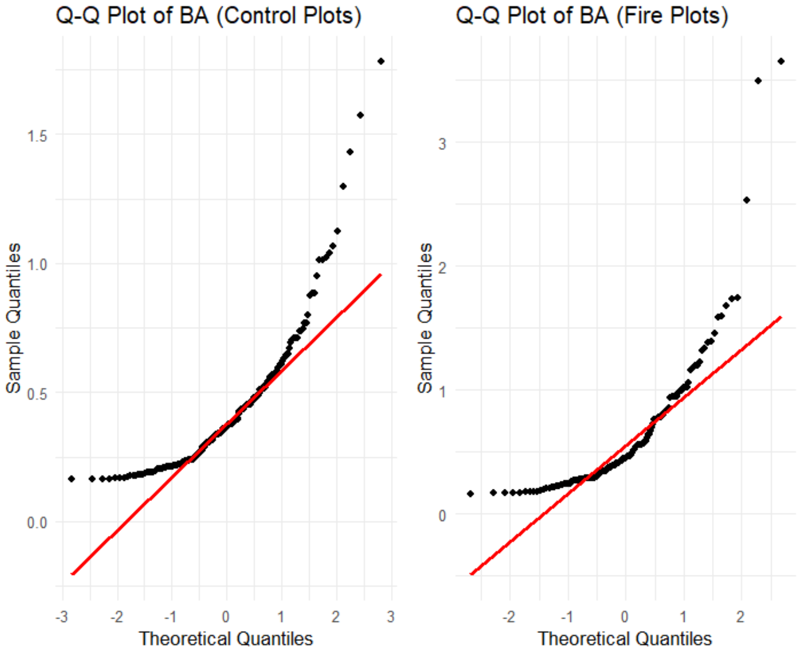

Figure 25: Q-Q plot analysis of red maple basal area across plot locations in the 2023 Shelburne Wildfire

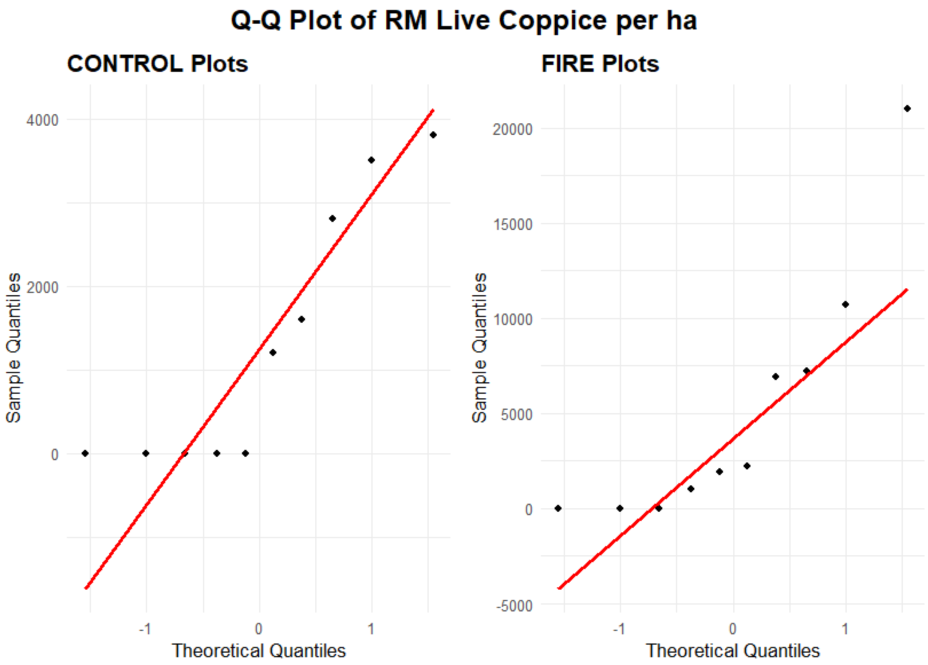

Figure 26: Q-Q plot analysis of red maple coppice found within control and fire plots in the 2023 Shelburne Wildfire

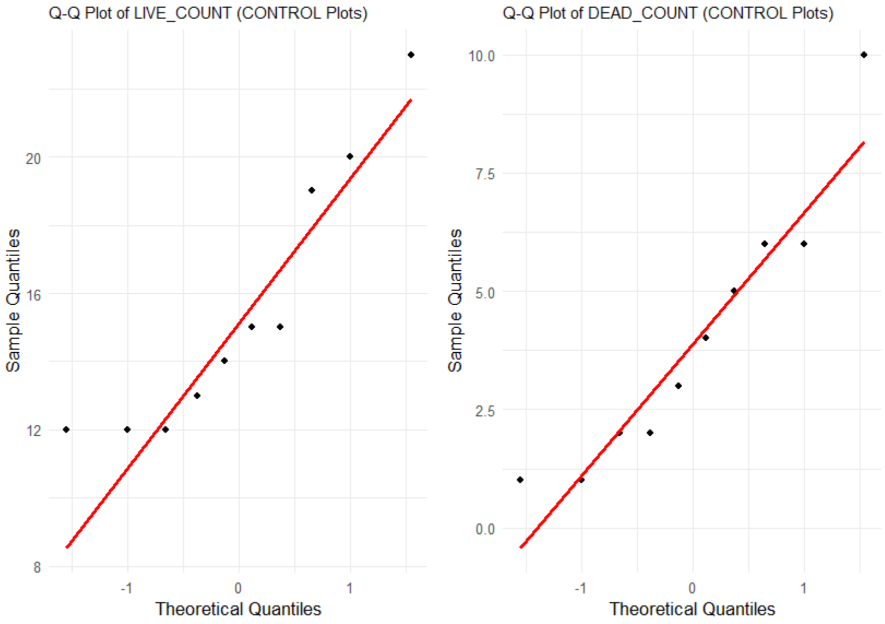

Figure 27: Q-Q plot analysis of living and dead red oak throughout control plots of the study location

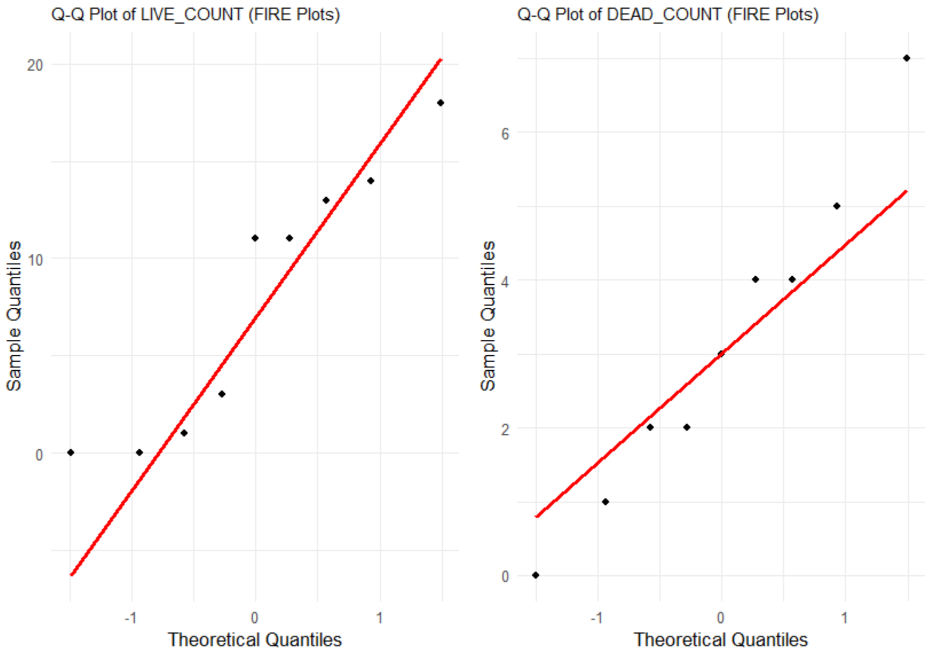

Figure 28: Q-Q plot analysis of living and dead red oak throughout fire plots of the study location

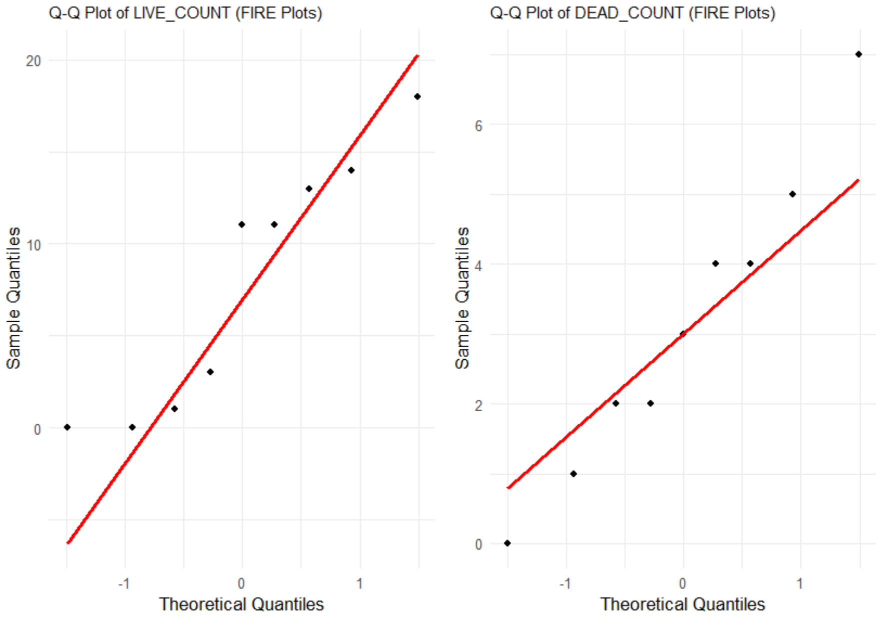

Figure 29: Q-Q plot analysis of living and dead red maple throughout control plots of study location

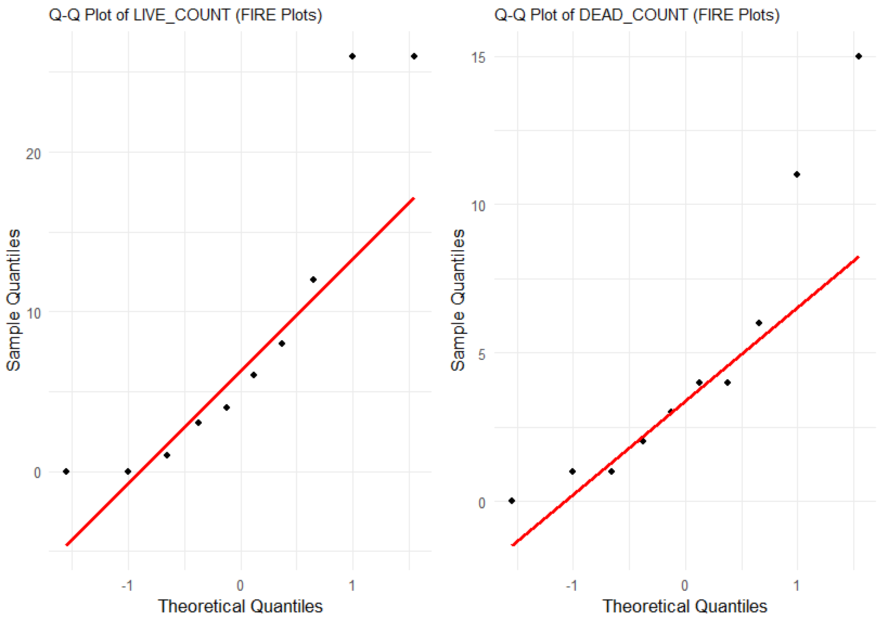

Figure 30: Q-Q plot analysis of living and dead red maple throughout fire plots of study location

6.0 References

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