Effects of prescribed fire intervals on bryophyte diversity and cover

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Abstract

The Long Island Central Pine Barrens are a globally rare fire-adapted ecosystem. Fire return intervals of 10-40 years are typical for Atlantic coastal pine barrens. However, intervals may be as low as 3-5 years in more open barrens systems. This study aims to understand the impact of various fire frequencies on bryophyte communities and determine an optimal fire interval to promote bryophyte cover and diversity. Bryophytes play an important role in rainfall interception and soil infiltration. Additionally, some species of moss serve as early successional pioneer species and stabilize recently burned soils. Research conducted in the New Jersey Pinelands indicates that bryophyte cover is highest in cut and uncut stands burned annually. At Brookhaven National Lab (BNL), pre-established plots were categorized as frequently or infrequently burned, or as unburned controls. Percent bryophyte cover was estimated along 25 meter transects in each location, and species present were recorded. Bryophyte cover was found to be very low in all plots, with unburned control plots having on average higher percent cover. Control plots had an average bryophyte cover of 0.85%, whereas infrequently and frequently burned plots had 0.1% and 0.08% cover respectively. This study might provide evidence that the Long Island Central pine barrens would benefit from a more frequent fire return interval, as our data might illuminate an intermediate fire regime that is detrimental to bryophyte cover and diversity within plots categorized as frequent, or that environmental conditions prevent

bryophyte growth. Further investigation is necessary to determine the effects of more frequent burns than those included in this study. This study supports the Department of Energy's goal to address the nation's environmental challenges. As a result of this study and sampling conducted for related research, the authors have developed their field research competency and improved their understanding of experimental design. The authors expanded technical skills in moss identification and ecology, field sampling, and microscopy.

Introduction

In disturbance-dependent ecosystems like Long Island's Central Pine Barrens, the presence, frequency, and intensity of fire is a crucial factor in shaping vegetation composition. Fire return intervals of 10-40 years are typical for Atlantic coastal pine barrens (Jordan, 2003). However, intervals may be as low as 3-5 years in more open barrens systems (Jamison et al., 2023). In areas with relatively frequent or intense fires, a dominant overstory of pitch pine (Pinus rigida) with co-dominant oak species (*Quercus* spp.) are observed. In the absence of fire, open-canopy pine barrens may be displaced by shadier dense-canopy mixed forest, with the eventual inclusion of species like red maple (*Acer rubrum*) (Jamison et al., 2023), eventually producing a forest dominated by beeches (*Fagus grandifolia*) and hickories (*Carya sp*.) (Jordan et al., 2003). This process is known as mesophication. Mesophication creates a positive feedback loop resulting in increased moisture, soil organic matter, and fire sensitivity (Nowacki & Abrams, 2008). A history of fire suppression has led to increasingly fire-sensitive forests in the northeast, and ongoing fire management may be one of the only ways to combat this trend (Vander Yacht et al., 2024).

The midstory shrub layer in the Long Island Central Pine Barrens is also impacted by fire frequency, but generally consists of huckleberries (*Gaylusaccia* spp.), blueberries (*Vaccinium* spp.) and in recently burned areas scrub oak, and coppicing black and white oaks (*Q. ilicifolia*, *Q. velutina*, and *Q. alba*.). The herbaceous layer is dominated by Pennsylvania sedge (*Carex pensylcanica*), bracken fern (*Pteridium aquilinum*), and sweet fern (*Comptonia peregrina*). The species composition of epiphytic and terrestrial bryophytes in pine barrens ecosystems, by contrast, remain relatively unknown. No work has been published on them to date at BNL, where this study was conducted.

Although mosses are generally killed in wildfires and prescribed fires, their response to the changed characteristics of frequently or recently burned areas is not well understood. Some bryophytes may spread more easily after a fire due to reduced understory vegetation, while others might do better in the wet, shady understory more characteristic of infrequently burned areas (Grover et al., 2020) (Glime, 2024).

Prior research on the interaction between fire frequency and bryophyte cover is somewhat limited. Previous studies conducted in the ecologically similar New Jersey Pine Barrens indicate that bryophyte cover is highest in annually burned stands (Buell & Cantlon, 1953) (Moul & Buell, 1955). Severely burned areas of the New Jersey Pinelands may also develop lichen and moss mats, whose composition may in turn influence the germination of different vascular plants (Sedia & Ehrenfeld, 2003).

Additionally, research conducted in other areas of the United States indicate that some species of moss may serve as early-succession pioneer species (Glime, 2024) and effectively stabilize recently burned soils (Grover et al, 2020). This study grew and propagated “fire

mosses" — *Ceratodon purpureus* (Redshank), *Funaria hygrometrica* (Cord moss), and *Bryum argenteum* (Silvergreen moss) — to stabilize the soils of recently burned hillsides.

The goal of this study is to examine the effect of fire return interval on the percent cover and diversity of bryophytes in the Long Island Central Pine Barrens. The investigation will focus on bryophytes present in frequently, infrequently, and unburned areas of BNL. We hypothesized that bryophyte cover would be higher in areas burned more frequently because of increased proliferation of early-successional bryophyte species. Additionally, we hypothesized that diversity would be greater with a more frequent fire return interval due to improved efficacy of wind dispersal of spores in more open stands.

Methods

BNL is a Department of Energy laboratory located within Long Island, NY's Central Pine Barrens. Of the lab's 5,265 acre property, approximately 3,445 acres are undeveloped woodlands. These woodlands are managed primarily through the use of mechanical treatments and prescribed fire towards the goal of maintaining forest health and wildlife habitat. BNL has not historically used active fire management. However, efforts in the past two decades have returned prescribed fire to a portion of BNL's woodland areas (BNL, 2021).

14 pre-established 25 by 16-meter plots were selected and categorized as frequently or infrequently burned, or as unburned controls. Frequently burned plots were defined as having one fire in the past 15 years and another in the 15 years preceding that. Infrequently burned plots as having one fire in the past 15 years, and none in the 15 years preceding that. Control plots did not have any fires within 30 years. At each plot, a 25 meter transect was established along one

side of the plot. A 1-meter square PVC quadrat was placed every 5 meters along the transect, inside the plot. Inside the quadrat, the percentage of soil and tree trunks and woody debris covered by bryophytes was estimated and recorded. A timed meander was conducted inside the plot; two investigators walked through the plot for ten minutes, flagging each bryophyte found. At the end of the ten-minute period, the number and identity of unique bryophyte species observed were recorded. Samples of unknown bryophytes were collected and keyed out or sent out for identification by a bryologist.

An analysis of variance test was performed on average percentage bryophyte cover and number of bryophyte species present. The alpha level was set at 0.05.

Results

Plots designated as unburned controls were found to have the highest average percent bryophyte cover at 0.85%. Infrequently burned plots had on average lower cover, at 0.10%. And frequently burned plots had the least cover, with only an average 0.08% of the forest floor being covered in bryophytes (Figure 1). The average number of bryophyte species present in control plots was 7 species. Infrequently burned plots had an average of 4.2 species present, and frequently burned plots had an average of 1.5 species present (Figure 2). For percent bryophyte cover, the calculated P-value from the analysis of variance test was 0.1693 and we failed to reject our null hypothesis. For bryophyte species count, the calculated P-value was 0.04, causing us to reject our null hypothesis.

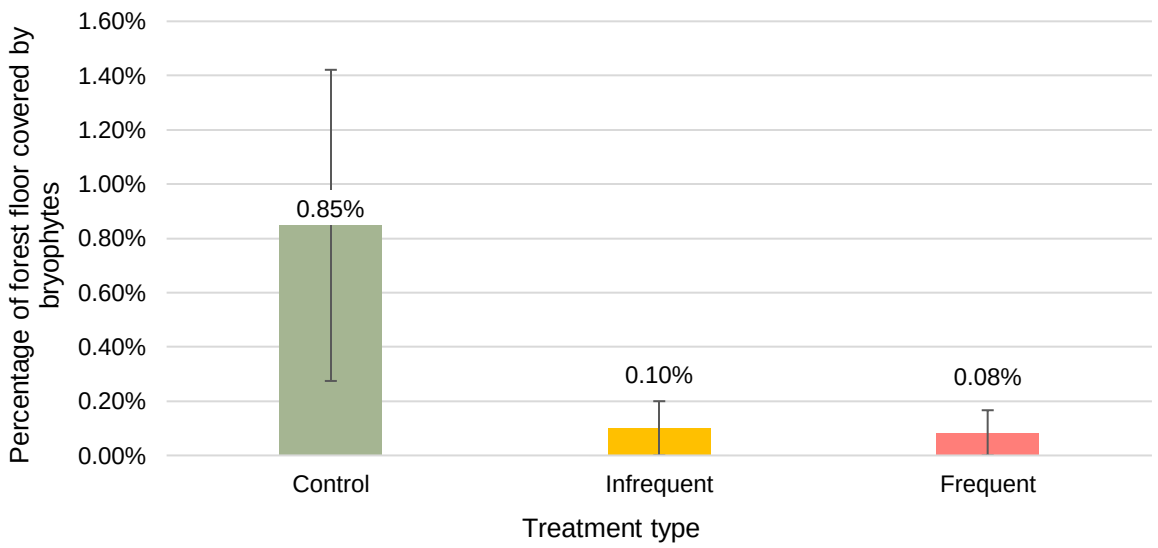

Figure 1. Average percentage of forest floor covered by bryophytes across treatment types, ± 1 standard error

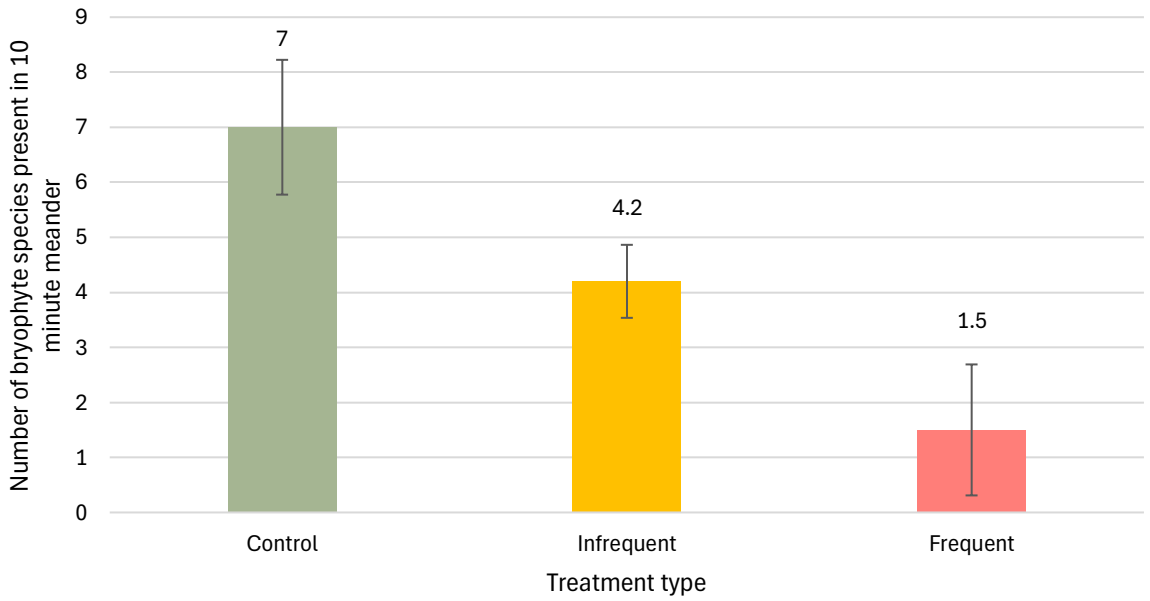

Figure 2. Average number of bryophyte species present in 10 minute timed meander across treatment types ± 1 standard error

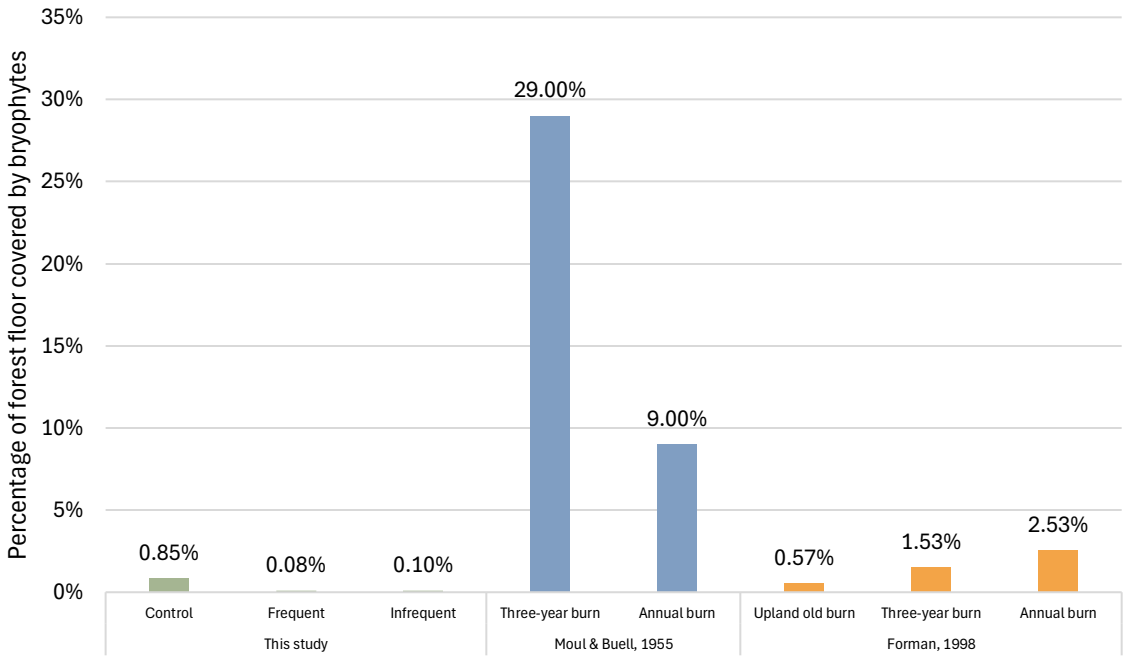

Figure 3. Average percentage of forest floor covered by bryophytes across treatment types, compared with ± 1 standard error

Table 1. List of species identified in plots surveyed.

DICRANACEAE

Dicranum flagellare (Hedw.)

Dicranum fulvum (Hook.)

Dicranum montanum (Hedw.)

Dicranum scoparium (Hedw.)

Dicranum scoparium (Hedw.)

HYPNACEAE

Hypnum imponens (Hedw.)

Platygyrium repens (Brid.)

LEUCOBRYACEAE

Leucobryum glaucum (Hedw.)

MNIACEAE

Plagiomnium cuspidatum (Hedw.)

POLYTRICHACEAE

Atrichum angustatum (Brid.)

Polytrichum commune (Hedw.)

THELIACEAE

Thelia hirtella (Hedw.)

Discussion

Our data do not support our hypotheses that more frequent fire return intervals lead to greater moss cover, as other research (Buell & Cantlon, 1953) (Moul & Buell, 1955) suggests. Further investigation is required to determine whether this trend continues in areas with more frequent fire return intervals than the plots we labeled as "frequent". As discussed above, recent research on similar inland communities suggests an optimal fire return interval of 3-5 years (Jamison et al., 2023). Our data may indicate the existence of a median range in which the fire interval is too infrequent for fire adapted species to succeed, and simultaneously too frequent for species preferring wetter, less frequently burned areas. Alternatively, the low overall cover may indicate ecological conditions that are unfavorable for moss growth across treatment types. The low sample size used in this investigation makes drawing conclusions from the data difficult.

Our data also do not support our hypothesis that bryophyte diversity increases with burn frequency, as described in previous literature (Glime, 2024). Additionally, this investigation did

not find many species characteristic of frequently burned areas, such as *Bryum argenteum*, *Ceratodon purpureu*, *Funaria hygrometrica*, *Marchantia polymorpha*, and *Polytrichum juniperinum* (Grover et al., 2020) (Glime, 2024). This trend could be attributed to relatively low overall burn frequency, as above. The relatively high volume of leaf litter – accumulated as a result of long-term fire suppression – may present unfavorable habitat for non-epiphytic mosses. Many of the species observed were found growing on trees and might suffer even from infrequent burning. This could explain the decrease in diversity in plots categorized as "frequent". The lower intensity of prescribed fires, which made up the bulk of the fire activity used to categorize plots, may also contribute to this phenomenon. Lower intensity fire may be insufficient to remove the litter and fuels that prevent moss germination.

Further investigation in areas burned more frequently over extended periods of time is necessary to determine whether the data reflect a negative correlation between fire frequency and cover/diversity or a median range, after which diversity and cover increase. These areas may not exist yet within the Long Island Central Pine barrens, highlighting the need to return fire management to the ecosystem. Due to the low sample size of this study, no conclusions can be definitively drawn from it, however, we lay out a foundation upon which other studies may build in the future.

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Not export controlled.

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