Report on the Cattle Barn Lot sugar maple forest, Mount Washington, Massachusetts

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Front piece, Sugar maple forest in the Cattle Barn Lot. Photo by Lee Frelich, November 16, 2024.

Introduction

On November 16, 2024, I visited the state-owned Cattle Barn Lot in Mount Washington, Massachusetts with Eleanor Tillinghast, Jared Lockwood and Ben Nickley. We hiked through the sugar maple-dominated forest stand of interest (defined below), some of the white ash stands and seeps in the lower-lying areas, and a few oak and white pine stands higher up the slope to the east. On November 17, Eleanor Tillinghast and I also hiked through the surrounding stands to the north and west, providing me with a good overview of the sugar maple-dominated forest and its setting within the landscape.

Green Berkshires, Inc. asked me to assess the ecological significance, current condition, and threats to the ecological integrity of the sugar maple stand in the Cattle Barn Lot. During 35 years of research with many colleagues and graduate students I have developed a particularly deep level of expertise on complex impacts of multiple factors in sugar maple forests at individual tree, stand and landscape scales. This includes research on climate change, changing disturbance regimes, deer browsing, invasive species, and their cascading effects and ecosystem legacy effects (e.g. Lorimer and Frelich 1984, Frelich and Lorimer 1985, 1991a, 1991b, Frelich et al. 1993, Frelich and Reich 1999, 2010, Fisichelli et al. 2013, Johnstone et al. 2016, Webster et al. 2018, Frelich et al. 2019, Sommerfeld et al. 2019, Frelich et al. 2020, Toot et al. 2020, Stralberg et al. 2020, Moss et al. 2024, Reed et al. 2024, 2025). Many of these papers are highly cited and were published in high-impact journals (e.g. *Nature Communications*, *Global Change Biology*, *BioScience*, *Frontiers in Ecology and the Environment*) and top-rated ecology specialty journals (e.g. *Ecology*, *Ecological Monographs*, *Ecosystems*, *Journal of Ecology*, *Forest Ecology and Management*). Combined with publications from many other researchers, there are few tree species that have as large a pool of knowledge to draw from as sugar maple.

The Core Sugar Maple Stand

A previous mapping of the vegetation types in the Cattle Barn Lot (Eiseman 2024, Figure 1) showed that much of the low-lying areas along Karner Brook are covered with the Northern hardwood-Hemlock-White pine forest vegetation type as defined by the Massachusetts vegetation classification (Swain and Kearsley 2014). Within this forest type is a core stand heavily dominated by sugar maple that lies in the lowlands on either side of Karner Brook. The largest acreage (175 acres as estimated by Ben Nickley) lies on the east side of Karner Brook, between the brook and the forest road, and includes major parts of cutting areas 2, 4, and 6. I shall refer to the sugar maple-dominated forest in these three cutting areas collectively as Stand A. A slightly smaller area lies west of the brook, shown on the map as cutting areas 1, 3, and 5 (Figure 1). I shall refer to these three cutting areas collectively as Stand B (all three cutting areas in Stand B are dominated by sugar maple). When referring to all the cutting areas generally, I shall use the terms stand, core stand, or core sugar maple stand.

The sugar maple core stand is second growth and now at the mature even-aged stage of stand development, with relatively evenly spaced large sugar maple canopy trees, with some white ash, black cherry, northern red oak and small amounts of other tree species. Some parts of the stand

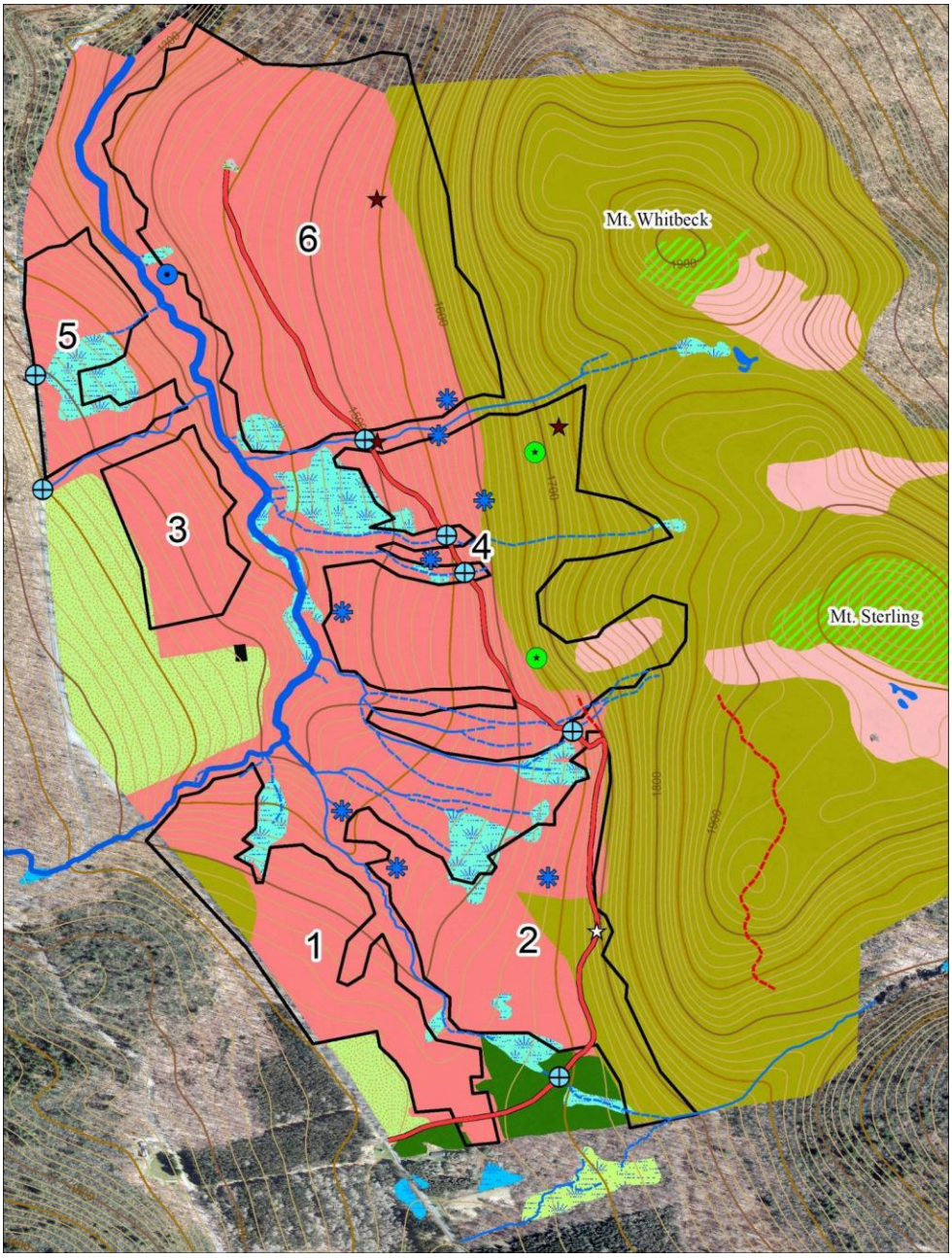

Figure 1. Map of the Cattle Barn Lot, showing vegetation types, streams and proposed cutting areas from Eiseman 2024. Proposed cut areas—black lines with polygons numbered 1-6; Meadows—light green; Northern hardwood hemlock forest –salmon; Oak-hemlock-white pine forest—olive green; Mixed oak forest/woodland—light pink; Pitch pine-scrub oak-mountain laurel—green and brown crosshatch; Streams—dark blue; Wetlands and seeps—light blue; Forest road—red line.

were thinned a few decades ago and those areas now have some young sapling to pole-sized sugar maple trees and a few birch trees (Eiseman 2024). The ecological legacy of the core stand and surrounding area is mostly intact, meaning that the stand was resilient to logging disturbance, able to 'remember' its pre-disturbance condition, and is on a path of recovery rather than divergence to an alternate state (Johnstone et al. 2016). The stand is about halfway through the process of recovering to conditions similar to those present prior to European settlement, after experiencing removal of most of the canopy about a century ago, as indicated by the generally good ecological health of the forest and high level of biodiversity in the core stand (Eiseman 2024). If left alone, the stand will gradually progress to uneven-aged stages of stand development over the next 100 years, as is typical for old, even-aged sugar maple stands (Frelich 2002).

However, there are some existing and potential challenges to this relatively intact ecological legacy and resulting high level of resilience. These are: invasion by European earthworms, the cascading effects of earthworm invasion, high deer populations causing additional cascading effects due to earthworm-deer interactions, projected future changes due to climate change, and potential impacts of proposed harvesting. Details are discussed below.

Landscape Context of the Core Sugar Maple Stand

Although sugar maple is widespread in western Massachusetts, stands with high sugar maple dominance, like the core stand in the Cattle Barn Lot, are uncommon in the immediate area. Consequently, surrounded by varied types of oak and pine forests, this sugar maple forest makes a high contribution to local biodiversity within the valley where it sits. Furthermore, the physiographic setting of the core sugar maple stand is unusual at a larger, more regional scale, as explained below.

A recent map of sugar maple abundance shows low to moderate abundance of sugar maple in the region surrounding southwestern Massachusetts, with areas of much higher abundances to the north in northern Massachusetts, Vermont and upstate New York, as well as the Catskills to the west (USDA Forest Service 2019, Figure 2, left). The Berkshire Plateau to the east also has somewhat higher abundances of sugar maple, and this current mapping is consistent with the early forest ecology research of Bromley (1935) who found numerous sugar maple stands on the Berkshire Plateau. An enlargement of the area surrounding the Cattle Barn Lot (Figure 2, right) shows that the Cattle Barn Lot sugar maple stand (orange arrow pointing to a small dark green pixel) is locally isolated from the other areas with high sugar maple abundance. Rather than a valley-bottom location like the Cattle Barn Lot sugar maple stand, the other areas with high abundance of sugar maple are on steep east-facing slopes of mountains that mark the northeastern and eastern boundaries of the town of Mount Washington, as well as deep gorges in the Taconics along the eastern boundary of New York (to the west of the town of Mount Washington).

Thus, the Cattle Barn Lot sugar maple forest, being in a valley bottom location, grows on a unique landform and is a distinct ecosystem type from the other nearby sugar maple-dominated

areas. However, all of the sugar maple-dominated areas have one thing in common: a cool, moist local climate caused by the landforms on which they are located. This includes sugar maple stands on east-facing slopes where the sun hits the area in the morning at the coolest part of the day, or, as in the Cattle Barn Lot sugar maple stand, a valley bottom where cold air settles at night, but which is on a bench high enough to avoid waterlogging during floods. Both physiographic settings also lead to low probabilities of fire, compared to south and west-facing slopes that have high-intensity solar radiation during the warmest (mid-day and afternoon) times of the day, and historically had drier soils and more frequent fires which supported oak and pine forests.

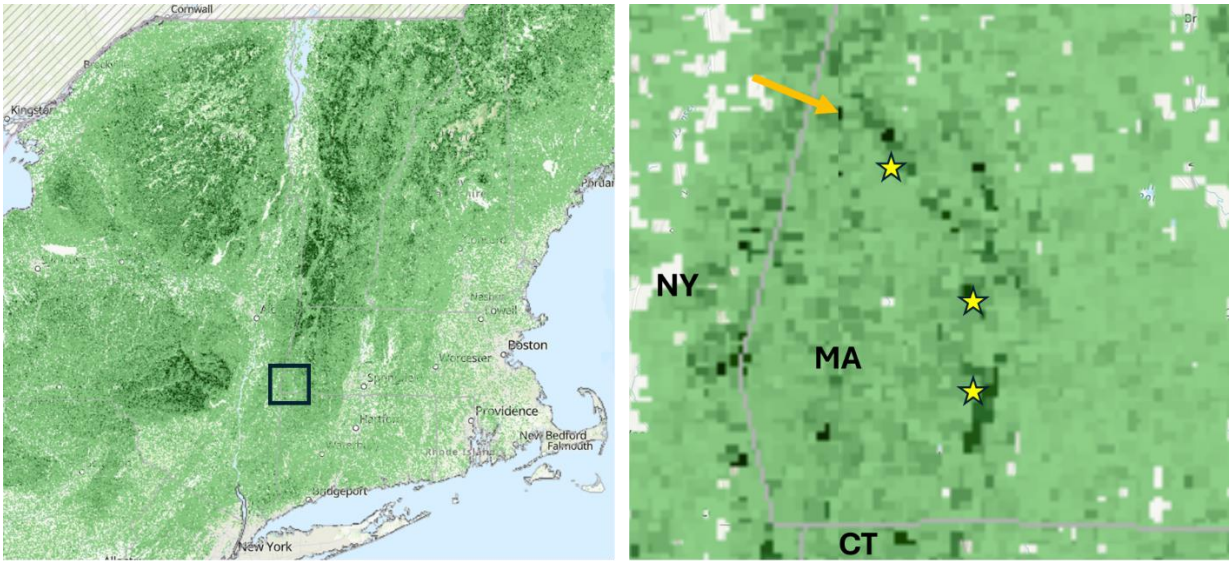

Figure 2. Contemporary sugar maple abundance—regional abundance (left) and enlargement of the part of the image in the black box in southwestern MA (right). Dark green indicates high abundance of sugar maple, light green indicates low abundance, and sugar maple is absent or present in trace amounts in forests in the grey/white areas. In the image on the right, light grey lines indicate the state boundaries between NY, MA and CT; Yellow stars indicate summits of Mounts Darby, Everett and Race (from north to south, respectively), which are on the eastern edge of the town of Mount Washington; The orange arrow points to the Cattle Barn Lot sugar maple stand (a small dark green pixel).

Climate Change

Within New England, sugar maple is more abundant towards the north and further south on east facing slopes or areas with cold air drainage, in other words places with relatively cool summer climates regionally or locally. However, it is important to note that moderate levels of sugar maple abundance occur well to the south of the Cattle Barn Lot in southwestern Massachusetts,

including an interesting region known as a ‘climate cool spot’ (McNeil et al. 2023) in the central Appalachian Mountains of West Virginia. Good evidence is presented showing that the cool spot is driven by the abundance of sugar maple. Its dome-shaped crown architecture and horizontal leaf arrangement increase the albedo (near-infrared reflectance by the canopy) and cause high evapotranspiration rates, both of which lead to a cooling effect by sugar maple on the local climate during the growing season. Thus, the cooling effect of sugar maple and their growth on landform positions that are cooler than surrounding areas reinforce each other.

In the Cattle Barn Lot, dome-shaped canopies of sugar maple are clearly visible. It is important to not disturb this crown structure at this time—the large canopy domes have just developed in the last few decades. Moreover, plenty of water is available to the core stand to maintain sugar maple’s high rate of evapotranspiration in this valley-bottom location with a brook flanked by slopes, along with intermittent streams and seepages that occur throughout the core stand and surrounding area. At the same time, and although much of the core stand (in Stand A) is on a west-facing slope, the valley-bottom location and low intensity of solar radiation during the warmest part of the day (late afternoon), due to the ridge to the west, limit the amount of evapotranspiration needed to keep the entire core stand cool. This means that the site is not warm and dry like it would be on a steeper west-facing slope in an exposed upper slope location. Furthermore, dense shade cast by sugar maple, due to its high LAI (leaf area index) helps to cool the stand, and, finally, cold air drainage and pooling occurs at night in this valley-bottom location which has slopes in all four cardinal directions from the core stand.

The relevance of all of this is that the Cattle Barn Lot sugar maple forest is a likely climate refugium for sugar maple—see Stralberg et al. (2020) for an explanation of the theory behind refugial locations (places where the local climate is decoupled from the regional climate)—for forests in a warming climate. As such, the core sugar maple forest should be defended as a refugium from future climate change rather than allowed to undergo a transition by facilitating a conversion to species adapted to a warmer and drier climate such as white and red oak.

Furthermore, the USDA Forest Service Tree and Climate Atlas projects little change (with high model reliability), or even a modest increase in abundance for sugar maple in southwestern Massachusetts for future moderate (RCP 4.5) or high (RCP 8.5) warming scenarios for the late 21st-century (Peters et al. 2020). This is visible in Figure 3 by comparing the current abundance of sugar maple in southwestern Massachusetts on the left to projected future abundance for the RCP 8.5 warming scenario on the right. Sugar maple is also projected to maintain its abundance even well to the south in the previously mentioned cool spot in West Virgina.

In the northeastern U.S., and western Massachusetts in particular, increasing evaporation with a future warming climate is likely to be offset to a large extent by greater precipitation, with relatively little change in frequency of severe droughts expected compared to northern hardwood forests of the Great Lakes region (Moss et al. 2024). The western Massachusetts region is very far from the Midwestern prairie-forest border where much larger negative changes in the current tree-friendly climate are expected (Toot et al. 2020). A projected increase in precipitation, combined with the valley-bottom location, seepages and high water-holding capacity of the soil

in the Cattle Barn Lot sugar maple stand are all consistent with this being a current and future climate refugium location for sugar maple.

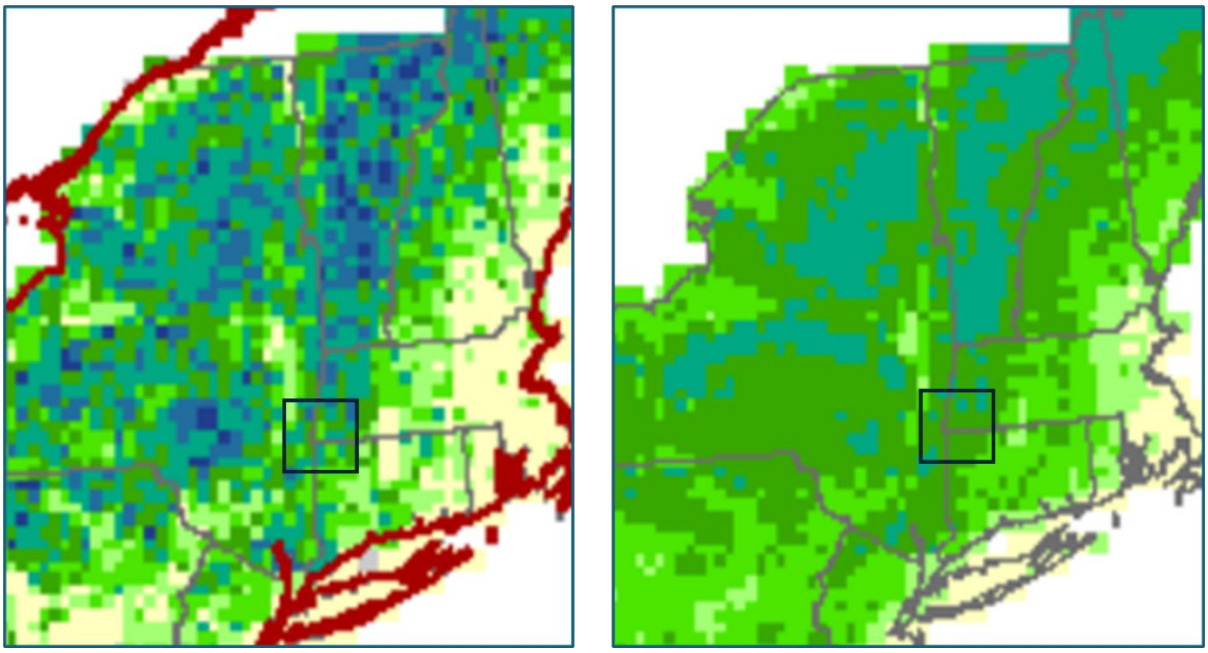

Figure 3. Current modelled (left) and projected future abundance of sugar maple under RCP 8.5, a high magnitude of climate warming (right). From the sugar maple webpage associated with Peters et al. (2020): https://www.fs.usda.gov/nrs/atlas/tree/318. Light and medium green colors indicate 4-6 and 7-10 percent importance values for sugar maple, while light blue and medium blue colors indicate 11-20 and 21-30 percent importance values in the area of interest (black box). Importance value is the average of the percent density of trees, percent basal area, and percent frequency of trees of a given species on study plots; it is a widely used measure of overall abundance, and sums to 100 when all species present are added together.

Earthworms, Deer and Invasive Plants

Some native earthworm species are present in Massachusetts, but they are low in abundance and the vast majority of earthworm biomass in forests of western Massachusetts is in several invasive species, mainly from Europe. In the areas of the Cattle Barn Lot that I walked, there was little evidence of non-native earthworm presence in cut areas 2, 4, or 6, east of Karner Brook. There was more evidence in cut areas 1, 3, and 5, on the west side of the brook. There was no evidence of jumping worms (earthworms from Asia in the genera *Amynthas* and *Metaphire*) anywhere in the Cattle Barn Lot or surrounding area during my visit.

There are five stages of European earthworm invasion (Loss et al. 2013), which began when European settlers arrived in a given area, and has progressed since that time, with many active fronts of invasion throughout the northern hardwood region in the northeastern U.S. and Canada.

- Stage 1 is earthworm free, which was formerly common in northern hardwood forests. This stage is characterized by a thick organic horizon (commonly known as duff) with a multi-decadal accumulation of leaf litter and distinct L (litter), F (fragmentation), and H (humus) layers and the leaf litter on top is matted down from snow sitting on it during the winter.
- Stage 2 has epigeic (litter dwelling) earthworms such as *Dendrobaena octaedra* that do some mixing within the L and F layers, but overall, the organic horizon is still thick with the same three layers present.
- Stage 3 has epigeic and endogeic (soil dwelling) earthworm species (*Aporrectodea* and *Octolasion* species, along with *Lumbricus rubellus*). The thickness of the forest floor is thinner at this stage due to consumption of leaf litter, but the biomass of earthworms is too small to consume all the litter that falls each year so that some F and H layer organic material is still present.
- Stage 4 heralds the arrival of anecic earthworm species, principally the nightcrawler (*Lumbricus terrestris*), which eats freshly fallen leaf litter each autumn and the following spring, causing more thinning of the organic horizon than in stage 3.
- Stage 5 is reached when the nightcrawler becomes dominant in the earthworm community, although the full suite of invasive earthworm species is often still present. Earthworm biomass is high enough at this stage to consume all of the leaf litter that falls each year by mid to late summer, so that a thin organic horizon is present only in late fall and spring, the F and H layers of the organic horizon are absent, and bare mineral soil is visible by late summer.

The changes to the forest floor by the time stage 5 is reached are accompanied by major changes in ecosystem function. The productivity of trees is reduced due to leaching loss of nutrients (N, P, K, Ca, Mg), warmer and drier soils during summer due to the absence of the insulating effect of the organic horizon, and disruption of the fine root system and mycorrhizae that were located in the lower layers of the organic horizon. At stage 5, invasive plant species from the Eurasian continent (which also arrived with European settlers) are facilitated by the new conditions on the forest floor, and diversity of native plant species in the understory (including tree regeneration) is reduced.

Strong interactions with deer also occur at stage 5. The impacts of deer on the understory plant community are exacerbated by the earthworm invasion (Fisichelli et al. 2013, Craven et al. 2017, Frelich et al. 2019, Reed et al. 2023). This is due to lower plant density caused by the earthworm invasion, but with the same deer density, hence a higher deer to plant ratio and large magnitude of impacts on plant species preferred by deer. Research on deer density in Wisconsin shows that higher deer densities reduce herb layer diversity and increase ferns which deer do not like to eat (Callan et al. 2013, Bouchard et al. 2013), an effect of deer grazing which is occurring in the Cattle Barn Lot. In addition, numerous interactions with other stress factors, and implications for

forest management, occur when earthworm invasion reaches stage 5 (Frelich et al. 2006, Frelich and Reich 2010, Webster et al. 2018).

In the Cattle Barn Lot, there was minimal presence of European earthworms in Stand A (stages 1 and 2) and more substantial presence of non-native earthworm invasion was observed in Stand B. There, the invasion stages were mostly 2 and 3, with some F and H layers present in the organic horizon, and minimal impacts at this time. However, within Stand B, stages 4 and 5 are evident in certain parts of cut areas 3 and 5, around the white ash-dominated stands and seepage areas. These latter areas provide an excellent habitat for European earthworms due to the high Calcium and Nitrogen content of ash leaf litter and constant supply of nutrient-rich moisture from ground water that has moved through bedrock and glacial deposits. The understories of these white ash and seepage sites are occupied by barberry, stiltgrass and other invasive plants (listed by Eiseman 2024) because of the facilitation by earthworms (Frelich et al. 2019) and high light availability due to death of ash trees from emerald ash borer. This is a problem for the surrounding forest due to the seed sources of invasive plant species, especially barberry in this case, and due to the potential expansion of areas with high nightcrawler densities at stage 5 of earthworm invasion.

The mentioned invasive plants can grow in sugar maple forests with intact ecological legacies (like the uninfested and minimally earthworm-infested areas of the Cattle Barn Lot), but not very well due both to thick leaf litter cover which is not an ideal germination habitat, and to the high leaf area index resulting in dense shade. Sugar maple stands that are left intact from the perspective of forest floor disturbance are resistant to increasing stages of non-native earthworm invasion. This is due to relatively slow decomposition of sugar maple leaf litter which results in production of organic acids that limit earthworm biomass and slow expansion of the nightcrawler. This phenomenon has been recently observed on long-term permanent plots in old-growth sugar maple forests in the Porcupine Mountains Wilderness State Park and Sylvania Wilderness in Upper Michigan, where the stage of invasion has not gone beyond 2 or 3 in 30 - 42 years since plot installation, despite having an invasion front of nightcrawlers present from the time of plot installation (Frelich, unpublished data from recent resurvey of these plots during summers of 2022-2024).

Disturbance to the forest floor in the Cattle Barn Lot (especially in Stand A and cut area 1) would make it harder for the forest to resist earthworm invasion and the above-mentioned cascading effects on the ecosystem and invasive plants. The potentially warmer soil temperatures in summer that would be brought about by expansion of the higher stages of earthworm invasion would oppose the effects of the previously mentioned well-developed evapotranspiration and shade cooling effects that work with the cold air drainage and pooling in the sugar maple forest, and with the slow decomposition of organic matter in sugar maple stands generally. Without extraordinary care, any use of equipment will spread earthworms as well as seeds of the invasive plant species into currently uninfested areas and likely become the added effect that overwhelms the ecological legacy of the core sugar maple stand, probably leading to loss of resilience that the stand has shown so far.

Of the several stress factors mentioned in the introduction, high deer population is one that can be removed or reduced. The stand has a relatively low density of sugar maples in the seedling-sapling layer due to deer. Maybe that will change—local observations of a massive sugar maple seedling germination event in 2023 should be followed up to see if it leads to restoration of the sugar maple seedling layer, which could develop into a sapling layer in the next 10-15 years, increasing shade at the forest floor that would limit the establishment and growth of invasive plant species. This phase of stand development could be enhanced by reducing deer density, to allow saplings to grow upwards faster than deer eat them downwards. More information (if available) about the history of deer density in this stand would be helpful in assessing how the stand got to its current condition.

Oaks are even more likely than sugar maple to be grazed during winter and not successfully recruited into the canopy. They are also not as shade tolerant as sugar maple, are unlikely to survive growing under the ferns at midsummer, and therefore even less likely to escape deer browsing than sugar maple—although note that northern red oak can survive in dense shade through the first summer after germination, but later on, in the second and third summers, will die in dense shade after exhausting the energy supply stored in the acorn. In gaps, these oak seedlings may survive, but only until tall enough to be noticed by deer. It would take very large gaps (2000+ square feet) to have enough light to allow red oak to grow upwards faster than deer eat them downwards. Therefore, facilitating oak is not likely to be very successful in the core stand at this time.

Sugar Maple Decline

Many papers have been published showing that sugar maple dieback has occurred throughout much of its range, even towards the northern edge of the range in Canada (Horsely et al. 2008, Pitel and Yanai 2014, Bishop et al. 2015, Moreau et al. 2020, Boakye et al. 2023). Dieback in these studies has been widely attributed to more frequent droughts associated with climate change, fluctuating soil temperatures and loss of nutrients (especially cations Calcium and Magnesium in the case of sugar maple) due to acid rain, and to insect pests that infest sugar maple trees under nutrient or drought stress. Soil measurements in these studies did show more dieback in drier stands or stands with lower cation levels. However, European earthworm invasion is widespread in forests of eastern North America and also causes warmer, drier soils and cation loss (Frelich et al. 2019). Most of the cited studies did not take earthworm invasion status into account. One study that directly compared dieback in sugar maple crowns among sites with differing earthworm invasion status levels found that earthworm invasion was directly linked to sugar maple dieback status (Bal et al. 2018), and a tree-ring study demonstrated that sugar maple trees showed more negative responses to droughts starting at the time when earthworm invasion reached stages 4-5 (Larson et al. 2010). Furthermore, recent analyses of response of sugar maple to climate show lower magnitude or no impacts of projected climate change in New England compared to earlier studies (Peters et al. 2020) or that there was no consistent pattern of sugar maple tree-ring response across large geographic areas with differing climates (Copenheaver et al. 2020). This suggests that multiple stresses from earthworm invasion

(Frelich et al. 2019) and deer browsing (Henry et al. 2021) are more important considerations at this point than climate change and the acidity of rainfall (which has been mitigated to some extent). The core sugar maple forest of interest here does not have dieback at this time, and its unique physiographic setting should provide a climate refugium, but deer, earthworms, and potential forest floor disturbance are still important factors.

Conclusions

The core sugar maple forest in the Cattle Barn Lot is a FOG (future old growth) stand of sugar maple with a largely intact ecological legacy, that, if left alone, will develop via natural stand development processes into secondary old growth with many features of primary old growth forest.

Within the area of interest, large sugar maple stands like that found in the Cattle Barn Lot are locally rare, since the stand is surrounded by a variety of oak and oak-pine forests. Therefore, this core stand contributes to the high level of local biodiversity, by hosting a number of species with high fidelity to the sugar maple forest type. Furthermore, the core stand is in a physiographic setting that is unusual for sugar maple more broadly across the landscape.

The core sugar maple stand is likely to persist in a warming climate. The crown architecture and leaf arrangement of sugar maple (dome effect) leads to a local cooling effect, and in addition the valley-bottom location is a climate refugium with cold air drainage and pooling, as well as good water supply.

Multiple stresses are impinging on the core stand, including impacts of high levels of deer browsing on woody (mostly winter) and grazing on herbaceous (mostly summer) plants, incipient earthworm invasion, with potential cascading effects that could enhance the spread of invasive plant species such as barberry. These could negate some of the above-mentioned cooling effects of the sugar maple core stand.

Disturbance of the forest floor would foster the spread of invasive earthworms and their major ecological cascades, threatening the resilience of the stand to a warming climate. Creation of gaps is not recommended at this time because the high abundance of ferns and deer browsing would limit recruitment of oaks or maples. Although gap creation ca 40 years ago allowed recruitment of a now pole-sized tree size class in parts of the area, the response is likely to be different now (as explained by the resilience debt concept (Johnstone et al. 2016), whereby responses to the same disturbance type that previously occurred are different due to unseen differences in resilience of the forest).

In addition, currently healthy white ash trees should be watched to see if they are resistant to emerald ash borer, and mature black cherry trees are not very abundant but are important as a wildlife food source and should be left intact.

In the absence of disturbance to the forest floor, the notably strong positive neighborhood effects for sugar maple (Frelich et al. 1993, Frelich and Reich 1999) should help to maintain the stand in

its current condition and resist expansion of the earthworm invasion and invasive plants until solutions are found to mitigate the high levels of deer browsing.

Potential Research and/or Citizen Science Projects

Citizen science projects that would help inform future ecological development and management of the cores sugar maple stand could include: (1) Measure air temperature hourly through at least a year using iButtons or Hobos at several locations in and around the core stand; (2) Establish a systematic series of small plots where abundance of tree seedlings and native and invasive plant species are monitored; (3) Some of these plots could be surrounded by deer exclosures to measure how fast the understory vegetation and tree regeneration would recover in the absence of deer browsing; (4) Monitor the movement of earthworm invasion fronts with transects from currently infested areas into less infested areas.

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