Lake States Fire Science Consortium

Cold-season precipitation gradients modulate the distribution of fire-tolerant forest taxa in the Finger Lakes region of New York State, USA

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The Finger Lakes region of upstate New York forms part of the easternmost section of the Interior Lowlands physiographic province of midcontinental North America. Its geographic location – straddling the lower Great Lakes and Appalachian Plateau – is the intersection of beech-maple, oak-hickory, and hemlock-northern hardwood forest associations[1]. This region is also an important ecotone where coastal communities such as pitch pine (Pinus rigida) barrens historically coexisted with Midwestern oak savannas[2]. The juxtaposition of these open-canopy, fire-adapted and fire-tolerant (pyrophilic) communities with extensive areas of late-successional, closed-canopy, fire-intolerant (pyrophobic) forests prior to Euro-American settlement circa 1790 suggests that variable regional fire regimes were important for maintaining this vegetation mosaic. Our research seeks to understand the relative importance of climate versus anthropogenic land-use history (i.e., Native American settlement and subsistence) on observed forest species composition.

Although lake-effect snowfall (LES) gradients have been identified as the dominant modulator of the distribution of mesic/xeric vegetation communities in northern lower Michigan[3], there has been no previous research on this relationship in other parts of the Great Lakes region, where LES gradients are even more pronounced. Our research evaluated the relative importance of climatic, ecological, topographic, pedologic, and cultural variables on the distribution of forest taxa in the Finger Lakes region prior to Euro-American settlement. By evaluating a wide range of potential environmental predictor variables, we identified those most strongly correlated with inferred regional fire frequency gradients.

Our past research used late 18th century land survey records (LSRs) to reconstruct forest composition and structure immediately prior to widespread Euro-American settlement of the Finger Lakes region and delineate spatial relationships between forests, environmental gradients, and Native American settlement patterns[4,5]. We compiled, digitized, and georeferenced compositional and structur-

Management Implications

1. Fire frequency was the most important environmental influence on regional forest composition in the Finger Lakes in the 18th century. Soil productivity and variables related to the distribution of open-canopy habitats (e.g., Native American land-use legacies) had minor influence on species composition.
2. The historic distribution of fire-tolerant forest taxa is strongly correlated with spatial gradients of lake-effect snowfall (LES) and snowpack persistence. Cold-season precipitation, including LES, likely exerted an important influence on fire frequency by modulating soil-moisture conditions, which in turn determined the overall suitability of sites to specific forest taxa (pyrophilic vs. pyrophobic) and the combustibility of available fuels.
3. Native Americans did not greatly alter the overall regional-scale vegetation pattern induced by LES gradients. However, the frequency of fires was likely greater in locales subjected to recurrent land-use activities related to Native American settlement and subsistence.
4. Forest managers working in the Great Lakes region must consider cold-season hydro-climatological variables, particularly LES totals and snowpack persistence, to plan the location and frequency of prescribed fires most effectively for the purpose of restoring fire-tolerant forest taxa and fire-adapted ecosystems.

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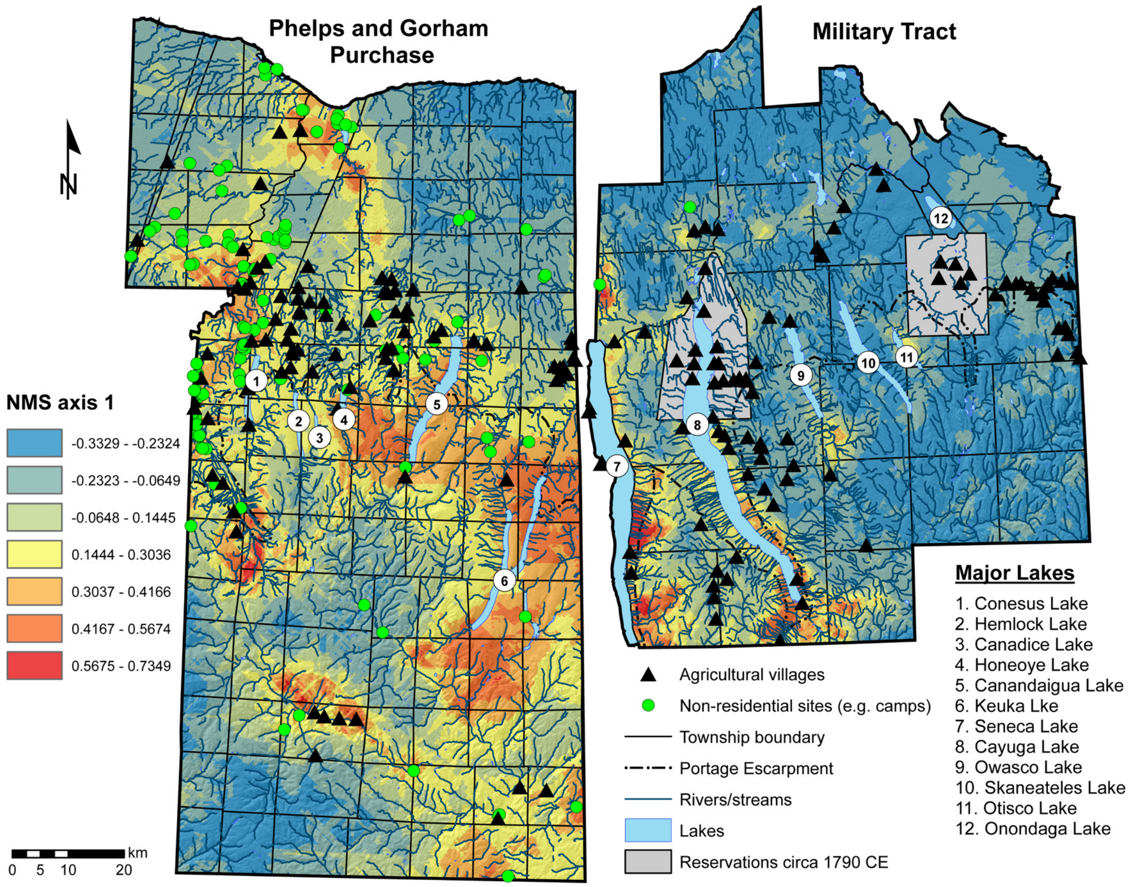

Figure 1. Interpolated map of non-metric multidimensional scaling (NMS) axis scores for the presettlement Finger Lakes vegetation fire frequency gradient data. **Note:** Numbered circles indicate major lakes.

al vegetation data, including (1) species identifications of bearing trees at township and section corners, (2) tree species inventories recorded along township and section survey lines, and (3) surveyors' assessment of stand appearance ("thinly timbered," "open land"), evidence of recent disturbance ("burnt timber," "windfall"), and indicators of anthropogenic land-use ("old Indian clearing," "camp"). Compositional and structural data were analyzed using non-metric multidimensional scaling (NMS) to determine the most significant underlying environmental gradients. We evaluated these gradients with respect to 37 environmental variables representing climate (temperature, precipitation, snowfall, moisture availability), topography (elevation, % slope, aspect), pedology (soil texture, productivity, drainage), cultural factors (proximity to Native American archaeological sites), and ecological metrics (fire frequency index [FFI], canopy density index [CDI], openland index [OI]) using correlation analysis.

Results and Implications

NMS produces a set of axes which each represent the collective influence of multiple variables. NMS Axis 1 (Figure 1) explained the greatest proportion (60.7%) of the variance in the presettlement Finger Lakes vegetation data and was strongly positively correlated with FFI, CDI, and OI. Collectively, this suggests that Axis 1 represents a nexus of interrelated variables pertaining to fire frequency and its influence on forest composition and structure. NMS Axis 2 explained an additional 19.7% of the total variance and was moderately positively correlated with Soil Productivity Index (PI). Finally, NMS Axis 3 explained 11.8% of the variance and demonstrated a weak positive correlation with OI. Correlation analysis of NMS axis 1 scores indicated that aside from the ecological variables (FFI, CDI, OI), precipitation of coldest quarter, precipitation of driest quarter, precipitation of driest month, mean annual snowfall and mean annual days >2 cm snowpack thickness possessed the strongest correlations to fire frequency, and all were negative relationships (Table 1). This strongly supports our interpretation that the geographic distribution and abundance of pyrophilic/pyrophobic forest taxa in the Finger Lakes region was largely modulated by patterns of cold-season precipitation, particularly LES and snowpack persistence, which in turn, controlled fire frequency at regional, sub-regional, and landscape spatial scales.

Prominent gradients in LES are characteristic of the Finger Lakes region and much of the wider Great Lakes region[3]. For example, the eastern portion of the study area (Military Tract) lies within the Lake Ontario snowbelt with 2000 – 3000 mm total annual snowfall[6], whereas the western portion (Phelps and Gorham Purchase) largely falls outside the snowbelt, with annual snowfall totals in some areas are <1000 mm[7]. Snowfall directly influences the distribution and abundance of forest taxa by altering soil-moisture conditions. For example, areas with low LES totals and less persistent snowpacks tend to

Environmental Variable	r	r2	p	Variable Type
Fire Frequency Index (FFI)	0.953	0.908	0.0000	Ecological
Canopy Density Index (CDI)	0.847	0.717	0.0000	Ecological
Openland Index (OI)	0.731	0.534	0.0000	Ecological
Precipitation of coldest quarter (mm)*	-0.677	0.458	0.0000	Precipitation
Precipitation of driest quarter (mm)†	-0.645	0.416	0.0000	Precipitation
Precipitation of driest month (mm)‡	-0.635	0.403	0.0000	Precipitation
Mean annul snowfall (mm)	-0.628	0.394	0.0000	Precipitation
Mean annual days >2 cm snowpack thickness	-0.605	0.366	0.0000	Precipitation
Precipitation Seasonality (Coefficient of Variation)	0.585	0.342	0.0000	Precipitation
Mean annual moisture balance (MAP/PET)	-0.583	0.339	0.0000	Moisture
Mean annual precipitation (MAP; mm)	-0.560	0.314	0.0000	Precipitation
Mean annual potential evapotranspiration (PET; mm)	0.539	0.290	0.0000	Moisture

*December-January-February
†December-January-February
‡February

Table 1. Pearson product-moment correlation coefficients (r), coefficients of determination (r2), and associated p-values for environmental and cultural variables (n = 37) with respect to non-metric multidimensional scaling (NMS) axis 1 scores (fire frequency gradient) of the Finger Lakes presettlement vegetation data. Variables are listed in descending order of r2 values. Footnote data for monthly and quarterly climate variables are based on 1981 – 2010 climate normals for Rochester, New York (Garoogian 2011).

enter the growing season with drier soils that can produce earlier and more severe water deficits, exacerbating later growing-season droughts. Forest litter in areas of reduced LES and more ephemeral snowpacks would be prone to earlier drying after snowmelt, contributing to more active fire regimes. Under such conditions, fire- and drought-tolerant taxa such as Quercus are favored over mesic, fire-intolerant Acer, Fagus, and Tsuga. The influence of regional snowfall gradients is evident in the geographic distribution of fire-tolerant taxa, which were more numerous in the central and western Finger Lakes region circa 1790, where LES totals were lower, snowpacks less persistent, and hydroclimate conditions were more conducive to the dominance of drought- and fire-adapted species (Figure 1).

Native American settlement and land-use practices were apparently a minor influence on the regional vegetation pattern, as proximity to Native American settlements was weakly negatively correlated with the multivariate indicator of fire frequency. However, various climatic, soil, and topographic variables exhibited even weaker correlations with the fire frequency indicators than most of the cultural variables tested. Importantly, our past research showed that Native American archaeological sites of the Finger Lakes region were commonly situated in areas with greater frequencies of fire-tolerant forest taxa and were especially common near open-canopy habitats (e.g., oak savanna, prairie, pine barrens). Although Native Americans – through deliberate and accidental fire ignitions, vegetation clearing, and agricultural/silvicultural practices – played a relatively minor role on vegetation communities at a regional scale, their influence was likely a more important factor at sub-regional, landscape, and local scales.

For Further Reading

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