Fire History Reconstruction of Southeastern Massachusetts: Foothills Preserve, Plymouth, MA

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Introduction:

This project looks at **Foothills Preserve** in **Plymouth, MA**. This land was formerly a natural **Atlantic White Cedar (AWC) swamp**, a rare ecosystem threatened by current stresses such as anthropogenic land use and climate change. Southeastern Massachusetts has been populated by **Native Americans** for thousands of years. In 1620 CE **European colonizers** arrived in Plymouth, which led to extensive **land clearing** and introduction of **western agriculture** (~1670 – 1700 CE). **Commercial cranberry cultivation** began in 1854 CE, which required converting the natural wetland to large-scale agricultural farms. Mass Division of Ecological Restoration is now leading **restoration efforts** on this land.

This project focuses on **reconstructing past fire history** of this region through conducting **charcoal analysis** on a **peat core** derived from Foothills Preserve. The core was collected in 2019 and extends to **>9000 years before present (YBP)**, but in this project, analysis was performed on a **50 cm** section of the core spanning **3819 – 162 YBP**. Learning about past fire history in the region can be used to **inform on future management of the land** to **protect natural ecosystems**.

Methodology:

- **Contiguously sample** core every **0.5 cm**, taking 1 cm^3 of peat.
- **Bleach** in **10% KOH** for at least 4 weeks.
- **Filter** through **125 µm sieve** using DI water to isolate and archive macrocharcoal.
- **Pipette** portion of sample into grooves of **Borgorov tray**.
- **Count** pieces of charcoal using **stereo microscope** at **15-25x magnification**, keeping track with a counter.
  - Charcoal classification:

    Color: **COMPLETELY** jet black, or shiny/iridescent.
    Shape: resembles plant material (cellular structure, angular, long and fibrous, spherical).
    Durability: fragments easily when probed.
- **Create Age Model**: ^{14}C Calibration, R-based Bayesian probability age model in Bacon.
- **Run Charanalysis** software: combine age model and charcoal counts to analyze statistically significant fire events, and metrics of fire frequency and severity.

Future Work:

- Continue sampling core to complete fire history reconstruction spanning >9000 – 0 YBP.
- Compliment this data with pollen work to reveal how certain species respond to fire disturbances.

Figures:

Figure 1: Foothills Preserve, Plymouth, MA, where the peat core was extracted.

Figure 2: Measuring tape along core to mark contiguous 0.5 cm samples.

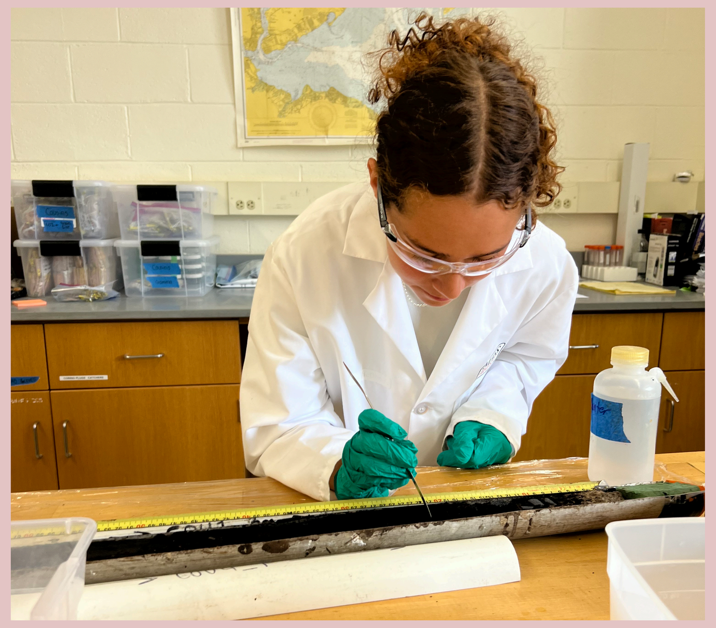

Figure 3: Excavation of sample using a scalpel, before dissolution in 10% KOH.

Figure 4: Sample contents in sieve, being sprayed with DI water to filter out particles <125 µm.

Figure 5: Portion of sample dispersed along Borgorov tray under a stereo microscope.

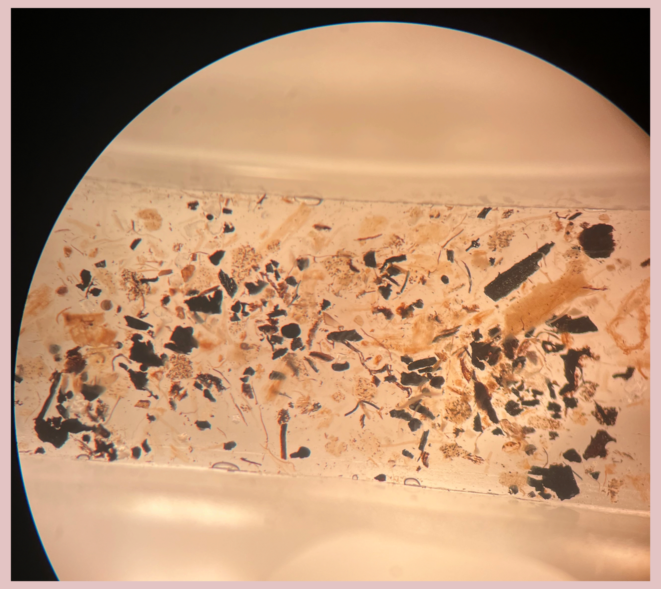

Figure 6: Sample contents under microscope, where charcoal is counted.

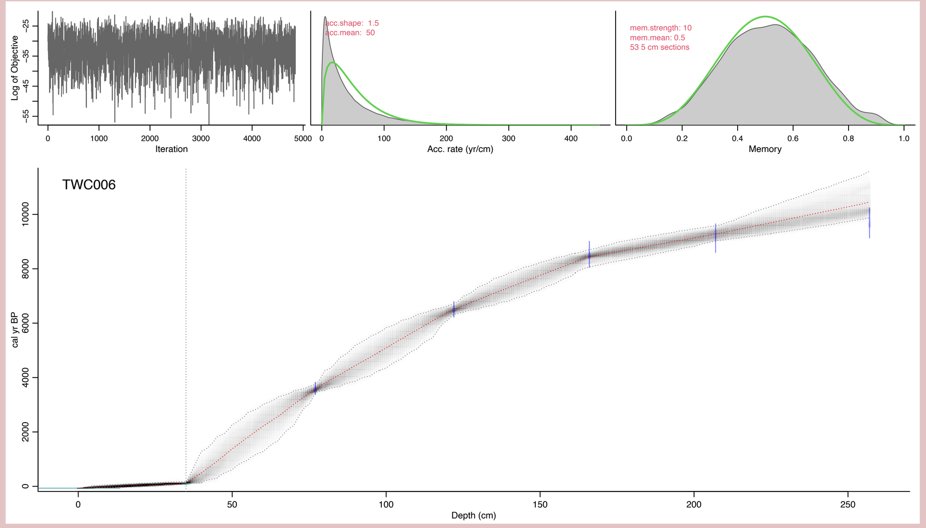

Figure 7: Bacon Bayesian probability age model for the core (conducted in R). The mean sediment accumulation rate for the record is 50 yrs/cm.

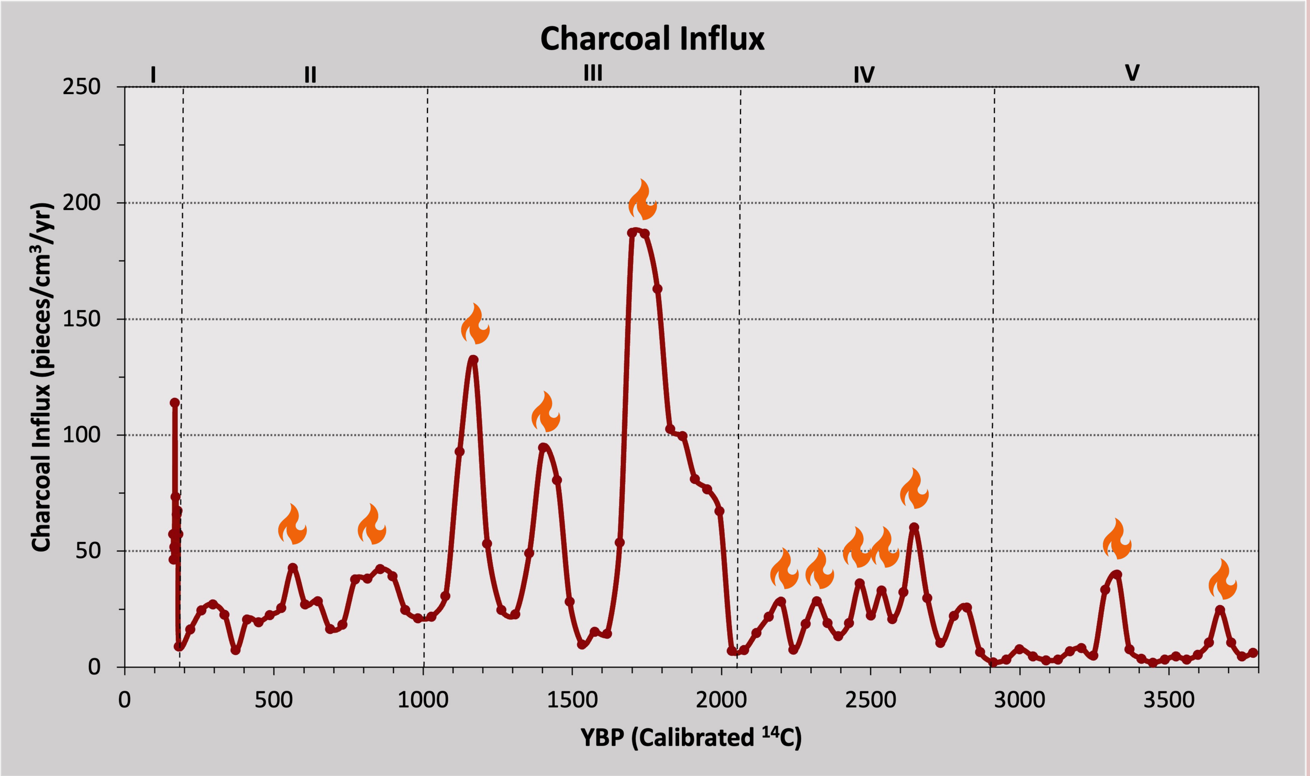

Figure 8: Graph displaying charcoal influx trends throughout the core. Years before present (YBP) spans from 3800 - 0 YPB along the horizontal axis, with charcoal influx (pieces/cm^3/yr) range on the vertical axis. The graph is divided into five periods based on fire behavior trends. Statistically significant peaks (>95% confidence interval) are identified with a fire symbol.

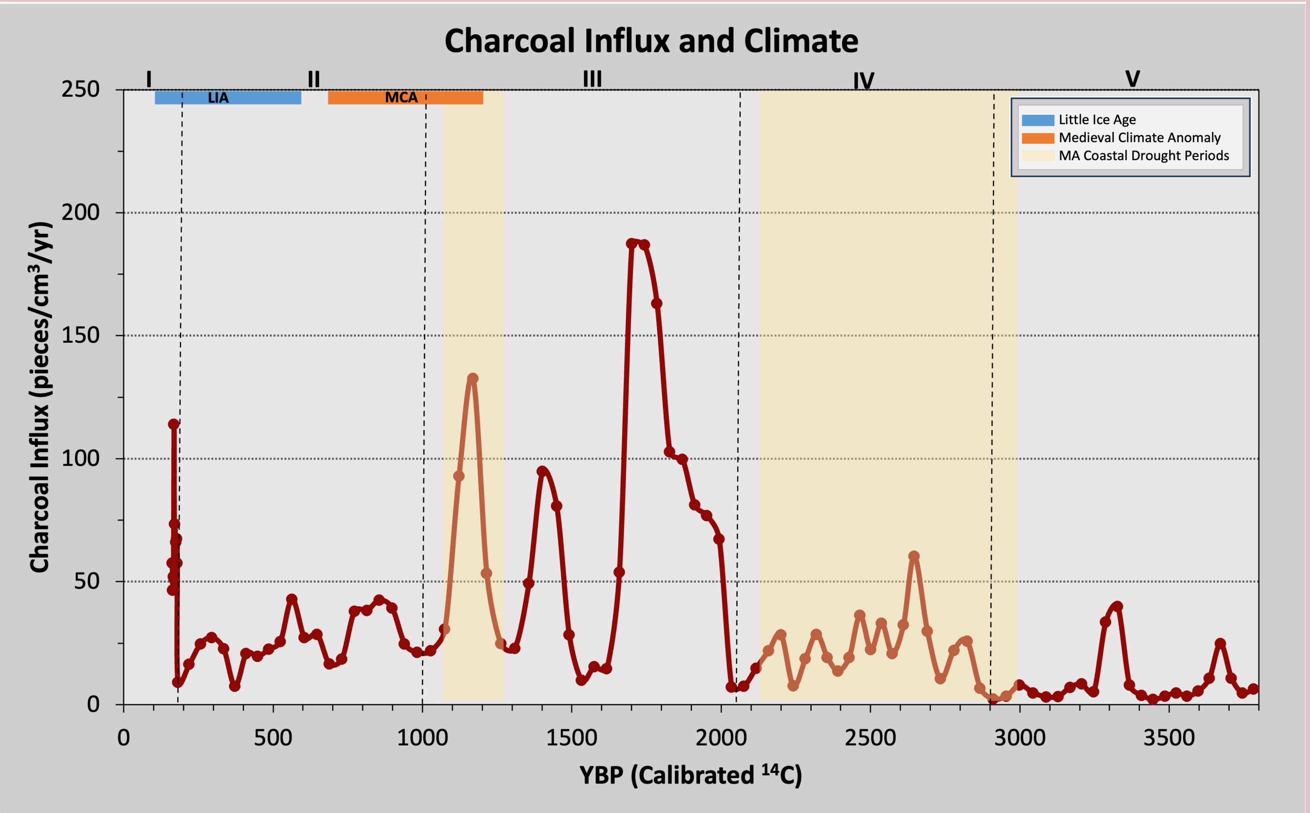

Figure 9: Graph displaying charcoal influx trends compared to late-Holocene climatic shifts. Periods of droughts are highlighted in yellow (Newby et al. 2014), and the duration of the Medieval Climate Anomaly (MCA) and the Little Ice Age (LIA) events are depicted by colored bars at the top of the graph (Shuman et al. 2018).

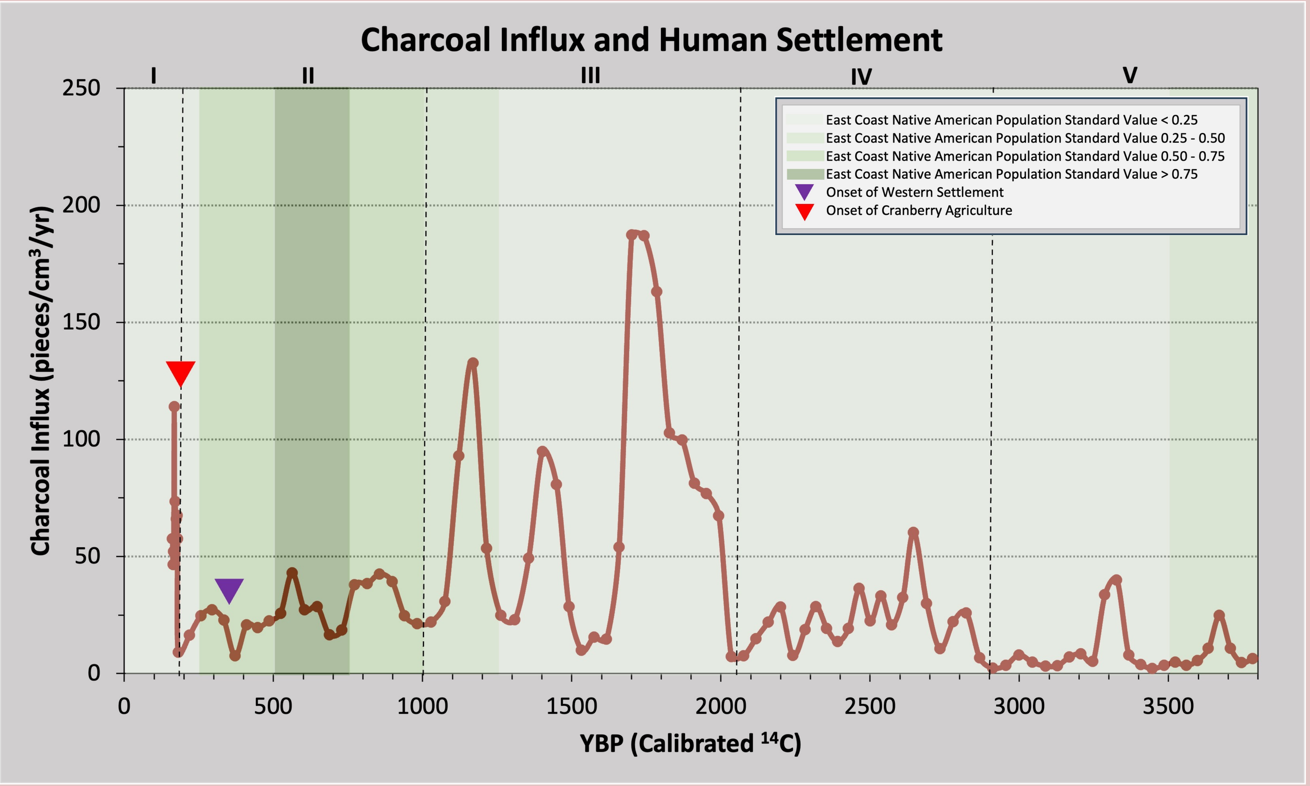

Figure 10: Graph displaying charcoal influx trends compared to human settlement trends. Green shading indicates Native American population standard value, with darker shading indicating greater population size (Munoz et al. 2010). The purple arrow indicates arrival of Western settlers, and the red arrow indicates onset of cranberry farming.

Results:

- Individual **charcoal counts** range from **82 – 7866 pieces/cm³**
- Individual **charcoal influx** levels range from **2.05 – 187.29 pieces/cm³/yr**
- **Total** charcoal count: **123,841 pieces**

Period V (3800 – 2900 YPB): **low amplitude, low frequency** fire events; one occurring every ~450 years.

Period IV (2900 – 2050 YBP): **low amplitude, high frequency** fire events; one occurring every ~170 years.

Period III (2050 – 1000 YBP): **high amplitude, low frequency** fire events; one occurring every ~350 years.

Period II (1000 – 181 YBP): **low amplitude, low frequency** fire events; one occurring every ~400 years.

Period I (181 – 162 YBP): low charcoal counts, high influx levels. **No significant fires**.

Discussion:

Period V (3800 – 2900 YPB): low fire severity and frequency, **seemingly unaffected** by the Native American population and transition into drought.

Period IV (2900 – 2050 YBP): low severity, high frequency fire behavior, likely influenced by an **extended 1000-year period of drought** in the Northeast.

Period III (2050 – 1000 YBP): high severity, low frequency fire events. Broadly, this period overlaps with elevated **anthropogenic burning**, identified in the Northeast region from 3000 – 500 YBP (Munoz et al. 2010). There may be multiple fires within each peak. A peak at ~1150 YBP evidently covaries with an **increase in Native American populations**, period of **drought**, and onset of **Medieval Climate Anomaly (MCA)**.

Period II (1000 – 181 YBP): low fire severity and frequency, presumably **not influenced** by **peak Native American levels**, introduction of **colonizers**, **MCA**, or **Little Ice Age (LIA)**.

Period I (181 – 162 YBP): large influx values associated with **high anthropogenic sedimentation rate** due to onset of **cranberry farming** practices.

Acknowledgements:

This work is/was supported in part by the USDA National Institute of Food and Agriculture, Massachusetts State Grange, McIntire-Stennis project 1021302 and the Living Observatory. Thanks to Town of Plymouth for facilitating site access. We are grateful to Brian Yellen, Julia Casey, Nathaniel Thomas, and Alyssa Chase (UMass EGCS) for sediment core collection and initial analysis, as well as Lily Sanborn (MIT/WHOI) for running the age model.

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