Nitrogen Cycling in Wetland Plant Leaves: A Spectral Experiment

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Introduction:

This project took place at the Tidmarsh Wildlife Sanctuary (Mass Audubon) and Foothills Preserve (Town of Plymouth) in Plymouth, Massachusetts. Tidmarsh, which actively farmed cranberries until 2010 (and 2015 at Foothills) was the largest freshwater wetland restoration project in Massachusetts.
It became a MassDER priority project in 2011 and underwent active restoration throughout 2015 and 2016. In 2017, 485 acres of restored wetland was acquired by Mass Audubon as a wildlife sanctuary, and 128 acres west of Beaver Dam Road was acquired by the town of Plymouth, which was restored in 2019 to 2021. Cranberry bogs are a large source of nitrogen, especially if they are flow-through bogs. Functional freshwater wetlands can break down nitrogen compounds in the environment. This made Tidmarsh and Foothills the perfect area for this project, centered around testing the relationship between surface water nitrogen and its effect on the spectral signature of wetland plant leaves.

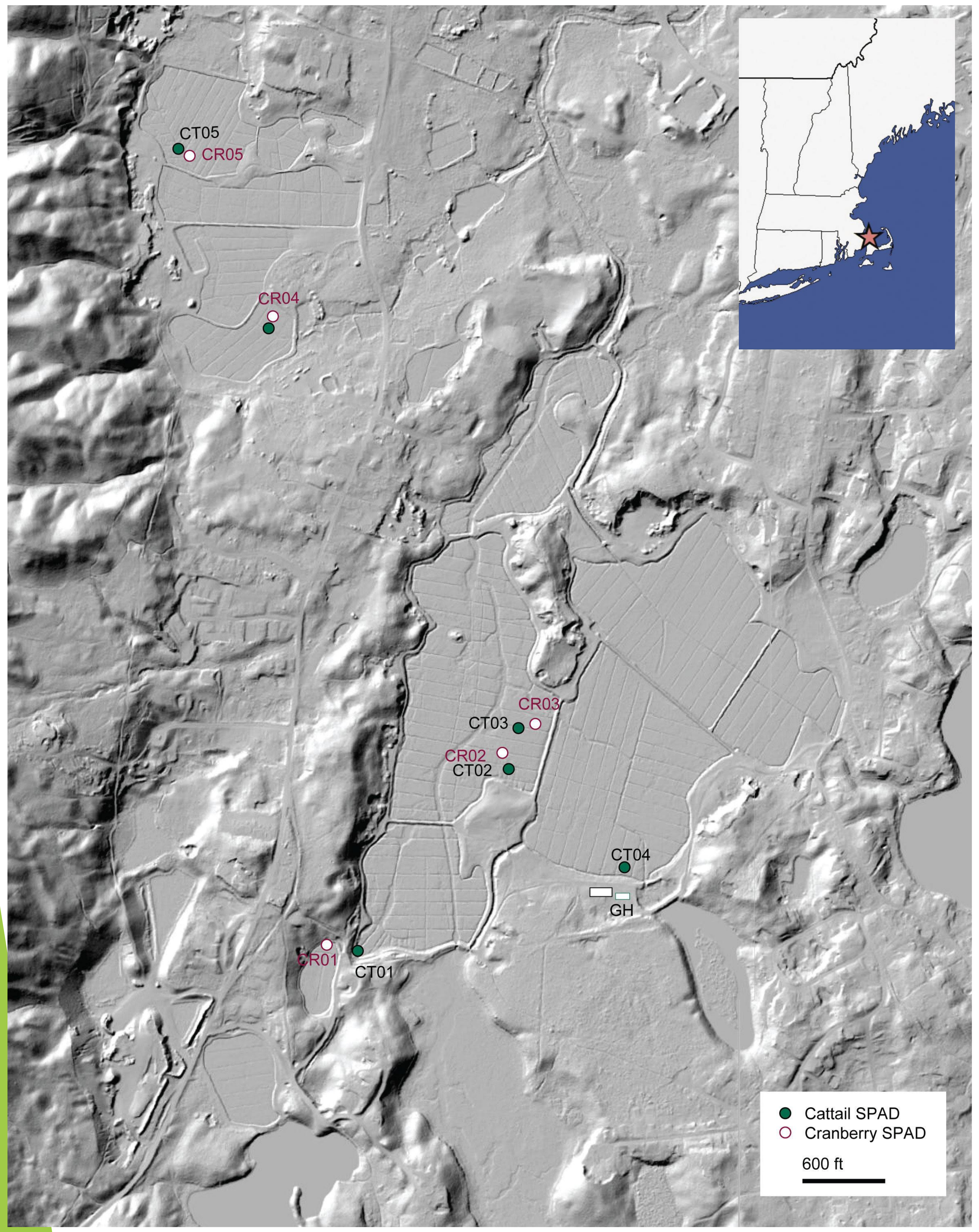

Figure 1. MassGIS state LiDAR (Light Detection and Ranging from 2011) shaded digital elevation map of Foothills Preserve (upper left) and Tidmarsh Wildlife Sanctuary (center right) before restoration of either site. Sample locations of field SPAD measurements on cranberry (CR) or cattail (CT) plants are plotted, and the Greenhouse (GH) location where experimental plants were grown is shown on the lower right.

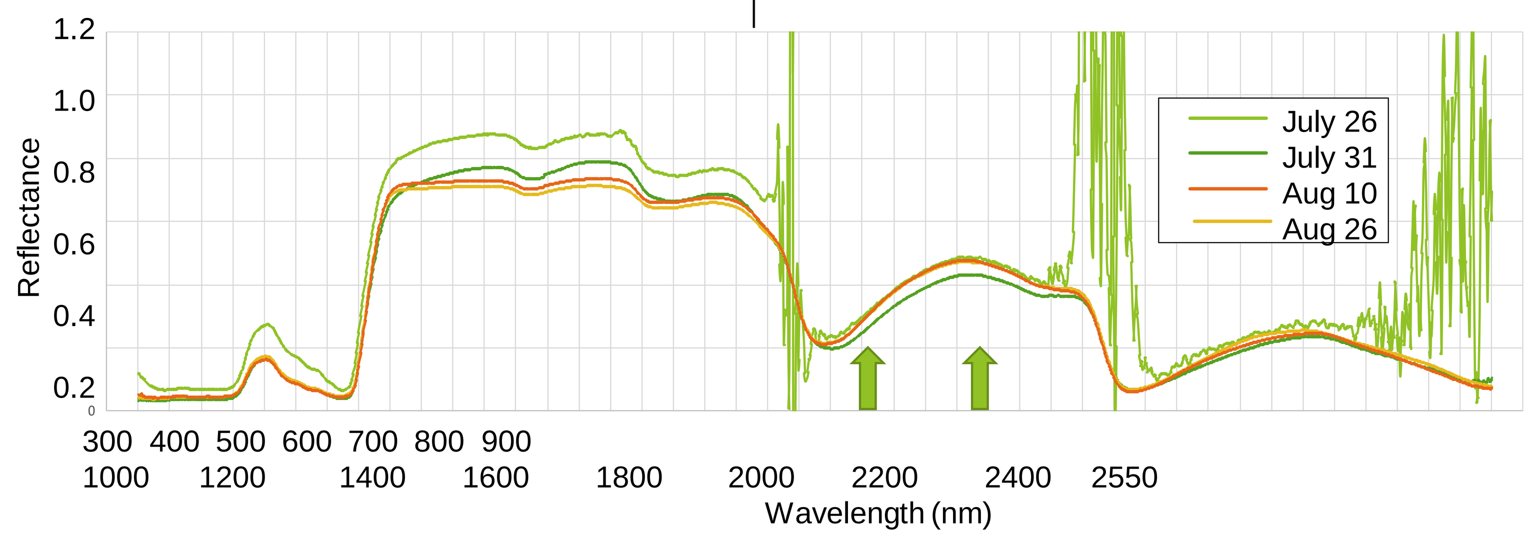

Figure 2. Example of Raw spectral data collected from the same plant on July 26 (no leaf clip, noisy data due to light interference), July 31, August 10 and August 26. Experimental nitrogen treatment was applied on July 26 after the first measurement. Arrows indicate wavelengths 1510 and 1680 nm, which are used to calculate NDNI.

Summary

This project was a proof-of-concept investigation into whether the amount of available nitrogen may affect the spectral signatures of wetland plants over time. To investigate this, we broke this project into two different experiments. First, we conducted a controlled greenhouse experiment consisting of five replicates of four species of plant and three different trials, varying nitrogen fertilizer application levels between each. We measured leaf spectra as an indicator of foliar nitrogen in response to nitrogen in the water supply. The second experiment was observational, conducted at five different sites and paired with water samples to illustrate natural in-situ relationships with no added inputs or treatments with SPAD field observations of two wetland plant species:

- Cattails (Typha), and
- Cranberry Plants (Vaccinium).

In the greenhouse, we grew four different wetland plants:

- Buttonbush (Cephalanthus occidentalis),
- Atlantic White Cedar (Chamaecyparis Thyoides),
- Shallow Sedge (Carex Lurida), and
- Red Maple (Acer Rubrum).

Methods

SPAD

-Measure of chlorophyll content; an indicator of plant growing conditions and leaf health. Can be related to others.

ASD Field Spectroradiometer

-A high resolution spectroradiometer that is designed for fast, precise spectral data measurements. With a ***Leaf clip***, light-controlled chamber for individual leaf to create repeatable conditions.

Normalized Difference Nitrogen Index (NDNI)

-Calculated from spectral signature, using wavelengths 1510, 1680, and the formula:

$$NDNI = \frac{log\left(\frac{1}{1510nm}\right) - log\left(\frac{1}{1680nm}\right)}{log\left(\frac{1}{1510nm}\right) + log\left(\frac{1}{1680nm}\right)}$$

Conclusions

This work forms preliminary baseline information for a larger, on-going project, and as such, is still in its pre-liminary stages. Nevertheless, data collected so far show promising trends. observe a decrease in Normalized Difference Nitrogen Index (NDNI) after nitrogen treatments in most of our experimental plants. Future work includes airborne scanning of wetlands estimate spectral signatures instead of physical samples. This would be much faster and cheaper than collecting samples and testing them in a lab. Eventually we would like to be able to scan for more than nitrogen, to get more in-depth data on water chemistry in areas with foliar cover.

Figure 3. Example of NDNI calculated from spectral data collected from the 5 replicates of the button bush plants subjected to the same treatment scanned on July 26 (no leaf clip, noisy data due to light interference and no individual plant ID's), July 31, August 10 and August 26. NDNI's drop rapidly following experimental nitrogen application on July 26 after the first measurement.

Figure 4. Experimental wetland plants in Living Observatory's Greenhouse at Tidmarsh, in Plymouth, MA in early July 2021. Plants shown from top left: red maple, top right: Atlantic white cedar, bottom right: sedge, and center front: button bush. Grey box in center of photo is an environmental sensor node recording climate conditions including temperature, humidity and light. Photo by Christine Hatch.

Figure 5. View of restored re-constructed stream at Foothiills Preserve, Plymouth, MA, Summer 2021, the first summer after restoration. Note abundant new wetland plant growth and ponded water on the surface. Photo by Christine Hatch.

Acknowledgements

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