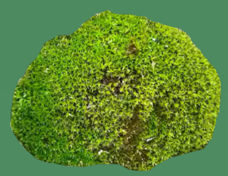
Light and Moisture Content as Determinants of Photosynthetic Activity in Southern Appalachian Mosses from Open and Shaded Habitats

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Abstract and Video

BACKGROUND

- Mosses are pioneers in ecological succession, prevent erosion, retain soil moisture, store and filter nutrients, and serve as refugia for fauna.
- Mosses are poikilohydric and ombrotrophic; they quickly desiccate and remain metabolically active only when sufficiently hydrated.
- They tolerate a wide range of light levels, from shady understory habitats to open-field habitats.
- Mosses reach peak photosynthesis (*A*) at intermediate water contents, before *A* declines as tissues further desiccate.
- There are *no studies* on moss ecophysiology in the Southern Appalachian Mountains (SAM); understanding responses to changes in moisture content and light will be crucial for predicting climate change impacts.

OBJECTIVES

To compare open-habitat to forest understory moss species to understand how they differ physiologically in response to varying light and moisture levels.

HYPOTHESES

1) Open-habitat acrocarpous species, growing in clump formations, will maintain physiologically suitable water contents longer than understory pleurocarpous (feather) mosses, extending their time for positive photosynthesis.
2) Mosses in understory low light habitats will have higher chlorophyll contents and lower a:b ratios than open-habitat mosses, but differences may be less in winter when understory habitats experience higher light levels.
3) Open-habitat mosses will undergo less stress from prolonged exposure to high light than those from shady forest understories.

METHODS

Moss Species

- ***Open-Habitat:*** *Ceratodon purpureus*, **CP**; *Polytrichum juniperinum*, **PJ**
- ***Forest Habitat:*** *Thuidium delicatulum*, **TD**; *Hypnum imponens*, **HI**

Physiological Measurements

- Determined **chlorophyll contents** in winter and summer using DMF extraction.
- Measured **light responses of photosynthesis (*A*)** using Li-6800 and LED light source with custom-built cuvette, allowing better control of RH (**Fig. 1**).
- **RWC** calculated as: (Fresh Wt – Dry Wt)*100/(Turgid Wt – Dry Wt).
- Measured **diurnal changes in RWC** in the field for a 3-day period following a rain event. Mosses were saturated at the start of the measurements.
- Built **drying curves** to determine relationship between *A* and RWC.
- Calculated **Water Use Efficiency** when $A \geq 90\%$ of A_{max} as: Ratio of water lost to total carbon assimilation over this time interval.
- Measured dark-adapted **chlorophyll fluorescence** after 1 hr exposures at varying levels of PAR (15, 500, 1000, 2000 μmol m^{-2} s^{-1}).

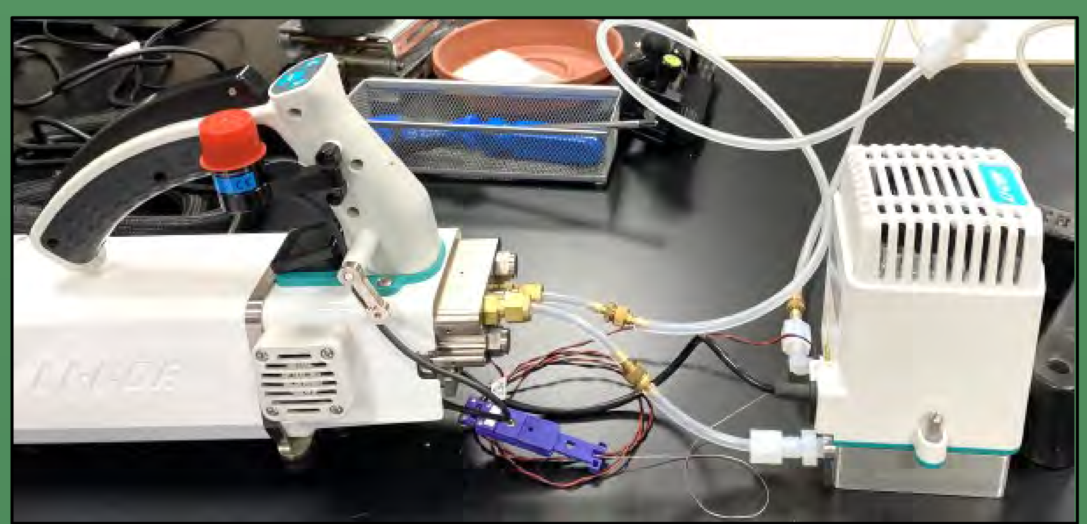



Figure 1. Left : Li-6800 system with LED light source and Nafion drying tubes.
Right: Custom-built moss cuvette with thermocouple for temperature measurement and a small cage fan to stir the air.

RESULTS

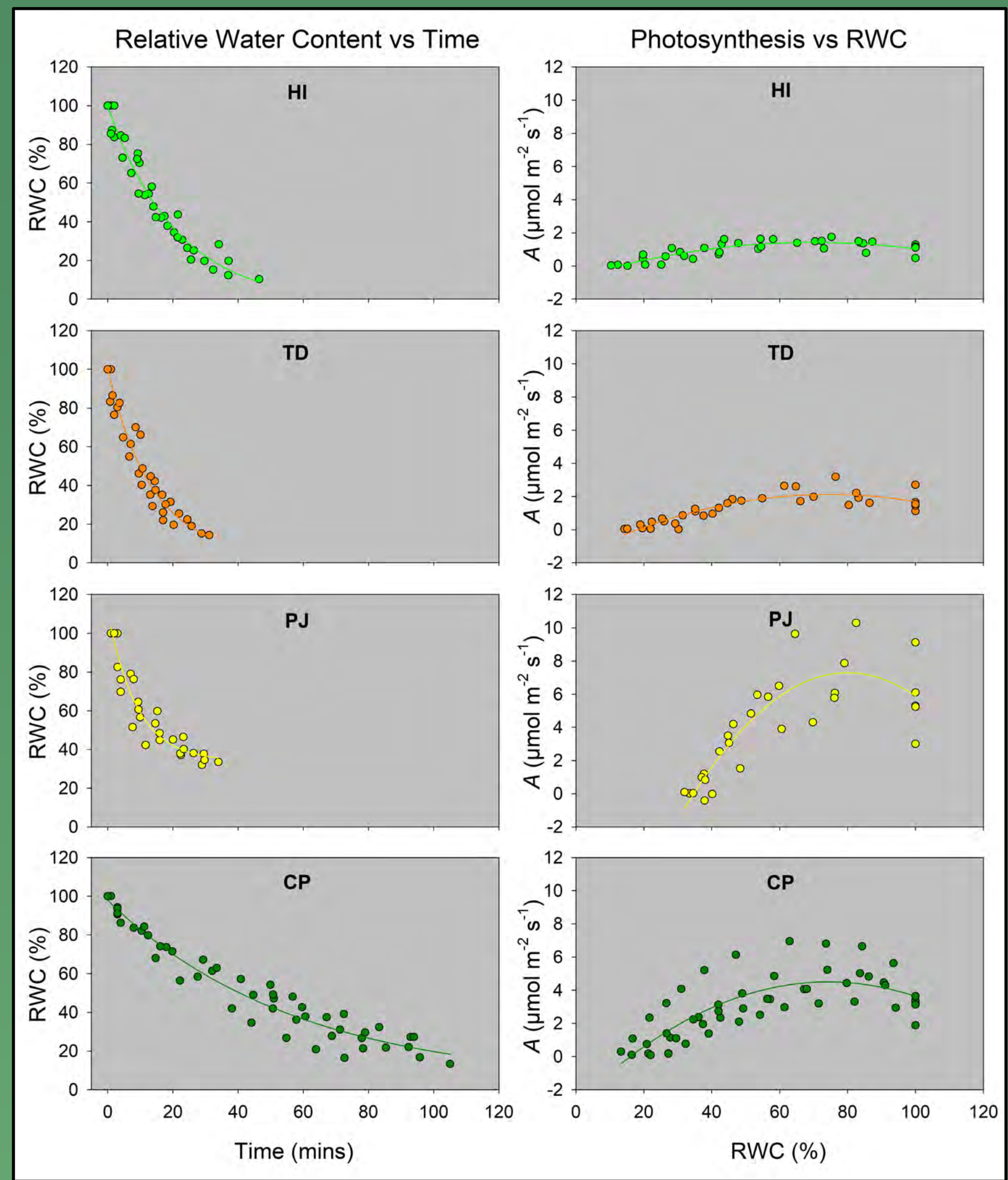
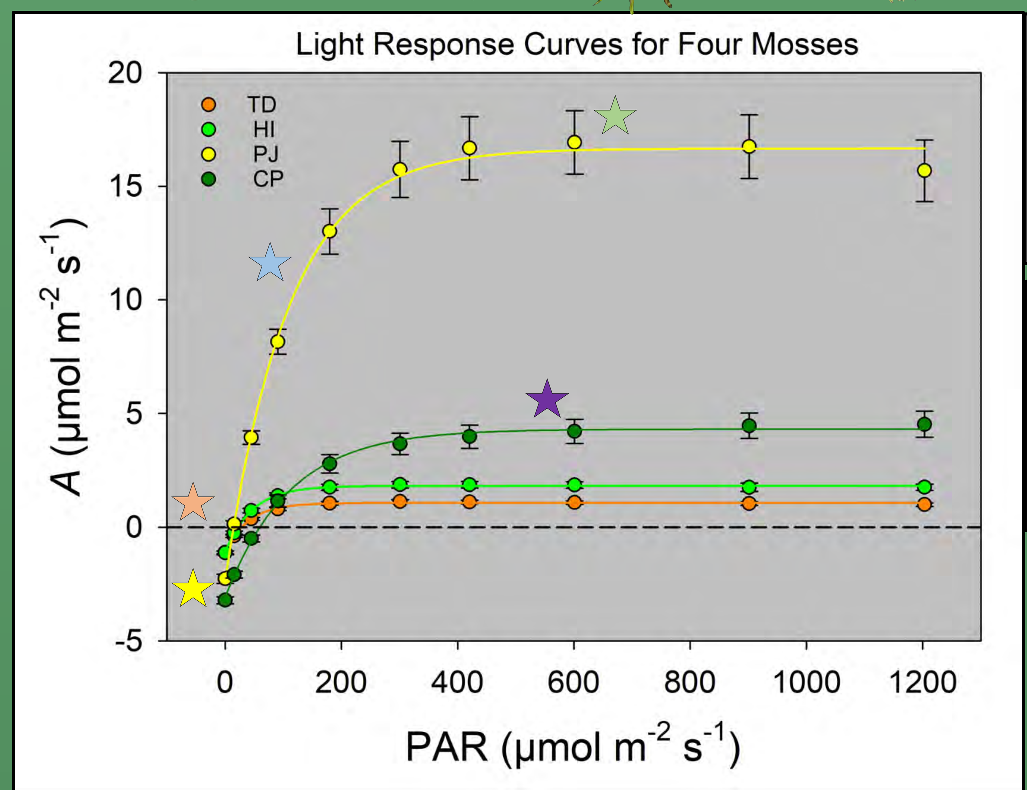


Figure 2. Left Column: RWC vs Time (n = 5); Right Column: Photosynthesis (*A*) vs RWC (n = 5).

Take Home Messages:

- Mosses dry in exponential decay fashion with time.
- CP, a cushion moss, dries the slowest of all four mosses.
- *A* for all mosses peaks between 65-80% RWC.
- *A* becomes negligible below 20% RWC for all mosses except PJ, which has a higher threshold of 40% RWC.
- *A* higher in PJ and CP (open habitat mosses) and lower in HI and TD (forest habitat mosses).



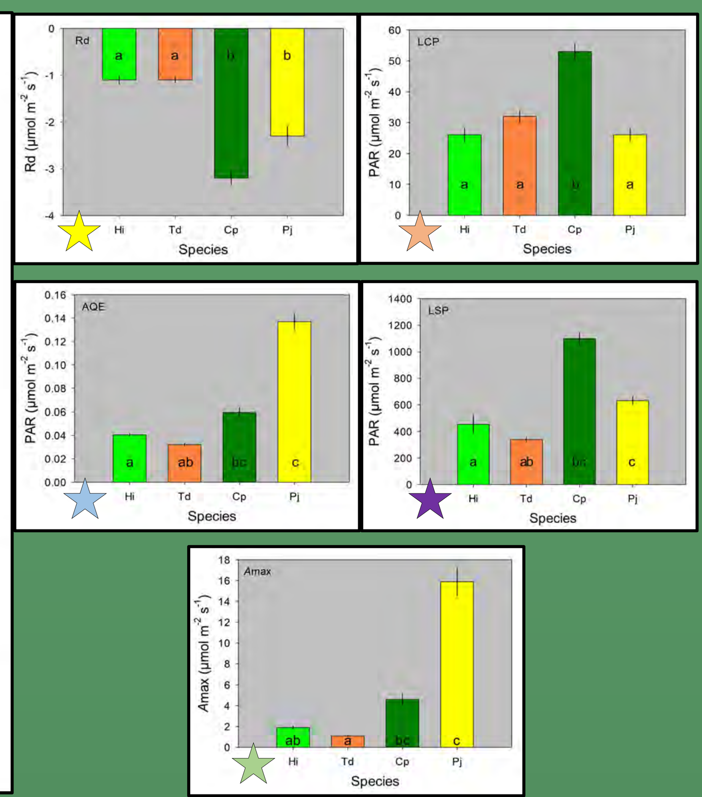


Figure 3: Top: Light Response Curves. Parameters derived from light response curves marked by stars and linked to graphs on the **right.** Differences significant at $p \leq 0.05$ (**n = 10**).

Rd = dark respiration; LCP = light compensation point; AQE = apparent quantum efficiency; LSP = PAR where *A* saturates; A_{max} = highest *A* observed.

Take Home Messages:

- Open-grown mosses (CP and PJ) have higher Rd rates than forest mosses. A_{max} and AQE trend higher in open-grown mosses.
- CP has highest LCP and LSP than other mosses.
- PJ has significantly higher AQE and A_{max} than other mosses.

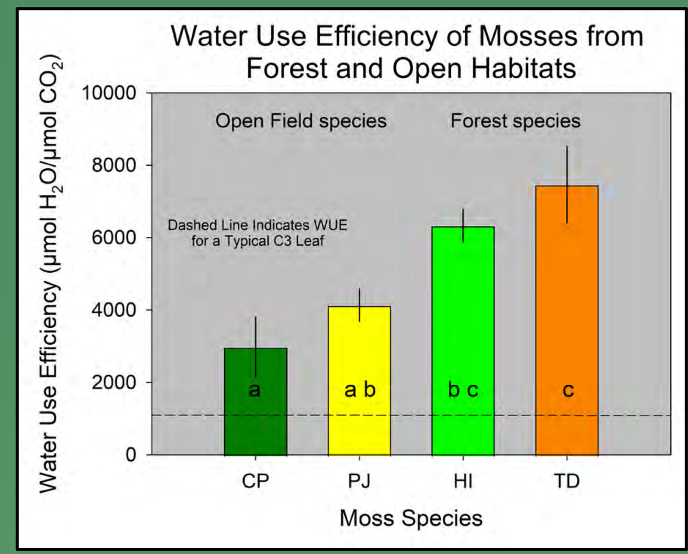


Figure 4. WUE of Mosses (n = 10).

Take Home Messages:

- CP and PJ have higher water use efficiency and HI and TD lowest.
- WUE higher for acrocarpous mosses compared to pleurocarpous mosses.
- Mosses lose ~2X to 7X as much water per CO_2 absorbed compared to a typical leaf from a C3 plant.

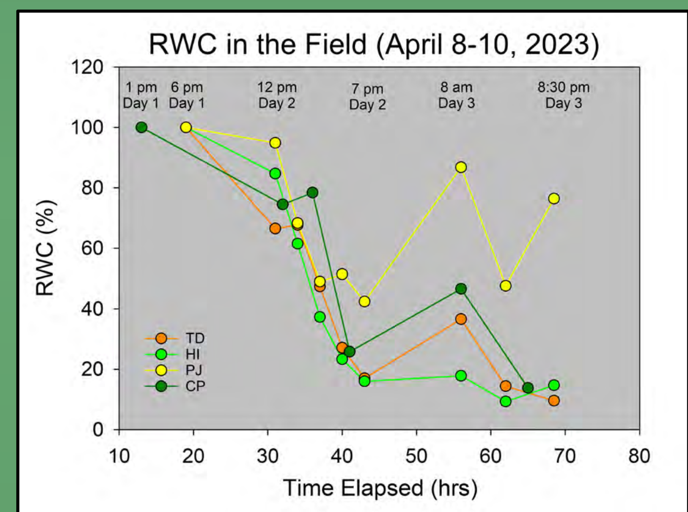
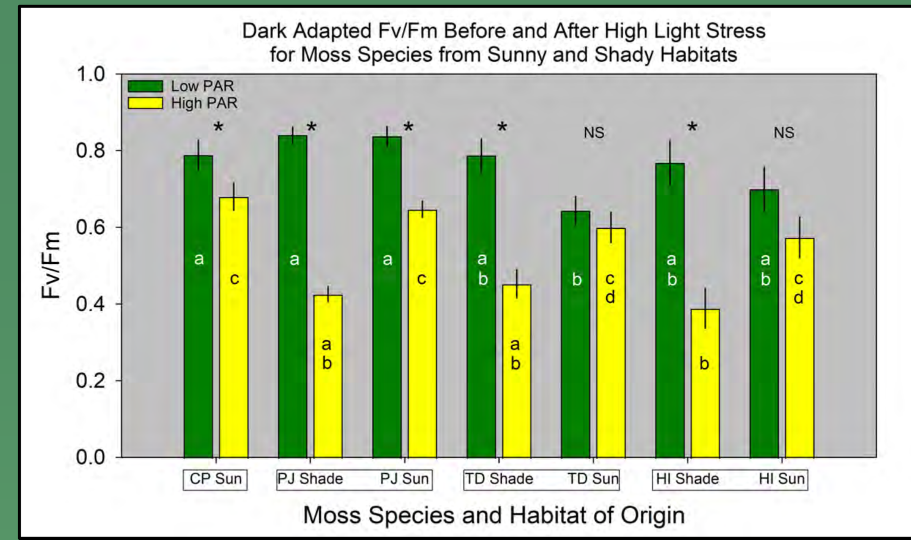


Figure 5. Field RWC vs Time (n = 10).

Take Home Messages:

- Mosses dried at moderate rates over two days and had RWC that would support positive *A* over this interval.
- Increases in RWC on Day 3 due to hydration from fog and/or dew.



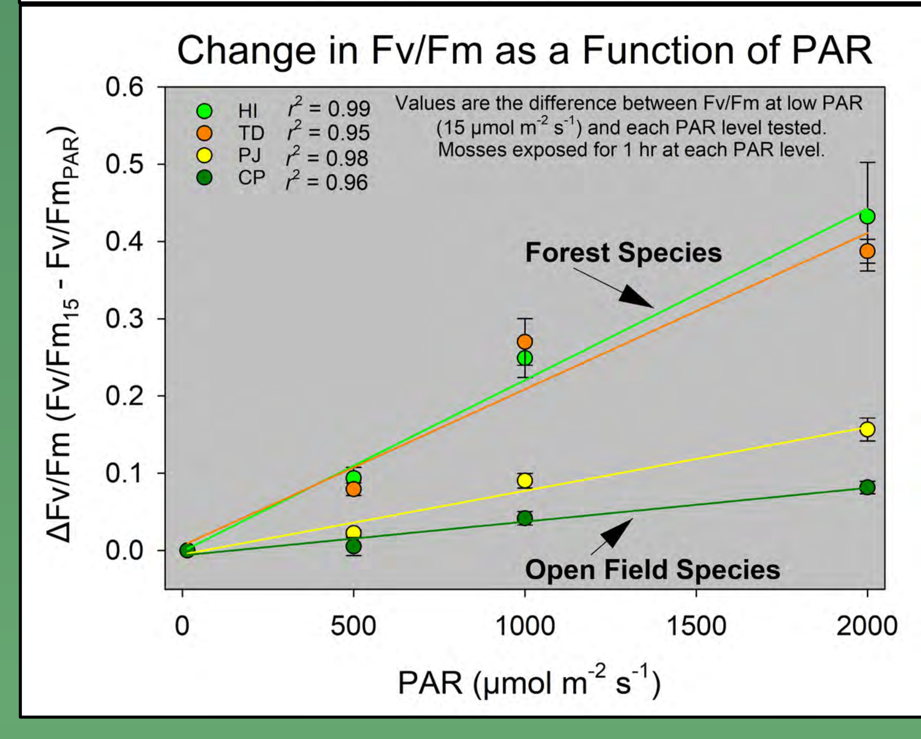


Figure 6. Top Left Graph: Dark-adapted fluorescence (Fv/Fm) from sunny and shady habitats.
Bottom Left Graph: Linear regressions of differences between Fv/Fm from low and higher PAR after 1 hr exposure.

Letters indicate differences within light treatment (**n = 5**);
Low and High PAR: 15 and 2000 μmol m^{-2} s^{-1};
Asterisks indicate differences in Fv/Fm between low and high PAR within a moss category.

Take Home Messages:

- Fv/Fm at low PAR (green bars) similar for all mosses grown in shade but lower for TD when grown in sun.
- High light stress (yellow bars) reduces Fv/Fm under all conditions except for HI and TD grown in sunny habitats.
- Stress is greater (low Fv/Fm) when mosses are grown in shady habitats.
- Stress increases linearly (lower graph) with increasing exposure to stress PAR.
- The slope of increasing stress with higher PAR is greater for mosses from forest habitats compared to those that are from open-field habitats.

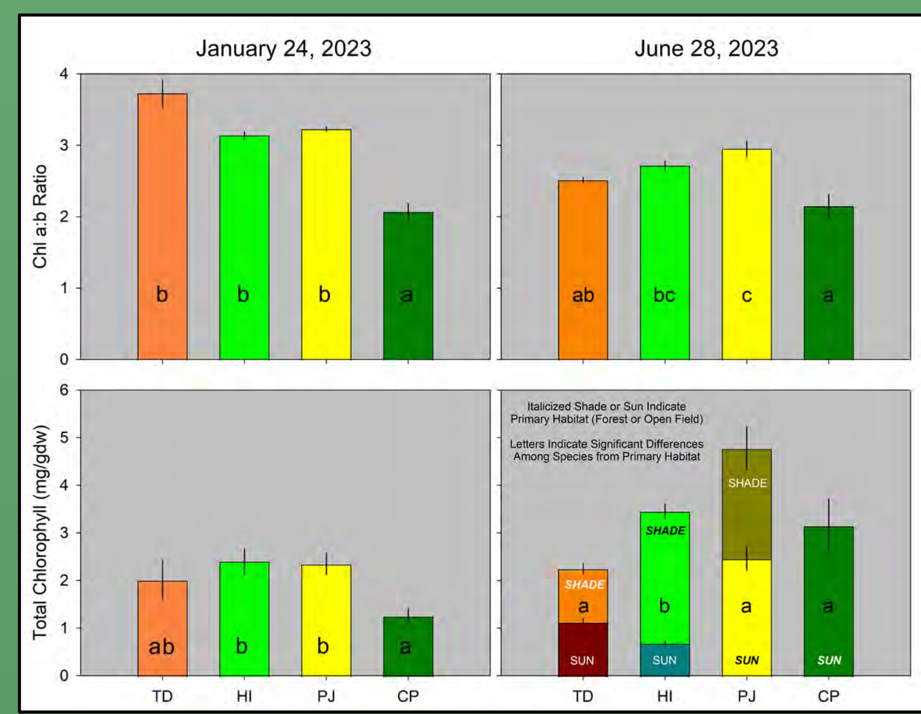


Figure 7. Total chlorophyll contents and chl a:b ratios of mosses from January and June 2023 (n = 10).

Take Home Messages:

- Total Chl similar in Jan and Jun.
- When grown in high-light habitats, total chlorophyll amounts are lower (lower right panel, bars marked as sun).
- Chl a:b ratios lowest in CP and do not change substantially from Jan to Jun.

CONCLUSIONS

- Photosynthetic rates peak at intermediate water contents before declining as the moss dries. Positive *A* maintained to 20% RWC except in PJ, where it is 40%.
- RWC may be a proxy for determining when SAM mosses are photosynthetically active, although prolonged exposure to high PAR may further reduce *A*.
- Habitat origin has a substantial impact on sensitivity to light stress: mosses grown in high light are less sensitive to light stress than those from low light habitats, irrespective of their primary habitat of origin (i.e., forest vs open-field).
- Open-habitat moss species may be more tolerant of warming and precipitation alterations due to climate change, because they are subject greater light and moisture stress than understory habitat moss species.
- With additional modeling, it should be possible to predict daily and annual carbon uptake by SAM mosses and predict impacts of future climate change on their productivity.

ACKNOWLEDGEMENTS

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