Multispectral remote-sensing: an emerging tool for monitoring wetland plant communities subjected to climate warming

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Introduction

Small-scale hyperspectral remote sensing presents an opportunity to connect ecological experiments conducted locally to landscape-scale surveys of ecosystem function. I tested whether recent evidence linking climate warming to functional trait variation in wetland plant communities can be substantiated using similar remote-sensing technology to that included in NASA's Landsat imaging program (USGS 2011). I documented the divergence of two passively warmed communities established in 2010 from two control standards using electromagnetic reflectance in the visible and near-infrared spectrum. Using these data, I link divergence in physiologic response measured on the local scale to the combined augmentation of mid-season heat stress and a prolonged growing season.

Some Theory

Regional circulation models predict a progressive warming of 1-6°C for the Midwestern region over the next 50-100 years (USGCRP 2009). Warming is predicted to act as a stress (Fraser et al. 2009; Rizhsky et al. 2002) to native communities and presents challenges for effective restoration and management of wetland resources. The strongest ecological impacts of climate warming will include an extension of the growing season in the spring and fall, and a greater probability of mid-season stress events. A simplified graphical representation of this prediction is shown below.

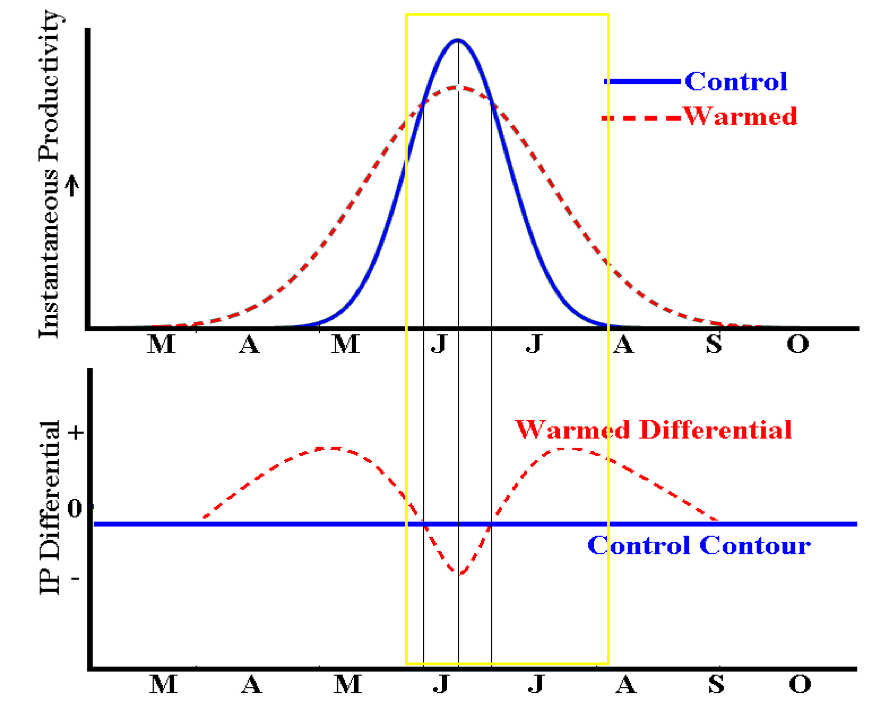


Figure 1. Instantaneous productivity (IP) (i.e. photosynthetic effort of existing biomass) is inversely proportional to strain. The area under the curve represents Net Primary Productivity (NPP) for a given plot. In this example, the IP differential is positive early and late in the growing season (owing to season length extensions) and negative during months when heat stress limits IP. Warming represents a change in the IP curve that leads to a shift in the timing and magnitude of stress/strain at the plot level.

Methods

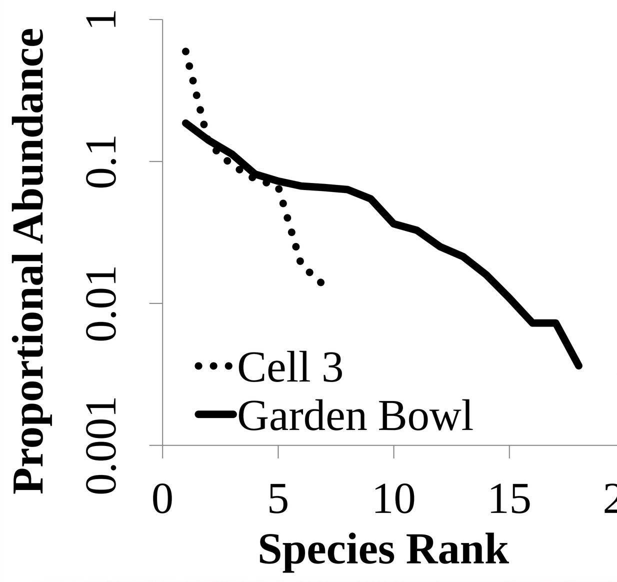


Figure 2. Site-averaged rank-abundance plots representing species diversity at peak production (August, 2010) for the two study sites.

Passively warmed Open Top Chambers (Gedan & Bertness 2009) and control plots were established in two field sites that differed in vegetation complexity (Figure 2). Cell 3 (pictured above in VNIR) represents a near monoculture of *Leersia oryzoides* with 89% mean proportional abundance in August for all plots (Figure 3). Garden Bowl has a more complex plant community and theoretically presents a greater challenge for detecting IP trends between treatments due to varying tolerances to thermal stress of the species present.

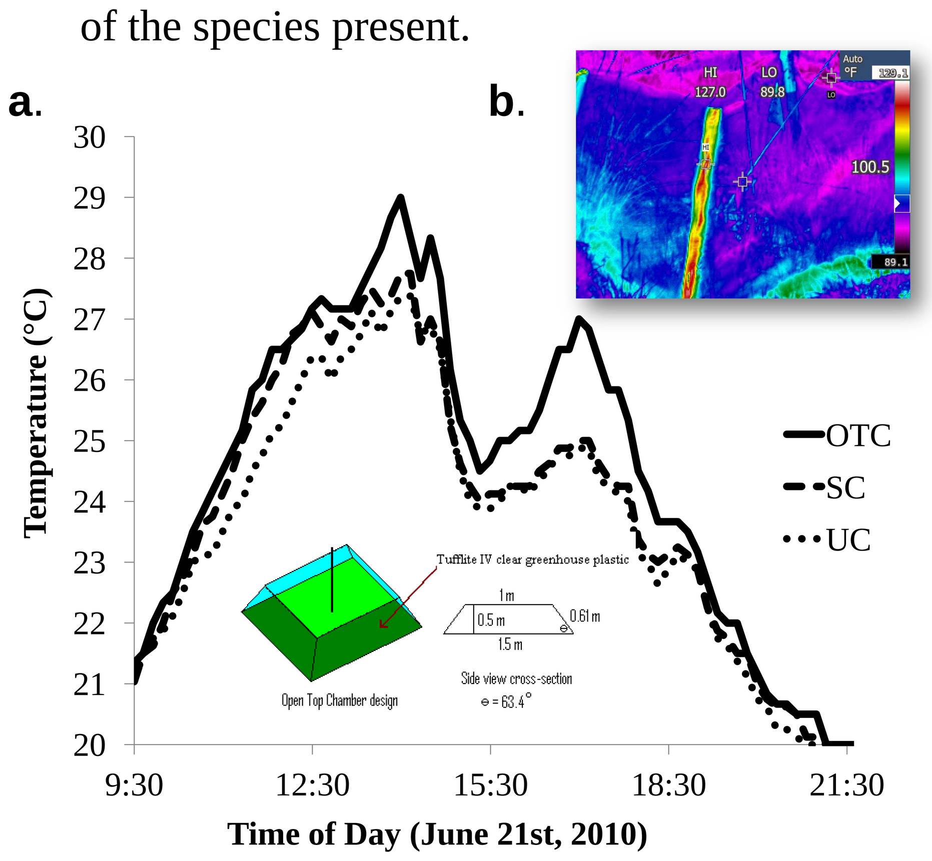
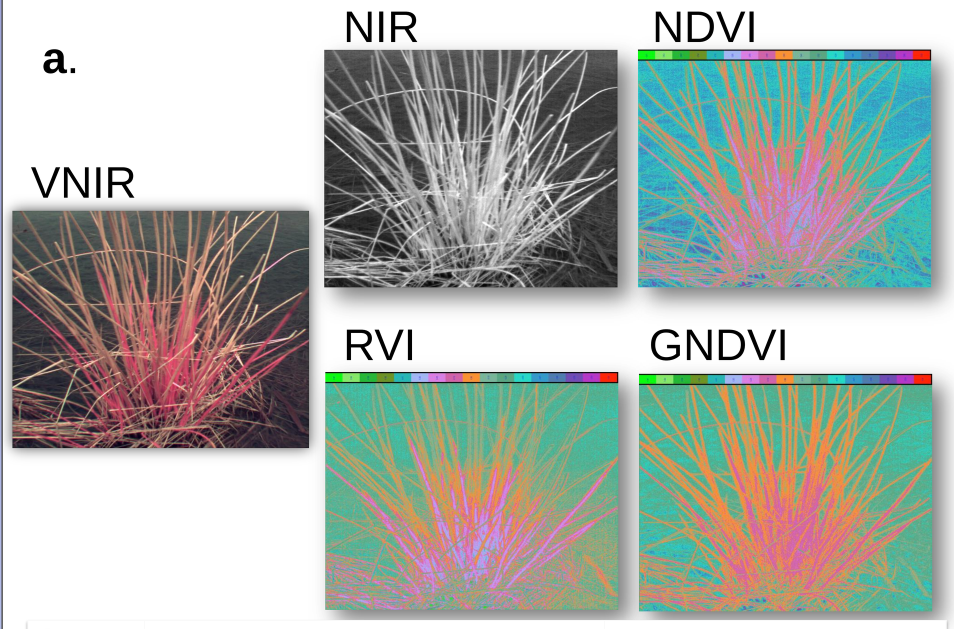


Figure 3. a. A typical mean air temperature profile recorded for plots passively warmed using Open Top Chambers (OTC), structural controls (SC), and un-manipulated controls (UC) (n=6). **b.** A thermal IR image of an example structure taken close to peak differential from ambient. **SCs comprised survey stakes surrounded with deer mesh and were included to account for potential non-thermal artifacts imparted by OTCs (not presented).*

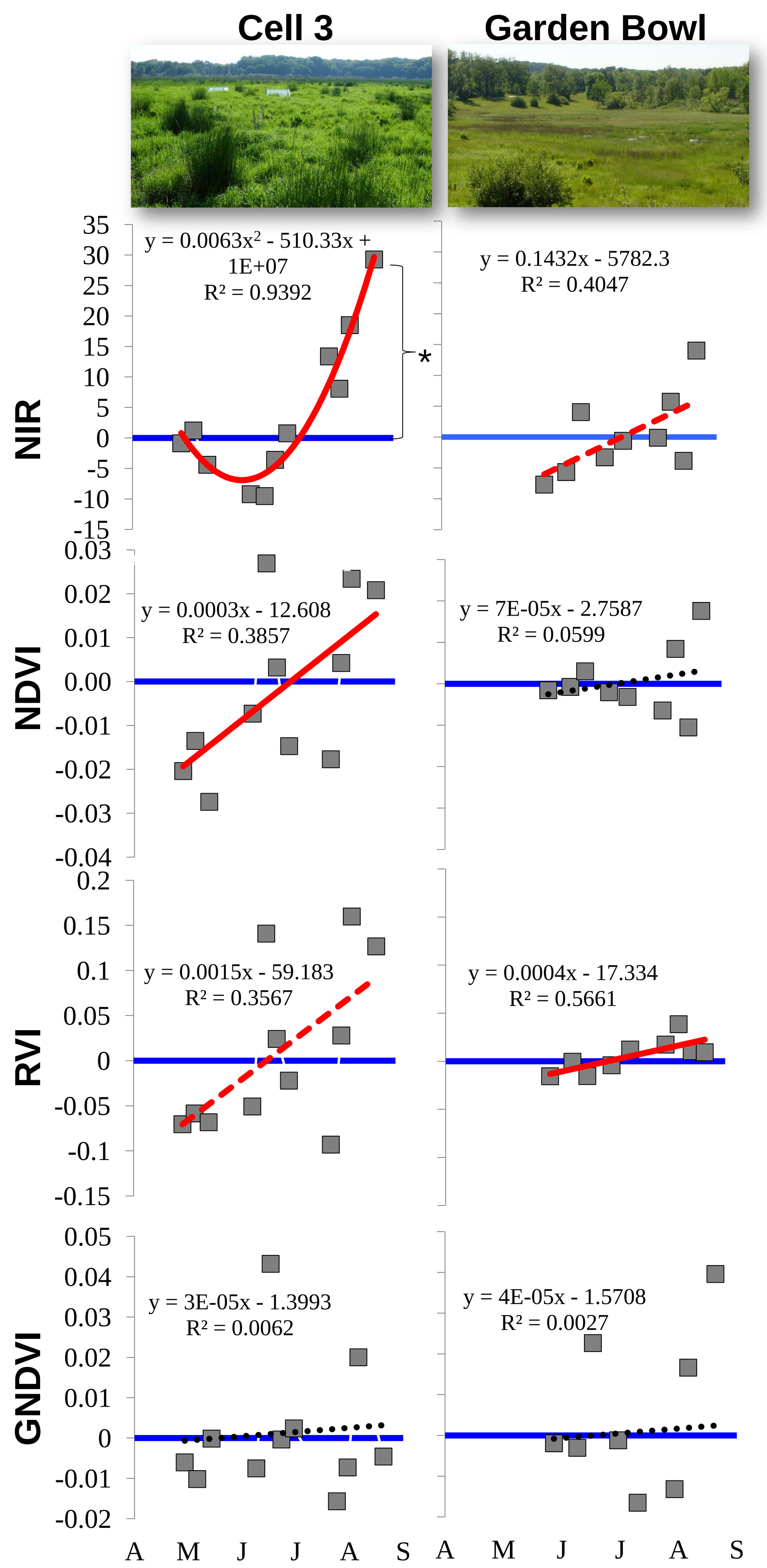
Hyperspectral images were captured using a TetraCAM ADC® camera at 10 time-points between May-September 2010 following treatment initiation. The TetraCAM ADC records color-processed images that approximate Landsat 7 instrument bands 2, 3, and 4 where NIR = 725-900nm, Red = 630-725nm, and Green = 520-600nm.

Results



b.	Calculation	Metric
VNIR	(For visualization) NIR/R/G ~ R/G/B	Red = living vegetation and incident radiation
NIR	NIR	[Functional Mesophyll]
NDVI	(NIR-RED)/(NIR + RED)	Leaf area index and biomass
RVI	NIR/R	Leaf Stress^{-1}
GNDVI	(NIR-GREEN)/(NIR+GREEN)	[Chlorophyll]

Figure 4. a. Processed hyperspectral imagery highlighting both senesced and living material for a single tussock of *Juncus effusus*
b. index calculations (where applicable) and associated biotic metrics (Carter & Knapp 2001).



Control contour, Significant OTC slope ($p<0.05$), Marginally significant ($p<0.07$) Not significant ($p>0.07$), (*) significant differential from control ($p<0.05$)

Figure 5. Residual differences between treatments (n=6) are represented to exclude variations in weather on different observation days.

With the exception of chlorophyll content (GNDVI), the difference in clustering about the control contour reflects the relative difference in vegetation complexity between the two sites. Vegetation indices incorporating red and near-infrared reflectance consistently increased over the observed period (note positive differential slopes in Figure 5). Cell 3 mature functional mesophyll (NIR) produced the strongest significant signal in keeping with the qualitative model in Figure 1 ($r^2 = 0.94$), indicating a transition from a negative differential in the middle of the growing season to a significant positive differential in the Fall ($p<0.05$).

Conclusions

These results suggest that warming of field plots led to an increase in mature functional mesophyll and an overall decrease in leaf stress over the course of the growing season, despite evidence of augmented thermal stress during the warmest summer months. Measured functional traits (not presented) confirm this trend, where community dominants are generally more massive when warmed. These data are part of an ongoing analysis to test the efficacy of plant functional traits to summarize wetland community responses to climate change, and to draw connections between climate-trait associations and hyperspectral remote sensing on multiple scales.

References

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