Dan Buonaiuto; Understanding the effects of temperature and light in ecological experiments; the delicate balance between complexity and inference

Dr. Dan Buonaiuto--- currently a postdoc in the Department of Environmental Conservation at The University of Massachusetts-Amherst, USA--- discusses his recent *Commentary* “Experimental designs for testing the interactive effects of temperature and light in ecology: the problem of periodicity”.

**About the Paper:**

Experiments in growth chambers are powerful tools for assessing organisms’ responses to the environment. They can critically allow researchers to isolate the effects of environmental variables that usually co-vary in the field; to figure out---for example--- the relative influence of warming temperatures and increasing daylength on spring growth. To do this, these experiments aim to simplify the environment in useful ways. However, when surveying the literature to prepare for my own growth chamber experiments during my PhD, I quickly learned these experiments are anything but simple.

Researchers must walk a fine line when designing these experiments. They at once need to simplify the environment enough to make clear inference about the mechanisms driving observed responses and maintain enough complexity in their experiment so that it can roughly match the environment that their study organisms would face in nature.

For my PhD experiment, I was interested in shifts in phenology of trees and shrubs due to temperature and photoperiod. I prepared to do what my lab – and many others---have done previously; to allow temperatures to fluctuate over the course of a 24-hour day so that plants experience cooler temperatures at night than in the day---just as they would in nature. However, I realized varying temperature and photoperiod in this way that mimicked nature meant that I would violate a cardinal sin of experimental design by unintentionally covarying predictors that we meant to isolate. I worried these background changes in daily temperature, or thermoperiod, can overshadow---or at least complicate---our ability to estimate of the true effect of day length treatments. I set out to describe the scope of this issue, and thus, this paper was born.

But there is good news--- there are several paths that researchers who are interested in the effects of daylength and temperature on ecological processes can take to deal with these issues. They range from simple statistical corrections to more elaborate experimental arrays. We present some of them in the paper, but I would also love to hear other creative solutions that any readers have implemented in their own work.

**About the research:**

Preparing this paper required me to read scientific literature about growth chambers studies far beyond the world of tree phenology that consumed most of my time during my PhD. I learned that trying to estimate the individual effects of temperature and daylength and their interactions is a common problem in ecology broadly, and from flies to frogs and fish--- many subfields have their own best practices for doing so. This was an important reminder for me that reading (and collaborating) broadly across disciplines is important for finding innovative approaches to solve your own experimental challenges. I am hopeful that researchers outside of phenology will read this paper and it will help them in their own experimental pursuits.

One lesson I came away with from this study is that thermo-periodicity should more than just a background condition for adding biological realism to studies---it is an axis of temperate variation that can have big effects on phenology, and one that is shifting in nature with climate change. We don’t have a lot of experiments to anticipate how much changes to these diurnal-scale temperature patterns will matter compared to coarser trends in mean temperature. It turns out that experiments that compare responses to temperature treatments with and without thermo-periodicity are more common in other study systems (e.g. turtles and frogs) than in phenology, and conducting some experiment like these will really help our ability to forecast the effects of climate change on plant phenology.

**About the author:**

I started learning how to identify plants during time spent as a hiking guide to make long treks more interesting for student participants. I am not sure how much the children appreciated stopping every few minutes to “key out” a new species, but I was hooked. Once I started noticing the subtleties of plants, I started wondering about them all the time, which put me on the path to research.

At the same time, I was watching these landscapes that I loved change rapidly and was learning more about the losses still to come with global change. I think this growing awareness that inspiration from nature can be motivation for meaningful engagement with conservation, restoration and climate change adaptation led me to my current work in conservation research, where I spend a lot of time thinking about how basic ecology and evolution can inform applied needs in the field of conservation.

I still try to spend most of my free time in nature---and lately I’ve been trying something new that was recommended to me by a few senior colleagues. As an ecological researcher, sometimes I find it all too easy to turn my time in nature into an ecological thought experiment—questions like “how could I test that” or “is that interesting thing I just saw going to be my next big grant proposal?” can dominate my time outdoors. That’s not a bad thing, but it’s just another way to always be working. So lately, I try to spend a few moments remembering back to the days before I “knew” plants. I try to appreciate the shades of green leaves around me without thinking about their photosynthetic rates or feel the wind on my face without thinking about measuring pollen dispersal distances. Just *being* in nature helps me appreciate all that I (and we as a scientific community) have learned, and is an important reminder of how much remains a mystery.

A person in a blue shirt

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Dan Buonaiuto

A person cutting a tree

Description automatically generated with low confidence

Here I am cutting dormant twigs to use in a growth chamber study (Photo credit: Lizzie Wolkovich)

Close-up of a tree branch with leaves

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Phenology, or the timing of seasonal life-cycle events can be studied in the field---or in the lab using growth chambers. Pictured here in both study environments is *Acer pensylvanicum,* a charismatic maple of Eastern North America. (Photo credit: Dan Buonaiuto)

A picture containing vase, houseplant, flowerpot, indoor

Description automatically generatedA picture containing houseplant, wall, indoor, flowerpot

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We use growth chambers for all kinds of ecology: phenology studies with dormant twigs, freeze tolerance experiments with tree seedlings and seed germination trials (Photo credits: Dan Buonaiuto, Cat Chamberlain, Dan Buonaiuto).