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A *Superior* Research Reader

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Greetings and welcome to A *Superior* Research Reader, a monthly reader on what we believe is current and relevant research to science and resource management on the Superior.

This Month's Edition:

Welcome Spring! To acknowledge the season change, this month's Reader will focus on *phenology*--the study of cycles, such as leaf out, flowering and fruiting times of plants and how they might shift over time. Phenological observations are becoming increasingly important as climate change begins to shift the timing of migrations and plant growth in unexpected ways. As a way to begin monitoring changes in these cycles across the landscape, the National Ecological Observatory Network (NEON) initiated the organization "Project Budburst". Through Project Budburst, professionals, students and citizen scientists can access an online tool to record information about phenological events they observe as well as access observations that others have made across the country. This tool helps us easily incorporate phenological monitoring activities into our daily program of work. As you know, climate change is something that we are incorporating into all aspects of management on our Forest, whether it is managing for mitigation, adaptation or resilience. Phenological data will be extremely useful for land managers across the region as we look for information on what species to plant in future vegetation management projects, plan for insect outbreaks and manage habitat for pollinators and wildlife. So take a walk on your lunch break or get out in the field to start observing the changes that accompany spring. Then visit Project Budburst to enter your information into the nationwide database. And if you need further inspiration, check out the articles we've provided for you below:

1) Local researchers use phenological observations from Cloquet and Ely to make conclusions about how climate change will affect insect outbreaks and other trophic interactions in our area.
2) Willis et al. examine the consequences of what can happen when species can't adapt their flowering time to compensate for changes in the timing of seasonal temperature shifts.
3) Buitenwerf and Higgins undertake a comprehensive global assessment of changes in vegetation phenology.
4) The USA National Phenology Network is developing a long-term, multi-taxa phenological database, to support conservation and management towards multi-agency, large-scale research and action.

Before you start reading, we wanted to take a moment to thank you! Last month we asked our readers what type of research they were interested in, and we are listening! Stay tuned for upcoming editions of A *Superior* Research Reader that will highlight your requests. We value your comments so please keep them coming. We welcome you to email us your feedback and suggestions.

Happy reading,

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Simulated Climate Warming Alters Phenological Synchrony Between an Outbreak Insect Herbivore and Host Trees

Schwartzberg et al. 2014. Oecologia.

ABSTRACT: As the world's climate warms, the phenologies of interacting organisms in seasonally cold environments may advance at differing rates, leading to alterations in phenological synchrony that can have important ecological consequences. For temperate and boreal species, the timing of early spring development plays a key role in plant–herbivore interactions and can influence insect performance, outbreak dynamics, and plant damage. We used a field-based, meso-scale free-air forest warming experiment (B4WarmED) to examine the effects of elevated temperature on the phenology and performance of forest tent caterpillar (*Malacosoma disstria*) in relation to the phenology of two host trees, aspen (*Populus tremuloides*) and birch (*Betula papyrifera*). Results of our 2-year study demonstrated that spring phenology advanced for both insects and trees, with experimentally manipulated increases in temperature of 1.7 and 3.4 °C. However, tree phenology advanced more than insect phenology, resulting in altered phenological synchrony. Specifically, we observed a decrease in the time interval between herbivore egg hatch and budbreak of aspen in both years and birch in one year. Moreover, warming decreased larval development time from egg hatch to pupation, but did not affect pupal mass. Larvae developed more quickly on aspen than birch, but pupal mass was not affected by host species. Our study reveals that warming-induced phenological shifts can alter the timing of ecological interactions across trophic levels. These findings illustrate one mechanism by which climate warming could mediate insect herbivore outbreaks, and also highlights the importance of climate change effects on trophic interactions.

Phylogenetic Patterns of Species Loss in Thoreau's Woods are Driven by Climate Change

Willis et al. 2008. Proceedings of the National Academy of Sciences.

ABSTRACT: Climate change has led to major changes in the phenology (the timing of seasonal activities, such as flowering) of some species but not others. The extent to which flowering-time response to temperature is shared among closely related species might have important consequences for community-wide patterns of species loss under rapid climate change. Henry David Thoreau initiated a dataset of the Concord, Massachusetts, flora that spans ≈150 years and provides information on changes in species abundance and flowering time. When these data are analyzed in a phylogenetic context, they indicate that change in abundance is strongly correlated with flowering-time response. Species that do not respond to temperature have decreased greatly in abundance, and include among others anemones and buttercups [Ranunculaceae *pro parte* (*p.p.*)], asters and campanulas (Asterales), bluets (Rubiaceae *p.p.*), bladderworts (Lentibulariaceae), dogwoods (Cornaceae), lilies (Liliales), mints (Lamiaceae *p.p.*), orchids (Orchidaceae), roses (Rosaceae *p.p.*), saxifrages (Saxifragales), and violets (Malpighiales). Because flowering-time response traits are shared among closely related species, our findings suggest that climate change has affected and will likely continue to shape the phylogenetically biased pattern of species loss in Thoreau's woods.

Three Decades of Multi-Dimensional Change in Global Leaf Phenology

Buitenwerf and Higgins. 2015. Nature Climate Change.

ABSTRACT: Changes in the phenology of vegetation activity may accelerate or dampen rates of climate change by altering energy exchanges between the land surface and the atmosphere and can threaten species with synchronized life cycles. Current knowledge of long-term changes in vegetation activity is regional, or restricted to highly integrated measures of change such as net primary productivity, which mask details that are relevant for Earth system dynamics. Such details can be revealed by measuring changes in the phenology of vegetation activity. Here we undertake a comprehensive global assessment of changes in vegetation phenology. We show that the phenology of vegetation activity changed severely (by more than 2 standard deviations in one or more dimensions of phenological change) on 54% of the global land surface between 1981 and 2012. Our analysis confirms previously detected changes in the boreal and northern temperate regions. The adverse consequences of these northern phenological shifts for land-surface–climate feedbacks, ecosystems and species are well known. Our study reveals equally severe phenological changes in the southern hemisphere, where consequences for the energy budget and the likelihood of phenological mismatches are unknown. Our analysis provides a sensitive and direct measurement of ecosystem functioning, making it useful both for monitoring change and for testing the reliability of early warning signals of change.

Organizing Phenological Data Resources to Inform Natural Resource Conservation

Rosemartin et al. 2014. Biological Conservation.

ABSTRACT: Changes in the timing of plant and animal life cycle events, in response to climate change, are already happening across the globe. The impacts of these changes may affect biodiversity via disruption to mutualisms, trophic mismatches, invasions and population declines. To understand the nature, causes and consequences of changed, varied or static phenologies, new data resources and tools are being developed across the globe. The USA National Phenology Network is developing a long-term, multi-taxa phenological database, together with a customizable infrastructure, to support conservation and management needs. We present current and potential applications of the infrastructure, across scales and user groups. The approaches described here are congruent with recent trends towards multi-agency, large-scale research and action.