NSRC Theme 2: Sustaining Ecosystem Health in Northern Forests

PROJECT TITLE:
A NEW NERC PHENOLOGY WORKING GROUP

Principal Investigators:

Lead PI: Ellen Denny, US Forest Service, Northern Research Station, 271 Mast Rd., Durham NH 03824. Phone: 603-868-7683. Fax: 603-868-7604. Email: ellen.denny@yale.edu

Co-PI: Brenden McNeil, University of Wisconsin-Madison, Dept. of Forest Ecology and Management, 1630 Linden Dr., Madison WI 53706. Phone: 608-263-9107. Fax: 608-262-9922. Email: bmcneil@wisc.edu

Cooperators:

Participating members of the USA National Phenology Network:

Mark D. Schwartz, UWisconsin-Milwaukee, Co-organizer of USA-NPN (mds@uwm.edu)
Julio Betancourt, USGS Desert Laboratory, Co-organizer of USA-NPN (jlbetanc@usgs.gov)
David Wolfe, Cornell University, Co-organizer of USA-NPN (dww5@cornell.edu)
Mark Losleben, UArizona/USGS, Asst. Dir. of USA-NPN (losleben@email.arizona.edu)

Researchers and Citizen Scientists within NERC:

Mary Beth Adams, USFS Fernow
Amey Bailey, USFS Hubbard Brook
John Brissette, USFS Durham
Lisa Doner, Plymouth State
David Ellum, Yale FES
Celia Evans, Paul Smiths
Ivan Fernandez, UMaine
Jeremy Fisher, UNH
Mark Friedl, BU
David Hollinger, USFS Durham
Sean Lawson, VT Monitoring Coop
D. Scott Mackay, SUNY Buffalo
Stacy McNulty, AEC, SUNY-ESF
Laura Meyerson, URI
Abraham Miller-Rushing, BU
Jacqueline Mohan, Harvard Forest
Georgia Murray, AMC
Keith Nislow, USFS Amherst
John O'Keefe, Harvard Forest
Leonard Perry, UVM
Nathan Phillips, BU
Richard Primack, BU
Andrew Richardson, UNH
Lindsey Rustad, USFS Durham
Susan Stout, USFS Warren
Phil Townsend, UWisconsin-Madison
Shaun Watmough, TrentU
Kathleen Weathers, IES
Doug Weihrauch, AMC
David Weinstein, Cornell
Xiangming Xiao, UNH

Amount requested: FY07: $33,603 FY08: $22,286 Total: $55,889

ABSTRACT

Phenology, defined as the study of the timing of seasonally recurring biological events, is increasingly recognized as a vital aspect of understanding how ecosystems will respond to climatic change. A study at two NERC sites, Hubbard Brook and Harvard Forest, indicates that recent warming trends are increasing the growing season length of northern forests. At the same time, this study, and related remote sensing studies, highlight that there is considerable, and poorly understood, spatial variability in the phenology of ecosystems in the northern forest region. To complement the momentum of the newly-established USA National Phenology Network, we propose to use NSRC funds to further the agenda of the NERC Phenology Group. This working group is a cooperative network of researchers and citizen-scientists, whose goals include coordinating phenological monitoring, facilitating data sharing, and synthesizing phenology data from the Northern Forest and the broader Northeastern US and Eastern Canada region.

The agenda of the working group is focused on developing the regional and spatially-explicit understanding of phenology that is necessary for predicting the ecosystem-level impacts of climate change on the northern forest region. This agenda has four components: (1) organize a workshop to bring together the region's phenology researchers, establish ground- and remote sensing-based phenological monitoring protocols, and outline further steps to create a coordinated regional network for phenological monitoring; (2) develop a website and other documents to disseminate information about the network and the monitoring protocols developed for the Northeast; (3) motivate and involve citizen scientists in phenological monitoring in the region; (4) contribute data to the USA National Phenology Network effort; and (5) synthesize ground-based, webcam and remotely-sensed phenology measurements with GIS layers describing potential drivers of phenology. Tangible products resulting from NSRC funding will include a set of recommended species and monitoring protocols for phenological observations in the Northeast, a regional phenology network website, region-specific materials for citizen-scientist training workshops, and peer-reviewed publications synthesizing observations and identifying the environmental drivers of spatial variability in the phenology of the northern forest region.

Introduction

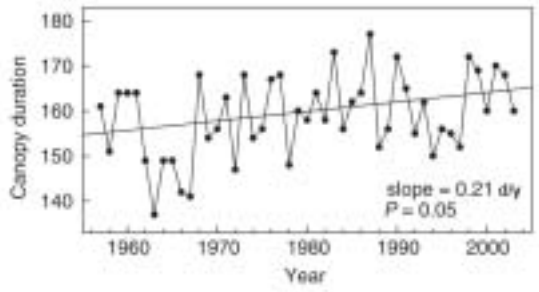

Figure 1. Modeled change in green canopy duration, a proxy for growing season length, at the Hubbard Brook Experimental Forest, 1957-2004. The slope, 2.1 d/y, indicates that the growing season length has increased by roughly 11 days over the last 50 years. Source: Richardson et al., 2006.

Phenology is the study of the timing of seasonally recurring biological events, and classic examples of phenological events include flowering dates of plants and migration dates of birds. Phenology is inherently a multi-disciplinary environmental science (Schwartz 2003), of relevance to basic ecological research (e.g., the effects of climatic variability and change on forest health), agriculture (e.g., pest and disease control), tourism (e.g., wildflowers and fall coloring), and human health (e.g., hay fever and vector-borne diseases). Various studies have demonstrated a trend of earlier leaf emergence and bloom dates over the last several decades for horticultural species in the Northeast (e.g. Schwartz and Reiter 2000, Wolfe et al. 2005). A recent analysis of long-term forest phenology data collected at the Hubbard Brook and Harvard Forest LTER sites (both foci of NERC research) not only documents a marked trend toward an earlier onset of spring and longer growing season length over the last four decades (Figure 1), but also highlights gaps in scientific understanding of the physiological controls and spatial patterning of the phenological responses of northern forest tree species to climatic factors (Richardson et al. 2006). Addressing these gaps is critical, as the effects of climate change on phenology has implications not only for carbon sequestration and primary productivity (via changes in growing season length), but also other ecosystem dynamics coupled to phenology, including hydrology, nutrient cycling, pest outbreaks, timing of allergy seasons, predator-prey interactions, and animal migrations (Schwartz 2003).

The increasing recognition of the importance of climate change consequences for phenology has inspired a rapid growth of phenology monitoring networks across Europe (e.g. European Phenology Network and UK Phenology Network) and North America (e.g. Naturewatch Canada and USA National Phenology Network [USA-NPN]). Since climate change will have unique effects on the phenology of each eco-region within these networks, the success of these networks will depend on the grassroots participation of cooperating individuals and institutions at the regional scale, which argues for the approach proposed here.

Project Goals and Objectives

The primary goals of the NERC Phenology Group are (1) to develop a cooperative network that would coordinate phenological monitoring, facilitate data sharing, and synthesize phenology data from the Northern Forest and the broader Northeastern US and Eastern Canada region, and (2) contribute more generally to the efforts of the growing USA-NPN.

These tasks will be accomplished by (1) organizing a workshop to build scientific consensus on protocols for monitoring the phenology of plant species in the Northeast, (2) disseminating protocols to encourage consistent phenological monitoring at NERC sites, (3) providing outreach to encourage citizen scientists to conduct phenological monitoring in their community or natural area, and (4) establishing a cooperative infrastructure whereby NERC researchers can synthesize regional phenology data and begin to integrate it with existing data on related regional ecosystem processes (e.g. carbon cycling, pest outbreaks).

Background and Justification

Previous studies indicate complex spatial patterns of forest phenology across the northeast region (Figure 2). A recent study (Fisher et al. 2007) found that remotely-sensed phenology was not well predicted by on-the-ground climatology, highlighting the need for improved field monitoring, which is a prerequisite to better understanding of relationships between land surface phenology and remotely-sensed phenology. Furthermore, although broad patterns of spring onset is largely controlled by dominant temperature gradients, fine scale heterogeneity can be attributed to topographic cold-air drainage (Fisher et al. 2006), delayed warming of the sea-surface (see Cape Cod above; Fisher et al. 2006, 2007), and forest species composition (Richardson et al. 2006, Fisher et al. 2007). Understanding and synthesizing these locally-variable drivers of phenology is imperative in order to accurately predict the regional phenological response to climate change. Moreover, linking the spatial pattern of phenology to variation in the environmental factors driving changes in phenological development will provide a foundation for identifying key climate-change factors that will potentially affect ecosystem dynamics of the northern forest through decadal-scale trends in phenology (e.g., earlier spring onset and delayed autumn senescence). Toward these ends, a cooperative regional phenology monitoring network represents a cost-effective means to obtain the spatially explicit and spatially extensive data necessary to model and predict, at a regional scale, the phenological consequences of anticipated climatic change.

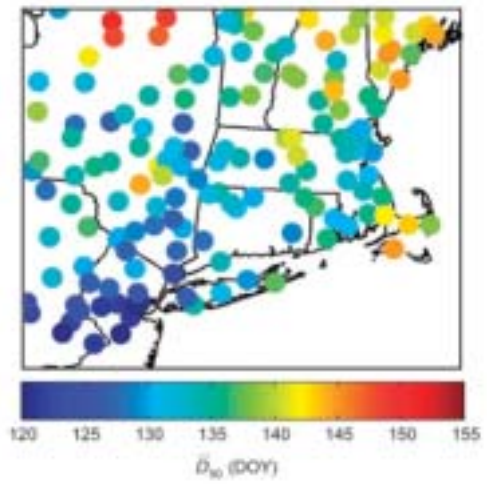

Figure 2. Average date of spring onset (50% canopy development), estimated from MODIS imagery. The date of onset varies by more than 30 days between northern New Jersey and the Adirondacks. Source: Fisher et al., 2007.

The NERC Phenology Group was initiated in January 2007, and in the last few months has received enthusiastic support from both researchers and citizen scientists throughout the Northeast. Preliminary discussions with representatives of the USA-NPN underscored the need for regional-scale organizations that will contribute to the national effort, and the co-PIs have been invited to participate in future USA-NPN planning activities, and to act as a liaison between national and regional efforts. At a grassroots level, the NERC phenology group has already begun to connect the many different groups in the Northeast who have been making phenology measurements in different ways over the last decade.

Approach

NSRC funding will enable our working group to carry out a four-part agenda:

1. Organize a workshop to bring together the region's phenology researchers, establish ground- and remote sensing-based phenological monitoring protocols, and outline further steps to create a coordinated regional network for phenological monitoring.
2. Develop a website and other documents to disseminate information about the network and the monitoring protocols developed for the Northeast.
3. Motivate and involve citizen scientists in phenological monitoring in the region.
4. Synthesize ground-based and remotely-sensed phenology measurements (existing and made by cooperators in 2008-09) in order to develop a regional perspective on the

potential impacts of climate change on phenology and related ecosystem processes.

Workshop

The PI's will organize a 1 ½ day workshop scheduled for Fall 2007 with an expected attendance of 25-30 collaborating NERC researchers, representatives of citizen science groups, and USA-NPN staff members. The workshop will be structured as a series of plenary sessions (short presentations by collaborators, with time for questions), followed by break-out sessions of smaller discussion groups (Figure 3). This format will allow participants to briefly share their diverse phenological research interests and methods as a lead-in to discussions about (1) approaches to integrating field observations with remote sensing data; (2) effective ways to engage citizen scientists in phenological monitoring; (3) specific protocols for coordinated phenological monitoring of northern forest species; and (4) plans for a regional synthesis, manuscript, including discussion of processes coupled to phenology. Break-out sessions will be followed by a gathering of all participants to hear and discuss the recommendations of each discussion group.

Some specific issues to address in discussions include (1) expectations of cooperators, given the lack of additional funding to support observer efforts; (2) identification of specific phenophases and species relevant to data end-users (e.g. budburst cannot be sensed remotely, but the overall patterns of greenup can be); (3) different types of phenological observation schemes (e.g. phenophase start dates vs. ordinal scale for canopy greenup and senescence); (4) aligning newly recommended observation protocols with existing/historical protocols; and (5) strategies for minimizing the inherent uncertainty in phenological observations.

The group will agree on a set of monitoring protocols before the spring of 2008, and all cooperators will be encouraged to use them either in place of or alongside their former methods for

Figure 3. Draft agenda for the proposed workshop including *potential* speakers and discussion facilitators.

Welcome (Denny, McNeil)
Intro to USA-NPN (Schwartz, Betancourt, Losleben)

Ecological significance of phenology
- Response to climate change (Wolfe)
- Biogeochemical impacts (Mackay, Rustad)
- Carbon/water cycling (Hollinger)
- Forest health (Mohan)
- Invasive species (Meyerson)
- Veg-insect-vertebrate interactions (TBD)

Methodology (for spring and fall; species observed)
- Ground observations (research)
  - Hubbard Brook (Bailey)
  - Harvard Forest (O'Keefe)
  - VT Monitoring Coop (Lawson)
  - Adirondack Eco Center (McNulty)
  - Fish and wildlife (Nislow)
- Ground observations (citizen science)
  - AMC (Murray)
  - Nature's Calendar NE (Miller-Rushing)
  - Cornell (Weinstein)
  - USA-NPN Project Budburst (Schwartz)
- Remote sensing
  - Webcam + tower NDVI (Richardson)
  - LTER digital camera protocol (Fisher)
  - MODIS/Landsat (Friedl, Xiao)

Breakout Session 1
- Approaches to integrating ground observations with remote sensing (McNeil, Fisher)
- Effective ways to engage citizen scientists in phenological monitoring (Murray, McNulty, Miller-Rushing)

Presentation and discussion of Session 1 conclusions

Breakout Session 2
- Specific protocols for coordinated phenological monitoring of northern forest species (Lawson, O'Keefe, Denny, Weinstein)
- Plans for a regional synthesis, manuscript, including processes coupled to phenology (McNeil, Richardson, Hollinger, Phillips)

Presentation and discussion of Session 2 conclusions

Workshop wrap-up

Poster session (to be included at end of first day)

at least two years. Once vetted in that first growing season, other NERC researchers and citizen scientists will be encouraged to begin monitoring phenology at their sites. Phenology data collected by the group in the 2008 and 2009 growing seasons will be used in a regional synthesis to be coordinated by the PIs, with input from working group members, and published as a peer-reviewed paper.

Working group communications

Since the USA-NPN is already committed to building an extensive cyberinfrastructure to collect, store and disseminate nationwide monitoring observations, NSRC funds would be focused on the creation of a regional website and publications to promote the regional network, facilitate regional cooperation, and provide information about specific monitoring protocols developed for the Northeast. The website would be developed once protocols have been agreed upon following the workshop.

Citizen science

The proposed activities of our group offer exceptional opportunities for citizen science involvement. The passing of the seasons is something to which people are naturally drawn, and at a fundamental level it inspires curiosity and interest. Phenological observation requires no equipment and minimal training, and every new data point helps paint a more spatially comprehensive picture. Phenology is an ideal jumping-off point for informing the public about the potential consequences of climate change, and enlisting their help in monitoring the outcome.

Representatives from several existing citizen science groups (e.g. Appalachian Mountain Club, Nature's Calendar New England) will be involved in the development of protocols for the Northeast, and their group members encouraged to help vet the new protocols during the 2008 growing season. Once protocols have been vetted, a broader group of citizen scientists will be trained and encouraged to collect phenological data in their communities to contribute to the USA-NPN database. To accomplish this, individual NERC researchers will be encouraged to run a half-day training workshop for citizen scientists at their home institutions. This effort will be conducted in conjunction with the USA-NPN outreach component (Project Budburst), which is still evolving.

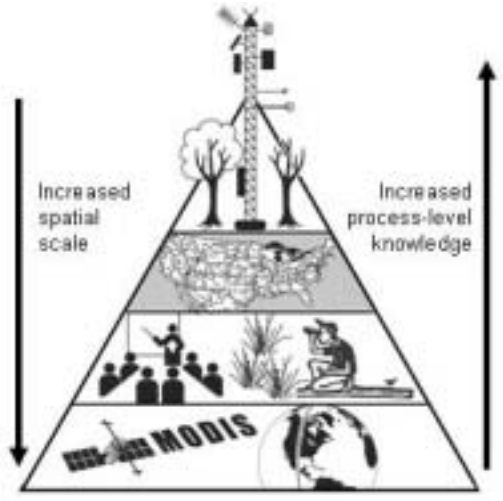

Figure 4. The NERC Phenology Monitoring group will follow the USA-NPN "pyramid" model of assimilating data from four components or tiers: 1) a cooperator network of locally intensive sites focused on process studies; 2) a cooperator network following agreed upon protocols for making standardized observations (including web-cams); 3) a citizen science network; and 4) remote sensing products (e.g., MODIS) that can be calibrated and assimilated to extend surface observations to the regional scale. Image adapted from Betancourt et al. *Eos*, submitted.

Data processing and products

A NERC phenology monitoring network will provide a true regional scope by following the USA-NPN "pyramid" model of assimilating phenological monitoring observations (Figure 4). At the base of this pyramid, we will create a

time series of region-wide maps displaying start of spring (SOS) measures derived from satellite remote sensing measurements. We will make satellite-based observations of phenology using data from NASA's Moderate Resolution Imaging Spectroradiometer (MODIS; see Figure 5). MODIS data are available from 2000 onward and are extensively used for phenology studies (e.g., Zhang et al., 2004) because they provide regional-scale observations of spectral reflectance on 36 imaging bands at spatial resolutions of 250m to 1 km. Several existing algorithms have been used to convert this spectral information into a measure of SOS (e.g. the MOD12Q2 product shown in Figure 5), and a major focus of the working group will be to identify the algorithm(s) that can (a) best represent the phenology of the northern forest and (b) be validated against ground-based measurements (including digital imagery and radiometric measurements, see Richardson et al., 2007). We will use a GIS-based approach to combine (1) the SOS maps obtained from the MODIS remote sensing data (2) observations uploaded to the USA-NPN website by citizen scientists, (3) observations made at NERC sites by working group cooperators, (4) measurements from a proposed webcam network (see Richardson et al., 2007 and NSRC proposal by Richardson and Hollinger), and (5) GIS data layers of factors observed to affect phenology (Figure 5). Such a spatially-explicit synthesis will provide considerable opportunity to identify the factors that will interact with climate change to affect the phenology and associated ecosystem dynamics of the northern forest.

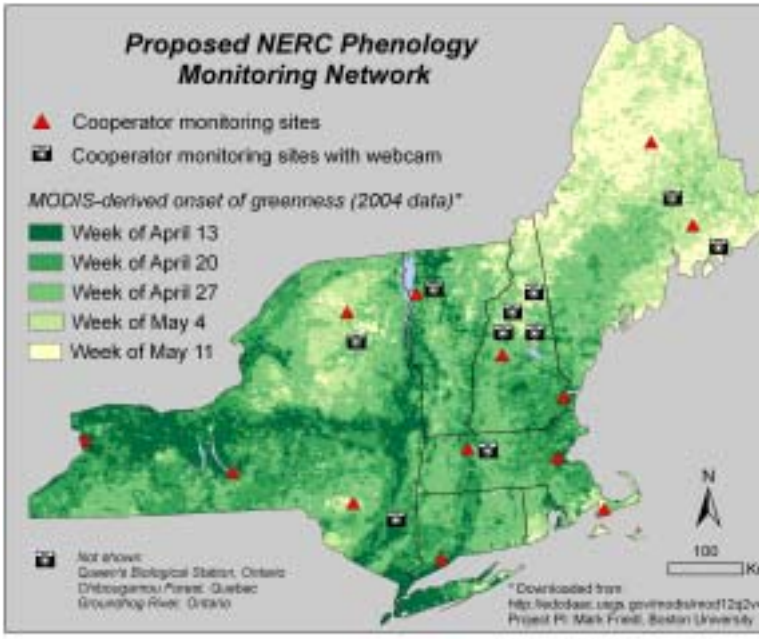

Figure 5. Proposed NERC phenology monitoring network. The MODIS remote sensing data and intensive monitoring sites will capture the ~30 day variation in the onset of spring.

Products and Outcomes

We will establish a cooperative phenology monitoring network for the Northeast that (1) supports and contributes to the USA-NPN program, (2) monitors phenology according to protocols established by and for the researchers and citizen scientists in the region, and (3) publishes peer-reviewed articles and white-paper documents geared toward (a) communicating the protocols and results of monitoring network, (b) expanding the network into additional scientific field sites and citizen scientist communities (e.g. schools, naturalist groups) and (c) synthesizing data obtained by the network in order to enhance understanding of the impacts of climate warming upon the phenology and coupled ecosystem dynamics of the Northeast region.

Specific tangible products include a set of recommended species and monitoring protocols for phenological observations in the Northeast, a regional phenology network website, region-specific materials for citizen scientist training workshops, and a peer-reviewed regional synthesis publication linking ground and remote sensing observations to environmental drivers.

REFERENCES

Betancourt, J.L., Schwartz, M.D., Breshears, D.D., Brewer, C.A., Frazer, G., Gross, J.E., Mazer, S.J., Reed, B.C., and Wilson, B.E. Submitted. Evolving plans for a USA-National Phenology Network (USA-NPN). *Eos, Transactions, American Geophysical Union*.

Fisher, J.I., J.F. Mustard, M.A. Vadeboncoeur. 2006. Green leaf phenology at Landsat resolution: Scaling from the field to the satellite. *Remote Sensing of Environment* **100**: 265-279.

Fisher, J.I., A.D. Richardson, and J.F. Mustard. 2007. Phenology model from surface meteorology does not capture satellite-based greenup estimations. *Global Change Biology*, in press.