Towards a USA-National Phenology Network

What is phenology?

Phenology is the study of periodic plant and animal life cycle events that are influenced by environmental changes, especially seasonal variations in temperature and precipitation driven by weather and climate. Included are the timing of leafing and flowering, agricultural crop stages, insect emergence, and bird, fish, and mammal migration. All of these events are sensitive integrators of both weather and climate, and are relatively simple to record and understand.

Why is phenology important?

Phenological events record, in a real and immediate manner, the consequences of environmental variability and change vital to the public interest. Phenological events such as the beginning of the growing season can vary by three weeks or more from year to year. Such variations have important environmental and socio-economic implications for Health (allergens and infectious diseases), Recreation (fall colors and wildflower displays), Agriculture (planting and harvest times, pest control), and Management of Natural Resources (water and timber) and Hazards (monitoring and prediction of drought and fire risk).

Why do we need a USA-National Phenology Network?

Phenology is a far-reaching component of environmental science but is poorly understood. Critical questions include how environmental factors affect the phenology of different organisms, and how those factors vary in importance on different spatial and temporal scales. Moreover, we need to know how phenology affects the abundance and diversity of organisms, their function and interactions in the environment, and their effects on fluxes in water, energy, and chemical elements at various scales. With sufficient observations and understanding, phenology can be used as a predictor for other processes and variables of importance at the national scale, and could drive a variety of ecological forecast models with both scientific and practical applications.

Despite their obvious importance, broadly distributed phenological data that take advantage of environmental gradients are almost non-existent in the USA. Lilac phenology is an important exception that previously was monitored at many locations across the country, but these measurements have been taken only sparsely since the early 1990s and need to be extended. The predictive potential of phenological data requires a new data resource- *a national network of integrated phenological observations and the tools to analyze them at multiple scales*. This network is essential to evaluate ongoing environmental changes, and can now capitalize on integration with other observation networks and remote sensing products, emerging technologies and data management capabilities, myriad educational opportunities, and a new readiness of the public to participate in investigations of nature on a national scale.

USA-NPN Vision Statement
USA-NPN will provide phenological information that can be used to understand the role of the timing of life cycle events in the biosphere. It will establish a nationwide network of phenological observations with simple and effective means to input, report, and utilize these observations, including the resources to provide the right information at the right time for a wide range of decisions made routinely by individual citizens and by the Nation as a whole.

How will USA-NPN operate?
A five-tiered, expandable observation network is proposed:

1. A backbone network of ~2000 evenly distributed sites with observations of indicator/native plant species linked to existing climatic networks, especially the National Weather Service COOP program;
2. Observations driven by specific research questions and made by technicians/scientists at established research sites, especially those in the Ameriflux, Long Term Ecological Research (LTER), and Agricultural Experiment Station networks;
3. Observations taken by students as a part of regular science curricula on school campuses;
4. Observations reported by a wide network of volunteer "citizen scientists"; and
5. Remote sensing observations that will allow "wall-to-wall" coverage in the U.S.

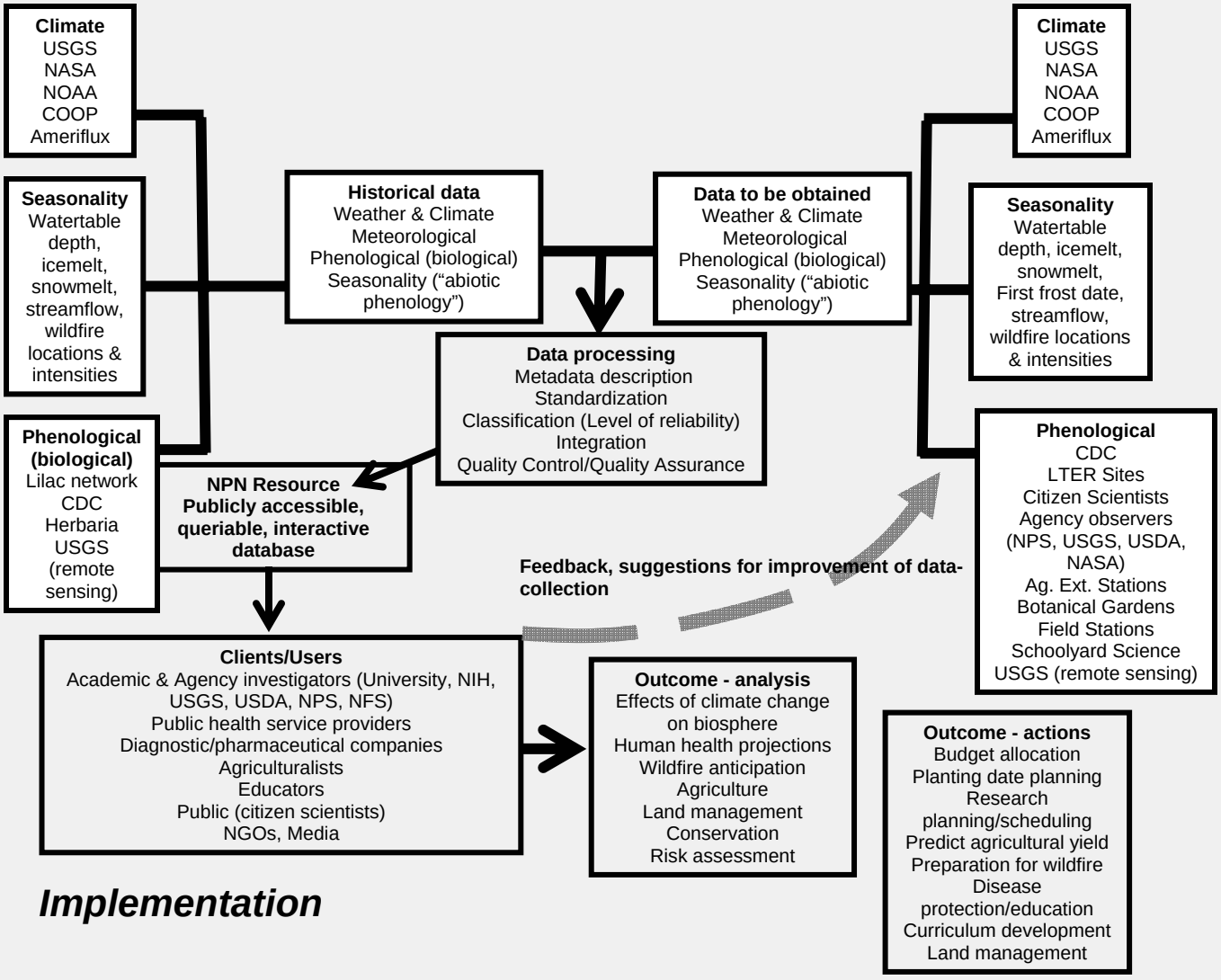
These observations will be entered into a database management system and made available to the public in mapped form and near real time (see prototype web page at http://www.npn.uwm.edu).

Who will benefit from the USA-NPN?
Many government agencies, economic sectors, and scientific disciplines will benefit from the data collected by the NPN and the subsequent analyses that will be possible for the first time. The Table below summarizes six major areas to which phenological research can contribute.

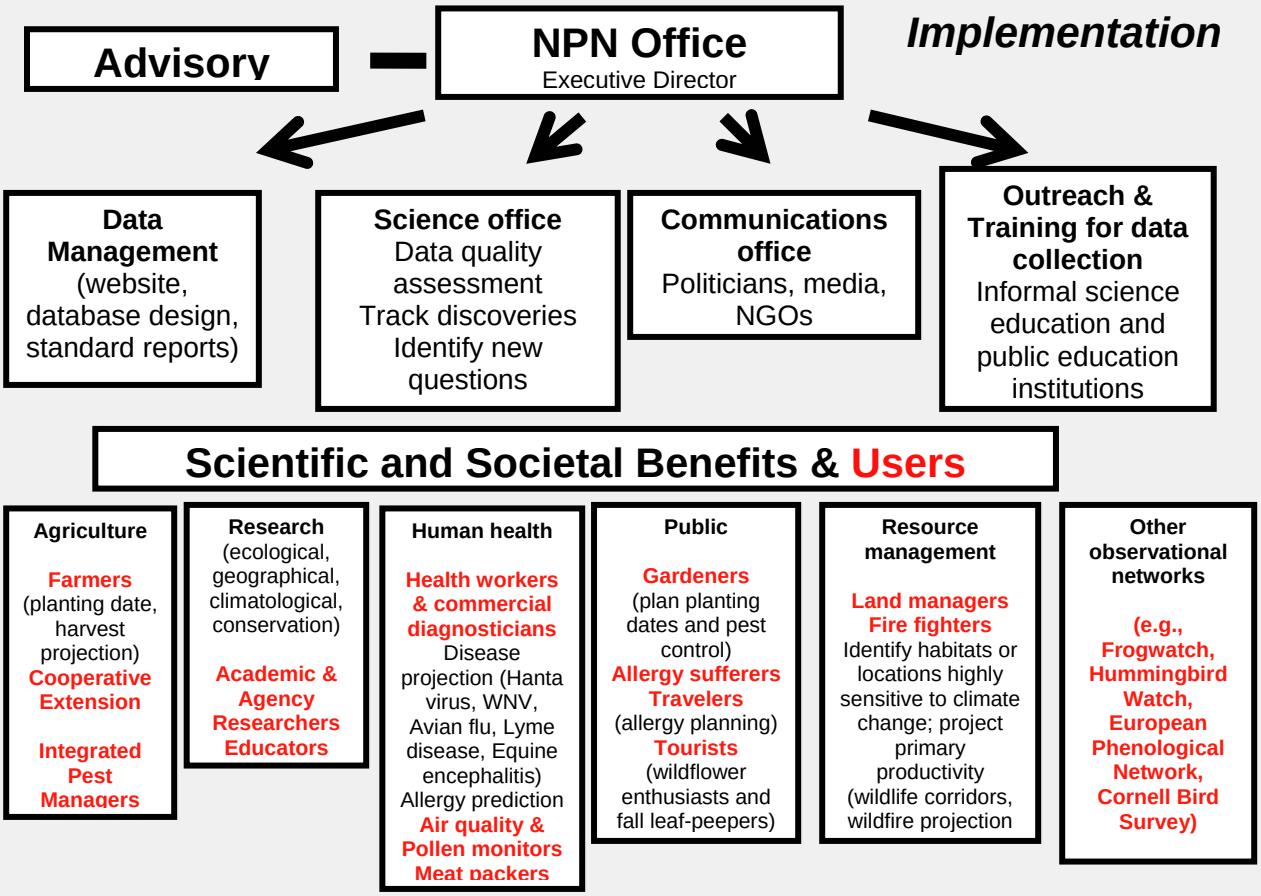
Scientific Research	**Human Health**
Effects of climate variability & change, ecological forecast models, ecological synchrony, carbon sequestration, ground truthing for remote sensing, ecohydrology	Timing and prediction of allergy (hay fever) and pulmonary (asthma) problems. Study of vector-borne diseases (lyme disease, West Nile virus)
Agriculture	**Natural Resources**
Timing of management activities (pest and disease control, planting, harvesting, and provision of pollinators), drought monitoring, range management	Prediction of forest pest and disease outbreaks, fire management, invasive species management, watershed management
Tourism and Recreation	**Education**
Informing tourists when and where to go for seeing bird migrations, wildflower displays, and fall colors	School children and citizen scientist involvement in scientific observations; establish college curriculum in phenology

Brief History of Planning Efforts for a USA-NPN: The idea for a USA-National Phenology Network has many instigators. J.M. Caprio (Montana State U.) initiated lilac phenological research in the USA, starting in 1956. He developed a network of volunteer observers (about 1000, growing to 2500 by 1972) eventually scattered throughout 12 Western states. Dr. Caprio's program stimulated development of a similar program in the Eastern USA, starting in 1961, under the direction of W.L. Colville (U. of Nebraska; about 300 observers in 1970). The Eastern network lost funding in 1986, but was continued at a limited number of stations by Mark D. Schwartz from the U. of Wisconsin-Milwaukee. The Western network was terminated upon Dr. Caprio's retirement, but was reactivated at a handful of sites by Dan Cayan (Scripps Institution of Oceanography) to complement his studies on changes in the timing of snowmelt discharge. Funded by NSF and other federal agencies, in August 2005 Mark D. Schwartz and Julio Betancourt (U.S. Geological Survey) organized a workshop to begin developing an implementation plan for a USA-National Phenology Network that would revitalize the lilac network and extend phenological observations to other native and non-native species (http://www.npn.uwm.edu). An Implementation Team was recruited with representation across disciplines and institutions, with the goal of launching the first monitoring activities in 2007:

USA-National Phenology Network Implementation Team
Baenziger, P. Stephen, *University of Nebraska*
Betancourt, Julio, *U.S. Geological Survey, Desert Laboratory*
Breshears, David, *University of Arizona*
Brewer, Carol, *University of Montana*
Cayan, Dan, *Scripps Institution of Oceanography*
Cecil, DeWayne, *U.S. Geological Survey (currently on appointment at NASA)*
Crawford, Ken, *National Oceanic and Atmospheric Administration*
Crow, Tom, *U.S. Department of Agriculture, Forest Service*
Dettinger, Mike, *U.S. Geological Survey/Scripps Institution of Oceanography*
Easterling, William, *Penn State University*
Gross, John, *National Park Service*
Inouye, David, *University of Maryland*
Jones, Bruce, *U.S. Geological Survey*
Law, Bev, *Ameriflux/Oregon State University*
LeDuc, Sharon, *National Oceanic and Atmospheric Administration*
Mazer, Susan, *University of California, Santa Barbara*
Morisette, Jeffrey, *National Aeronautics and Space Administration*
Pielke, Roger, *Colorado State University*
Post, Eric, *Penn State University*
Reed, Bradley, *U.S. Geological Survey*
Schwartz, Mark D., *University of Wisconsin-Milwaukee*
Sheffner, Ed, *National Aeronautics and Space Administration*
Turner, Woody, *National Aeronautics and Space Administration*
Van Vliet, Arnold, *Wageningen University*
Waide, Jack, *U.S. Geological Survey*
Waide, Robert, *LTER Network/University of New Mexico*
Wolfe, David, *Cornell University*



Implementation


Advisory
NPN Office
Executive Director
Implementation
Data Management (website, database design, standard reports)
Science office Data quality assessment Track discoveries Identify new questions
Communications office Politicians, media, NGOs
Outreach & Training for data collection Informal science education and public education institutions
Scientific and Societal Benefits & Users
Agriculture
Farmers (planting date, harvest projection)
Cooperative Extension
Integrated Pest Managers
Research (ecological, geographical, climatological, conservation)
Academic & Agency Researchers
Educators
Human health
Health workers & commercial diagnosticians
Disease projection (Hanta virus, WNV, Avian flu, Lyme disease, Equine encephalitis)
Allergy prediction
Air quality & Pollen monitors
Meat packers
Public
Gardeners (plan planting dates and pest control)
Allergy sufferers
Travelers (allergy planning)
Tourists (wildflower enthusiasts and fall leaf-peepers)
Resource management
Land managers
Fire fighters
Identify habitats or locations highly sensitive to climate change; project primary productivity (wildlife corridors, wildfire projection
Other observational networks
(e.g., Frogwatch, Hummingbird Watch, European Phenological Network, Cornell Bird Survey)

NPN Draft table of Objectives and Products
Developed March 23, 2006 at NPN Workshop in Tucson

Objectives	Short-term Products (1-2 years)	Mid-term Products (5 years)	Long-term Products (10+ years)
LEADERSHIP AND FUNDING INVESTMENTS			
Secure a network coordinator ***NEED:*** To provide a point person that can provide leadership and full-time attention to the development of NPN ***STAKEHOLDERS:*** All (Public, Researchers, and Decision and Policy makers) ***FUNDING:*** USGS? Other options? (Post-doc or short-term agency rotations?)	Develop job description for Director Produce short overview document (2 pages) on NPN to help sell position and program NPN Implementation Team sub-team briefings to agency contacts in DC area Letters of support from associated agencies (USGS, NPS, NASA, USFS) highlighting value added by participating in NPN Secured position (USGS?) Filled position	Short-term agency position rotations in addition to NPN Director Ongoing support for secured Director Obtain institutional support and resources for supporting staff and researchers	Short-term agency position rotations in addition to NPN Director Ongoing support for secured Director Ongoing institutional support and resources for supporting staff and researchers
Develop interagency working group ***NEED:*** To increase communication, clarify roles and buy in. ***STAKEHOLDERS:*** Federal agencies ***FUNDING:*** Agencies choose and send their own representatives	Established working group to facilitate communication Documented interest and roles for each agency to help develop buy in for each agency (Possibly bring in USDA: CSREES, RMA, ARS, ERS; BLM; BIA, FWS, NOAA; Others: OBFS). Initial working group meetings to guide early development of NPN	Ongoing working group meetings to guide development of NPN	Ongoing working group meetings to guide development of NPN
SPECIES, SITES, AND MEASUREMENTS			
Geographical expansion of the lilac network, emphasizing co-location with COOP stations (Expand the lilac network to the Ag. Exp. Stations, campuses) ***NEED:*** To provide a standard for evaluating native species responses at the national scale (e.g., tie to remote sensing, invasive species), to create a new national resource for utilizing ecological data for decision makers ***STAKEHOLDERS:*** All, especially Researchers in short term ***FUNDING:*** NSF LTREB or RCN Regional USDA Hatch funding assoc w Ag. Exp. Sta. NIH options?	Functional wall-to-wall (to the extent possible) lilac network Training program for operation of the network Table of seasonal timing of the dates of key lilac phenophases	Expand wall-to-wall network to other regions with other-than-lilac indicator species Updated Table of seasonal timing of the dates of key lilac and other indicator species phenophases Set of relationship between indicators at the National scale and native species	Automated sensor network to enable extensive set of remote observations. Table of seasonal timing of the dates of key phenophases Understanding of species-specific indicators for relationship between indicators at the National scale and native species and other key metrics (ecosystem properties; landscape phenology)

Objectives	Short-term Products (1-2 years)	Mid-term Products (5 years)	Long-term Products (10+ years)
Monitor a small set of key plant species of regional importance (e.g., dominant species and invasives) to complement the lilac network on as large a scale as possible ***NEED:*** To allow targeting of species whose phenology is of socioeconomic and scientific importance in understanding the ecosystem consequences of phenological dynamics and its regional variability, and to improve efficiency and reduce uncertainty of remote sensing applications ***STAKEHOLDERS:*** All, especially R and D in short term ***FUNDING:*** Natl. Geographic? NSF RCN, NEON Resource management community USDA, USGS, DOI, NASA Regional USDA Hatch funding assoc w Ag. Exp. Sta. NIH options? Need to id State agencies NSF & NIH infectious disease programs?	Initial step for Wall to wall coverage of a small set of key species Developed protocols for the key species and phenophases Baseline data from an initial set of data Establish initial citizen science network Develop funding strategy for long-term support, and address associated infrastructure questions Initiate formal working relationships with various agency groups Identify options for short-term appointments within agencies	Closer to Wall to wall coverage of a larger set of key species, with some regionally intensive coverage Complete design of national coverage Integration of phenological education into college curriculums Implement short-term appointments within agencies Developed protocols for the key species and phenophases Establish expanded citizen science network	Completed wall to wall coverage of a larger set of key species, with regionally intensive coverage System for tracking invasive species responses Ways to link phenological events with socioeconomic events (e.g., fires, outbreaks) Secure long-term funding source Set of basic scientific relationships for species responses and other predictive relationships (e.g., biogeochemistry) Establish formal working relationships with various agency groups
Addition of non-plant species to network of socioeconomic importance: rapid response ***NEED:*** To integrate plant phenology with other developing and ongoing phenological observations that extend the usefulness of phenological data ***STAKEHOLDERS:*** All, especially Researchers in short term ***FUNDING:*** NSF, NIH (disease vectors)	Identify options and key collaborators Identify key non-plant species with broad geographic ranges and/or broad public appeal	Initiate some of the options and key collaborators Rapid response analysis associated with the non-plant species (e.g., CDC) Develop predictive models of non-plant phenological responses to climate change	Understand role of animal phenology in population dynamics and community composition. Identify and understand ecological winners & losers, role of phenology in range shifts and extinction vs. colonization.
Expansion to include seasonality data ***NEED:*** To greatly expand range of economic sectors and stakeholders affected by climate change ***STAKEHOLDERS:*** Land and water managers, urban planners, tourist industry, insurance industry ***FUNDING:*** USDA, Forest Service, USGS, insurance industry, tourism industry	Identify key seasonal indicators of climate change such as: -timing of snowmelt and peak stream flows -lake ice-in and –out dates -snow cover days; start of ski season -start dates for fire season, hurricane season, etc. Identify most sensitive regions for specific seasonal indicators, and obtain funding for economic impact and decision-support tool development	Develop document(s) for policy-makers and specific stakeholder groups and regions regarding economic impacts of seasonality historical trends and forecasts based on GCM models	Provide planning strategies and new decision-support tools for stakeholders.

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Identify non-traditional datasets for use as baselines ***NEED:*** To obtain additional insights on past phenological trends from non-traditional data sources such as the Thoreau journals ***STAKEHOLDERS:*** Elements of the public, like birding groups, naturalists, historians; universities. ***FUNDING:*** The Nature Conservancy? Audubon Society National Geographic NSF	Unearth existing, non-traditional datasets, perhaps through collaboration with local historical societies, libraries, universities	Document and exploit potential "gap-filling" to existing and planned NPN sites and datasets. Use such datasets to raise public awareness of and appreciation for the tradition of phenological monitoring in the U.S.	Establishment of public phenology courses and/or training through local naturalist societies and historical groups Analyses of shifts in phenology since the onset of the recent warming trend, and shifts in more social-sciences areas such as public and private interest in and tracking of phenology
Economic analyses of phenological change (e.g. vineyards, orchards, etc.) as a means to emphasize the importance of the NPN ***NEED:*** What are the economic implications of climate variation/change as affecting phenological and associated ecological changes Improved cost-cutting measures and cost savings measures associated with improved planning ***STAKEHOLDERS:*** Especially Decision and Policy makers in most sensitive areas ***FUNDING:*** NIH USDA esp. RMA and Econ Research Agency Private: Pew? NGOs NPS esp. for fire mgmt, invasive sp	Add economist (resource and/or agri.) to implementation team Add AVV to implementation team Identify and initial quantification of examples where there are the most direct ties to economic impacts of phenology and the related phenological measurements needed Get phenology tie into Our Changing Planet	Glossy document for policy makers and general public on economic impacts Analysis of economic impacts of climate variation/change that incorporates phenological results Enhance the economic component of decision making tools	Linkages with international networks and associated reports/working groups (FAO, IPCC) Develop improved mitigation strategies (e.g., for invasives species, forest health, fire risk …) that build off phenological observations (e.g., phenological "red flags")
Survey potential sites and develop protocols for collections in existing research areas (e.g., LTER, AmeriFlux) and resolve: 1. Species to monitor; 2. Phenophases to monitor; 3. Feasibility at each site and within each network ***NEED:*** To allow expansion of sites collecting data and engages active participation of various other networks to mutual advantage, and provide exponential increases robustness of what is learned from NPN base and from existing networks ***STAKEHOLDERS:*** All, especially R & D ***FUNDING:*** Ameriflux funders: DOE, USDA, NSF NPS? NSF RCN, NEON	Obtain funding for workshop(s) to identify species, phenophases, and feasibility across networks (e.g., tie to Amerflux meeting) Mapping the spatial compatibility of existing networks (e.g., NPN and Ameriflux) to optimize sampling locations associated with phenology Develop relationship with NEON – clearly defined roles and responsibilities: bring species into NEON Make sure to identify other less obvious networks to work with	Implement coordinated observations based on identified species and protocols Demonstrate benefit to cooperating networks / enhanced interpretation of other products Bring species into NEON Developed linkages with other international phenology networks (e.g., EPN)	Synthesis on temporal (e.g., interannual, decadal) variation in response between phenology/seasonality and other measurements made by networks Improved regional maps based on phenology data with error bars that can be applied to ecosystem management in a climate-change context Portfolio of demonstrated examples linking phenology results to improved land management Provide the nation with a current analysis of pace of response to climate variation/change and its spatial variation Contribution to improved predictive capability for atmospheric land surface dynamics predictions

Objectives	Short-term Products (1-2 years)	Mid-term Products (5 years)	Long-term Products (10+ years)
Implement NPN within partner agencies; start making measurements for NPN within partner agencies ***NEED:*** To develop initial working data sets and develop working relationships with partner agencies ***STAKEHOLDERS:*** All, especially R & D ***FUNDING:*** Natl. Geographic? NSF RCN, NEON Resource management community USDA, USGS, DOI, NASA Regional USDA Hatch funding assoc w Ag Exp. Sta. NIH options? Need to id State agencies	Defined issues to be identified for interagency agreement Identify existing/needed interagency agreements Initiate and complete new needed interagency agreements	Expand coverage as detailed in other parts of this table	Expand coverage as detailed in other parts of this table
DATABASE / DATA MANAGEMENT ISSUES			
Further design and development of the information infrastructure ***NEED:*** Facilitate broad utilization of data and derived information ***STAKEHOLDERS:*** All ***FUNDING:*** NSF Cyber infrastructure USGS (tied to coordinator for NPN) Foundations	Survey users to determine data entry and reporting needs and preferences. Develop data management policies Define web site function specifications and implement web-based data entry and reporting Interactive web site features to serve specific audiences (e.g., schools, researchers, media) Tools for interactive mapmaking and relational databases Identify data mining tools Design QA/QC protocols	Develop advanced data mining, GIS, visualization tools. Design and implement sophisticated analysis tools Develop explicit linkages to supporting on-line databases (climate, topography, etc) Produce real-time, standardized reports linking phenological observations to key indices of health, agriculture, and to other application areas	National/international reputation as a national resource: recognized as a reliable, citable source of information Addressed major computer science challenge associated with phenology information management Interactive visualization database that integrates and synthesizes data at multiple scales and is very popular and useful Automated procedures to search distributed databases, analyze search results, and produce spatially explicit analyses.
Develop clearinghouse (metadata base) for phenological data ***NEED:*** Promote use of currently hard-to-find phenological data; promotes interdisciplinary research and syntheses ***STAKEHOLDERS:*** All ***FUNDING:*** NSF, USGS (key NPN development task). Could be started on voluntary basis by implementation team members or as student project.	Define and document required, preferred, and optional metadata content, including field values to facilitate searching Identify and document organized databases in key areas including agriculture, horticulture, zoology (birds, frog, etc.) Report information on existing data sets via web forms	Develop agreements and direct data links to existing phenological data sets. Document and populate metadatabase with research and informal observations (e.g., by individual, or with non-standard protocols)	Implement advanced tools that used metadata documentation to guide automated data searches, synthesis, analysis, and reporting procedures.

Objectives	Short-term Products (1-2 years)	Mid-term Products (5 years)	Long-term Products (10+ years)
Actively acquire and display high priority/high impact datasets and metadata ***NEED:*** Provide 'quick win'; demonstrating value of data and is 'proof of concept' ***STAKEHOLDERS:*** NPN implementation team and supporters ***FUNDING:*** NSF, USGS Little or no funding required in short term.	Acquire existing, long-term phenological and seasonal data with clear link to social values. These will likely include cherry blooming, wheat, lilac data, Lake Mendota ice, etc. Display results with a short interpretation.	None	None
APPLICATIONS ***GENERAL NEED:*** For each **Applications** area listed below, identify existing decision models and support tools, provide immediateness of delivery, and demonstrate that application of phenology has a diverse set of significant socioeconomic impacts			
Allergens ***STAKEHOLDERS:*** Public / human health / allergy sufferers / medical community /pharmaceutical community ***FUNDING:*** NIH Pharmaceutical USDA	Obtain existing pollen data applicable for lilac comparison. Obtain medical partners for proposals Evaluation of existing pollen records and lilac records as initial evaluation of potential linkage.	Increase public awareness of phenology applications to allergies Create a prototype new resource for the medical community of a new pollen index based on phenology data. Obtain NIH funding for continued development	Widely deploy a new resource for the medical community of a new pollen index based on phenology data.
Integrative Pest Management [IPM] ***STAKEHOLDERS:*** USDA COOP Ext. Farmers Home Gardeners Landscapers Petrochemical / pest control specialists ***FUNDING:*** USDA Chemical companies State and regional IPM programs	Identify existing IPM forecast models that could benefit from enhancement by phenology monitoring. Proposals for quantifying relationship between plant and pest phenology from improved controls Involve IPM specialists	Develop schedules of important pest phenologies. Implement / benchmark improved IPM forecast models.	Document more efficient pesticide use and associated impacts.
Invasive Species Management ***STAKEHOLDERS:*** USGS, NPS, USDA, BLM, USFS, Farmers, Ranchers, Home gardeners, Indian tribes ***FUNDING:*** USGS, NPS, USDA, BLM, USFS, states, private companies	Develop target species lists for phenological monitoring Identify invasive species for which seasonality is an important component of the life cycle Develop dynamic climate zone / ecotone map based on phenology	Integrate phenology monitoring with system for tracking the movement and intensity of invasive species	Develop understanding of life history variation in the evolution of invasiveness Contribute to untangling of relative roles of climate change vs. other factors in driving invasive species documents Improve forecasting and management for invasive species

Objectives	Short-term Products (1-2 years)	Mid-term Products (5 years)	Long-term Products (10+ years)
Tourism and Recreation – wildflower blooming / fall foliage / cherry blossoms / ski hills / bird watching ***STAKEHOLDERS:*** Tourists (domestic/foreign), Tourism industry (restaurants, hotels, hunters, fishermen, etc.) ***FUNDING:*** State agencies Hotel industry State and National Parks Ski industry Transportation industry? NGOs: Boone and Crockett, Natl. Wildlife fund	Identify key species and abiotic metrics to monitor (cherry trees, maples, mosquitoes, lake thaw, birds…) Generate baseline maps for key tourism indices and post on web Identify current models and decision tools being used and existing available data (e.g., Breeding Bird Survey)	New rapidly-deployable data that can be used in predictive tools to benefit tourism and recreation industry Establish linkages to existing data and efforts to collect those data	Documented substantial impact on tourism industry in multiple areas More adaptable management for industry operating under uncertain climate
Commodity trading / futures markets ***STAKEHOLDERS:*** Food industries / agro-business, stockholders ***FUNDING:*** Food industries / agro-business, stockholders USDA, Dept of Commerce, trade associations	Identify elements of stock market that are linked to phenology Linking phenology data to planting/harvest dates and yields of major agricultural commodities (wheat, rice, corn, cotton) Recruit an agri. economist to provide estimates of potential phenology impacts	Better predictive models for commodity traders and agri. economists	Documented substantial impact on commodities industry in multiple areas More adaptable management for industry operating under uncertain climate
Agricultural planting / harvest planning ***STAKEHOLDERS:*** Farmers, UDSA, Seed grain companies Food industries / agro-business, ***FUNDING:*** USDA	Identify target crops and regions for developing optimal relationships between phenology and planting/harvest dates Develop phenology-based planting date guides for selected crops	Expand the scope from initial foci crops to more regions and more crops	Reduced economic losses associated with climate variation
Infectious diseases and associated vectors ***STAKEHOLDERS:*** Homeland security NIH CDC Medical community USDA Red Cross & other NGOs ***FUNDING:*** Homeland security NIH CDC Medical community USDA	Identify which vectors have phenological cycles and have potential major impact Recruit partners from medical community Begin to develop a system for early detection and rapid response	Prototype a system for early detection and rapid response	Implement a system for early detection and rapid response Improve health care and crisis management in variable/changing climate Mitigate expenses of late responses
Fisheries management ***STAKEHOLDERS:*** USFW, fishing industry, recreational fishermen ***FUNDING:*** USFW, state agencies like Fish & Game, Game & Boat Commission, etc.	Connect with stakeholders and work with representatives to ID interests in and applications to NPN	Baseline analyses of links between aquatic and/or near-shore phenology and important elements of fishing industry, such as onset and length of fishing season, seasonal availability of key species, etc.	Develop predictive models of role of phenology and climate change in fishing markets and fish-tourism industry.

Objectives	Short-term Products (1-2 years)	Mid-term Products (5 years)	Long-term Products (10+ years)
Urban applications – horticulture/landscaping/golf courses/construction? ***STAKEHOLDERS:*** Golf course, park, athletic field, public garden managers; City planners, urban horticulturalists, landscapers. Construction firms, highway construction/repair services ***FUNDING:*** Private sector stakeholders, city agencies, DOT USDA	Identify key urban centers for initial focus, e.g., New Orleans, NYC, Chicago, Miami, etc. Obtain funding for regional needs assessment	Obtain funding for development of decision-support tools and economic impact assessments. Initiate funded projects	Provide decision-support tools involving phenology network data and short and long term climate predictions. Reduced economic losses in urban areas due to better decision support tools for a changing climate Expand to other cities, regions
Fire risk management ***STAKEHOLDERS:*** Public, Agencies, especially USFS ***FUNDING:*** USFS JFSP	Identify species and phenophases likely to be most useful in assessing fire risk	Implement phenological observations and integrate with developing fir risk management tools	Reduced uncertainties, losses, and management costs associated with fire risk management
ECOLOGICAL RESEARCH APPLICATIONS			
Phenology & Remote sensing linkages / Carbon sequestration and management ***STAKEHOLDERS:*** Landscape-scale+ scientists ***FUNDING:*** NASA NSF DOE USDA DOI	Identify method for relating lilac responses to response of key indicator species relevant for remote sensing Evaluate current land and climate data and models for spatial analysis of phenology	Prototype new tools for ground truthing and calibration of remote sensing data Integrate improved phenological observations with driver for models of ecosystem/land surface dynamics (NPP and NEE) Evaluate new earth observations for impact on phenology monitoring	Reduced uncertainties in modeling of key land surface processes at landscape scale
Identification of baseline and changes in synchrony in plants and animals ***STAKEHOLDERS:*** Possible human health applications, hunting, tourism, and the scientific community ***FUNDING:*** NSF	Identify species that are trophically linked, where phenological synchrony is vital to, e.g., reproductive success	Quantify roles of abiotic factors (precipitation, temperature) in variation in trophic synchrony, and spatial variation in those roles	Develop applications to human health, tourism, fishing & hunting, etc. Predictive models of implications of asynchrony for community structure and dynamics.
Water resource management ***STAKEHOLDERS:*** Public, Researchers, Decision and Policy makers ***FUNDING:*** NSF USGS State Agencies	Identify seasonality and phenological measurements most applicable to water resource management Begin obtaining relevant seasonality and phenological measurements	Prototype improvements of existing models that incorporate seasonality and phenology	Improved predictive models that incorporate seasonality and phenology

Objectives	Short-term Products (1-2 years)	Mid-term Products (5 years)	Long-term Products (10+ years)
EDUCATION AND OUTREACH			
Spring Calendars ***STAKEHOLDERS:*** Public, youth groups, libraries ***FUNDING:*** NSF education NGOs: Pew	Compile informational package on different metrics of spring Develop tool kits for K-12 teachers on phenology monitoring and climate change programs Identify college and university faculty for collaboration in developing curricula Establish linkages with other outlets (libraries, youth groups, master gardeners)	New curriculum packages for colleges and universities Develop interactive website for K-12 teachers and students	Phenology network is an integral part of a national educational environmental program encompassing both K-12 and college curricula