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Monitoring phenology in US national parks through citizen science: Some preliminary lessons and prospects for protected areas

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Abstract

Phenology—the timing of seasonal events such as flower production, insect emergence, bird migrations, and snowmelt—has profound significance for people and ecosystems. Many US national parks monitor phenology through citizen science projects that use tools developed by the USA National Phenology Network. We summarize the scope of such efforts conducted over the past decade and identify some preliminary lessons and recommendations for others who wish to develop new projects. Successes include an enormous wealth of data relevant to resource management and park operations, and attainment of goals for resource management, education, and public engagement. Challenges include long-term sustainability, limited capacity to analyze data, and the ongoing demands of matching volunteer interest and capacity with the geography and natural history of studied species. Practical recommendations pertain to project planning, design, and volunteer engagement, and highlight the need for working and communicating across organizational and disciplinary boundaries. With careful planning and awareness of opportunities and pitfalls, citizen science-based phenology monitoring can benefit any protected area.

Introduction

Phenology refers to the timing of seasonal events such as flower production, insect emergence, bird migrations, and snowmelt. It is relevant to the function and persistence of biological communities and to the work of public land managers. For example, the timing of leaf emergence relative to cold snaps and rainfall can affect forest productivity. The timing of spring growth and fall senescence can affect managers' ability to identify invasive plants, assess fire risk, and schedule management actions. The timing of raptor migration or synchronous firefly emergence can affect park visitation and public events. Because the timing of many seasonal events is sensitive to climate change, phenology also provides a useful opportunity to detect and forecast climate change impacts on biological communities.

For these reasons, staff, research scientists, partners, and volunteers study phenology in many national parks, wildlife refuges, state parks, and other protected areas. For example, amateur birders use mobile apps to record species they see while hiking, or contribute observations of raptors at organized Hawk Watch sites during migrations. Hikers record leafing, flowering, or fruiting on designated plant phenology trails or monitoring sites. Modelers use images from satellites and ground-based cameras to study landscape-scale spring leaf-out and onset of fall foliage. Academic researchers study the timing of interacting species such as plants and pollinators, migrants and food sources, invasive and native species. Fire managers track the seasonal growth and drying of vegetative fuels. Interpreters engage visitors in monitoring flowering, butterfly activities, and frog calls to enrich the visitor experience. Table 1 offers examples of publications with a variety of natural resource topics and

TABLE 1. Examples of phenology studies and protocols in national parks or that are particularly relevant to national park management. Most of these studies used data or tools from the USA National Phenology Network.

Publication	Focal variable(s)	Key results
Bradley 2014	IS	Phenological information can enable the detection of invasive species using remote sensing.
Breckheimer et al. 2020	V, FA	Wildflower blooming and visitation are becoming mismatched at Mount Rainier National Park.
Buckley and Foushee 2012	V	Park visitation has shifted earlier in the year since 1979.
Crimmins et al. 2017	FA, FP, T, W	USA-NPN phenological data can be used to develop predictive models for a range of species.
Elmore et al. 2016	T	Citizen science and remote sensing data can be combined to measure forest tree phenology at continental scales.
Feldman et al. 2018	T, W	High-quality training and evaluation of effectiveness are important for phenology citizen science.
Heberling et al. 2019	FP, T	Warming is causing a phenological mismatch between leaf-out of canopy trees and understory plants, reducing the carbon budgets of understory species.
Hegeman et al. 2014	F	The frequency and size of wildfires in the Mojave Desert are increasing. New models allow managers to assess vulnerability to wildfires.
Matthews et al. 2014	FA, FP, T	Protocols for monitoring plant phenology as a part of the California Phenology Project.
Medvigy et al. 2016	T	Downscaling of climate models improves simulations of leaf emergence phenology in California but effects diminish at fine scales. Results were enabled by coordinated data collection across California national parks.
Melaas et al. 2016	T	Ground-based and remote sensing networks can be used to assess regional phenology models and show how community composition influences forest phenology.
Middleton et al. 2013	W, E	Large carnivore recovery and landscape-level changes in vegetation phenology have influenced the demography of migratory elk in Yellowstone National Park.
Monahan et al. 2016	SA	Spring is arriving earlier at 76% of natural resource parks, relative to the historic range of variability.
Rosemartin et al. 2015	FP	Provides lilac and honeysuckle phenology data across the United States from 1956 to 2014.
Tierney et al. 2013	FA, FP, IS, T, SA, W	Phenology monitoring protocols for NPS inventory and monitoring network.
Wallace et al. 2016	IS	Models map the presence and predict the phenological status of invasive buffelgrass in southern Arizona, including Saguaro National Park.

E: Ecosystems; F: Fire; FA: Flowering annuals; FP: Flowering perennials; IS: Invasive species; SA: Spring arrival; T: Trees; V: Visitors; W: Wildlife approaches ranging from professional studies to citizen science programs. The National Park Service (NPS) houses many more such publications in the online IRMA (Integrated Resource Management Applications) Data Store portal (irma.nps.gov/DataStore/).

In 2008, scientists, managers, and educators laid the foundation for the USA National Phenology Network (USA-NPN) to support the study of phenology. Since then the network has developed databases, protocols, a mobile app for data collection, data visualization and forecasting products, educational and training resources, and much more to support phenology research and education. A strong emphasis of USA-NPN is monitoring phenology on public lands (Figure 1).

Here we provide a snapshot of where, how, and to what effect USA-NPN citizen science tools have been used in national parks to monitor phenology. We focus on USA-NPN and NPS because of their long-standing partnership on phenology research. We focus on citizen science because (1) it generates a large proportion of phenology data available to scientists and managers; (2) standardized citizen science phenology monitoring has only recently been applied to protected areas, so there is still much to learn and improve; (3) NPS staff are often more deeply involved in phenology citizen science than in traditional phenology research conducted by university scientists; and (4) NPS and other land management agencies increasingly use citizen science to achieve their conservation missions and engage public audiences. While we focus on national parks, the lessons we identify are applicable to many other protected area systems. Furthermore, though there is a focus on plant phenology in many park efforts, we also highlight integrated monitoring of plants and animals, which provides unique engagement opportunities and scientific information on species interactions.

Our goals are to illustrate how national parks and their partners collaborate with USA-NPN to foster science and education in parks, and to invite and inspire

FIGURE 1. Park staff and volunteers learning how to monitor plant phenology at Lassen Volcanic National Park. NATIONAL PARK SERVICE

additional parks and programs—as well as other resource management agencies and partners—to collaborate with USA-NPN. We use records of park-specific phenology monitoring in the USA-NPN database as well as responses to a survey of park staff to highlight patterns, practices, and lessons that can inform future phenology monitoring in parks.

USA National Phenology Network and national parks

USA-NPN is based at the University of Arizona and has been funded primarily by the US Geological Survey to aid decisionmaking, scientific discovery, and an improved understanding of phenology from a diversity of perspectives. USA-NPN develops and provides tools, training, education, and community support to enable people to collect, visualize, and analyze phenological data. It also curates models that forecast species' activity and compare current and historical conditions (Table 2). The data collection tools are housed within an application called Nature's Notebook, which runs on both desktop computers and mobile devices. The modeling products operate only on desktop computers. All programs, products, and tools comply with federal policies governing information management, including paperwork reduction, privacy, accessibility, and security. Over 500 organizations have registered with and submitted data to Nature's Notebook, including national parks, national wildlife refuges, nature centers, extension programs, and schools.

To study phenology in general, NPS, partner organizations, and researchers use the USA-NPN tools, along with independent research methods and other citizen science programs such as PhenoCams, HawkWatch, iNaturalist, and eBird. At several parks multiple programs are used in concert. Here, however, we focus on the use of USA-NPN citizen science tools to monitor plant and animal phenology in national parks.

USA-NPN and NPS have collaborated for over 10 years, generating a large and permanent dataset relevant to parks' resource management, interpretation and education activities, and seasonal operations. From 2009–2019, 36 parks used Nature's Notebook for data collection, and 47% of them continue to do so (Figure 2). The data have documented changes in many phenophases (specific life-cycle stages) for a wide range of plant species, including earlier timing of leaf-out in deciduous trees (Melaas et al. 2016) and blooming in perennial wildflowers. The results are practically useful to resource managers who need, for example, to plan fieldwork months in advance or to remove invasive species before they produce seeds (Taylor et al. 2020). The projects also help volunteers and other visitors understand how parks are changing and may be affected by external dynamics such as climate change. The collaboration between NPS and USA-NPN also led to nationwide analysis of how the timing of spring arrival has changed over the past 100 years, finding that for 76% of parks spring is arriving earlier compared to historical conditions (Monahan et al. 2016; see Advancing Spring Onset for more information). Through the partnership, USA-NPN staff with expertise in volunteer engagement, ecology, protocol development, data management, and compliance with federal policy consult and collaborate with NPS staff to collect and apply phenological information.

TABLE 2. USA-NPN tools to support phenology monitoring and data exploration.

USA-NPN Tool	Description
Nature's Notebook https://www.usanpn.org/natures_notebook	Phenology monitoring application, including monitoring protocols and tools for data entry
Phenology Observation Portal https://www.usanpn.org/data/observational	A web interface for downloading phenology data collected via *Nature's Notebook*
Visualization Tool https://www.usanpn.org/data/visualizations	A web interface for exploring phenology data in map, graph and calendar form
Extended Spring Indices https://www.usanpn.org/data/spring_indices *Pheno Forecasts* https://usanpn.org/data/forecasts	Maps that use models to predict species activity based on climate drivers; available through the visualization tool and as data layers for analysis

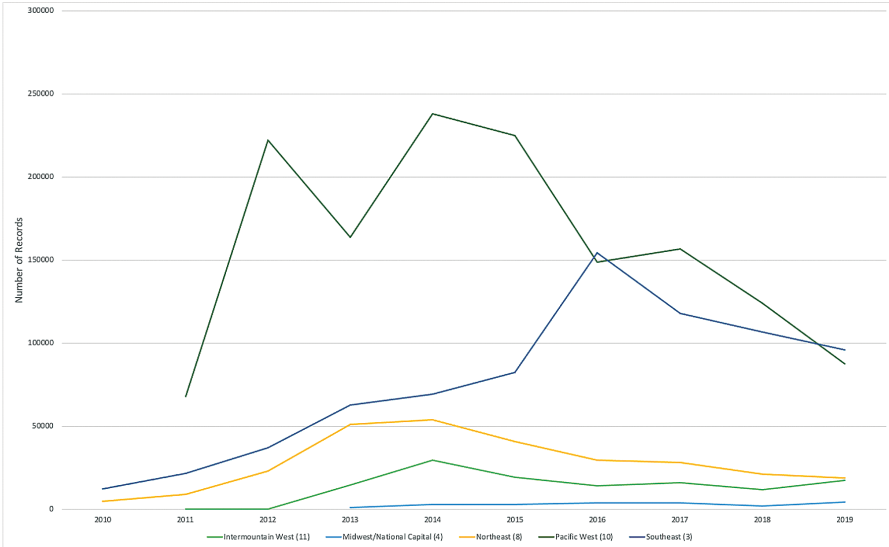

FIGURE 2. Observation records submitted to Nature's Notebook from national parks 2010-2019. Data are aggregated by traditional NPS region, with the number of parks in parentheses.

Survey of park staff

To gain insight into how parks have used USA-NPN tools for citizen science over the past decade, in February–March 2019 we conducted an online survey of NPS staff associated with phenology citizen science projects. We asked open-ended questions about current project status, use of USA-NPN tools, project goals, lessons learned, and recommendations. We received responses from 12 people whose projects are conducted in 13 parks across the continental US: Acadia, Great Smoky Mountains, Lassen Volcanic, and Sequoia-Kings Canyon National Parks; Boston Harbor Islands and Golden Gate National Recreation Areas; Chiricahua, Coronado, Devils Postpile, and Pipestone National Monuments; John Muir and Saugus Iron Works National Historic Sites; and Wilson's Creek National Battlefield. While the number of respondents is far too small to constitute a statistically representative sample, we offer the following summary as preliminary impressions of NPS engagement with phenology.

By far the most commonly used USA-NPN tool was Nature's Notebook, which staff and volunteers use to collect data. All respondents said their project goals related both to science and resource management, and to visitor engagement and learning (Table 3).

Parks are seeing an array of resource management and education benefits from monitoring phenology with USA-NPN tools. Six parks reported progress towards understanding status, trends, causes, and consequences of changing phenology. For example, coordinated monitoring across four California parks shed light on the complex impacts of winter temperature and rainfall on several plant species (as presented in Mazer et al. 2015) and on the climate drivers of oak phenology across the United States (see Gerst et al. 2017). One park reported

TABLE 3. Principal goals of park-based phenology projects that used USA-NPN tools.

Resource management goals	Interpretation, education, and public engagement goals
• Inform restoration projects by knowing phenological patterns in native and invasive species in different locations • Establish phenology baselines so changes can be tracked in the future • Determine if any species may be vulnerable to environmental change because of phenological mismatches between interacting species • Determine trends in green-up across landscapes to inform seasonal field work plans • Determine phenological trends for multiple populations and whether some locations might serve as climate refugia in the future • Understand baseline and trends in phenology of plants used ceremonially by tribes	• Communicate about local (place-based) impacts of climate change • Teach skills in close observation and the processes of science, especially data collection • Engage visitors in scientific methods that they can conduct at home or in their communities • Teach people about plant biology and ecology through a specified focal project • Engage and educate local community members, especially youth

detecting a phenological mismatch between interacting species. Another reported success in using USA-NPN data on the timing of spring, including historical analyses and short-term forecasts, to help plan field work.

Most parks were successful in engaging visitors in close observation of nature, and learning about plant biology and ecology, the process of doing science, and the local impacts of climate change. They enabled visitors to deepen their understanding of the relationship between timing of plant and animal life cycle stages and climate change and discover citizen science that they can do at home. Across respondents, goals related to natural resource management are slowly being met, depending on how rapidly data are collected and analyzed.

However, even with tools provided by USA-NPN and other organizations, citizen science project leaders confront challenges related to volunteer engagement and management. To understand changes in phenology, there need to be enough volunteers who can reliably collect data from multiple locations and with sufficient frequency that the chosen phenological variables can be accurately estimated in one or more populations. That can require recruiting and training a large pool of volunteers, ensuring their ability and commitment to collect data at times and locations appropriate to the species under study, and overcoming logistic challenges inherent to field work. The task is complicated in some parks where field sites are hard to reach, and may be far from the regular workstations of project coordinators who can provide oversight and guidance. Another challenge is to match data collection protocols, volunteers' interests and abilities, resource managers' needs for information, and on-the-ground logistics. The solution may require an iterative trial-and-error approach over one or more field seasons. It also requires the appropriate level of staffing, something that can be hard for parks to maintain if they rely on seasonal or term positions in the face of uncertain annual budget cycles.

Finally, some respondents noted that the USA-NPN's protocols are too onerous for some volunteers (e.g. how close a flower bud is to breaking open in the spring, or how many flowers are present on a plant whose branches are beyond reach). This may be especially the case with monitoring led by interpretive staff during public programs, as opposed to projects led by resource management staff with trained repeat volunteers. As a result, interpretive staff may lose interest in phenology monitoring and the learning opportunities that it provides. Again, the challenge is about designing a project to yield both good information and positive experiences for all participants.

Recommendations for parks and partners

The survey results and the experiences from several years of collaboration between USA-NPN and NPS suggest some recommendations for successful phenology monitoring programs in national parks and other protected areas. Here we identify and discuss a few key considerations. Additional recommendations are explored in the many online guides, toolkits, and descriptions of best practices for citizen science. Examples include the Federal Crowdsourcing and Citizen Science Toolkit and the US Forest Service Citizen Science Toolkit. The USA-NPN's Local Phenology Leader's Certification Course can help with program design and other hurdles specific to using Nature's Notebook.

Identify a specific need or question for a citizen science project—e.g., a question related to resource management, interpretation, visitor protection, or some other core park operation. A specific rationale such as "Tracking the timing of seed production in native vs. invasive plants helps us plan prescribed fires" can be more helpful than a general rationale such as "monitoring the timing of flower production tells us whether climate change is affecting park ecosystems." A question or need does not have to be new. If there is an existing research or monitoring project, it may be productive to add a citizen science component to it. In either case, linking to a core park function strengthens the incentive and justification to inspire and retain volunteers, analyze data, ensure adequate staffing and funds, and maintain continuity of operations.

Involve staff from both resource management and interpretation divisions to design and implement citizen science projects. Collaboration will help ensure everyone understands the project's goals and what is needed to achieve them. It can also help parks avoid too-complicated protocols, activities that lack the support of interpreters, or data collection that does not inform resource stewardship. In general, such collaboration is essential for balancing the scientific, management, educational, and public-engagement goals that are the hallmark and strength of citizen science.

Leverage the resonance of phenology across cultures. For millennia, cultures around the world have cultivated knowledge on the timing of plant and animal life cycle events. There are opportunities to engage North American Indigenous communities and approaches to understanding phenology in national parks (Chisholm Hatfield et al. 2018). A culturally responsive approach to phenology could also engage other marginalized groups. For example, park staff could center the voices of diverse audiences in project designs and study seasonal events that are personally or culturally meaningful to diverse communities around a park or other protected area.

Plan for and commit to an appropriate level of staffing. It may be tempting to think of citizen science as less labor-intensive than professional science, but effective citizen science projects demand dedicated staff time, especially for volunteer recruitment and management. Guidelines developed in the California Phenology Project (CPP) state that "parks must have at least one employee who will serve as the project coordinator; the coordinator will need to dedicate at least eight hours per week to monitoring, data entry, and coordinating volunteers. If resources permit, ideally a park can split duties between a project coordinator, a volunteer coordinator, and a data manager." Additional recommendations are provided in the CPP resources, which, while focused on California, are relevant to protected areas across the United States.

Find and engage "super volunteers." Such people are individuals with sustained high levels of interest and commitment. They participate frequently and for a long period of time, collect a lot of data, and may be able to train or motivate other volunteers. For a wide variety of reasons they may feel a strong attachment to a park, or even a particular study plot. Finding them may be a matter of serendipity but recruiting through local naturalist communities and hobby groups (Master Gardener clubs, local Audubon chapters, nature-oriented social media groups, etc.) makes it more likely.

Develop plans to help projects persist through transitions. It is possible that a project coordinator or other key staff will change jobs, potentially stranding a project. Similar hazards exist when new leaders are hired or budgets change. Success with transitions requires documentation, planning, and coordination. One approach is to create a tiered monitoring program in which one or a few species are always monitored, but others can be dropped or added back in. Engaging "super volunteers" can also help sustain a project through staff transitions.

Connect with others. Friends' groups and other research and education partners play big roles in successful phenology efforts by complementing what park staff can provide. For example, NatureBridge runs immersive youth programs affiliated with Golden Gate National Recreation Area that have helped engage youth in the CPP, and sustained data collection when park resources were limited. Schoodic Institute has established phenology trails in Acadia National Park, which engage students and adult volunteers in monitoring changes through the seasons. The USA-NPN staff, and leaders of programs at other parks, refuges, and nature centers, are a resource for new ideas and solutions. Interested practitioners can join the Phenology Leaders' Community of Practice, which includes a listserv and regular conference calls on a range of subjects.

Communicate about projects by using USA-NPN tools. Many of the challenges associated with citizen science projects can be met by communicating about the project in compelling and strategic ways with key audiences. USA-NPN's data visualization, mapping, and forecast tools yield images that can inform and excite volunteers, potential volunteers, funders, managers, local and national resource stewardship program leaders, and other key stakeholders. They can be shared broadly through reports, newsletters, websites, social media, and other channels. They do not require sophisticated analysis of data, and indeed could even entice people with analytical skills (such as graduate students looking for thesis projects) to extract further meaning from existing datasets.

Conclusion

An ever-clearer picture is emerging of how phenological change has and will continue to shape ecosystems and their management, both within and beyond national park boundaries. A strong foundation has been laid to further the work of phenological monitoring through partnerships, information infrastructure, and protocols—through USA-NPN and many other organizations such as eBird, Project Budburst, and FrogWatch. As exemplified by Figure 2 and Table 1, phenological studies are popular and growing in national parks and other public lands and are now a significant area of research in ecological and conservation fields. There have been clear early successes in phenology-related education, science, and resource management in parks. Using what we have learned from these successes, USA-NPN will continue to invest in long-term relationships and work closely with partners to build and expand tools and products.

We see great potential for continued and expanded benefits of phenological monitoring in national parks and other public lands. First, science can benefit. Wider and thoughtful adoption of protocols and tools will lead to more understanding of phenological change, particularly with regard to potential mismatches among interacting species and the consequences such mismatches may have on community structure, function, and perseverance. Second, natural resource management and public understanding of environmental change can benefit. More analysis, visualization, and communication of data on phenological trends will increase everyone's understanding of how natural systems are changing, and better inform the decisions and actions of resource managers. The stories of seasonal change at parks present powerful opportunities to capture the public's imagination. Third, phenology monitoring can benefit a broader and more synthetic understanding of our changing world that comes through mutual engagement of scientists, management agencies, and diverse public communities. Many people in the ecology, natural resource, and interpretation fields are recognizing powerful Indigenous approaches to understanding phenology. The inclusive and democratic ethos of citizen science, coupled with the ease and cultural relevance of phenology monitoring, enables parks and communities to broaden who is involved in coproducing the knowledge that informs stewardship of public lands.

References

Bradley, B.A. 2014. Remote detection of invasive plants: A review of spectral, textural and phenological approaches. *Biological Invasions* 16(7): 1411–1425. https://doi.org/10.1007/s10530-013-0578-9

Breckheimer, I.K., E.J. Theobald, N.C. Cristea, A.K. Wilson, J.D. Lundquist, R.M. Rochefort, and J. HilleRisLambers. 2020. Crowd-sourced data reveal social–ecological mismatches in phenology driven by climate. *Frontiers in Ecology and the Environment* 18(2): 76–82. https://doi.org/10.1002/fee.2142

Buckley, L.B., and M.S. Foushee. 2012. Footprints of climate change in US national park visitation. *International Journal of Biometeorology* 56(6): 1173–1177. https://doi.org/10.1007/s00484-011-0508-4

Chisholm Hatfield, S., E. Marino, K.P. Whyte, K.D. Dello, and P.W. Mote. 2018. Indian time: Time, seasonality, and culture in Traditional Ecological Knowledge of climate change. *Ecological Processes* 7: 25. https://doi.org/10.1186/s13717-018-0136-6

Crimmins, T.M., M.A. Crimmins, K.L. Gerst, A.H. Rosemartin, and J.F. Weltzin. 2017. USA National Phenology Network's volunteer-contributed observations yield predictive models of phenological transitions. *PloS One* 12(8): e0182919. https://doi.org/10.1371/journal.pone.0182919

Elmore, A.J., C.D. Stylinski, and K. Pradhan. 2016. Synergistic use of citizen science and remote sensing for continental-scale measurements of forest tree phenology. *Remote Sensing* 8(6): 502. https://doi.org/10.3390/rs8060502

Feldman, R.E., I. Žemaitė, and A.J. Miller-Rushing. 2018. How training citizen scientists affects the accuracy and precision of phenological data. *International Journal of Biometeorology* 62(8): 1421–1435. https://doi.org/10.1007/s00484-018-1540-4

Gerst, K.L., N.L. Rossington, and S.J. Mazer. 2017. Phenological responsiveness to climate differs among four species of Quercus in North America. *Journal of Ecology* 105(6): 1610–1622. https://doi.org/10.1111/1365-2745.12774

Heberling, J.M., C. McDonough MacKenzie, J.D. Fridley, S. Kalisz, and R.B. Primack. 2019. Phenological mismatch with trees reduces wildflower carbon budgets. *Ecology Letters* 22(4): 616–623. https://doi.org/10.1111/ele.13224

Hegeman, E.E., B.G. Dickson, and L.J. Zachmann. 2014. Probabilistic models of fire occurrence across National Park Service units within the Mojave Desert Network, USA. *Landscape Ecology* 29(9): 1587–1600. https://doi.org/10.1007/s10980-014-0078-z

Matthews E.R., K.L. Gerst, S.J. Mazer, C. Brigham, A. Evenden, A. Forrestel, B. Haggerty, S. Haultain, J. Hoines, S. Samuels, and F. Villalba. 2014. *California Phenology Project (CPP) Plant Phenological Monitoring Protocol: Version 1*. Natural Resource Report. NPS/PWR/NRR—2014/763. Fort Collins, CO: National Park Service.

Mazer, S.J., K.L. Gerst, E.R. Matthews, and A. Evenden. 2015. Species-specific phenological responses to winter temperature and precipitation in a water-limited ecosystem. *Ecosphere* 6(6): 1–27. https://doi.org/10.1890/ES14-00433.1

Medvigy, D., S.H. Kim, J. Kim, and M.C. Kafatos. 2016. Dynamically downscaling predictions for deciduous tree leaf emergence in California under current and future climate. *International Journal of Biometeorology* 60: 935–944. https://doi.org/10.1007/s00484-015-1086-7

Melaas, E.K., M.A. Friedl, and A.D. Richardson. 2016. Multiscale modeling of spring phenology across deciduous forests in the eastern United States. *Global Change Biology* 22(2): 792–805. https://doi.org/10.1111/gcb.13122

Middleton, A.D., M.J. Kauffman, D.E. McWhirter, J.G. Cook, R.C. Cook, A.A. Nelson, M.D. Jimenez, and R.W. Klaver. 2013. Animal migration amid shifting patterns of phenology and predation: Lessons from a Yellowstone elk herd. *Ecology* 94(6): 1245–1256. https://doi.org/10.1890/11-2298.1

Monahan, W.B., A. Rosemartin, K.L. Gerst, N.A. Fisichelli, T. Ault, M.D. Schwartz, J.E. Gross, and J.F. Weltzin. 2016. Climate change is advancing spring onset across the U.S. national park system. *Ecosphere* 7(10): e01465. https://doi.org/10.1002/ecs2.1465

Rosemartin, A.H., E.G. Denny, J.F. Weltzin, R.L. Marsh, B.E. Wilson, H. Mehdipoor, R. Zurita-Milla, and M.D. Schwartz. 2015. Lilac and honeysuckle phenology data 1956–2014. *Scientific Data* 2: 150038 https://doi.org/10.1038/sdata.2015.38

Taylor, R.V., W. Holthuijzen, A. Humphrey, and E. Posthumus. 2020. Using phenology data to improve control of invasive plant species: A case study on Midway Atoll NWR. *Ecological Solutions and Evidence* 1(1): e12007. https://doi.org/10.1002/2688-8319.12007

Tierney, G., B. Mitchell, A. Miller-Rushing, J. Katz, E. Denny, C. Brauer, T. Donvan, A.D. Richardson, M. Toomey, A. Kozlowski, J. Weltzin, K. Gerst, E. Sharron, O. Sonnentag, and F. Dieffenbach. 2013. *Phenology Monitoring Protocol: Northeast Temperate Network*. Natural Resource Report. NPS/NETN/NRR—2013/681. Fort Collins, CO: National Park Service.

Wallace, C.S.A., J.J. Walker, S.M. Skirvin, C. Patrick-Birdwell, J.F. Weltzin, and H. Raichle. 2016. Mapping presence and predicting phenological status of invasive buffelgrass in southern Arizona using MODIS, climate and citizen science observation data. *Remote Sensing* 8(7): 524. https://doi.org/10.3390/rs8070524

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