Webinar Transcript

USA National Phenology Network: Informing Science, Conservation and Resource Management

Speaker:
Jake Weltzin, U.S. Geological Survey; USA National Phenology Network

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Ashley Isham: Good afternoon from the U.S. Fish and Wildlife Service's National Conservation Training Center in Shepherdstown, West Virginia. My name is Ashley Fortune Isham, and I would like to welcome you to our webinar series, held in partnership with the U.S. Geological Survey's National Climate Change and Wildlife Science Center. They are based out of Reston, Virginia.

The NCCWSC Climate Change Science and Management Webinar Series highlights their sponsored science projects related to climate change impacts and adaptation and aims to increase awareness and inform participants like you about potential and predicted climate change impacts on fish and wildlife.

We appreciate you joining us today. I would like to welcome Emily Fort, Data and Information Coordinator from the NCCWSC's science center in Reston, Virginia, to introduce our speaker today. Emily, welcome.

Emily Fort: Thanks, Ashley. We're so happy to participate today. I want to take a minute to introduce Jake.

Jake assumed his position as Executive Director of the USA National Phenology Network in August 2007. Jake's interest in natural history developed as he grew up in Alaska and served as an exchange student in the Australian outback. He obtained his Bachelor of Science from Colorado State University, Master of Science from Texas A&M University, and Ph.D. from the University of Arizona.

Following a postdoctoral fellowship at the University of Notre Dame, Jake went to the University of Tennessee, where he served as assistant and then associate professor. Jake is currently interested in how the structure and function of plant communities and ecosystems might respond to global environmental change, including atmospheric chemistry, climate change, and biological invasions. His research spans temperate and tropical grasslands and savannas, temperate woodlands, deciduous forests, and sub-boreal peatlands.

Again, welcome, and Jake, I'll turn it over to you.

Jake Weltzin: Thank you very much. I'm very pleased to be here. I've really been looking forward to this presentation for some time, because it's essentially a chance for me to describe the activities of the network over the last six years.

I feel like, over the first several years of giving talks, and I know there are several friends out there who've been very supportive in the past, very patient, as we've developed our vision and our mission and our activities for the network, that a lot of times it seemed like it was always just a vision.

We've been around since 2007, and so this is a great opportunity to describe, again, where we've come and what our capacity is. I'll spend a little bit less time today on vision, but I'm sure you'll be able to see that in the slides as I move forward in my presentations here today.

I do have a fair number of slides, and they're what I'd call information-rich. I know this is being recorded, and I'd like to treat this as a resource, so people can go back to this presentation, find links to documents or websites or whatever to get more information. I'll move right along, but I love giving these kinds of talks, these updates, and we'll get started on that.

Again, I'm Jake Weltzin. I'm an ecologist with U.S. Geological Survey. I'm also the director of the National Phenology Network that's run out of the Ecosystems mission area, headquarters office in Reston, part of U.S. Geological Survey. The base funding for the Phenology Network comes from the Ecosystems mission area, and also the National Climate Change and Wildlife Science Center. About one-third of my resources come from the NCCWSC. We bring in other resources from other organizations -- some of you were on the call today -- to make a total budget for about one million dollars for operation.

What I'd like to do today is just recognizing that there's a pretty broad group of folk who are on the call. Some folks, this is your first time to hear about the network. Others are well established. You might have scientists, might have resource managers.

I'd like to spend the first few minutes just talking about the network itself and where we're going and what our priorities are, then shift to a practical example and try to show you how we can link science to management activities, then the next section focusing on Nature's Notebook, which is our ground-based observing system focused on plants and animals, plant-animal activity, phenology, across the nation, and then a smattering of examples as to how currently people are using Nature's Notebook, either the data from the notebook or as infrastructure or capacity for their own activities, including a number of organizations we have here online.

Just as a quick recap, phenology, of course, is the study of the timing of life-cycle events in plants and animals, but you can also extend it to ecological systems and seasonal patterns of biological activity. It's essentially very easy to observe. It's very sensitive to environmental variation. When we have a warm spring, we have early flowers. Nice cold weather in Georgia today, and Chicago, and there's not a lot of biological activity going on outdoors when you look at organisms.

The interesting thing about phenology, it links to populations, communities, ecosystems, and also ecosystem services, because the timing of plant-animal activity can be, essentially lifted up.

You can think of it in a hierarchical manner so you can think about how is it affecting a population in a community etc. It scales very nicely from leaf to globe when stomates open on a leaf in Alaska. You can measure that change locally but also over time globally by measuring CO2 concentrations at Mauna Loa.

It's a very, very nice integrative discipline that incorporates biological and physical aspects and helps us understand our natural world. More importantly perhaps than that, because we're a human society, we need to understand, how is phenology affecting our lives? How is it a part of our lives? How can we understand phenology to help us think about how do we manage agricultural processes?

How can we manage timing of manipulations in, say, old fields? How do we set hunting seasons? We need to know something about the timing of vectors, a disease, or when to go find invasive species or how changes in the timing of onset of vegetation, say, might affect wildfire season.

There's a whole host of different kinds of applications that I'll be trying to describe as I go through this talk. There's a very nice description of a lot of this in a very recent paper by Carolyn Enquist et al. in the National Journal of Biometeorology - a paper that just came out describing how we can use phenology and science activities to understand resource management issues in the field.

Again, probably some of you are pretty familiar with the network, and I think what I'll try to do here is just try to simplify down to brass tacks what we're trying to do, essentially trying to make phenology information and data models available to scientists, resource managers, and the public.

Collecting, organizing, describing, improving, delivering of raw and derived data products that we can use in a variety of applications, thinking about relationships with fires in the Western United States, thinking about changes in pollen production in Junipers in the Albuquerque region and across the Southwest and how that affects pollen production and human allergies, and how are we tracking the timing of carbon dynamics across continental scales.

There's quite a bit more information in our brand new five-year strategic plan that's available there online. Essentially, our three key goals are advance science, inform decisions, and communicate and educate. Those of you who are familiar with the U.S. Global Change Research Program's strategic plan will probably recognize those key themes.

Basically, what does the network then look like in terms of its structure? We have a broadly distributed group of organizations that are working together where we're looking at conducting intensive science, understanding processes and mechanisms at relatively small scales in a limited number of sites, more extensive observation sites where data are being collected and fed into models.

We can engage volunteer and education networks, and we can understand how this all links together by linking and remote sensing. Really what we're after here is trying to create essentially a national framework for science and monitoring of phenology. There's no way that you can create a national framework without engaging a whole suite of partners. We have many more partners than this.

These are just the big logos, if you don't mind my saying, so up here right now, but we really value all of the partners who are part of the network. Many of them are actually collecting information data and contributing to our database, but we also have many folks who are using the data or using, again, the capacity. I'll describe that more in a few minutes.

This one slide has quite a lot of information in it, but it's like the one slide that, if I could describe the network and what we do, it would be here. I decided to show it in this manner. However, if you'd like more detail, I recently gave a webinar focused on this process of information, essentially retrieval and the process of adding value to those data in this manner.

Essentially, once you've defined your science questions, we're working on providing opportunities for people to acquire information depending on which organization is collecting phenology information. We are then using essentially APIs and automated web services to essentially aggregate the data into a raw database that we maintain.

Here, actually, I'm positioned at the University of Arizona. We work to develop derived data products and produce maps. We work to add value to those data products by putting them into models. We work to create and integrate data across different kinds of data streams of biological and climatological. We work on forecasting. We work on communicating those data out to a variety of users, and then return that information back to the stakeholders who are part of the network.

Along the way, the information is stored in a variety of different online data portals, including DataONE. We became a DataONE member node just a few days ago. That's how information flows. Essentially, if you're participating in the network, like NEON is, they'll use protocols that are exactly the same as the standardized protocols in Nature's Notebook, but they use their own system. With the APIs, essentially data can be collected at a NEON location, and it can be spit out in maps almost instantaneously. That's the vision for how we're managing information.

Changing topics a little bit, after describing the network and how we operate conceptually, I'd like to step back a little bit, and talk about how we can use information related to phenology for a very practical purpose, especially natural resource management. The example I'm going to provide essentially describes how we can think about changes in phenology as less of an impact, but maybe more in terms of adaptive capacity.

If it's an early spring, and the flowers on the dogwood come out early, what does that mean? What is the impact or the importance of that? Is that the impact, or is it the adaptive capacity that those dogwoods are showing to a changing environment? When we think about doing vulnerability assessments, we need to understand adaptive capacity on a species-specific basis, or for surrogates, so that then we can better understand which taxum might be sensitive, or not, to changing environments.

This is in a very interesting case that has actually not yet been summarized. I have this big line here showing the relationship, as it turns out, from a variety of different papers just over the last couple of years that are showing how changes in phenology can be linked to changes in species performance -- either population size, abundance, or even species distributions.

There are a number of papers that have described this -- a number of very good examples for birds, for plants, for mammals -- but it hasn't actually been put together. When we look at this, here's the pattern that's emerging. It's a little complicated, so I'll walk you through an example.

If you think about an organism, we describe what is this change in phenology that we observe, you find that there might be some small changes in phenology, or maybe a large change in the timing of, say, migratory bird arrivals. The trend that's emerging from these papers is essentially that organisms that don't show much of a change in phenology, even in a changing environment, are those organisms that are tending to show decreases in abundance or changes in their species distribution.

This is a very well known example, the Pied Flycatcher that is a migrant from North Africa up into Europe. The timing of its prey has changed, but the timing of the migration has not, so we end up with what we might call a "brittle response" or inflexible phenology.

In contrast, as it turns out, there are some organisms that are showing lots of changes in phenology. They're very phenotypically plastic. Those are organisms, like invasive species like Purple loosestrife that are tending to show increases in abundance or changing their distribution. As just a conceptual model, but again, there's a lot of information here to support that yet to be summarized.

One way that you can think about this is to think about sensitivity. This is some work by Elsa Cleland and Lizzie Wolkovich, who pushed us a little bit further by saying, "Let's think about in terms of the changes in phenology, in terms of the sensitivity, or the days that an organism changes the timing of its phenology, per degree centigrade -- some standard rate." Negative here would be earlier, positive here would be later in the year.

What they did is they went to a number of existing datasets, and looked at vegetative and flowering phenologies, just for plants and for native species. They didn't have enough information for invasives. They looked to see whether there was a relationship, again back to performance, and again in terms of sensitivity. They put it on a sensitivity scale.

Essentially, what this is doing is testing that model that I just described a moment ago. I'll walk you through this. As it turns out, it's almost completely supportive of this in this meta-analysis approach, where organisms that showed earlier and greater phenological responses tended to be those organisms that were increasing in their abundance. In other words, they're adapting to the changing environment.

Organisms that didn't show much difference in their sensitivity didn't show much difference in their performance. Whereas, those that actually were later, showed some declines. Who knows exactly what's happening there -- maybe mismatch -- or what the mechanism is. We don't know exactly, but it's very compelling evidence for the pattern that we had seen.

What this means is that we can use sensitivity. If we know the phenological sensitivity of an organism, we might actually be able to predict its change in population size or species distribution -- quite important for a resource manager.

In fact, we have tools that resource managers and others use here to understand what is the vulnerability of species to climate change or environmental variation. Forest Service developed a SAVS tool, and the NatureServe has their Climate Change Vulnerability Index, CCVI.

These are two tools right now that are being used. There have been a couple of interesting comparisons of them. At George Wright Society, a couple years, there's a really nice paper on this. This particular vulnerability assessment focuses a lot on phenological mismatch. Both of these assessment tools require a fair amount of phenological understanding of the system.

In contrast, the NatureServe CCVI focuses a lot on adaptive capacity. In other words, those organism that have that phenotypic plasticity, those are the ones that are actually more capable of adjusting to a changing environment like climate change.

Really, what this means is that we need more phenological information on a species-specific basis, or if we can find surrogates. We do know that there are biogenetic relationships among taxa that help explain their phenological responses to shifting environments. I don't have time to go into that here in this talk. Essentially, if we can get sensitivity data, then we can understand what the phenology is likely to be, and what the implications are for population.

Wolkovich, who was on that paper I described a little bit earlier, actually said, "Let's take a look at this, and let's think about species' sensitivity, from a variety of different projects that are already out there -- experimental data and observational data." Experimental are where we're forcing the environment to change, versus in situ observations.

What they found here, for both leafing and flowering, there are very strong differences in the realized or the observed sensitivity of species, between experiments and observations. What this means, essentially, is that we don't know exactly which is the best tool for determining species' sensitivity, but it's clear that we need both experiments and observations until they can determine what's going on.

I hope that helps describe a little bit how, if we can understand phenological sensitivity and place it into a conceptual model, we might be able to link from an existing understanding about observed changes in phenology, the sensitivity to environmental change, all the way back to population size, species distribution, et cetera.

We think about managing an organism at a given location. If we knew something about the phenology, it's sort of a bit of a bell weather for population size, distribution. Genetic adaptation is a component in there too. I probably won't have time to get into that too much here today, but that's always an important factor.

What I'd like to do here right now is change gears a little bit again and now talk about on how we actually go about collecting and organizing phenological information across the nation. Up until a few years ago, although there was a fair amount of phenological information either being collected in refuges or parks or collected through experiments through academia or some historical naturalists, Leopold, Lewis and Clark, the list of datasets going on, the Mohawk dataset, for example, there's no consistent protocol or standard for multi-taxa approach.

That's what Nature's Notebook is all about. When we think about trying to accumulate and organize phenological information on a national scale, this is sort of what you're facing. You've got mammals. You've got birds. You've got amphibians. You've got plants. How do you conceptually integrate those all into a contemporary observing system using a set of standardized protocols, how do you manage the information, how do you aggregate, how do you deliver, et cetera.

Those we've been working on for the last five years. The name of that activity and the online interface is Nature's Notebook. It comes along with standardized protocols. Essentially, what we're doing is collecting information on plant and animal activity across the nation for hundreds of taxa that allow folks to track and understand changes in phenology.

I've tried to distill it all into one slide. What is Nature's Notebook? Again, we've been working on it for about five years online at usanpn.org/natures_notebook. What it is is a ground-based, multi-taxa, national-scale observing system. It depends on standardized protocols.

We just had a paper come out today in the "International Journal of Biometeorology" by Denny et al. describing those standardized protocols and how the system works. Essentially we use what we call status and abundance monitoring where you describe the status of an organism at a given point in time. You can also record the abundance or the intensity, the canopy development or number of birds observed.

Right now, we have standardized protocols for over 900 plant and animal species. We don't encourage people to track all of those taxa, but, as you'll see, we provide a central capacity for other organisms to build off of. They have requested that we add taxa for them.

For example, we work very closely with NEON, the National Ecological Observatory Network, parks in California, refuges in New Mexico that ask for taxa specific protocols.

We have web services that allow us to share information either internally or with external partners. We have several mobile apps and a couple of platforms that focus on full documentation.

We are policy compliant. We do have an OMB control number for the Paperwork Reduction Act. Information collection clearance is not required for any federal organization participating in Nature's Notebook or any federally funded activity participating in Nature's Notebook.

We have an extensible framework, and I'll describe that more in a few minutes. We can add taxa. We can add sites. We can create your own sub site, essentially, so you can track your data through space and time. The activity so far has produced about seven hubs that use either the data collected through Nature's Notebook or data products produced in collaboration with partners using Nature's Notebook data.

Generally, find plants and animals, learn how to observe and get registered for reporting online or on your phone. We've had a fair amount of success. We've got about three million records. This map is a little old. We've got about three million records in the database right now.

Just about one million records rolled in last year, so we have an increasing number of records that are coming in from a variety of different monitoring locations. These are all of the monitoring locations registered across the continent and beyond, although data are not provided by every one of those stations.

The metadata documentation is freely available online. Go to www.usanpn.org/results/data here, and you can download your data. You can get the FGDC metadata, learn about the documentation provenance changes through time. We have quality assurance and quality control built in.

There's a technical document online that you can find on the reports page. We provide annual state of the data reports, so that people can get a better feeling for what is available, how we can use it, et cetera. We have data use and attribution policies, and that's a very science focused activity.

You can go online on our website at usanpn.org and use our vis tool. You can plot the locations where different species are being monitored. You can show their different phenological phases. You can layer on climatology.

You can run an animation to find the time period and time step that you would like as well, so a very nice tool. You can also look right down at an individual organism at an individual site and compare it to another individual organism at a different individual site. It's a very nice online tool.

I'll just give you one example. One of our partners is using Nature's Notebook on the ground, but then also thinking about phenology information can be integrated across scale. I'll talk more about that in a few minutes.

This is about a project that's occurring out at the USDA Agricultural Research Service site outside of Las Cruces, New Mexico near the Jornada LTER site, which is Chihuahuan desert. We have technicians and scientists who are tracking phenology of organisms on the ground near the weather station.

There's actually going to be a NEON station going in here very, very close on this site. They're using cameras to look at canopy level phenology, unmanned aerial vehicles to get high resolution imagery, satellite imagery.

Then there are some very rich historical datasets out here on this site that had used a particularly different kind of protocol for tracking phenology. The focus now is to understand and compare differences between historical and contemporary phenology, observing systems, and then develop crosswalks so we can better integrate back through time.

That's just one example of how one of our partners is implementing phenology on the ground, across scale, for a variety of different applications.

What I'd like to do now is just spend a few minutes talking about some example applications. I've got a few mini case studies here and then sort of a potpourri, if you will, a smattering of different kinds of applications, recognizing there's a pretty broad audience.

I think the goal is to describe, as best I can, some real boots on the ground applications of phenology information and then also a little bit of extra capacity there that, if people are interested in it, they can contact us or follow up on their own so they can better understand what the potential here is, not only what's happening but maybe some of the potential.

As I've mentioned before, we are developing and implementing essentially what is a national framework for science and monitoring and decision making. What I'd like to do in the next several slides here is highlight some of the relationships that we have established as a USGS funded activity but a broad collaborative with some of our key resource management organizations, Fish and Wildlife Service, and Park Service.

Essentially, what we do is provide a core capacity and have had a lot of really good communication with folks across the service. Again, we allow organizations to leverage on that core capacity and build programs or activities that meet their needs but they don't have to necessarily recreate all the steps for a national phenology network and information management system, protocols, et cetera. It's working, I think, actually very, very well.

One of our closest relationships is with the Fish and Wildlife Service Inventory and Monitoring Program. We're working very closely with Jana Newman on that. Essentially, what we're doing is using our infrastructure to create service friendly portals and taxa and protocols, et cetera, providing apps that are customized, data download tools, et cetera, so that if you start doing phenology monitoring at a given location, then you can extrapolate that out across the entire nation or wherever phenology monitoring or education outreach need to occur.

We're working on integrating not only the science but also education outreach through the visitors' services and focusing right now, of course, on the refuge system, but there are a lot of other applications across the rest of the service.

If you were to go, for example, onto that website I was just showing you, one of the first projects we were working in building out a relationship and providing capacity for the service for the refuge system is a pilot project. This is at Valle de Oro National Wildlife Refuge.

This is, as you probably know, an urban wildlife refuge. It's the first urban wildlife refuge to be established in the southwest United States. It's just south of Albuquerque. It's actually down in an industrial area. It's an old dairy. It's mostly hay fields, but you can see there's a fair value for birds, mammals, et cetera, within that system.

Also, it sits right on the Rio Grande. This is a drainage canal alongside the Rio Grande. There's this whole system up and down the middle Rio Grande that these are all federal lands that are along that Rio Grande valley. It's important to consider how this particular new refuge, as it changes, it was just very, very recently acquired, how it changes and how it might fit into a landscape context.

These are the key elements that we're focusing on in this pilot for understanding that landscape context. As we work to convert the system over to a more natural system, folks in our restoration, what are the changes in phenology? What's the baseline that we can use to try to understand success of restoration activity?

How can we use phenological information for resource management, tracking populations and species interaction? We lay a lot of focus on system services, particularly water and flooding and flood control in the system, but also very strong stakeholder engagement.

We're right there on the south end of Albuquerque. There's going to be a lot of opportunity to get people involved and down there on the refuge as it changes through time.

Another example of how we are building capacity with partners, in particular with the National Park Service. This is a pilot that's occurring in California. The name of this project is California Phenology Project. It originated from a climate change response program funding to UC Santa Barbara, University of Arizona, the Phenology Network, and USGS that is focusing on understanding patterns of phenology across the entire California National Park System, all 19 units, with a focus just on 7 units for the last couple of years.

Since 2011, this project has been going. We have a great diversity of ecosystem types here. The key questions for this particular project, and there's more information on the project website, are -- What are the climate change impacts on natural resources, cultural resources across the park system? How can we manage those resources? How do we engage the public in activity through education and outreach all across these huge environmental gradiants that we see in California? How can we move these activities out beyond just the Park Service? What about our other partners in the region? What about the California Reserve System, et cetera?

There's a whole host of activities that can occur in the state under the agency of the California Phenology Project that crosses organizational boundaries. We're getting some very nice results from the study already, where we can see very strong environmental controls on organismal phenologies, focused mostly on plant species.

There was one more example of how we're using the national framework to work and collaborate very closely with our colleagues and partner organizations along the Appalachian Trail. Not just Park Service, but Appalachian Mountain Club, the Appalachian Trail Conservancy, and the communities that are all along this stretch of the Appalachian Trail.

It's probably relatively cold all along the AT today.

First, we have to start out with monitoring protocols. We produce standardized protocols for tracking phenology. There's one in the California region that'll be coming out relatively soon.

Essentially, the questions that are guiding the activities here are, "How do we best use phenology to understand resource management and decision making along such a long latitudinal gradient and such a variety of different systems? How can we understand climate change impacts on indicator taxa?"

For example, we're creating custom mobile apps for collection of data, online and offline, along the stretch of the trail identifying indicator taxa for monitoring, et cetera, so great potential here. A brand new website that you can go visit and learn more information as well.

What I'd like to do now is change gears a little bit and talk about a few other applications. One little bit longer example is just a wonderful example of how we're facing these resource management crises.

This is an example here in the Tucson Basin, near and dear to my home, where we have Sonoran desert upland system dominated by columnar cacti and some shrubs, mesquite, Palo Verde, et cetera. Very nice diversity, very well-used in Saguaro National Parks east and west, a variety of different partners in the region. This project right now is focused on the Catalina Mountains just north of Tucson.

What you see here is it looks like paradise, although this is all invasive buffelgrass introduced from Africa. It's becoming a real problem in the system. It has not at all adapted to fires. Very fire-prone, leaves a lot of above-ground tissue, burns very hot.

So those do not do well when they are burned, in fact it's one of the saddest-looking things, which is not so good for tourist industry here, let alone resource management. We have mountains, the lower cloaks of these mountains that are essentially becoming invaded by this buffelgrass, and this fire-enhancing feedback that can reach right up into oak systems and up into the Catalinas themselves.

So, how do you deal with this? It's an enormous problem to strap on a backpack sprayer, go out and spray herbicide all over your green tissue of your buffelgrass -- once you know where it is. There are relatively narrow windows, because you have to time the application of herbicide to when the vegetation leaves are green.

That's oftentimes when it's quite hot, so it looks like a beautiful day out there on the rock probably about 110 degrees with your backpack sprayer on. Or, you could be a bit more enterprising and use helicopters to apply herbicide to the Sonoran desert development to get rid of your buffelgrass.

Of course, I'm teasing just a little bit there, but this is actually being considered right now by the National Park Service as a tool to manage buffelgrass. It's an enormous problem and there's been a number of different trials looking at efficacy of spraying across buffelgrass systems to manage buffelgrass.

An environmental assessment, I think, is either still under way or was just completed, so it is a real potential tool for managing buffelgrass. Again, what we need to know is, "When is the buffelgrass green so we can go out and apply herbicide, and what's the timing of seeds?"

This brings me to an example recently described in a paper by Alyssa Rosemartin et al. in "Biological Conservation," essentially an example of how we use Nature's Notebook to go out and track timing of when seeds are present on buffelgrass at given plots, or also the development of the canopy foliar greenness.

Nature's Notebook allows us to track when sampling occurred, when seeds were present on the buffelgrass. You can see there's very narrow windows of time here in these red boxes where there are no seeds present, so there's almost always seeds present. If you do a mechanical control, that means going in and pulling it out. You have to watch out for spreading seeds.

We can think about, "How does the canopy greenness change through time? If there are thresholds, say 20 percent, what are the windows of time we can go out and actually do herbicide application and control?"

The issue here, of course, is that there's a lot of area that needs to be treated. It would be wonderful if we could extrapolate and get a better handle, from a much broader perspective, how patterns of greenness can be detected. We need to know where buffelgrass is, essentially, and when it is green. We've been working with some collaborators.

Cynthia Wallace, U.S. Geological Survey, and the Park Service, using, again, Nature's Notebook data, but then linking it up with MODIS imagery, the Enhanced Vegetation Index.

There's a lot of information here on this slide, but essentially what we've done is gone in and pulled out, from a single pixel right near this single monitoring location, the same data as we saw in the last slide, but a longer time series. What you can see is patterns of greenness through time from 2010 through 2013. These are 23-day periodicities during the course of the year.

There would be January of 2011 through...This is December of 2013. You can see a very strong signal in the MODIS imagery and how well it relates to the images of greenness that I was showing in the last slide, so very nice, tight correlations which suggest that we actually can use MODIS imagery.

If we go to daily data which is available from MODIS, we can get a much better handle on where things are green. There's a nice, strong, leading impact of rainfall on the amount of greenness -- rainfall in the blue, and greenness.

We can couple all this information together to get a very good handle on relationships between the timing of rainfall, the timing of green-up, where green-up occurs, because rainfall is very patchy in this system. There's a lot more work to be done here, clearly. This is hot off the press, just came in yesterday. I thought I'd feature it to show how you can actually work across scales.

I'd like to change topics here a little bit. Again, those were a couple of longer case studies. I'd like to set up the next four or five slides and then I'll start to wrap up here.

There are different kinds of applications for how we can use phenology information from Nature's Notebook and combine it, for example, with other datasets, or do other kinds of activities with Nature's Notebook as a tool. This is a quick example showing how...I won't go into much detail, a lot of information here.

For 2011 and 2012, what we did is combined Nature's Notebook data, which has tree flowering data in it because flowers of trees are important for migratory birds because the insects come and get resources from the flowers themselves, and then also use eBird data to look at Tennessee Warblers and the timing of their migration through the system, through time, using eBird checklists.

We have eBird checklists in the blue, and proportional trees reported flowering from Nature's Notebook in green. 2011 was sort of a typical year, but recall the spring of 2012 when lakes in Maine hardly froze. We had fires in downtown Minneapolis very early in 2012.

Of course, 2013 was not like that at all, but a great shift towards earlier tree flowering, not much change in the timing of Tennessee Warblers through the area. What that means is that the overlap between the two different sets of organisms was much constrained.

This is just describing a pattern. A lot of science needs to be done here, but again, showing the capacity for the integration of datasets across different kinds of projects.

Another application of using Nature's Notebook data. This is one that was just published last year in "Geophysical Research Letters." The scientists took a model of leafing for red maple and a number of other taxa, of leaf-out dates, and generalized it to the region by using Nature's Notebook data instead of from a single location where the model was developed.

They refined the model and improved it across the entire range of red maple, looked at historical patterns of leafing, and then into different GCM pathways, CMIP5 data showing potential changes in CO_2 concentration much earlier out to 2100, and with stabilizations due to emissions, we have a sort of leveling off of this response.

They also found that, if we look at different pathways that are having different forcings: warmer, relatively cooler here, what happens with these higher emissions is that you end up reducing the time that spring rolls up across the nation.

Not only are you advancing spring very significantly here if you think of that as timing of red maple leafing, then you also reduce the amount of time that it takes for spring to roll across the continent.

Sorry, there was a lot of information in that slide, and in this one as well. Again, think of this perhaps as a resource. The way I try to describe this particular set of panels, which was published in EOS just a few months ago, was essentially trying to characterize ecological drought, the impacts of drought on biota, essentially, by taking a systems perspective.

What we've done is, we've worked with colleagues to develop an index of spring, called the first leaf index or the spring index, extended to the entire nation described in another paper, and essentially looked at the timing of the onset of spring as an anomaly, so this would be earlier and this would be later, relative to the long-term mean, going back to about 1900, for the nation.

2012, recall, we talked about. Very early year, in fact probably earlier in spring using this particular index than any other year in the last 100 years, based on the instrumental record. We can also look at where the anomalies are on a point basis, and we see very strong warming that year -- negative 20 days relative to the long-term average.

We can also calculate a damage index. I won't spend much time on this, but essentially, a way to understand the impact of that false spring. Spring came very early across this region, but then there was atypical frost, the last frost that hammered the apple crop production in Michigan, and concord grapes as well.

We can also think about that during the same time period, the thermal time to peak NDVI, and then peak NDVI essentially just showing that it got warm early and greenness was relatively low that year. This was later on in the year.

When you focus in on the Great Lakes region here in this box, essentially, this is the line showing a very early spring in 2012 relative to the average of the previous 10 years, and what you get is a very early spring that may cause and exacerbate drying later in the year. You end up with summer drought you can measure on a regional scale.

Again, there's a lot of science, a lot of work still needs to be done, but some very compelling patterns that link changes in organismal activity all the way to something like regional scale drought impacts, ecological drought.

Starting to wrap up here. As you can see, I've been scaling up a little bit. What we can start to do with phenological information that's so tightly linked to climatology...Through the fingerprint of the biotic response, we can understand climate change impacts and climate change variability impacts.

Hopefully, this little GIF that you're seeing is showing changes in the spring index, as I described in the last slide, spatially, through time, from 1950 until just recently. You can see lots of variation from year to year, there's lots of details there. We're working on developing tools and will be showing these data out through the NPN website.

This is going to be a data product that we're working on. Then you can do things like look at differences in onset date between 2013 and 2012, doing comparisons here. Think of the blue as cool spring, relative, in 2013 compared to 2012. We can see these large patterns that show up on a continental scale. This is one of the things we've been working on, to deliver phenological information.

It's very important, though, to put it into a continental-scale context. I won't spend much time on this, this is from Bill Hargrove. He took MODIS imagery and defined the 50 most different phenological ecoregions across the US, essentially creating what we call regions of synchrony.

So, if we know that there's a particular region that responds relatively similarly, then we can define its phenological functional type, perhaps focus sampling within those regions, and do scaling.

We're working across a number of different scales here, as well. We're working with a variety of different stakeholders and partners, including the North Central Climate Science Center and the PhenoCam network out of Harvard University, to implement phenology projects with PhenoCam, putting out cameras to track phenology.

The North Central CSC is providing cameras for this region, where you can see there's quite a hole. I don't have time to get into that much more, but the PhenoCam website has a lot more information.

We're also focusing on communicating and educating the American public. One way is to produce indicators. So there is a phenology indicator. The spring index that I was talking about a few minutes ago is actually a global change indicator in the EPA reports.

We're working very closely with the U.S. National Climate Assessment, U.S. Global Change Research Program to produce an indicator for their new indicator system as well, focused on leafing and blooming dates from data collected in Nature's Notebook.

We're working closely with some of our other partners on strengthening tribal nations, providing capacity for tribal nations where we have educational and outreach activities that can be implemented.

For example, at the Haskell Indian Nations University where we're implementing a “Phenology Walk” off of a concept of phenology trail, similar to the Appalachian Trail, where we can focus on culturally significant plants and they can use the infrastructure of Nature's Notebook for phenology monitoring, education outreach, understanding, et cetera.

We're working very hard too, keeping in mind the fact that we have a new generation coming. We're focused on getting people outside and engaged in America's great outdoors. Again, Nature's Notebook is a fantastic opportunity to engage the new generation.

That wraps it up. I'd like to point out that we do manage a couple of websites. The National Phenology Network, usanpn.org, is the entrée to the network. Get information, find out information about education outreach, get partnered, et cetera.

We also have Nature's Notebook, which I've mentioned several times. We have a separate website for that that allows people to come in and do phenological monitoring. The two work very closely together, and it's a very exciting time because this is capacity that can be essentially almost franchised out to some of our natural resource partners, and for science and society.

Thank you very much.

Ashley: Great, thank you, Jake. We did have a couple come in during the presentation. The first one was from Karl Ford, he says, "How does NPN differ from Project Budburst?"

Jake: Thanks Karl, I appreciate that. There are actually a lot of other organizations that are doing phenology monitoring for a variety of different taxa. Most of them tend to be very taxon-specific. The Florida Bluebird Society, for example, a great partner, focused on bluebirds. Project Budburst is focused on plants.

We're, of course, a multi-taxa organization. We focus on providing programmatic capacity from a science-based perspective. When we encourage people to get involved, we are focused on documenting every single aspect of what we do through the protocols. Documenting provenance, documenting terms of use, et cetera.

We encourage people to get involved for longer periods of time. What we're after is a 30-year dataset, or a 30-year program after a 30-year dataset that we'll need to understand climate change impact. That's probably one of the key differences. We can talk a bit more about that later on.

Ashley: All right, great. Thank you. The next one is from Bruce Marcot, and his question is that he worries about the errors of identification and other information when crowdsourcing databases from citizen scientists. How are you calibrating, verifying and vetting contributions?

Jake: That's a great question, Bruce. I appreciate that question as well. That is an issue with all aspects of crowdsourced activities. I'd like to point out that about half the data in our database right now are coming from professionals, people who get paid to collect phenological information or organize others to collect phenological information for them.

Across all different user groups, it's very important to have quality assurance and quality control built in. We describe that in the technical documentation on the quality assurance and quality control of our data.

Quality assurance is working to prevent people from making errors where we can, so we control the fillable fields, we provide standardized descriptions of what to look for, we provide images where we can, we provide descriptions of where organisms are. Certain things, we don't allow people to edit dates in the future, et cetera, so a lot of quality assurance built in.

Quality control is a lot harder -- once you have a piece of information, determining the potential quality or validity of those data in a post-hoc way. We've been working on implementing that. We're actually working very closely with NEON. We have a data projects working group that's focused on identifying best practices for quality control of data.

Once you have a piece of data, we would deliver both raw and tagged datasets that people can use. We're also using a number of other ways to determine quality of information, or the ability of people to identify phenological phases and enter the data in.

For example, we have a paper that's right now in "Natural Science Education," it's in revision there, where we actually compared professionals versus members of the public who are trained volunteers to collect and identify phenological phases. Actually, it's pretty good, about 90 percent rate of similarity, so we feel like the data are probably pretty good.

There are issues with species adaptation -- some might say it's a red maple, could be a silver maple, et cetera. Those will always be hard to do, but we'll be working on incorporating tools that help us separate those out through time.

I think the proof in the pudding might be the papers that have come out. If you get papers in "Global Change Biology," "Geophysical Research Letters," "Earth Interactions," to us sounds like, OK, people are actually able to go in, download the data, work with the data, knowing what the caveats are, and then come up with very nice regional to national-scale science activities. Thank you.

Ashley: Thank you. We have another question from John Cobb, and it says, "Can you speak about the ability to use these repositories programmatically, through APIs or other mechanisms?"

Jake: Sure. John, that's an excellent question. We do have web services. We are not quite, perhaps, what you might call a service-oriented architecture, but very close. Particularly with the online system, by having APIs and web services for data in or data out, we can easily share capacity for other organizations to build on our standard protocols. We can deliver our standardized protocols through an API. We can receive data through an API.

I failed to mention, when there was an earlier question about other different projects that are out there, we're working with a number of organizations right now to essentially ingest their data into our database. If their protocols are quite different, that takes an enormous amount of work, and so it requires a crosswalk. There has to be a crosswalk, sometimes even from one dataset to the next, but that's most readily done through APIs.

One contemporary example is when NEON collects phenology information, using protocols that are exactly the same as what we use in Nature's Notebook, then, through APIs, their data essentially become immediately available through the Nature's Notebook online user interface, the database that I was showing you there. We can start to actually integrate different datasets.

There are a lot of different kinds of protocols out there, all the way to Lewis and Clark's diaries or Leopold's data. Integration is a very difficult activity, but the APIs will certainly facilitate that. We run our mobile apps off of the APIs, for example.

Does that answer your question, John? Well, I hope so. If you need more info, let me know.

Ashley: Yes, it just took him a moment to write it. He said, "Yes, thank you."

Jake: Great, thanks.

Ashley: The next question is from Cari, and she says, "Are phenological observations made only for terrestrial species, or are they also made for aquatic species?"

Jake: We have phenological protocols available for plants and animals and, within animals, birds, reptiles, amphibians, mammals, insects, and aquatic organisms -- so all the western salmon, for example. We don't have a lot of taxa. We've been focusing mostly on terrestrial plant observing. That's a little easier.

NOAA has lots of phenological information on marine phenology. There are issues with understanding and/or finding phenological information from, say, the marine realm, because different terminology is used. We're working a little bit on information architecture -- say, with OBIS -- to try to understand how one might go and find good phenological information on, say, walrus or fish runs or phytoplankton or shad, et cetera.

Yes, we do have protocols for a great variety of taxa, but in part it's driven a little bit by our stakeholders and what their particular needs are, and we haven't got a lot of, say, aquatic collaborations going quite yet.

If I can just change topic here, I did see there was a question about planning to extend this to Alaska. Yes. In fact, Alaska, we've got a part of the Nature's Notebook. In fact, anybody can participate in Nature's Notebook, as long as they have the species and can identify the species, no matter where they are. We have data that are rolling in, or sites have been registered, at least, in Greenland, in Micronesia, and certainly Alaska, U.S. Virgin Islands, Guam.

The system is relatively broad. We've got a number of monitoring sites in Hawaii. There's not a lot of data rolling in from those regions, although there is a paper currently in review at "Global Biogeography" on some of the patterns seen in Alaska, and a recent paper by Eugenie Euskirchen, who was looking at modeling the phenology in the Alaska arctic and used Nature's Notebook data to improve her models.

We're certainly nationwide and are also working with other national phenology networks in a variety of ways to share information or to share capacity. The Swedish phenology network, we've talked to Brazil, we're talking to the Bhutanese, which is sort of exciting about phenology monitoring.

The Turks, [indecipherable 0:57:00] which is “Nature’s Notebook” in Turkish. We're having fun working with the international community as we expand out. Of course, Canada and Mexico are key partners. There's a fair amount of interest, but we haven't moved to that next level of strong international, intellectual collaboration, data sharing, et cetera. There's some capacity for that there.

Ashley: All right. Great! I'm not seeing anything. I just wanted to say thank you, Jake. That was a wonderful presentation. We already have had some comments that say what a great overview and thank you for inspiring them to get started.

Jake: Great. We look forward to work with anybody out there. Thank you very much. I really appreciate it.

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