Signs of the Seasons: A New England Phenology Program

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Abstract

As global climate records continue to break, average New England air temperature increases are among the highest in the continental United States, and sea surface temperatures in the Gulf of Maine have increased faster than 99 percent of the rest of the world's oceans. Little is known about how marine and upland biota respond to these environmental changes. Citizen science is being used to document and compare current phenology (the timing of life cycle events) for individual species with historically documented relationships between temperature changes and the onset of particular phenophases, such as leafout or gamete release. Signs of the Seasons (SOS) is a citizen science–driven phenology-monitoring program in northern New England that observes 19 upland and coastal indicator species and was developed by University of Maine Cooperative Extension, Maine Sea Grant, and partnering research scientists. This article provides an overview of SOS structure, research partnerships, lessons learned, challenges, and next steps.

Climate change is accepted as one of the most urgent threats to humanity and Earth's ecosystems (IPCC 2014; NASA 2017; World Economic Forum 2017). Scientists, policymakers, and citizens have never been more essential to addressing the multitude of climate-related challenges. To understand and address these challenges requires vast quantities of information collected across space and time, as well as a sea change in understanding, attitudes, and engagement across the political spectrum and in every community—large and small, rural and urban.

Since individual researchers and institutions have limited human and financial resources to collect climate data, citizen science can be used to advance and support the work of professional climate scientists by producing large quantities of geographically dispersed data over many years. Citizen science can also help engage and energize people of all ages in understanding, generating, using, and acting upon sound climate science.

Phenology, the study of the timing of seasonal biological changes, is perfectly suited to engaging citizen scientists. Phenological events—such as bird and amphibian calls, reproduction, and migration, and unfolding leaves or flowering and fruit ripening—are easy to monitor, and many people already enjoy observing these changes in their own communities as the seasons turn.

The University of Maine Cooperative Extension and Maine Sea Grant developed the Signs of the Seasons (SOS) phenology-monitoring program in 2010, in partnership with an advisory committee of climate scientists, educators, and biologists from academic institutions, state and federal agencies, and nonprofit organizations throughout Maine. The program was conceived to address two main objectives:

- Filling the critical need for phenology data to characterize the biological effects of climate change.
- Empowering citizens to become part of the response, and ultimately, solutions to climate change through the program, by increasing their climate literacy, engaging in participatory research, and sharing their knowledge and experiences with others.

In this article, we provide an overview of the scientific context for focusing on phenology and a summary of the program structure, accomplishments, and lessons learned to date. Profiles of several research collaborations illustrate how we have been able to leverage invaluable expertise, catalyze participant engagement, and extend our impacts.

THE ROLE OF PHENOLOGY IN UNDERSTANDING OUR CHANGING CLIMATE

Phenology has emerged as one of the most important indicators of climate change. Indeed, the climate research community considers it as "the simplest process in which to track changes in the ecology of species in response to climate change" (IPCC 2007). Warming temperatures affect the timing and intensity of the seasons. In the United States and particularly in the Northeast, winter is the fastest-warming season, (Fernandez et al. 2015; Tebaldi, Adams-Smith, and Kenward 2017). Warm winters mean that spring begins earlier. The onset of spring has advanced by two to five days per decade over the past thirty years (IPCC 2007). These changes are altering the phenology of species and ecological relationships and processes around the world (IPCC 2014; Miller-Rushing et al. 2010). For example, migratory North American birds are failing to keep pace with the earlier *green-up* of vegetation in spring, when their young insect prey emerges (Mayor et al. 2017). Understanding such changes in phenology and ecological relationships are crucial for assessing the effects of climate change (Primack et al. 2009). Yet, because individual species change in different ways and at different rates, the effects are challenging to predict.

For centuries, farmers, fishermen, foresters, hunters, and gardeners in Maine and beyond have been collecting and using phenology data to optimize their planting, harvesting, and hunting. Historical records of these data can be found in drawers, attics, and museums throughout the state, and even today, most professionals who work the woods, waters, and fields still keep such records. Phenology influences cultural events such as Maine Maple Sunday and blueberry festivals. It also affects public health management such as tracking the occurrence and spread of tick-borne illnesses and the seasonal activities of their mammalian hosts.

Signs of the Seasons Structure and Partnerships

In 2009, the USA National Phenology Network (USA-NPN, www.usanpn.org) was formally initiated as a consortium of individuals and organizations that work on different observational scales to collect, share, and use phenology-related data and information. USA-NPN developed and oversees Nature's Notebook, a publicly accessible, national database to store long-term records of these observations. A record 2.4 million data entries were submitted in 2016.

Developed in 2010, Signs of the Seasons was one of the USA-NPN's earliest partner programs. Drawing upon more than three decades of experience developing and coordinating citizen science and environmental monitoring programs in Maine, UMaine Cooperative Extension and Maine Sea Grant developed a structure and approach in partnership with a 10-member advisory committee of researchers, educators, and outreach professionals working throughout Maine. In 2013, the program expanded to New Hampshire through a long-standing partnership with New Hampshire Sea Grant and Cooperative Extension.

Signs of the Seasons uses standard USA-NPN protocols to train volunteers to collect and enter their data directly to Nature's Notebook. Participants complete a 2.5-hour training with an introduction to relevant climate and phenology science and hands-on practice observing 19 indicator species. The indicator species were selected for their climate sensitivity, their economic and cultural importance, and their accessibility, as they are all easily identified and ubiquitous across the region. Once trained, SOS volunteers independently observe and record the phenology in their backyards, parks, schoolyards, and other public spaces. Signs of the Seasons includes unique protocols and online data management for rockweed, *Ascophyllum*

SIGNS OF THE SEASONS PARTNERS AND ADVISORS

Acadia National Park

Coastal Maine Botanical Gardens

Maine Audubon

Maine Maritime Academy

New Hampshire Sea Grant

Schoodic Institute

University of Maine scientists and educators

University of Maine Climate Change Institute

University of New Hampshire Cooperative Extension

US Fish and Wildlife Service

USA National Phenology Network

nodosum, a dominant species of seaweed found on sheltered intertidal shores in the North Atlantic.

In addition to our relationship with USA-NPN, we work closely with scientists at institutions throughout the region who use SOS data in their own research and with organizations with complementary missions and programmatic activities and strong networks of volunteers, such as Maine Audubon, Acadia National Park, the Coastal Maine Botanical Gardens, and UMaine Cooperative Extension's 4-H and Master Gardener programs. Working with our research and outreach partners, we provide technical support and field opportunities for volunteers, as well as science seminars, webinars, and updates on the contributions of SOS data to climate and phenology science in the Northeast and to national initiatives led by USA-NPN. Following is a profile of three such partnerships, each focused on different species.

Wading into Intertidal Phenology with a Coastal Monitoring Program

Climate-related impacts on terrestrial ecosystems are more extensively documented than impacts on marine ecosystems and coastal processes (Rosenzweig et al. 2008). Given Maine's economic and cultural dependence on marine resources and working waterfronts, and indications that the Gulf of Maine is warming faster than more than 99 percent of the global ocean (Pershing

et al. 2015), there is a great need for more information. Signs of the Seasons developed a coastal phenology-monitoring effort to help document biological responses to these temperature changes, with an initial focus on rockweed, *Ascophyllum nodosum*, ubiquitous along rocky shorelines in the region. *Ascophyllum nodosum* reproductive phases begin as water temperatures warm in spring and are easily recognized. A long-term record of the onset of *A. nodosum* reproductive phases will help researchers understand how shifts in ocean temperature influence its reproduction, with potential for broader effects in nearshore marine ecosystems given *A. nodosum's* role as a foundational species. Working with Jessica Muhlin, associate professor of marine biology at the Corning School of Ocean Studies, Maine Maritime Academy, we developed three protocols for tracking *A. nodosum* phenology, growth rates, and associated water quality parameters. SOS data contribute to Muhlin's broader research questions about how *A. nodosum* growth and reproduction influence nearshore marine ecosystems in a changing climate.

Investigating Climate-related Threats to the Common Loon

Perhaps no other bird species is as closely associated with the state of Maine as the common loon, *Gavia immer*. For 34 years, Maine Audubon Loon Count volunteers have tracked loon presence and abundance on lakes and ponds (see Stockwell and Gallo this issue). This study, led by Susan Gallo, wildlife biologist with Maine Audubon, has documented increasing populations of adult loons, but numbers of loon chicks have remained low. Loons are especially vulnerable to climate-related stressors because they are heat intolerant and they take seven years to reach sexual maturity. Increased intensity and duration of rainfall events can wash away loon nests, and they may be susceptible to increased insect outbreaks and expanding diseases, which are also caused by warming temperatures and earlier onset of spring. In 2015, SOS and Maine Audubon developed a partnership to augment the loon count data

Participants in the rockweed-monitoring project.

with phenology observations of loon breeding activities and appearance and growth of chicks throughout spring and summer months. In 2016, SOS worked with the USA-NPN to incorporate loon chick phenophases—distinct events in life cycles of plants or animals with start and end points—into the Nature's Notebook database to increase uniformity and accuracy of observations.

Uncovering the Past through Maine's Historic Phenology Data

Renowned natural historians including Henry David Thoreau and Aldo Leopold created detailed scientific catalogs of plant flowering dates and other phenology observations. Historical records of annual first flowers, first leaves, and first migratory bird arrivals can serve as baselines for researching the effects of climate change on biota and biological processes. In his journals for the Oxbow region of northern Maine, hunting guide L. S. Quackenbush recorded daily observations of first flowering, leaf out, and migratory bird arrival dates. Caitlin McDonough, David H. Smith Conservation Biology Fellow at the University of Maine, has been conducting research to compare past and current records of the Oxbow region, working with scientists at the University of Maine at Presque Isle. Along with meeting presentations and a webinar, McDonough cohosted a phenology hike with SOS on Cadillac Mountain in Acadia National Park, another of her research areas, providing an opportunity to introduce SOS participants to the value of linking historical records with the current-day observations they are making as citizen scientists.

SOS Program Impacts

Participant response to the program has been strong. From 2011 to 2016, 248 volunteers contributed 216,681 terrestrial and freshwater aquatic phenology records to Nature's Notebook, and from 2014 to 2016, 61 coastal volunteers contributed 13,314 records on *A. nodosum* phenology, growth, and water quality to the SOS Coastal Observers database. Results from SOS annual survey of volunteers illustrate progress toward the program's climate literacy and engagement goals, as nearly three-quarters of respondents have reported increased understanding of climate change science, which they attribute to their involvement in the program. Nearly half (45.5 percent) have said that their involvement with Signs of the Seasons has made them more likely to take action(s) to address climate change.

Signs of the Seasons data are used by collaborating scientists and partners, including those just profiled, as well as by Acadia National Park, and through national and regional USA-NPN studies focused on phenology of hardwood forests, lilacs, and onset of spring. USA-NPN data, to which SOS contributes, have been cited in 63 peer-reviewed scientific articles.

Lessons Learned, Challenges, and Next Steps

We gauge our success and recalibrate our approaches based on annual formal participant evaluations and feedback from trainings, webinars, and conferences. Given Maine's strong stewardship ethic, the most important lesson we have learned is the immediate and long-term value of leveraging existing state, regional, and national networks to develop mutually beneficial, durable partnerships that advance common research, outreach, and education goals. *This cannot be overemphasized.* We plan to extend these efforts by developing new research partnerships and volunteer networks focused on monitoring phenology of Maine's valuable agricultural, wild-harvested, and other ecologically important species, such as lowbush blueberry, sugar maple, and amphibians. In addition to generating useful data and providing field research experiences for participants, these partnerships offer learning opportunities and feedback that citizen scientists need to inform and motivate their efforts. The partnerships also foster collaboration and social connections between citizen scientists and research partners.

At the national scale, our role as a partner organization and local leader of the USA-NPN allows us to draw upon the resources, expertise, and data infrastructure they provide and to share our own best practices and receive input from other practitioners across the network. Signs of the Seasons participates in national and regional meetings of the USA-NPN, and in 2016, SOS helped reinvigorate and formalize the Northeast Regional Phenology Network through coordination of a two-day conference attended by leading phenology scientists, educators, and science communication professionals throughout the Northeast and across the country.

Signs of the Seasons' primary challenge is attracting and retaining a cadre of volunteers who are able to commit to the program over fairly long periods of time. As dedicated weather watchers know, variability in seasonal and annual weather patterns is high, making long-term data collection essential if we are to truly detect climate change signals. For example, even a long SOS record of seven years of data on red maple leafout

is still highly variable (Figure 1). Our efforts to address this challenge include tailoring our recruiting efforts to focus on existing entities of structured citizen volunteers and environmental monitoring organizations.

In addition, to support and encourage consistent monitoring and data entry for Signs of the Seasons, we have been working to establish long-term monitoring sites hosted by organizations such as the Coastal Maine Botanical Gardens, Wells National Estuarine Research Reserve, Maine Audubon Fields Pond station, and Acadia National Park. We also plan to establish long-term trailside monitoring sites within state and national parks and forests. Continual upgrades in USA-NPN's Nature's Notebook database and data visualization tools, a mobile application for data entry, science webinars, and other educational resources have been critical to attracting and retaining our volunteers and facilitating consistent data entry.

We foresee the need to provide more resources and opportunities for SOS participants to learn about the connections to our changing climate and for participating in field research with our science partners. Ultimately, we hope participants find ways to share their own knowledge within their communities to promote local action.

Engaging volunteers along with continuing and expanding our collaboration with partner organizations for long-term monitoring sites will support our goals while retaining and expanding our network of informed observers in future seasons. 🐀

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FIGURE 1: **Timing of Red Maple Spring Leaf Appearance***
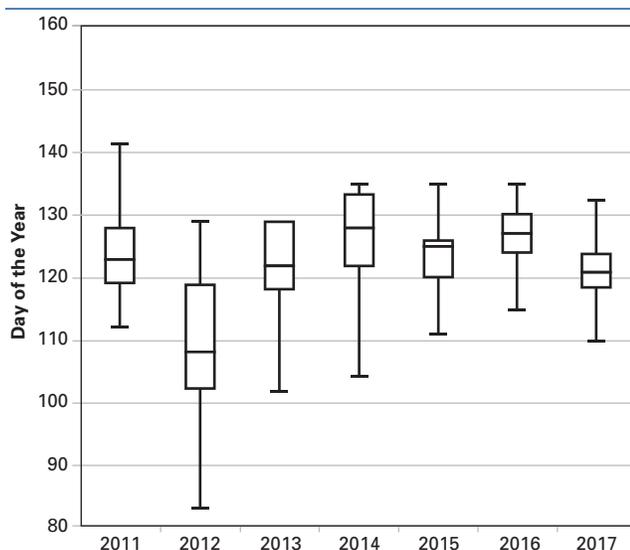
*The boxes in the graph represent the most common dates that red maple leaves appeared in a given year in Maine, with the middle line in the box equaling the median. The horizontal bars at the end of the vertical lines represent the latest (top) and earliest (bottom) date recorded for that year.

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Esperanza Stancioff is an associate extension professor with the University of Maine Cooperative Extension and Maine Sea Grant. Her work focuses on climate change adaptation and designing and implementing applied research and educational programs for high-priority areas in marine and coastal ecosystems. Her projects include a number of adaptation efforts focused on reducing climate-related impacts, as well as the development and coordination of state, regional, and national networks. Stancioff co-manages the Signs of the Seasons program.

Beth Bisson is the interim director and extension program leader of Maine Sea Grant at the University of Maine. She provides leadership and support for the program's research, extension, and communications activities and serves as a liaison to the program's diverse partners and constituents in Maine and across the national Sea Grant Network. Beth co-manages the Signs of the Seasons program.

Sara Randall is a researcher and coordinator focused on ecological responses to environmental change, developing policy and management solutions, and sustaining natural resource–based economies. As assistant coordinator for Signs of the Seasons, she helped citizen scientists document the local effects of climate change by monitoring phenology. Applied marine field research she coordinated led to the discovery that predation, driven by warming ocean temperatures, is the root cause of decline in Maine's soft-shell clams.

Jessie Muhlin is an associate professor of marine biology at Maine Maritime Academy. Her research interests focus on the reproductive ecology, population genetics, and food-web ecology of fucoid seaweeds in the northwestern Atlantic. Jessie is actively involved in art-science collaborations using marine algae as inspiration.

Caitlin McDonough MacKenzie is a David H. Smith postdoctoral research fellow at the University of Maine's Climate Change Institute. She studies the paleoecology and historical ecology of alpine and subalpine plant communities in New England; her research supports conservation efforts by integrating across management scales and bridging stakeholder groups at federal, state, and local levels.

Susan Gallo is a wildlife biologist with over 20 years of experience in wildlife monitoring, conservation policy, and land/forest management. Since 1998, she has been a wildlife biologist with Maine Audubon and the director of the Maine Loon Project. Other projects include coordination of the Maine Amphibian Monitoring Program, initiation of an Important Bird Area program for Maine, and development of a Forestry for Maine Birds program.