



Updates to standardized plant and animal observation protocols of the USA National Phenology Network

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Abstract

The USA National Phenology Network (USA-NPN) was established to coordinate the collection of rigorous, high-quality phenology observations to support scientific discovery and management decisions and to increase awareness of phenology, its relationship to environmental conditions and its influence on ecosystems. A cornerstone of the USA-NPN's infrastructure and data collection activities is a suite of rigorous, standardized phenology observation protocols, published in 2014 (Denny et al., *Int J Biometeorol* 58:591–601, 2014). In the years since, users have requested modifications and additions to the existing protocols. Here, we describe changes that have been made to the original protocols since their publication in 2014. These modifications have been made to reduce confusion in the phenophase definitions, include new taxonomic groups, and expand protocols to more fully capture certain life cycle stages. We anticipate continued expansion of the protocols and future updates can be found in the University of Arizona Research Data Repository (USA National Phenology Network 2014).

Keywords Phenology · Plant · Animal · Phenophase · Monitoring · Protocol

Introduction

The USA National Phenology Network (USA-NPN) was established in 2007 to coordinate the collection of rigorous, high-quality phenology observations to support scientific discovery and management decisions and to increase awareness of phenology, its relationship to environmental conditions and its influence on ecosystems (Schwartz et al. 2012). A diverse community of scientists, resource managers, and educators helped to shape the Network at its inception and a growing body of partners and collaborators continue to shape priorities and directions to best meet the needs of end-user communities. Since the establishment of the USA-NPN, professional and volunteer observers have contributed over 30 M phenology records from across the country. These observations are increasingly used in science and decision-making including invasive species management, conservation, and remote sensing applications (Crimmins et al. 2022).

A cornerstone of the USA-NPN's infrastructure and data collection activities is a suite of rigorous, standardized

phenology observation protocols. The USA-NPN's phenology observation protocols are described in Denny et al. (2014). The standardized protocols are designed to quantify the onset, duration, and intensity of phenological stages of plants and animals to understand how life cycles track environmental variation. Specifically, these "status and intensity" protocols entail (1) repeated assessment of phenophase "status" to provide explicit information on presence as well as absence of a phenophase; (2) intensity or abundance of phenophases; (3) independent tracking of different and potentially overlapping phenophases; and (4) monitoring of multiple individuals within a population. The protocols can be used alone or within the USA-NPN's *Nature's Notebook* platform (Rosemartin et al. 2014).

As described in Denny et al. (2014), the original USA-NPN protocols were developed with input from a large and diverse community of researchers and resource managers with expertise in phenology, ecology, or climate change science, and/or practical experience in the collection and analysis of human-observed field data of select taxonomic groups. In the years since the release of these original protocols, users have requested the development of protocols for new species as well as modifications to existing protocols. In response, we have made several refinements, particularly with the aim of reducing confusion in the phenophase

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definitions. We have also expanded the protocols to include additional taxonomic groups. Finally, we expanded bird and insect protocols to more fully capture reproductive and juvenile life cycle stages. Here, we describe the additions, changes, and enhancements made in recent years to the original protocols presented in Denny et al. (2014).

Summary of phenology observation protocol updates, changes, and enhancements

The original USA-NPN protocol publication (Denny et al. 2014) included detailed plant and animal phenophase definitions as an electronic supplemental document. An updated version of those Plant and Animal Phenophase Definitions is included as a supplement to this update to the protocols (Online Resource 1). Changes to the definitions document since the original version are outlined below.

Plants

Plant functional groups

- A functional group for “Forb (semi-evergreen)” was created to better capture the phenology of forb species that sometimes retain green leaves throughout the dormant season.
- Phenophases for “Colored leaves” and “Falling leaves” were added to the “Tree/Shrub (drought deciduous)” functional group to enable their capture in species and/or years where there are distinct leaf color and leaf fall stages.

Phenophase definitions

- The “Initial growth” phenophase definition for grasses was revised to include re-greening of dried stems or leaves, as occurs in some perennial grasses.
- The “Breaking leaf buds”, “Young leaves” and “Leaves” phenophase definitions for trees were revised to avoid confusion about when a leaf is considered “unfolded”. The definitions now state that the leaf base should be visible at its point of attachment to the petiole, or if there is no petiole, to the stem. Previously the definitions could have been interpreted to mean the petiole must be visible at its point of attachment to the stem, but that is not required.
- The “Young leaves” and “Leaves” phenophases for trees were revised to reflect the fact that leaves sometimes arise from nodes and stem tips instead of a bud.
- The “Colored leaves” and “Colored needles” phenophase definitions for trees were revised to make it more clear that color due to drought or other stresses that cause

leaves to senesce should be included in addition to typical late-season color.

- The “Falling leaves” and “Falling needles” phenophase definitions for trees were revised to make it clear to include only the falling of newly-senesced leaves, and not the falling of dried leaves that remain on a plant for long periods of time (marcescent leaves) as often happens with oak and beech species.
- The “Flowers or flower buds” phenophase definition was revised to make it clear that over-wintering, dormant or resting flower buds should not be included, only flower buds that are showing active growth between visits.
- The “Flower heads” phenophase definition for grasses, sedges and rushes was revised to make it more clear to stop reporting the presence of flower heads once the fruits (grains) begin to develop.

Intensity questions

- The intensity questions for “Leaves”, “Needles”, “Colored leaves” and “Colored needles” were revised to make it more clear that observers should be considering the percentage of “potential canopy space” (i.e. the space your tree’s canopy typically fills at the height of the growing season) in their estimates.
- The intensity questions for “Emerging needles” and “Young needles” for pines were revised to specify that estimates should be of the number of needle bundles rather than the number of individual needles.

Animals

Animal functional groups or guilds

- Significant changes were made to the phenophases included for insect groups to enable monitoring of the egg, larval and pupal stages. Protocols were also developed for several new insect groups.
- Significant changes were made to the phenophases included for birds to more fully capture territorial and breeding behavior.

Phenophase definitions

- The “Active individuals” and “Active adults” phenophase names were changed to “Live individuals” and “Adults” to avoid confusion about our meaning of the term “active”. The phenophase is meant to include all live individuals or adults detected during a site visit whether or not they are actively moving about. We also added the phrase “or heard” to the definition because detection may be by sight or sound.

- The “Active subadults”, “Active caterpillars” and “Active nymphs” phenophase names for insects were changed to “Subadults”, “Caterpillars” and “Nymphs” to avoid confusion about our meaning of the term “active”, as explained above.
- The “Feeding” phenophase definition for birds was revised to include foraging behavior. This is because it can be hard to determine whether a bird is actually feeding on the food item it is clearly hunting for. The intention of this phenophase is not so much to report that a bird is eating (since they do that all year round), but rather to give observers the opportunity to report what it is trying to eat during a given time of year.
- The “Singing males” phenophase name for birds has been changed to “Singing individuals” because in some species, singing by males and females is hard for all but expert birders to distinguish. Rather than have observers report a “?” for the behavior simply because they are unsure whether the singing bird is a male or female, we decided to just make the phenophase inclusive of females.
- The “Dead individuals”, “Dead adults”, “Dead caterpillars” and “Dead nymphs” phenophase definitions were changed to remove the phrase about including those found on roads. Although animals found dead on roads should certainly be included, it seemed unnecessary to mention that specifically in the definition, especially for very small insects that would rarely be noticed dead on a roadside.

Intensity measures

- The intensity measure for “Fresh eggs” for amphibians was changed to clarify the intent to estimate the number of eggs observed rather than the number of “individual animals”.

Conclusions

The intention of the USA-NPN is to maintain rigorous, standardized observation protocols in a static way, to enable the collection of consistent observations over time. However, as users of the observation protocols and the resulting phenology observations provide feedback, we find the need to adapt the protocols. Given the intent of the USA-NPN to enable data collection to support current science and management needs, we anticipate continuing to expand protocols for existing taxonomic groups as well as creating protocols for new taxonomic groups in the future. Any future versions of the USA-NPN Plant and Animal Phenophase Definitions can be found in the University of Arizona Research Data Repository (USA National Phenology Network 2014).

Supplementary Information The online version contains supplementary material available at <https://doi.org/10.1007/s00484-023-02444-0>.

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Data Availability The current version of the USA-NPN Plant and Animal Phenophase Definitions document (included as an electronic supplement to this article) is publicly available in the University of Arizona Research Data Repository (ReDATA) as part of this record: <https://doi.org/10.25422/azu.data.20736700> (USA National Phenology Network 2014). All past and future versions will also be maintained there.

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