# A new approach to generating research-quality data through citizen science: The USA National Phenology Monitoring System

USA npn National Phenology Network

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## Why monitor phenology?

Phenology is the study of recurring plant and animal life cycle events, and changes in phenological events like flowering and bird migrations are among the most ***sensitive biological responses to climate change.*** Across the world, many spring events are occurring earlier—and fall events are happening later—than they have in the past. However, not all species are changing at the same rate. These ***different shifts in timing are shaking up ecosystems*** and altering interactions and processes that took place in the past. Thus, for ecological reasons it is critical that we improve our understanding of species' phenologies and how these phenologies are responding to recent, rapid climate change.

Photo: E.Denny

## Why engage citizen scientists in monitoring efforts?

Remote sensing and webcam technologies are being developed to monitor leaf phenology at a landscape level, but ***ground observations are still invaluable*** to "ground-truth" the remote methods, and to capture observations that are still not possible or practical to see from afar, such as budbreak, flowering and most animal observations. However, in order to get widespread ground observation data, ***we need many more observers than we have*** within the professional science and resource management community.

Phenological events like flowering and bird migrations are easy to observe, culturally important, and, at a fundamental level, naturally inspire human curiosity. Thus, encouraging citizen scientists to participate in phenological monitoring is an excellent opportunity to ***expand our spatial coverage of ground observation data***, and to engage people in understanding the impacts of climate change in the world around them.

Photo: T. Crimmins

***The challenge is to design a monitoring program that makes it possible for citizen scientists (and scientists, too!) to collect, record and share research-quality data.***

## The USA-NPN Effort

The USA National Phenology Network has recently initiated a national effort to encourage people at different levels of expertise—from backyard naturalists to professional scientists—to observe phenological events and contribute to a national database that will be used to greatly improve our understanding of spatio-temporal variation in phenology and associated phenological responses to climate change.

To do this, we have developed a new approach to monitoring which is based on a traditional approach that is very common in the United States and Europe. The new approach is appropriate for general monitoring of plant and animals, and we welcome everyone to participate.

Photo: B. Haggerty

**Join us at www.usanpn.org and click "Observe!"**

Photo: W.D. Peachey

## Traditional Approach
### ("Phenological Event Monitoring")

**How to do it:**

1. Watch for the occurrence of a series of *"phenological events"*[1]
2. Record the date of event occurrence
3. Stop checking for an event once it has occurred

**Observation Data for a hypothetical deciduous tree**

KEY: X=Event occurred

| Phenological Events | 2-Apr | 5-Apr | 8-Apr | 11-Apr | 14-Apr | 19-Apr | 20-Apr | 23-Apr | 26-Apr | 1-May | 3-May | 5-May | 8-May |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Leaf budburst | | X | | | | | | | | | | | |
| First leaves unfolded | | | X | | | | | | | | | | |
| All leaves unfolded | | | | X | | | | | | | | | |
| 75% of full leaf size | | | | | X | | | | | | | | |
| 50% of leaves colored | | | | | | | | | X | | | | |
| All leaves colored | | | | | | | | | | | X | | |
| 50% of leaves fallen | | | | | | | | | | | | X | |
| All leaves fallen | | | | | | | | | | | | | X |
| First flowers | | | | | | X | | | | | | | |
| Full flower | | | | | | | X | | | | | | |
| End of flowering | | | | | | | | X | | | | | |
| First fruits ripe | | | | | | | | X | | | | | |

**It adequately captures:**

- First instance of a phenological event for a plant in any given season
- Phenology of plants growing in temperate regions where life stage events unfold in a predictable progression every year

**However, there is no way to capture:**

- Sampling frequency and an estimate of error in the reported event date
- Unusual events (e.g. killing frost)
- Repeating phenological events within a season (e.g. repeat blooming)
- Duration of the plant's life stages

## The New Approach
### ("Phenophase Status Monitoring")

**How to do it:**

1. Plan to make regular observations (every 2-3 days is ideal)
2. Record the date every time an observation is made
3. At each observation, record the status of each of several *"phenophases"*[2]
4. Continue making observations throughout the year

**This approach solves many of the shortcomings of the traditional method:**

**1**
Evaluation of phenophase status by answering a series of "Yes/No" questions is very intuitive for most observers

**2**
Calculation of uncertainty in the date a phenophase began or ended can be done with the recording of phenophase "absence"

*"Emerging leaves" began Apr 5 with a possible error of -3 days and ended Apr 10 with a possible error of -2 days*

**Observation Data for a hypothetical deciduous tree**

KEY: N=No Y=Yes ?=Did not check

Phenophases

| Do you see... | 2-Apr | 5-Apr | 8-Apr | 11-Apr | 14-Apr | 19-Apr | 20-Apr | 23-Apr | 26-Apr | 1-May | 3-May | 5-May | 8-May |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Emerging leaves? | N | Y | Y | N | Y | Y | N | N | ? | N | N | N | N |
| Unfolded leaves? | N | N | Y | N | N | Y | Y | Y | ? | Y | Y | Y | N |
| ≥75% of full leaf size? | N | N | N | N | N | N | Y | Y | ? | Y | Y | Y | N |
| ≥50% of leaves colored? | N | N | N | N | N | N | N | N | ? | N | Y | Y | N |
| All leaves colored? | N | N | N | N | N | N | N | N | ? | N | N | Y | N |
| ≥50% of leaves fallen? | N | N | N | N | N | N | N | N | ? | N | N | Y | N |
| All leaves fallen? | N | N | N | N | N | N | N | N | ? | N | N | N | Y |
| Open flowers? | N | N | N | N | Y | N | N | N | Y | Y | Y | N | N |
| Full flowering? | N | N | N | N | N | N | N | N | Y | N | N | N | N |
| Ripe fruit? | N | N | N | N | N | N | Y | Y | Y | ? | Y | Y | N |

**3**
Unusual events can be captured

*A second round of budbreak and leaf emergence after a killing frost, insect defoliation or severe drought*

**4**
Multiple occurrences of a phenophase can be tracked

*Two distinct flowering episodes in an area with unpredictable water availability*

**5**
Duration of phenophases can be calculated

*Dispersal of ripe fruit lasted from Apr 20 (-1d) to May 7 (-2d)*

**This approach is also well-suited to irregular sampling intervals, one-time observations of a plant, and the observation of animal phenology.**

## How do we use the new data?

Data collected by the Phenophase Status Monitoring Approach can be valuable for many analyses in its raw state. However, it is also very ***important to be able to compare this contemporary data with historical phenological event data*** collected by the traditional approach. The translation of this new data to the traditional format is very straightforward.

**Many important phenological events can be calculated from the transitions from "No" to "Yes" and "Yes" to "No" in the observation of phenophase status:**

**Observation Data for a hypothetical deciduous tree**

KEY: N=No Y=Yes ?=Did not check

Phenophases

| Do you see... | 2-Apr | 5-Apr | 8-Apr | 11-Apr | 14-Apr | 19-Apr | 20-Apr | 23-Apr | 26-Apr | 1-May | 3-May | 5-May | 8-May |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Emerging leaves? | N | Y | Y | N | Y | Y | N | N | ? | N | N | N | N |
| Unfolded leaves? | N | N | Y | N | N | Y | Y | Y | ? | Y | Y | Y | N |
| ≥75% of full leaf size? | N | N | N | N | N | N | Y | Y | ? | Y | Y | Y | N |
| ≥50% of leaves colored? | N | N | N | N | N | N | N | N | ? | N | Y | Y | N |
| All leaves colored? | N | N | N | N | N | N | N | N | ? | N | N | Y | N |
| ≥50% of leaves fallen? | N | N | N | N | N | N | N | N | ? | N | N | Y | N |
| All leaves fallen? | N | N | N | N | N | N | N | N | ? | N | N | N | Y |
| Open flowers? | N | N | N | N | Y | N | N | N | Y | Y | Y | N | N |
| Full flowering? | N | N | N | N | N | N | N | N | Y | N | N | N | N |
| Ripe fruit? | N | N | N | N | N | N | Y | Y | Y | ? | Y | Y | N |

**To make the calculation, the range of dates on which the event could have occurred is determined. Then a midpoint can be calculated and reported as the estimated date of occurrence with an uncertainty of ± *x* number of days:**

| Phenological event* | Occurred between | | Estimated date | Uncertainty |
|---|---|---|---|---|
| **Leaf budburst** (beginning of "Emerging leaves") | Apr 11 | Apr 14 | Apr 12 | ± 1.5 days |
| **First leaves unfolded** (beginning of "Unfolded leaves") | Apr 14 | Apr 19 | Apr 16 | ± 2.5 days |
| **All leaves unfolded** (end of "Emerging leaves") | Apr 19 | Apr 20 | Apr 19 | ± 0.5 days |
| **75% of full leaf size** (beginning of "≥75% of full leaf size") | Apr 19 | Apr 20 | Apr 19 | ± 0.5 days |
| **50% of leaves colored** (beginning of "≥50% of leaves colored") | May 1 | May 3 | May 2 | ± 1 day |
| **All leaves colored** (beginning of "All leaves colored") | May 3 | May 5 | May 4 | ± 1 day |
| **50% of leaves fallen** (beginning of "≥50% of leaves fallen") | May 3 | May 5 | May 4 | ± 1 day |
| **All leaves fallen** (beginning of "All leaves fallen") | May 5 | May 8 | May 6 | ± 1.5 days |
| **First flowers** (beginning of "Open flowers") | Apr 11 | Apr 14 | Apr 12 | ± 1.5 days |
| **Full flower** (beginning of "Full flowering") | N/O | N/O | -- | -- |
| **End of flowering** (end of "Open flowers") | Apr 14 | Apr 19 | Apr 16 | ± 2.5 days |
| **First fruits ripe** (beginning of "Ripe fruits") | Apr 19 | Apr 20 | Apr 19 | ± 0.5 days |

*Note the first instance of budburst and the second instance of flowering have been ignored to simplify this example.

## Conclusion

These features greatly ***enhance the utility of the resulting data for statistical analyses*** addressing questions such as how phenological events vary in time and space in response to global change. This new approach is an important step forward, and its widespread adoption ***will increase the scientific value of data collected by citizen scientists***.

## Definitions

Photo: E.Denny

[1]**Phenological event:** A ***precisely defined point in the annual life cycle*** of a plant or animal, generally marking the start or end point of a phenophase. The occurrence of a phenological event ***can be pinpointed to a single date and time*** (in theory, if not in practice). Examples include the opening of the first flower, or the end of leaf fall on a plant.

[2]**Phenophase:** An ***observable stage or phase in the annual life cycle*** of a plant or animal that can be defined by a start and end point. A phenophase generally ***has a duration of a few days or weeks***. Examples include the period over which newly emerging leaves are visible, or the period over which open flowers are present on a plant.

***For definitions of specific phenological events and phenophases, please see the accompanying handout or visit*** www.usanpn.org ***and view the species profile pages.***