A new approach to generating research-quality phenology data: The USA National Phenology Monitoring System

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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.

Join us at Nature's Notebook
www.usanpn.org
click "Observe"

Traditional Approach
("Phenological Event Monitoring")

How to do it:

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

This approach adequately captures:

1
Phenology of plants growing in regions where life stage events unfold in a predictable progression every year

Leaf events always progress in this order with no deviation due to weather conditions in a given year

2
First instance of a phenological event in any given season

First leaves unfolded on Apr 8

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						

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

For definitions of specific phenophases, please see the accompanying handout or visit

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"

"Breaking leaf buds" 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
Breaking leaf buds?	N	Y	Y	N	Y	Y	N	N	?	N	N	N	N
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	N	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.

An Illustration with Real Data

This graph demonstrates several possible ways flowering phenology can be recorded for a plant, and illustrates how phenophase status monitoring yields more complete information than the three phenological event monitoring examples. Creosote bush (*Larrea tridentata*) is a desert shrub whose annual pattern of flowering varies according to precipitation, and often includes several discrete flowering episodes.

"First flower" event only

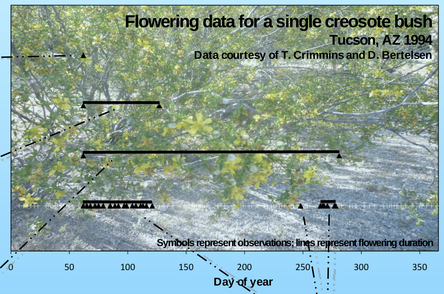
1 recorded observation ( ):
No information about duration of flowering
Mar 3

"First flower" and "End of flowering" events

2 recorded observations ( ):
End of flowering was recorded at end of first flowering episode so subsequent episodes are missed
Mar 3 to May 8

"First flower" and "End of flowering" events

2 recorded observations ( ):
End of flowering was recorded at end of all flowering episodes but there is no information about how flowering episodes were distributed over the season
Mar 3 to Oct 7



"Open flowers" status

103 recorded observations:
Consecutive observations of open flowers ( ) separated by observations of no open flowers ( ) indicate three distinct flowering episodes during the season
Mar 3 (-4d) to May 7 (-5d); Sep 3 (-3d) to Sep 7 (-4d); Sep 21 (-4d) to Oct 6 (-2d)

Using the Data for Analysis

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
Breaking leaf buds?	N	Y	Y	N	Y	Y	N	N	?	N	N	N	N
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	N	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 Breaking leaf buds")	Apr 11	Apr 14	Apr 12	± 1.5 days
First leaves unfolded (beginning of "Leaves")	Apr 14	Apr 19	Apr 16	± 2.5 days
All leaves unfolded (end of "Breaking leaf buds")	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

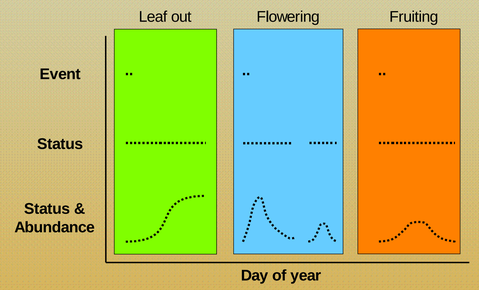
*Note the first instance of budburst and the second instance of flowering have been ignored to simplify this example.

Future Enhancements

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 and others.

The ***addition of abundance measures*** to status monitoring will enhance the utility of resulting data even more. This is a future direction for the USA National Phenology Monitoring System.

Stay tuned….



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