Phenology

as an Indicator of a Changing Climate

LoriAnne Barnett
Education Coordinator, USA-NPN
Local Drought Impact Group

Take-Aways:
- Phenology
- Phenology indicates change
- Phenology & management
- Nature’s Notebook
- Local applications
Phenology

Just to be clear...

**phRenology** – a pseudoscience focused on measurements of the human skull and size of the brain

**phOnology** – a branch of linguistics concerned with the organization of sounds in language
Phenology

What is phenology?

*The science of the seasons*

- Blooms and buds
- Hibernation, migration, emergence
- Easy to observe

...it is the study of recurring plant and animal life-cycle stages, or phenophases, and their relationship to environmental conditions.
Phenology

Who observes phenology?
- Scientists
- Gardeners/Agriculturists
- Land managers
- Educators
- Youth
Primary goal
- Observe phenological events
- Understand how plants, animals & landscapes respond to climate change.
- *Create a standardized dataset for use in multiple types of research.*

Mission
- Make phenology data, models and related information available to scientists, resource managers and the public.
- Encourage people of all ages and backgrounds to observe and record phenology.
A Multi-taxa, National-scale

- Plant and animal phenology observation program
- Professional & Citizen science
- Core protocols for research

Nature’s Notebook is for scientists, naturalists, volunteers, land managers, park rangers, and YOU!
USA National Phenology Network

654 plant species and 243 animal species = ~900 total
1815 observers reporting (6201 total) making ~250,000 observations
Phenology

When observing phenology, know what you are looking for...

- Annual (1)
- Biennial (2)
- Perennial (2+)

PLANT LIFE CYCLE

GERMINATION

SEED/EMBRYO

GREEN GROWTH

LEAVES

SET SEED

MATURE

BEAN FLOWER

...and when it occurs
Phenology

Phenophases – Animals

Mating

Live Birth

ADULT

ANIMAL LIFE CYCLE

Feeding

YOUNG ADULTS

Active Individuals

Live Birth

©Wikipedia
ANIMAL > Mammal, Bird, Snake

Activity
- Active individuals
- Feeding

Reproduction
- Male combat
- Mating

Development
- Young individuals
- Dead individuals

Method
- Individuals at a feeding station

PHENOPHASES

PLANT

Leaves
- Breaking leaf buds
- Leaves
- Colored leaves

Flowers
- Buds
- Flowers or flower buds
- Pollen release

Fruits
- Ripe fruits
Phenology

History and Phenology

Research, spring timing and range

Record keeping
- Journals, herbarium
- Crowd-sourced data, lilacs
- Spring Index

Species and ecosystems are influenced by global environmental change
Local Drought Impact Group

**Take-Aways:**

- Phenology
- *Phenology indicates change*
- Phenology & management
- *Nature’s Notebook*
- Local applications
Phenology indicates change

Results

• 43 species at Walden Pond bloom 7 days earlier than 150 years ago

• 1/3 of species the Leopolds’ recorded are arriving 2-3 weeks earlier

Primack, Miller-Rushing, 2011.
Phenology indicates change

Phenology and Climate Change
Research, spring timing and range
A three-way mismatch

EARLIER

English Oak

SAME TIME EACH YEAR

Winter Moth

Both et al. 2006 Nature
Life Zones

Arizona's Biomes

PICTURE KEYS

P  Ponderosa Pines
J  Junipers
PP  Pinyon Pines
JT  Joshua Trees
S  Saguaros

COLOR KEYS

Tundra  
Forests  
Woodland  
Chaparral  
Desert Grasslands  
Desert

http://alliance.la.asu.edu/maps/AZ_biomes_web.pdf
Phenology indicates change

Onset of summer flowering in a ‘Sky Island’ is driven by monsoon moisture
Theresa M. Crimmins, Michael A. Crimmins, and C. David Bertelsen

Low elevation - monsoon precipitation
• More favorable conditions result in earlier flowering date
• The wetter the year, the earlier the flowers appear

Relationship between July precip and first flowering date for 6 species recorded along a route on Mt. Kimball, Santa Catalina Mountains, Tucson, AZ. 1984-2009
Phenology indicates change

Documented changes in phenology across the United States

**Observed Changes in Phenology Across the United States - Southwest**

*California, Nevada, Utah, Colorado, Arizona, and New Mexico*

**Background**

Phenology — the seasonal timing of life cycle events in plants and animals such as flowering, hibernation, and migration — has been linked to shifts in the timing of allergy seasons, public variation to National Parks, and cultural festivals. Change in phenology, recognized as a bio-indicator of climate change impacts, has also been linked to increased wildlife activity and pest outbreaks, shifts in species distributions, spread of invasive species, and changes in carbon cycling in forests. Phenological information can and already is being used to identify species vulnerable to climate change, to generate carbon models of carbon sequestration, to manage invasive species, to forecast seasonal allergens, and to track disease vectors, such as mosquitoes and ticks, in human population centers.

This is one in a series of eight geographic region-focused information sheets that summarizes documented changes in plant and animal phenology over the past century across the United States. This summary is based on long-term studies (10 years or more) published in the primary scientific literature since 2001. A forthcoming manuscript synthesizes the findings of the eight regional information sheets.

This information was developed in support of the U.S. Global Change Research Program’s National Climate Assessment and can be used to facilitate preparation for the cascading effects of ongoing climate change.

**The Southwest**

The western and southwestern regions of the U.S. consist of a variety of biomes, ranging from deserts and coastal areas to mountains and forested regions [1, 2]. Climate also varies widely, ranging from Mediterranean and semiarid steppe, to mid-latitude desert and alpine. This region is considered a biodiversity “hot spot” in terms of the number of endemic species [3]. Temperatures in the Southwest have increased more than other regions in the continental U.S. [1, 2]. Drought is also an important component of the climate landscape of the Southwest. Major droughts, including those described as “megadroughts,” can persist for long durations and are expected to become more severe in the future [4]. The human population in this region has nearly quadrupled since 1990, increasing competition for already over-allocated water resources [1, 2].

**Changes in Phenology - Highlights**

*Timing of snowmelt in the alpine and timing of precipitation in the desert are key phenological drivers in the Southwest*

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https://www.usanpn.org/pubs/reports
Phenology indicates change

- Spring flight of butterflies advance by one month over 31 years
- Earlier snowmelt in Rockies influences timing of sub-alpine blooming
- Yellow-bellied marmots emerge earlier from hibernation
- Nearctic-Neotropical migrant birds arrive earlier
- Hummingbird – food source mismatches
- Drought conditions affect bloom time of desert adapted plants
- Timing of egg laying in Mexican Jays
Phenological patterns are important, economically and biologically
... and sensitive to climate
... and sensitive to climate change.

“Phenology...is perhaps the simplest process in which to track changes in the ecology of species in response to climate change.” (IPCC 2007)

“Because of their close connection with climate, the timing of phenological events can be accurate indicators of climate change.” (EPA 2010)
Take-Aways:

- Phenology
- Phenology indicates change

*Phenology & management*

- Nature’s Notebook
- Local applications
Climate-relevant information for Landscape Assessments
Phenology & management

Shifts in the Timing of Management Actions
Advising the timing of herbicide application to invasive buffelgrass
Advising the timing of herbicide application to invasive buffelgrass

Canopy foliar greenness (%); 1 SD

- Green (%)
- Flowers
- Seeds
- Sample_date
“The phenological status of vegetation represents the primary driver influencing fuel availability and moisture content.”

(2012, De Angelis, A. Bajocco, Ricotta, S.)
Local Drought Impact Group

Take-Aways:

- Phenology
- Phenology indicates change
- Phenology & management

*Nature’s Notebook*

- Local applications
10 minutes to get set up
Observations

Enter your observations below or via smartphone. You can edit the sites, plants or animals you’ve selected and more.

Sites
- Pima County Extension
- Green Valley Cooperative Extension
- Pima Extension Office (P)
- Santa Rita Experimental Range

My Plants & Animals
- PROVEL-1
- PROVEL-2
- CARGIG-1
- FOUSPL-1
- FOUSPL-2
- LARTRI-1
- LARTRI-2
- SIMCHI-1
- SIMCHI-2
- DCVVIS-1
- DCVVIS-2
- ECO KRI-3

Details for this Organism
PROVEL-1
velvet mesquite (Prosopis velutina)
Path? No
Wild? Unknown
Gender? Unknown

Enter Observations
- Enter Observation Data »
- Download My Data (430) »

FAQs | Terms of Use

Nature's Notebook is a project of the USA National Phenology Network.
USA National Phenology Network

Trees and Shrubs *Semi-deciduous*

**Directions:** Fill in the date and time in the top rows and circle the appropriate letter in the column below. y (phenophase is occurring); n (phenophase is not occurring); ? (not certain if the phenophase is occurring).

Do not circle anything if you did not check for the phenophase. In the adjacent blank, write in the appropriate measure of intensity or abundance for this phenophase.

<table>
<thead>
<tr>
<th>Do you see...</th>
<th>Date:</th>
<th>Time:</th>
<th>Date:</th>
<th>Time:</th>
<th>Date:</th>
<th>Time:</th>
<th>Date:</th>
<th>Time:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young leaves</td>
<td>y n ?</td>
<td></td>
<td>y n ?</td>
<td></td>
<td>y n ?</td>
<td></td>
<td>y n ?</td>
<td></td>
</tr>
<tr>
<td>Leaves</td>
<td>y n ?</td>
<td></td>
<td>y n ?</td>
<td></td>
<td>y n ?</td>
<td></td>
<td>y n ?</td>
<td></td>
</tr>
<tr>
<td>Flowers or flower buds</td>
<td>y n ?</td>
<td></td>
<td>y n ?</td>
<td></td>
<td>y n ?</td>
<td></td>
<td>y n ?</td>
<td></td>
</tr>
<tr>
<td>Open flowers</td>
<td>y n ?</td>
<td></td>
<td>y n ?</td>
<td></td>
<td>y n ?</td>
<td></td>
<td>y n ?</td>
<td></td>
</tr>
<tr>
<td>Fruits</td>
<td>y n ?</td>
<td></td>
<td>y n ?</td>
<td></td>
<td>y n ?</td>
<td></td>
<td>y n ?</td>
<td></td>
</tr>
<tr>
<td>Ripe fruits</td>
<td>y n ?</td>
<td></td>
<td>y n ?</td>
<td></td>
<td>y n ?</td>
<td></td>
<td>y n ?</td>
<td></td>
</tr>
<tr>
<td>Recent fruit or seed drop</td>
<td>y n ?</td>
<td></td>
<td>y n ?</td>
<td></td>
<td>y n ?</td>
<td></td>
<td>y n ?</td>
<td></td>
</tr>
</tbody>
</table>

Check when data entered online: ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Comments:

- YES
- NO
- UNCERTAIN
- No record if you did not check
USA National Phenology Network

<table>
<thead>
<tr>
<th>Species: desert ironwood</th>
<th>Nickname: OLNtes01</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Do you see...?</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Young leaves</td>
<td>y n ?</td>
</tr>
<tr>
<td>Leaves</td>
<td>y n ?</td>
</tr>
<tr>
<td>Colored leaves</td>
<td>y n ?</td>
</tr>
<tr>
<td>Flowers or flower buds</td>
<td>y n ?</td>
</tr>
<tr>
<td>Open flowers</td>
<td>y n ?</td>
</tr>
<tr>
<td>Fruits</td>
<td>y n ?</td>
</tr>
<tr>
<td>Ripe fruits</td>
<td>y n ?</td>
</tr>
<tr>
<td>Recent fruit or seed drop</td>
<td>y n ?</td>
</tr>
</tbody>
</table>

Check when data entered online: [ ]

https://www.usanpn.org/nn/guidelines

Leaves

Flowers

Fruits
| Species: | ocotillo |
| Nickname: | FOUSPL-1 |

**Do you see...?**

<table>
<thead>
<tr>
<th></th>
<th>y</th>
<th>n</th>
<th>?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young leaves</td>
<td>101 – 1,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leaves</td>
<td>95% or more</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flowers or flower buds</td>
<td>3 to 10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Open flowers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fruits</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ripe fruits</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recent fruit or seed drop</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Check when data entered online:**

- [ ]
USA National Phenology Network

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My Plants & Animals
- PROVEL-1
- PROVEL-2
- CARGIG-1

Details for this Organism
- PROVEL-1
  - velvet mesquite (Prosopis velutina)
  - Behav: Anac.

Enter Observations

Enter Observation Data »
Download My Data (430) »

Nature’s Notebook mobile apps for Android and iPhone.
USA National Phenology Network

Phenology by Location

Location: Multiple
Search: mesquite 55 species
Name: Common
honey mesquite [912 obs.]
velvet mesquite [122 obs.]

Phenology for 2011

Phenology for 2012

Partner: Optional...

Click an observation at right to retrieve notes for it.

Select a species or individual at left.

1955 Year Change Location Remove Download: XML CSV

2011 Year Change Location Remove Download: XML CSV

2012 Year Change Location Remove Download: XML CSV
You MUST have your account completely set up online first to use the mobile apps!
Local Drought Impact Group

Take-Aways:

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- Local applications
Local applications

Buffelgrass

Photos credit: Wikimedia Commons (Starr)
Local applications

Santa Rita Experimental Range

Common and cloned Lilac

Photos credit: L. Barnett
Local applications

What is a Phenology Trail?
A phenology trail is a network of *Nature’s Notebook* observation sites. Each site has at least two plant and/or animal individuals tagged for data collection.

Observations help us remember what happened, and when.
Local applications

Tucson Phenology Trail
- Biosphere 2
- Tucson Audubon Mason Center
- UA Campus Arboretum
- Sam Hughes Neighborhood
- Pima Extension Offices (2)
- Rincon Heights Neighborhood
- SRER
- Borton Elementary School
- Tumamoc Hill
- Arizona Sonora Desert Museum

Total of 75 Miles, start to finish
3-10 species tagged at each
Local applications

Species being monitored
- Jojoba
- Velvet mesquite
- Yellow paloverde
- Blue paloverde
- Ocotillo
- Creosote
- Florida hopbush
- Saguaro
- Penstemon (parryi)
- Texas Ranger
- Desert Ironwood
- Buffelgrass
Whoever sees the land as a whole is likely to have an interest in it. –A. Leopold
QUESTIONS?
Thank you!

You’re invited to connect with USA-NPN...

• Sign up for a phenology e-newsletter (quarterly)
• Join the Nature’s Notebook community and become an observer: Contribute to science while having fun!
• Discover new tools and resources for work or play

lorianne@usanpn.org
loriannebarnett