Phenological responses to climatic variation among California native plants: inter-annual and spatial patterns detected by the California Phenology Project (CPP)

Susan Mazer
Dept. Ecology, Evolution & Marine Biology
University of California, Santa Barbara
mazer@lifesci.ucsb.edu

www.usanpn.org/cpp
CPP:
Statewide phenological monitoring program to track the effects of local climate and climate change on the seasonal cycles of wild plant species

www.usanpn.org/cpp
Scientific goals:

Establish a phenological monitoring network in 7 pilot parks (and at UC Reserves, botanic gardens, etc.) using standardized protocols

Cover a large geographic area

Sample across environmental gradients

Assess the effects of climatic conditions on the seasonal cycles of California taxa to predict responses to future climate change
Public service:

Guide resource management decisions

Educate park visitors

Prepare the public to observe and to interpret changes in the landscape

Engage citizen scientists in genuine research
California Phenology Project  www.usanpn.org/cpp

With funding from the National Park Service (NPS) Climate Change Response Program, the California Phenology Project (CPP) was launched in 2010 as a 3-year pilot project to develop and test protocols and to create tools and infrastructure to support long-term phenological monitoring and public education activities in California. A primary focus of the effort is how to recruit and engage California residents and visitors in the collection and interpretation of phenological data.

The CPP is initially focusing on plants in seven pilot parks, encompassing desert, coastal and mountain biomes, and building upon existing monitoring protocols and programs of project collaborators. In addition, new project products and infrastructure are being designed to support monitoring and educational activities for 18 California NPS units and parks in adjacent states.

Please explore our website to learn more about phenology, the origin and current activities of the CPP, where the CPP is currently monitoring plant phenology, and how to become involved. Also visit the news tab for recent updates and upcoming events.

Project collaborators include the National Park Service (NPS), the University of California, Santa Barbara (UCSB), and the National Coordinating Office of the USA National Phenology Network (USA-NPN).

Visit our cooperators and points of contact page to contact us directly or to learn more about the project partners who are currently spearheading this effort.
Vital stats in a nutshell

- 30 species monitored in 7 national parks
- 8 species monitored in multiple parks
- > 950 tagged monitored individuals
- > 763,000 observation records (2011-2014)
  - CPP observations account for ~20% of observations submitted to the USA-NPN database from 2010-2014
  - With three years of data, can detect associations between phenological onset dates and seasonal rainfall and monthly minimum temperature.
The California Phenology Project: 7 pilot parks

NPS heroes:
Angie Evenden
Stassia Samuels
Allison Forestal
Will Elder
Fernando Villalba
Sylvia Haultain
Denise Robertson
Christy Brigham
Josh Hoines

Seasonal interns, contractors and volunteers
cpp species profiles: coyotebrush

what does this species look like?
this shrub can be up to three meters tall. the leaves are toothed, oval, and sticky. coyotebrush is dioecious, meaning that each plant either produces flowers with only male parts or with only female parts. the male flowers produce yellow pollen and appear yellowish from a distance, and the female flowers produce fruit and are white. the flower heads appear round and disc-like.

when monitoring this species, use the usa-npn broadleaf evergreen (with pollen, no leaf buds) trees and shrubs datasheet.

species facts:
- the cpp four letter code for this species is ba-pl.
- ba-pl is a member of the sunflower family (asteraceae).
- this species arises as a secondary pioneer species after fire or grazing.
- baccharis derives from the greek word "bakkaris", referring to plants with fragrant roots, and pilularis refers to sticky globs on the flower buds.
- native americans used the heated leaves to reduce swelling, and the wood to make arrow shafts and houses.
- this species is an important nectar source for wasps, flies, and butterflies.

where is this species found?
- found in many habitats including coastal bluffs and oak woodlands.
- found from 0 to 750 meters elevation, but occasionally up to 1500 meters.
- this species is occasionally found on serpentine soil.

open flowers
- can you see the anthers or stigma?
- proportion of open flowers should be recorded at the scale of individual flowers, not inflorescences (i.e. count individual flowers!).

ripe fruits
- the fruit is a tiny, one-seeded capsule tipped with a tuft of white hairs.
- fruits are grouped in a seed head and change from yellow-green to tan or light brown as they ripen.
- when fully dry, the fruits are blown from the plant.

for more information about phenology and the california phenology project (cpp), please visit the cpp website (www.usanpn.org/cpp) and the usa-npn website (www.usanpn.org).

download from the cpp website:
www.usanpn.org/cpp
Using NPN datasheets

**Baccharis pilularis**
Coyotebrush

Download from the CPP website:
www.usanpn.org/cpp
How do local conditions (monthly temperature and rainfall) preceding leafing and flowering affect the onset date (DOY) of these phenophases?
Example: Effects of May temperature on the onset of late summer flowering of coyotebrush
Baccharis pilularis sites monitored by the CPP (2011-2013)

Redwood NP

Pepperwood Preserve

Golden Gate

John Muir NHS

Rancho Marino NR

Coal Oil Point

Santa Monica Mtns NRA
Baccharis pilularis: Across California, points are site means (1-9 plants/site).

Climate data obtained from PRISM website: prismmap.nacse.org/nn/

2012: Onset of Flower Buds & Flowers

\[ R^2 = 0.41 \]
\[ y = 2.26x + 177.4 \]
\[ p < 0.0010 \]
\[ N=23 \text{ sites} \]

Warmer May maximum temperatures delayed flowering
Conditions in different months may have different effects

\[ \text{DOY (Day of year of onset)} = a \times (\text{May Tmax}) + b \]
Conditions in different months may have different effects

DOY (Day of year of onset) = a (May Tmax) + b

\[ \text{DOY} = a_1 x_1 + a_2 x_2 + a_3 x_3 + a_4 x_4 + a_5 x_5 + a_6 x_6 \]

\begin{align*}
X_1 &= \text{Tmin (°C) (preceding January)} \\
X_2 &= \text{Tmin (°C) (preceding February)} \\
X_3 &= \text{Tmin (°C) (preceding March)} \\
X_4 &= \text{PPT (mm) (preceding January)} \\
X_5 &= \text{PPT (mm) (preceding February)} \\
X_6 &= \text{PPT (mm) (preceding March)}
\end{align*}
Effects of Jan-Feb-March temperature and rainfall on the onset of late summer flowering
Effects of Tmin & rainfall depend on the month: sites and years (2011-2013) pooled

*Baccharis pilularis*: Flowers and Flower Buds ($R^2 = 0.32$)
Quercus lobata
Valley Oak
Quercus lobata sites monitored by the CPP (2011-2013)

Sedgwick Ranch
Santa Monica Mtns.
Effects of Tmin depends on the month; High rainfall delays leaf bud break

**Quercus lobata**: Breaking Leaf Buds \( R^2 = 0.96 \)

- Effects of Tmin depends on the month; High rainfall delays leaf bud break.
- **Quercus lobata**: Breaking Leaf Buds \( R^2 = 0.96 \)
- PPT (mm) (preceding Dec)
- DOY
- Tmin (°C) (preceding Dec)
- Tmin (°C) (preceding Jan)
- Tmin (°C) (preceding Feb)
- PPT (mm) (preceding Jan)
- PPT (mm) (preceding Feb)
- PPT (mm) (preceding Feb)
- P > 0.0601

Quercus lobata: Breaking Leaf Buds (\( R^2 = 0.96 \))
Effects of Tmin & rainfall on flowering time depend on the month

**Quercus lobata:** Flowers or Flower Buds ($R^2 = 0.97$)
Targeted Species: California buckwheat

*Eriogonum fasciculatum*
*E. fasciculatum* sites monitored by the CPP (2011-2013)

- Sedgwick Ranch
- Santa Monica Mtns NRA
- Joshua Tree NP
Effects of Tmin & rainfall depend on the month

_Eriogonum fasciculatum_: Flowers or flower buds ($R^2 = 0.74$)
### R² of multivariate GLM

<table>
<thead>
<tr>
<th>Species</th>
<th>Breaking Leaf Buds</th>
<th>Young Leaves</th>
<th>Flower buds or Flowers</th>
<th>Open flowers</th>
<th>Pollen Release</th>
<th>Fruit</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Baccharis pilularis</em></td>
<td></td>
<td>0.35</td>
<td>0.32</td>
<td>0.48</td>
<td></td>
<td>0.32</td>
</tr>
<tr>
<td><em>(Jan-Feb-Mar)</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Baccharis pilularis</em></td>
<td>0.26</td>
<td>0.27</td>
<td></td>
<td>0.60</td>
<td></td>
<td>0.38</td>
</tr>
<tr>
<td><em>(Jun-Jul-Aug)</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Quercus lobata</em></td>
<td>0.96</td>
<td>0.97</td>
<td>0.85</td>
<td>0.87</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>(Dec-Jan-Feb)</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Eriogonum fasciculatum</em></td>
<td>0.48</td>
<td>0.74</td>
<td>0.52</td>
<td></td>
<td></td>
<td>0.71</td>
</tr>
<tr>
<td><em>(Dec-Jan-Feb)</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Qualitative Predictions

<table>
<thead>
<tr>
<th></th>
<th>Warmer winters</th>
<th>Wetter winters</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>↓</td>
<td>↓</td>
</tr>
<tr>
<td><strong>Baccharis pilularis</strong></td>
<td>Earlier flowering</td>
<td>?</td>
</tr>
<tr>
<td><strong>Quercus lobata</strong></td>
<td>Later leaf-out</td>
<td>Later leaf-out</td>
</tr>
<tr>
<td></td>
<td>Later flowering</td>
<td>Later flowering</td>
</tr>
<tr>
<td><strong>Eriogonum fasciculatum</strong></td>
<td>?</td>
<td>Earlier flowering</td>
</tr>
<tr>
<td>Plant</td>
<td>Warmer winters</td>
<td>Drier winters</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>-------------------------</td>
<td>---------------------</td>
</tr>
<tr>
<td><em>Baccharis pilularis</em></td>
<td>Earlier flowering</td>
<td>?</td>
</tr>
<tr>
<td><em>Quercus lobata</em></td>
<td>Later leaf-out</td>
<td>Earlier leaf-out</td>
</tr>
<tr>
<td></td>
<td>Later flowering</td>
<td>Earlier flowering</td>
</tr>
<tr>
<td><em>Eriogonum fasciculatum</em></td>
<td>?</td>
<td>Later flowering</td>
</tr>
</tbody>
</table>

→ Changes in the timing of floral and vegetative resources
Summary

• Effects of higher Tmin on DOY differ among winter months, phenophases, and species
• Effects of monthly rainfall on DOY are stronger than Tmin but not necessarily more consistent
• Multivariate models can account for a very high proportion of the variance in spring phenology
• The associations between monthly conditions and the onset of subsequent onset dates differ among phenophases and species.
• Species-specific responses could lead to a seasonal thinning of floral resources
Thank also to:

Dr. Liz Matthews (UCSB)
Dr. Kathy Gerst (NPN)
Brian Haggerty (UCSB)
**Baccharis pilularis**: Effects of Tmin differ between male and female phenophases

A. Pollen Release: $R^2 = 0.48$

- Tmin (°C) (preceding Jan): $p < 0.0051$
- Tmin (°C) (preceding Feb): ns
- Tmin (°C) (preceding March): $p < 0.0052$

Warm March conditions *delay* pollen release.
**Baccharis pilularis**: Effects of Tmin differ between male and female phenophases

### A. Pollen Release: $R^2 = 0.48$

- **Tmin (°C) (preceding Jan)**: $p < 0.0051$
- **Tmin (°C) (preceding Feb)**: ns
- **Tmin (°C) (preceding March)**: $p < 0.0052$

### B. Fruit: $R^2 = 0.32$

- Warm March conditions *advance* fruiting
- **Tmin (°C) (preceding Jan)**: ns
- **Tmin (°C) (preceding Feb)**: ns
- **Tmin (°C) (preceding March)**: $p < 0.0147$
**Baccharis pilularis: Across California**, points are site means (1-9 plants/site). Climate data obtained from PRISM website: prismmap.nacse.org/nn/

Sites include: **Golden Gate NRA, Redwood NP, Santa Monica Mtns NRA**

---

### 2012: Onset of Flower Buds & Flowers

![Graph showing the relationship between Mean Maximum Temp (May 2012) and Mean Day of Year of Onset for 2012: Onset of Flower Buds & Flowers. The equation of the trend line is \( R^2 = 0.41 \), \( y = 2.26x + 177.4 \), with a significance level of \( p < 0.0010 \) and 23 sites.]

### 2012: Onset of Open Flowers

![Graph showing the relationship between Mean Maximum Temp (May 2012) and Mean Day of Year of Onset for 2012: Onset of Open Flowers. The equation of the trend line is \( R^2 = 0.67 \), \( y = 4.77x + 162.4 \), with a significance level of \( p < 0.0001 \) and 18 sites.]

Warmer May maximum temperatures *delayed* flowering