The California Phenology Project:

Using phenology to detect plant responses to climate change

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USA National Phenology Network

www.usanpn.org/cpp

USA npn National Phenology Network

NATIONAL PARK SERVICE

UCSB Phenology Stewardship Program

UNIVERSITY OF CALIFORNIA Natural Reserve System

OUTLINE

- What is phenology? How is phenology related to climate and climate change?
  - Case studies
- California Phenology Project (CPP)
- USA National Phenology Network (USA-NPN)
- Botany for CPP observers

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Phenology is the science of the seasons

Spring wildflowers

Foliage color change

Migration patterns

Phenology *is the study of recurring plant and animal life cycle stages (****phenophases****)*

Phenology is the science of the seasons

Spring wildflowers

Foliage color change

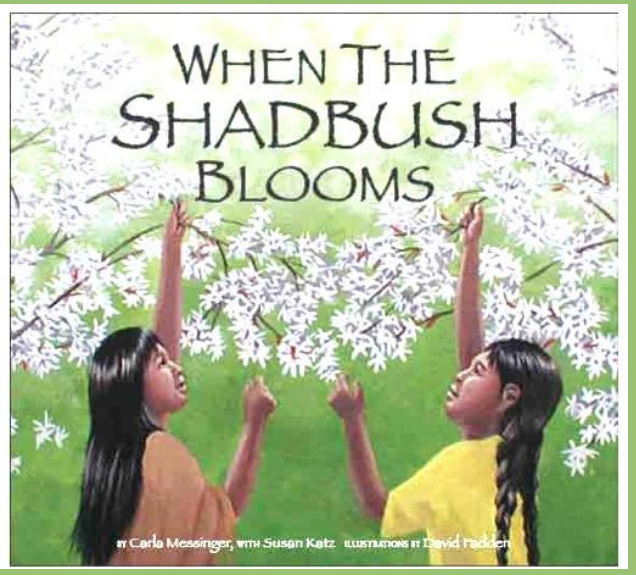
Migration patterns

Other examples?

Phenology: economic importance

Phenological indicators used by fisherman: plant phenophases can predict the best time to hunt

Fisherman on the east coast of Canada would not fish for shad (*Alosa sapisissima*) until after the shadbush (*Amelanchier* spp.) flowered.



Beaubien, E.G. 1991. Phenology of Vascular Plant Flowering in Edmonton and across Alberta. MS thesis, University of Alberta.

Phenological indicators used by hunters: plant phenophases can predict the best time to hunt

Okanagan indians used blooming of mock-orange (*Philadelphus lewisii*) as an indicator that marmots were fat and ready to hunt.

Turner et al., 1980. Ethnobotany of the Okanagan-Colville Indians of British Columbia and Washington. Occ. Pap. Brit. Col. Prov. Mus. No. 21., Ministry of Provincial Secretary and Government Services Provincial Secretary, Victoria, B.C.

Phenological indicators used by indigenous people: plant phenophases can predict harvest times of animals

The Nuu-Chah-Nulth tribe of Vancouver Island used the ripening of salmonberries (*Rubus spectabilis*) to predict the return of adult sockeye salmon (*Oncorhynchus keta*) to freshwater.

Bouchard & Kennedy, 1990. Clayoquot Sound Indian Land Use. Report prepared for MacMillan Bloedel Ltd.
Peacock, S. L. 1992 Piikani Ethnobotany: Traditional Plant Knowledge of the Piikani Peoples of the Northwest Plains. MS thesis, University of Calgary.

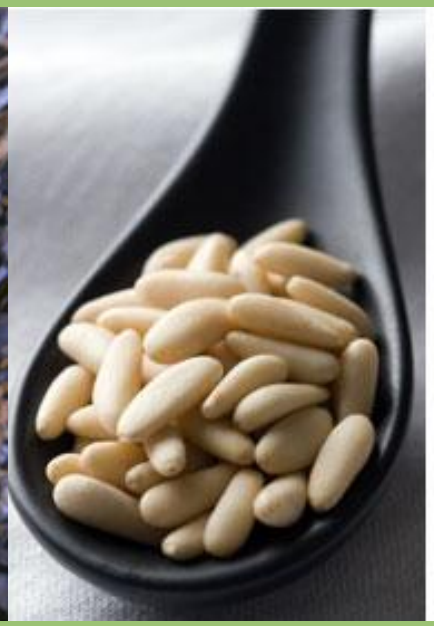
Phenological indicators used by indigenous people: plant phenophases can predict harvest times of animals

The Blackfoot tribe of s. Alberta and Canada used the flowering of the buffalo bean (*Thermopsis rhombifolia*) to indicate that bison males (*Bison bison*) had eaten enough spring browse to be ready to hunt (their meat was sufficiently marbled with fat).

Johnston A. 1982. Plants and the Blackfoot. Prov. Mus. Alberta Nat. Hist. Occ. Pap. No. 4, Alberta Culture, Historical Resources Division, Edmonton, Alberta.

Phenological Indicators used by indigenous people: plant phenophases at one location can predict harvest times for plants at another location

The Tubatulabal tribe of Kern County (CA) used the ripening of coffeeberry fruits (*Rhamnus californica*) at low elevations to indicate that pinyon pine (*Pinus monophylla*) seeds in the mountains were ready to harvest.



Anderson, M. Kat. 2002. UC Davis.

Phenology: biological importance

Plants & animals are dynamic over the seasons

Vegetative phenology

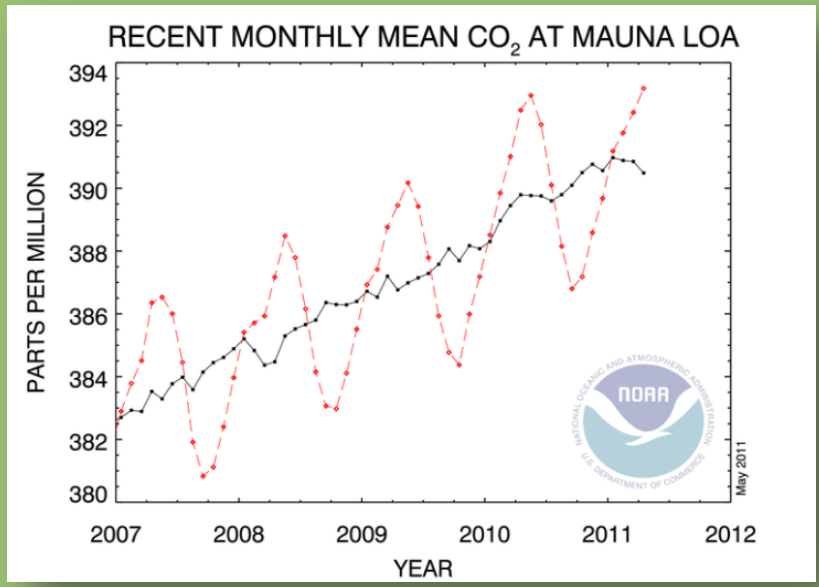
Reproductive phenology

Phenology: biological importance

Plants & animals are dynamic over the seasons

Vegetative phenology:

- Leaves provide energy to the plant for reproduction & growth, food for herbivores, shade and protection for understory animals
- Influences global biogeochemical cycles (e.g., C-cycle)



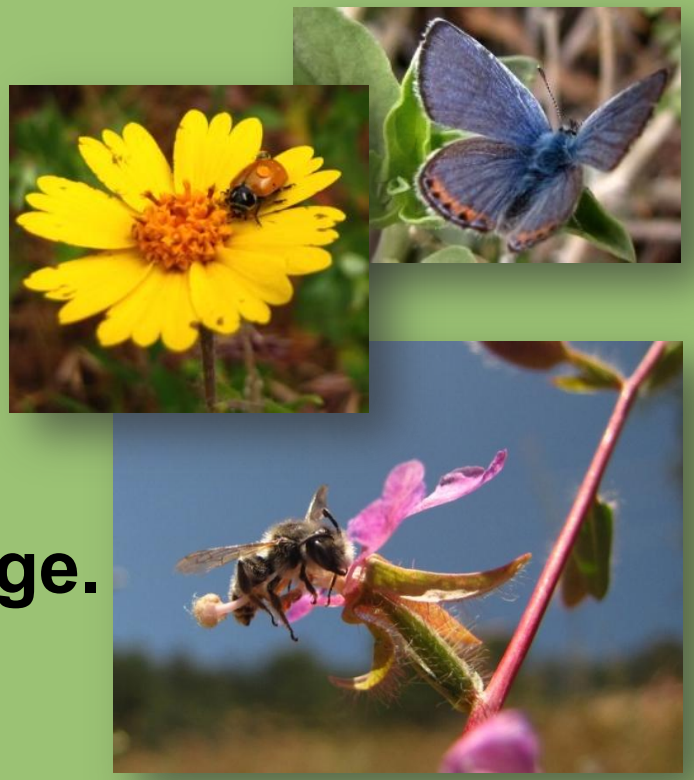
Phenology: biological importance

Plants & animals are dynamic over the seasons

Reproductive phenology:

- Plant reproduction depends on flowers → fruits
- Many flowers provide nectar & pollen for pollinators
- Many plants provide fruits & seeds for animals

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)

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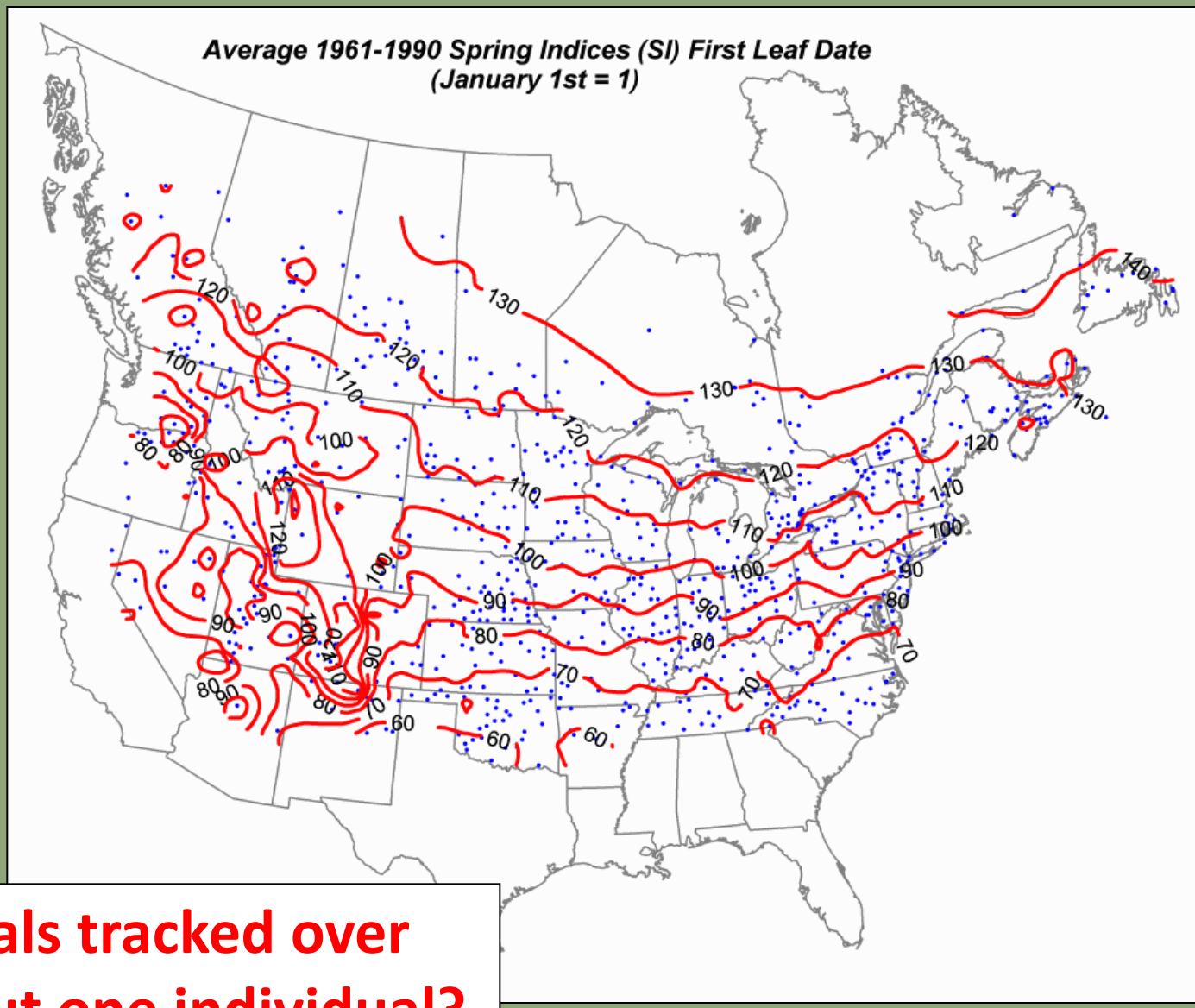
Common Lilac Monitoring Nationwide

- The first phenological monitoring effort in the U.S.
- 1950's - 1990's: ~3500 private citizens monitored lilac plants in backyards and gardens
- Each year, they sent postcards reporting the date of first bloom to Professor Joe Caprio at Montana State Univ.
- First bloom dates of these lilacs have been used:
  - To show the effects of elevation and latitude on the onset of spring
  - To generate predictive maps for safe sowing dates
  - To assess climate change throughout the U.S.

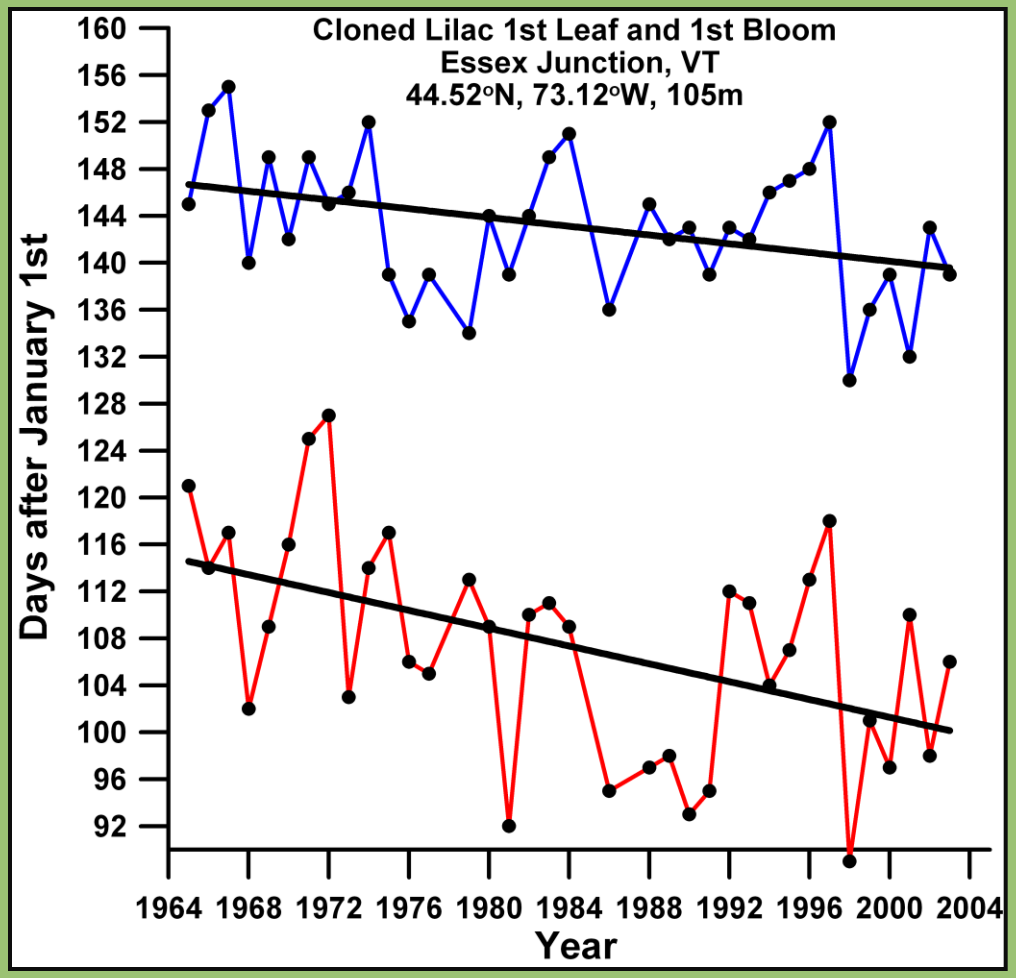
Common Lilac Leaf Phenophases

Common Lilac Monitoring Nationwide



Many individuals tracked over time… what about one individual?

Phenology is an indicator of environmental change



Phenology for one Lilac individual

Date of first flower

Date of first leaf

Phenological events in this lilac have advanced as the climate has warmed

“Phenological mismatches” may cause population crashes

Leafing out earlier

English oak

Emerging earlier

Winter moth

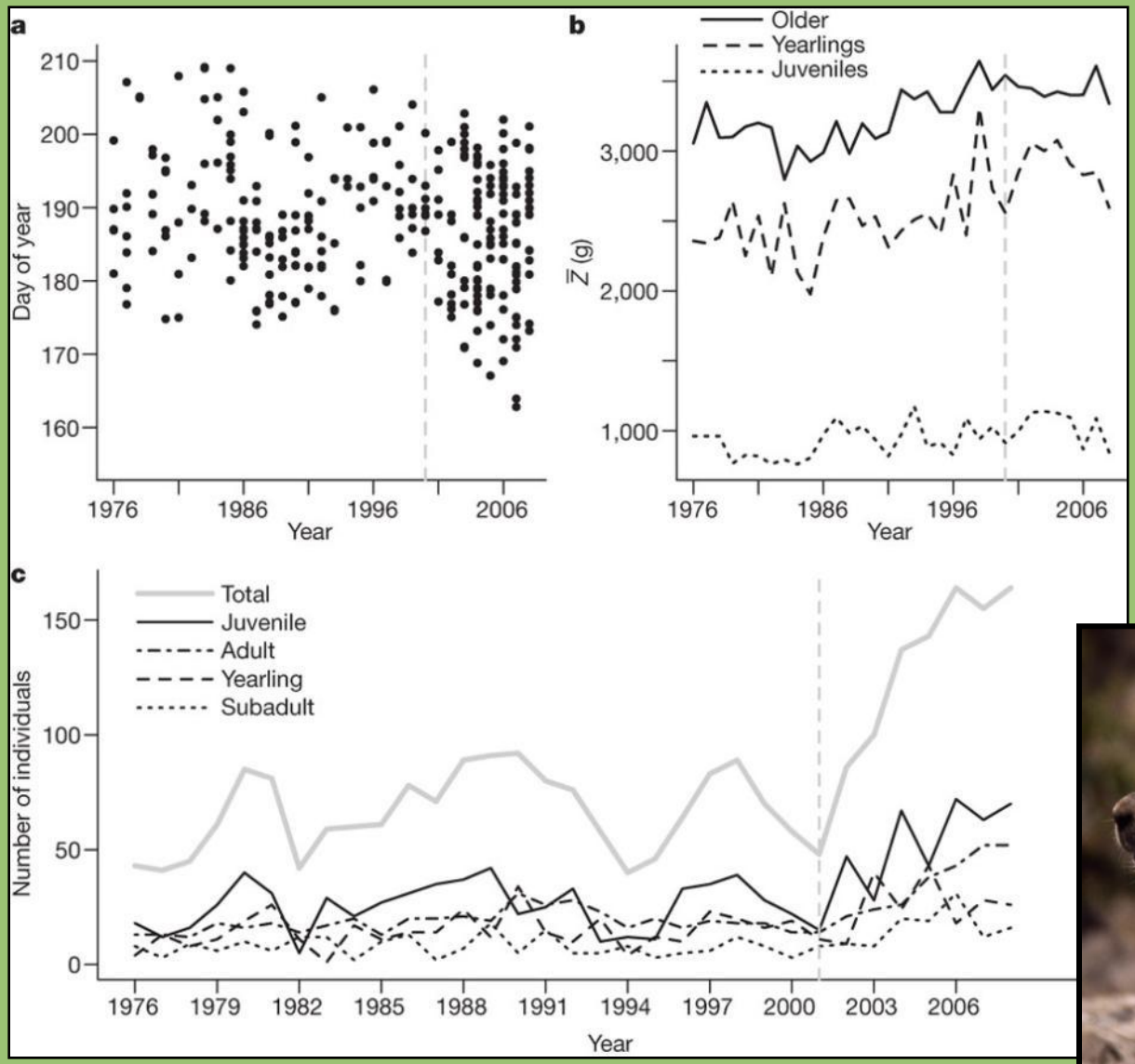
Pied flycatcher

Migrating the same time each year

Bird populations have declined by 90% where food for nestlings is peaking earlier in the season and the birds’ arrival and breeding events are now mistimed.

Both et al. 2006 *Nature*

Shifts in phenology result in changes in body mass and population dynamics



(a) time of weaning
(b) mean mass on August 1st
(c) total abundance at each age class

Ozgul *et al.* 2010

*Can you think of other potential **ecological** consequences of changes in plant phenology as a result of climate change?*

*Can you think of a few potential **economic** consequences of changes in plant phenology as a result of climate change?*

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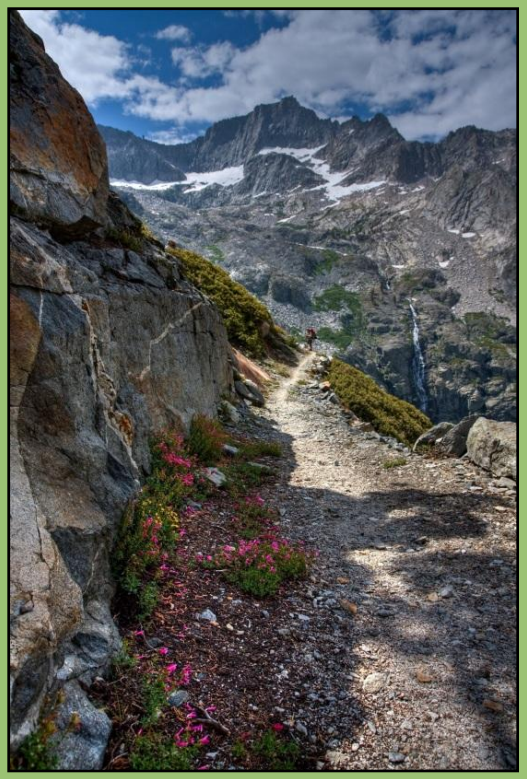
California Phenology Project



California Phenology Project: Goals

establish a coordinated phenological monitoring network

monitor across a large geographic area and along key environmental gradients

1) ***address important scientific questions,***
2) ***guide resource management decisions, &***
3) ***educate the public about phenology & climate change research***

California Phenology Project

- identify key scientific questions
- facilitate selection of focal species for three bioregions (desert, coastal, mountains)
- identify historical datasets
- develop phenophase descriptions appropriate for California plant taxa
- develop and refine monitoring protocols, infrastructure, and tools in pilot parks
- develop outreach and education programs to engage Citizen Scientists in phenological monitoring

CPP scientific questions

- What are the phenological responses of iconic, widespread species to environmental variation and climate change?
- Which taxa or functional groups are most sensitive to climate change?
- Do communities or habitats differ in their general responses to climate change?
- Are relationships between plant and animal mutualists disrupted by climate change?

CPP: focal species

Joshua Tree, *Yucca brevifolia*

- Ability to address scientific questions
- Ability to engage Citizen Scientists
- Proximity to other monitoring efforts
- Species of local management concern
- Indicator species

CPP in the National Parks

Monitoring by Citizen Scientists

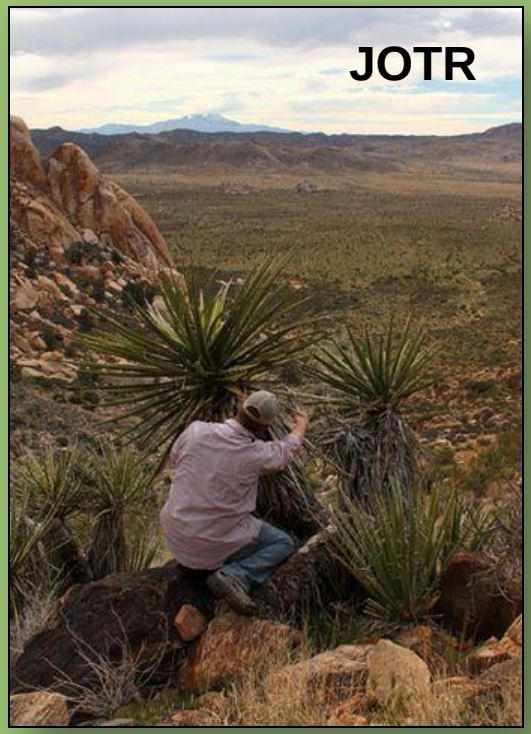
1. Visit and monitor labeled and mapped plants: each plant is visited frequently when it is phenologically active
   (e.g., CPP plants in National Parks)

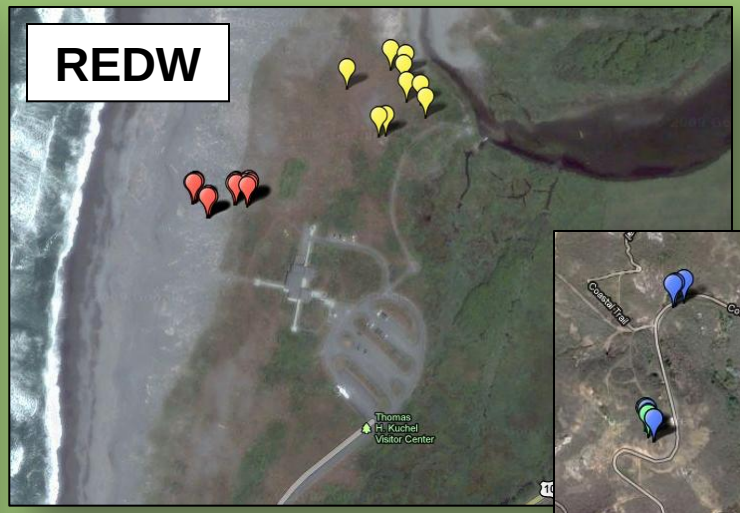
2. Visit and monitor labeled (unmapped) plants whenever it's convenient
   (e.g., plants in a schoolyard)

3. Visit and monitor unlabeled plants whose location you're familiar with
   (e.g., the big tree at the corner)

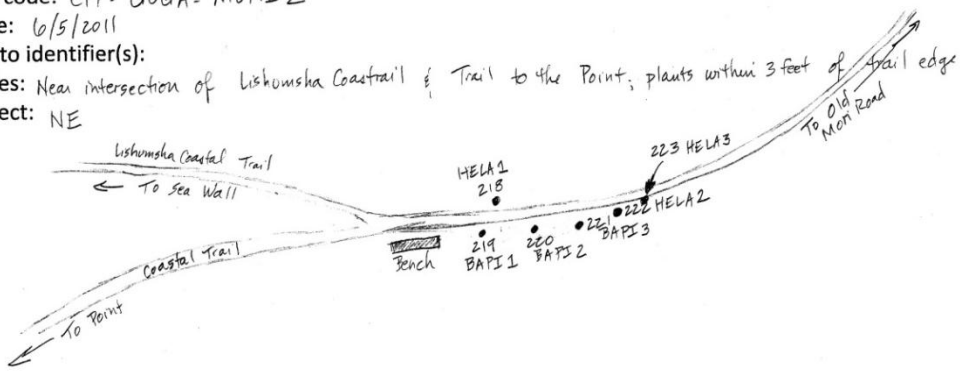
4. Visit and monitor unlabeled plants one time, or opportunistically
   (e.g., plants you encounter while hiking the Pacific Crest Trail)

CPP: monitoring infrastructure





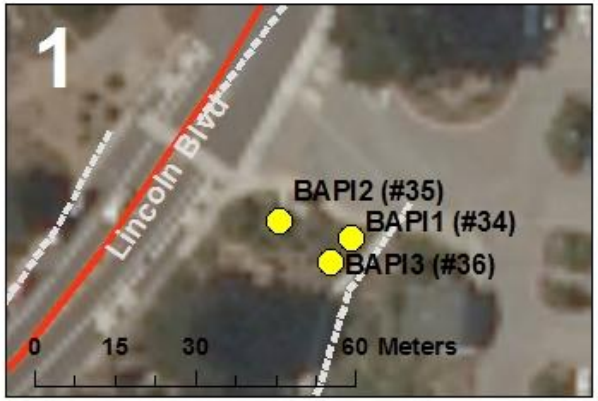
Site code: CPP- GOGA- MORI 2
Date: 6/5/2011
Photo identifier(s):
Notes: Near intersection of Lishumsha Coastrail & Trail to the Point; plants within 3 feet of trail edge
Aspect: NE

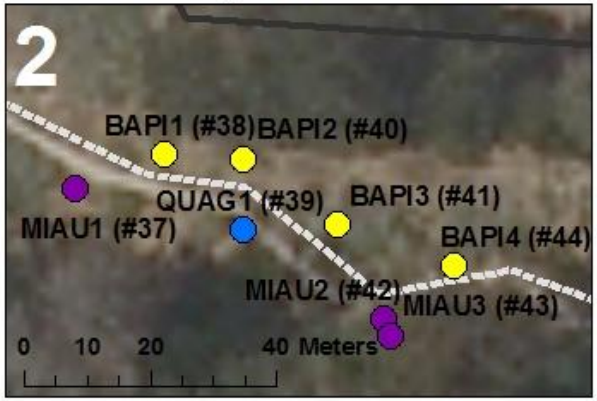


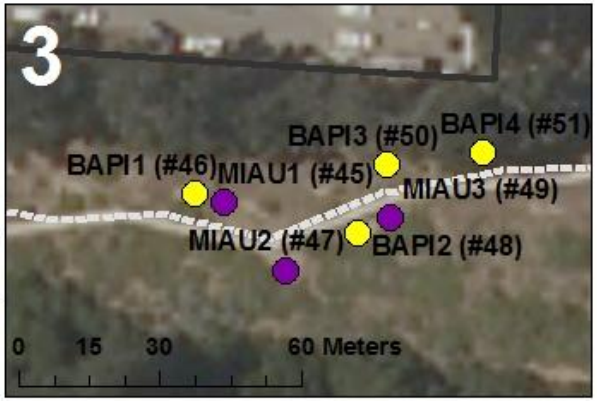
CPP: monitoring infrastructure

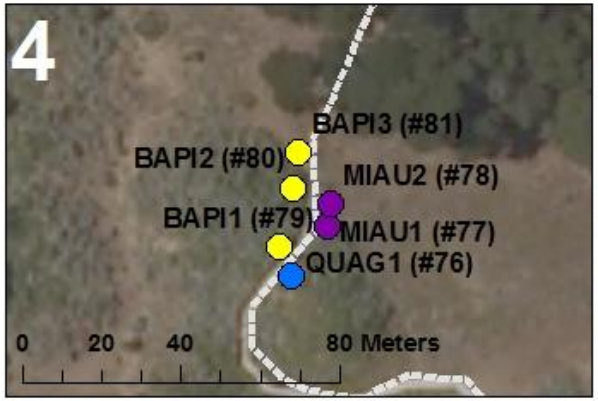
CPP GOGA (Presidio)
Lobos Dunes to Mountain Lake (LDML) Monitoring Sites

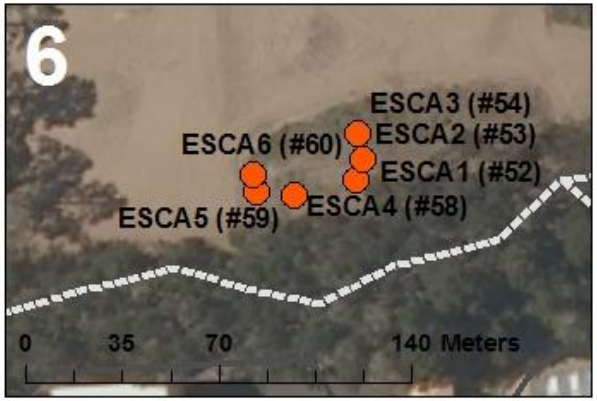
CPP GOGA (Presidio) Lobos Dunes to Mountain Lake (LDML) Monitoring Sites and Plants

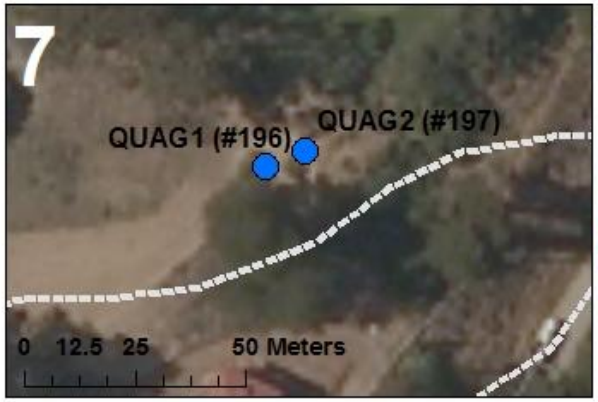


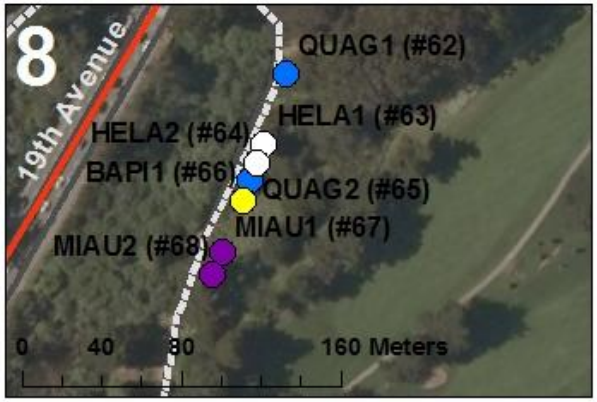


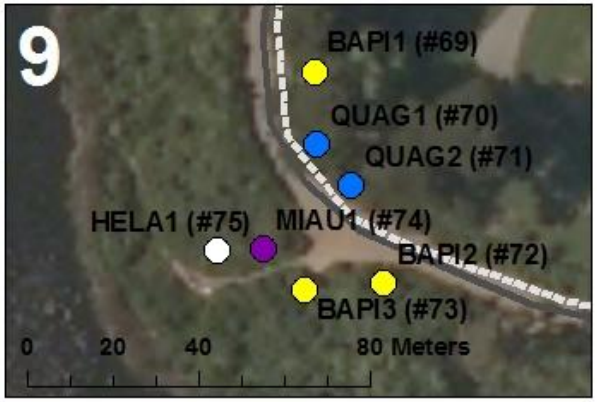


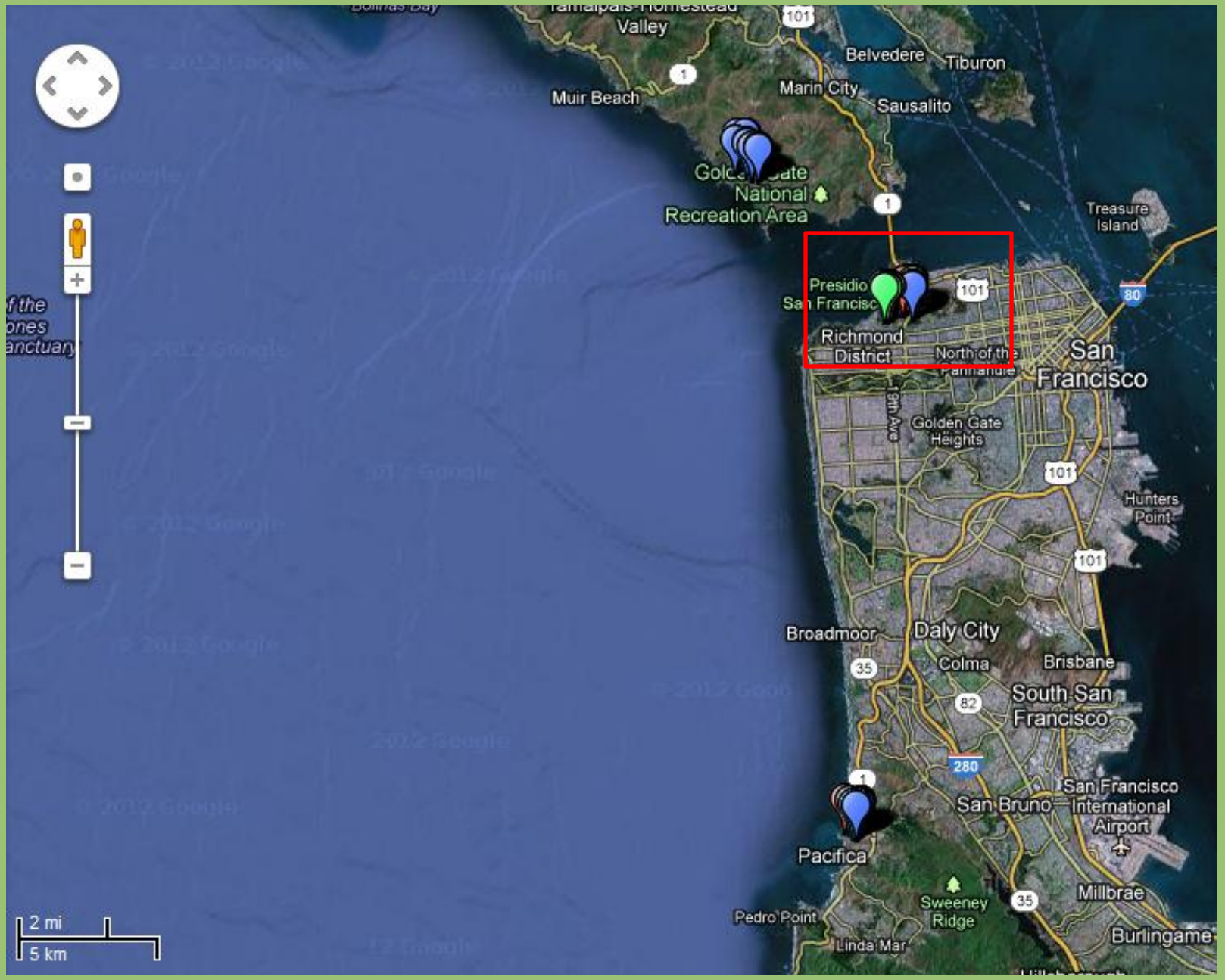


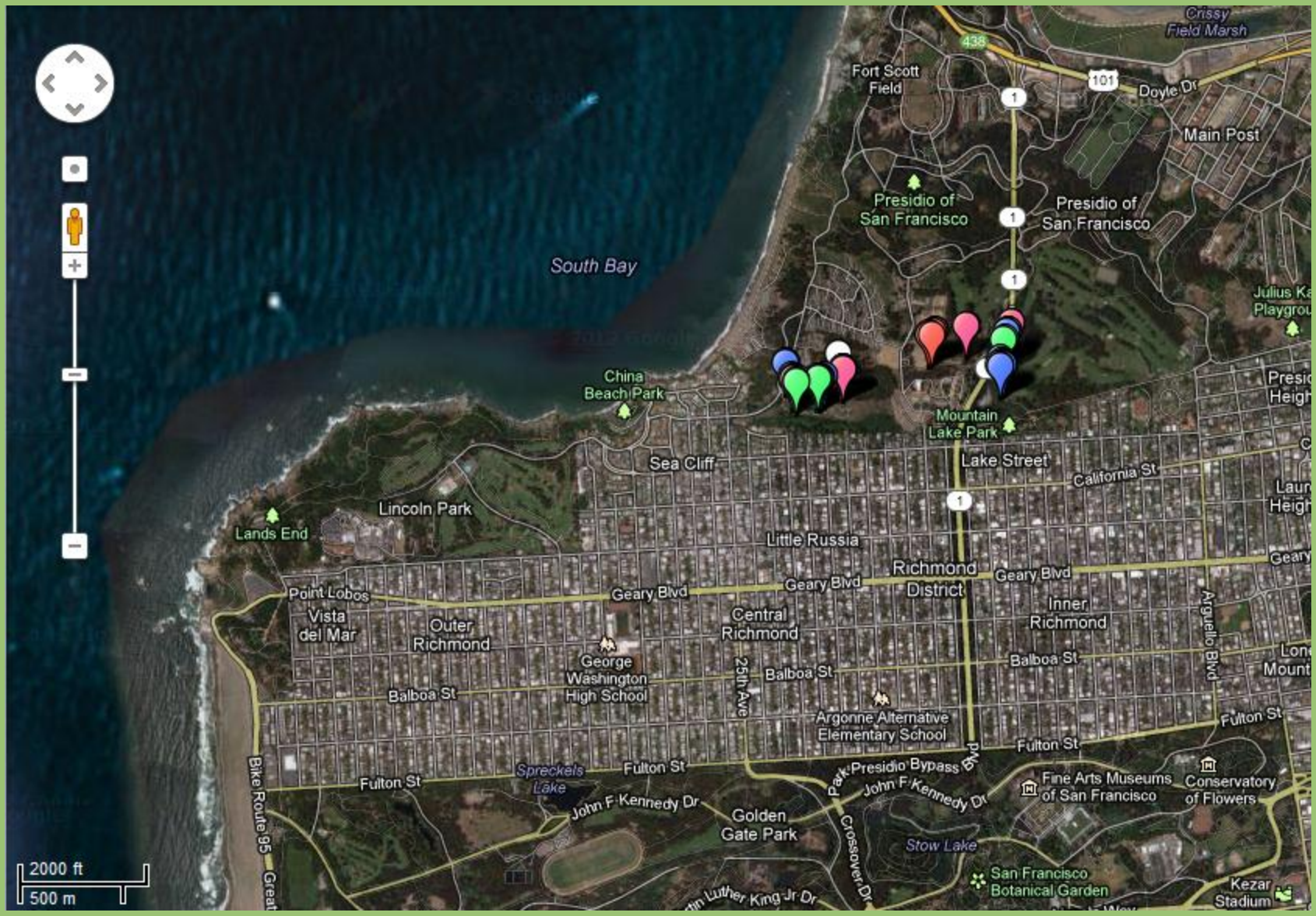


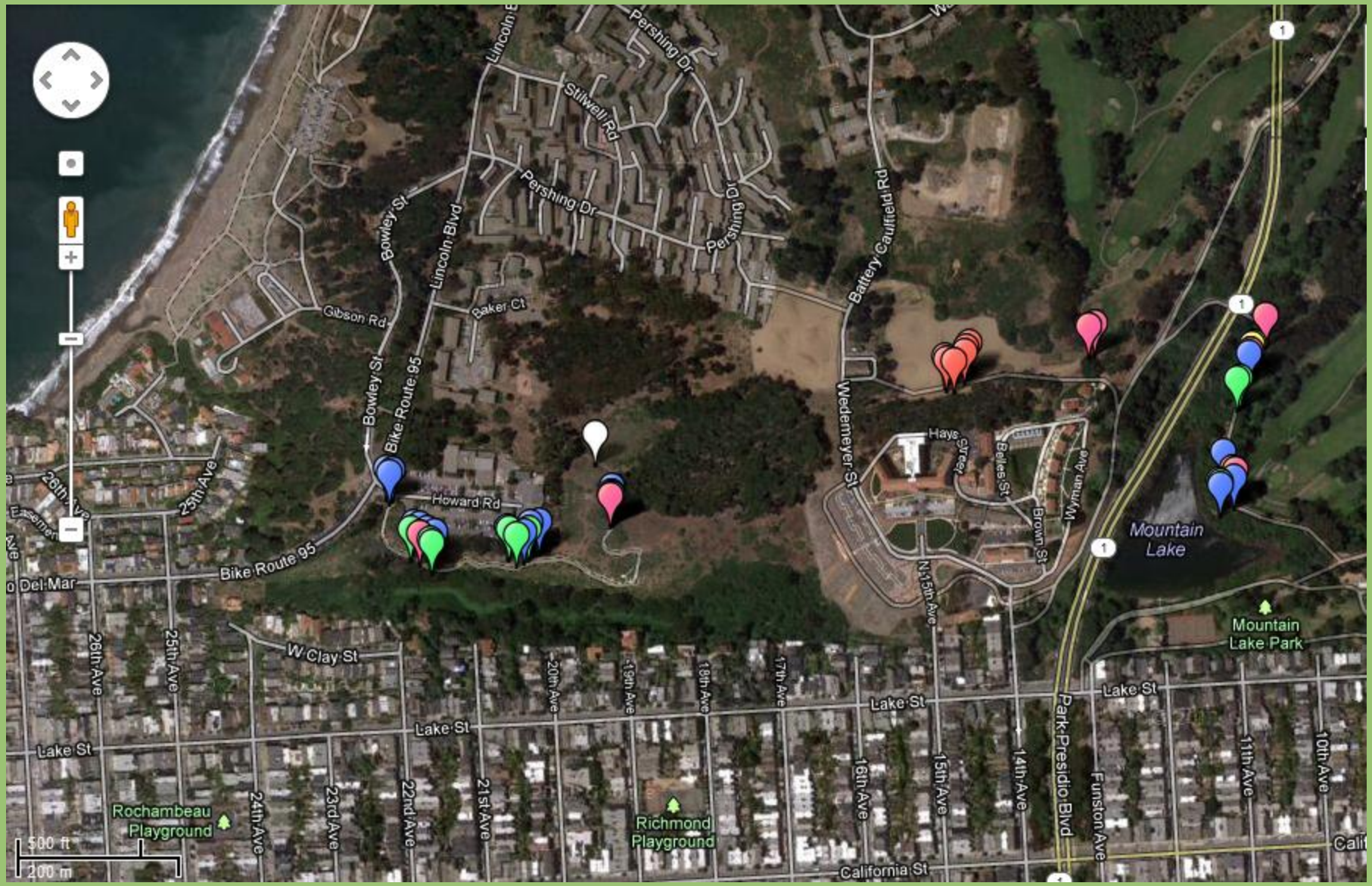




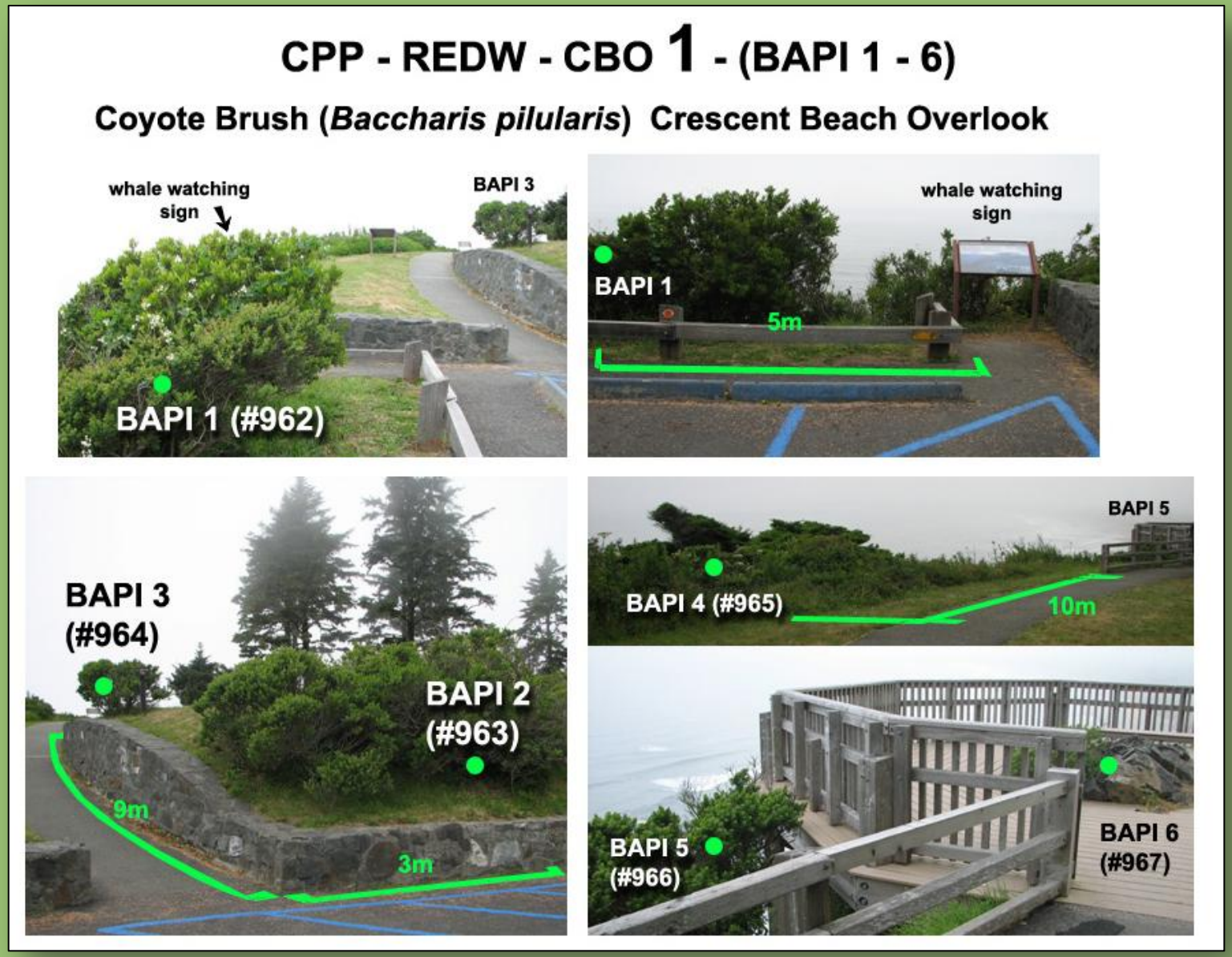



Valley
Belvedere
Tiburon
Muir Beach
Marin City
Sausalito
National
Recreation Area
Treasure
Island
Presidio
Richmond
District
San
Francisco
Golden Gate
Heights
Hunters
Point
Broadmoor
Daly City
Colma
Brisbane
South San
Francisco
San Bruno
San Francisco
International
Airport
Pacifica
Millbrae
Sweeney
Ridge
Pedro Point
Linda Mar
Burlingame
2 mi
5 km


South Bay
Crissy Field Marsh
Fort Scott Field
Doyle Dr
Main Post
Presidio of San Francisco
Presidio of San Francisco
China Beach Park
Mountain Lake Park
Sea Cliff
Lake Street
California St
Lincoln Park
Lands End
Little Russia
Richmond District
Geary Blvd
Point Lobos
Vista del Mar
Outer Richmond
Central Richmond
Inner Richmond
Arguello Blvd
George Washington High School
25th Ave
Balboa St
Argonne Alternative Elementary School
Fulton St
Spreckels Lake
Park Presidio Bypass
John F Kennedy Dr
Fine Arts Museums of San Francisco
Conservatory of Flowers
Golden Gate Park
Stow Lake
Crossover Dr
San Francisco Botanical Garden
Kezar Stadium
Bike Route 95
2000 ft
500 m


Pershing Dr
Stilwell Rd
Pershing Dr
Lincoln Blvd
Bowley St
Pershing Dr
Battery Caulfield Rd
Gibson Rd
Baker Ct
Lincoln Blvd
Bowley St
Bike Route 95
Wedemeyer St
Hays St
Bolles St
Brown St
Howard Rd
25th Ave
Bike Route 95
Del Mar
Mountain Lake
Mountain Lake Park
W Clay St
26th Ave
25th Ave
20th Ave
19th Ave
18th Ave
17th Ave
Lake St
Lake St
Lake St
Park Presidio Blvd
Funston Ave
11th Ave
10th Ave
24th Ave
23rd Ave
22nd Ave
21st Ave
16th Ave
15th Ave
14th Ave
Rochambeau Playground
Richmond Playground
California St
500 ft
200 m

CPP: other monitoring tools



CPP: outreach and education

CPP: other monitoring tools

Species: Coast Live Oak (*Quercus agrifolia)*

Group Name: ______________________

Site: Lobos Dunes-Mountain Lake (LDML)

Subsite (#): _____

Phenophases

Young leaves: A leaf is considered youung once the leaf stalk (petiole) or leaf base is visible, but before the leaf has reached full size or turned the darker green color of mature leaves on the plant.

***Fresh* flower**: The flowers of the oak tree are pendulous strands of catkins (think of a strand of beads).

***Fresh* fruit**: Look inbetween the leaf stalk and the main stem (the leaf armpit) to find *fresh* fruits developing.

Ripe fruit: The ripe fruits of the oak are acorns.

Plant Number ___________

Do you see…? (Circle Y or N)		How many do you see? Less than 3 (<3); 3 to 10; More than 10 (>10)
Young leaves	**Y or N**	___________
Fresh flower	**Y or N**	___________
Fresh fruit	**Y or N**	___________
Ripe fruit	**Y or N**	___________

Plant Number ___________

Do you see…? (Circle Y or N)		How many do you see? Less than 3 (<3); 3 to 10; More than 10 (>10)
Young leaves	**Y or N**	___________
Fresh flower	**Y or N**	___________
Fresh fruit	**Y or N**	___________
Ripe fruit	**Y or N**	___________

Plant Number ___________

Do you see…? (Circle Y or N)		How many do you see? Less than 3 (<3); 3 to 10; More than 10 (>10)
Young leaves	**Y or N**	___________
Fresh flower	**Y or N**	___________
Fresh fruit	**Y or N**	___________
Ripe fruit	**Y or N**	___________

Plant Number ___________

Do you see…? (Circle Y or N)		How many do you see? Less than 3 (<3); 3 to 10; More than 10 (>10)
Young leaves	**Y or N**	___________
Fresh flower	**Y or N**	___________
Fresh fruit	**Y or N**	___________
Ripe fruit	**Y or N**	___________

CPP: outreach and education

CPP: outreach and education

National Phenology Network Data Sheet
Site One

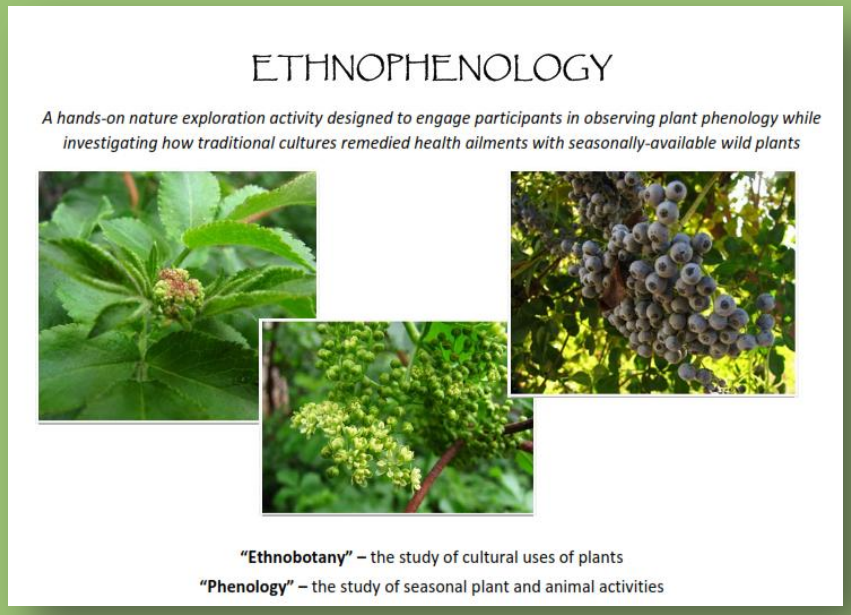
School Name: Date: Weather:

Plant ID Tag	New Leaves	Leaves	Fresh flowers	Open Flowers	Pollen	Fresh Seeds	Ripe Seeds	Recent
BAPI 3	N Y		N Y	N Y				
BAPI 2	N Y		N Y	N Y				
HELA 4	N Y	N Y	N Y	N Y				
BAPI 1	N Y		N Y	N Y				
HELA 5	N Y	N Y	N Y	N Y				
HELA 6	N Y	N Y	N Y	N Y				

CPP: outreach and education

Phenology education materials available on the CPP website:

- Lesson plans for primary educators
- Activities for formal and informal education settings
- Undergraduate lecture series
- Readings and discussion questions for advanced undergraduate or graduate seminar in phenology



California Phenology Project

www.usanpn.org/cpp

- Tools for monitoring: maps, monitoring guides, species profiles, and more
- Includes a wide array of phenological education materials for formal and informal settings
- CPP documentation: scientific questions, species-selection process, and more
- Powerpoint presentations
- CPP *DRAFT* Interpreters' Guide
- ***Instructions for joining the CPP listserv***

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What is the USA-NPN?

A collaborative monitoring network that brings together citizen scientists, government agencies, non-profit groups, educators, and students of all ages to monitor the impacts of climate change on plants and animals in the U.S.

USA-NPN monitoring sites

USA npn National Phenology Network

nature's notebook

a project of the USA-NPN

www.usanpn.org

- 300+ plant species
- 160+ animal species
- Core protocols

1 Search plants & animals

2 Learn how to observe

3 Register yourself

4 Start reporting

Using USA-NPN datasheets

Baccharis pilularis

Coyotebrush

Using USA-NPN datasheets

Baccharis pilularis

Coyotebrush

Trees and Shrubs *Broadleaf evergreen (with pollen, no leaf buds)*

Do you see...	Date: / Time:	Date: / Time:	Date: / Time:	Date: / Time:	Date: / Time:
Young leaves	y n ? _____	y n ? _____	y n ? _____	y n ? _____	y n ? _____
Flowers or flower buds	y n ? _____	y n ? _____	y n ? _____	y n ? _____	y n ? _____
Open flowers	y n ? _____	y n ? _____	y n ? _____	y n ? _____	y n ? _____
Pollen release	y n ? _____	y n ? _____	y n ? _____	y n ? _____	y n ? _____
Fruits	y n ? _____	y n ? _____	y n ? _____	y n ? _____	y n ? _____
Ripe fruits	y n ? _____	y n ? _____	y n ? _____	y n ? _____	y n ? _____
Recent fruit or seed drop	y n ? _____	y n ? _____	y n ? _____	y n ? _____	y n ? _____
Check when data entered online:	☐	☐	☐	☐	☐

Comments:

Using USA-NPN datasheets

	Date:
Do you see...	**Time:**
Young leaves	y n ? _____
Flowers or flower buds	y n ? _____
Open flowers	y n ? _____
Pollen release	y n ? _____
Fruits	y n ? _____
Ripe fruits	y n ? _____
Recent fruit or seed drop	y n ? _____
Check when data entered online:	☐

Comments:

Coyotebrush
(Baccharis pilularis)

Phenophase Definitions

nature's notebook

Directions:
As you report on phenophase status (Y, N or ?) on the datasheets, refer to the definitions on this sheet to find out what you should look for, for each phenophase in each species. To report the intensity of the phenophase, choose the best answer to the question below the phenophase, if one is included. Feel free not to report on phenophases or intensity questions that seem too difficult or time-consuming.

Leaves

Young leaves
One or more young, unfolded leaves are visible on the plant. A leaf is considered "young" and "unfolded" once its entire length has emerged from the breaking bud so that the leaf stalk (petiole) or leaf base is visible at its point of attachment to the stem, but before the leaf has reached full size or turned the darker green color or tougher texture of mature leaves on the plant. Do not include fully dried or dead leaves.

How many young leaves are present?
Less than 3; 3 to 10; 11 to 100; 101 to 1,000; 1,001 to 10,000; More than 10,000;

Flowers

Flowers or flower buds
One or more fresh open or unopened flowers or flower buds are visible on the plant. Include flower buds that are still developing, but do not include wilted or dried flowers.

How many flowers and flower buds are present? For species in which individual flowers are clustered in flower heads, spikes or catkins (inflorescences), simply estimate the number of flower heads, spikes or catkins and not the number of individual flowers.
Less than 3; 3 to 10; 11 to 100; 101 to 1,000; 1,001 to 10,000; More than 10,000;

Open flowers

CPP species profiles

California Phenology Project: monitoring guide for Coyotebrush (*Baccharis pilularis*)

CPP site(s) where this species is monitored: Golden Gate National Recreation Area, Redwood National Park, Santa Monica Mountains National Recreation Area

Photo credit: stonebird (Flickr)

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 **BAPI**.
- BAPI is a member of the sunflower family (Asteraceae).
- This species arrives 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.

Photo credit: Jerry Kirkhart (Flickr)

Photo credit: KQED QUEST (Flickr)

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.

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)

California Phenology Project: monitoring guide for Coyotebrush (*Baccharis pilularis*)

Brian Haggerty

Young leaves
Young leaves are generally thinner and lighter colored than mature leaves.

Crystal Anderson

The flowers pictured to the left have only male parts (anthers) and will not produce fruit.

The flowers pictured to the right have only female parts and will produce fruit. Each flower may produce a single seed.

Crystal Anderson

Miguel Viera

Flowers or flower buds
When monitoring flower abundance for this species, count each inflorescence as a single flowering structure! For example, if there are two inflorescences with many flowers or buds each, then abundance should be recorded as <3.

Steven Krause

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)!*
***Note**: flower phenophases are nested; if you record **Y** for "open flowers" you should also record **Y** for "flowers or flower buds"*

Crystal Anderson

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.

Steven Krause

Ripe fruits
The fruit is considered ripe when it is tan or light brown.
***Note**: fruit phenophases are nested; if you record **Y** for "ripe fruits" you should also record **Y** to "fruits"*

*Phenophases not pictured: **Pollen release, Recent fruit or seed drop***

Version 2, March 2012

OUTLINE

- What is phenology? How is phenology related to climate and climate change?
  - Case studies
- California Phenology Project (CPP)
- USA National Phenology Network (USA-NPN)
- **Botany for CPP observers**

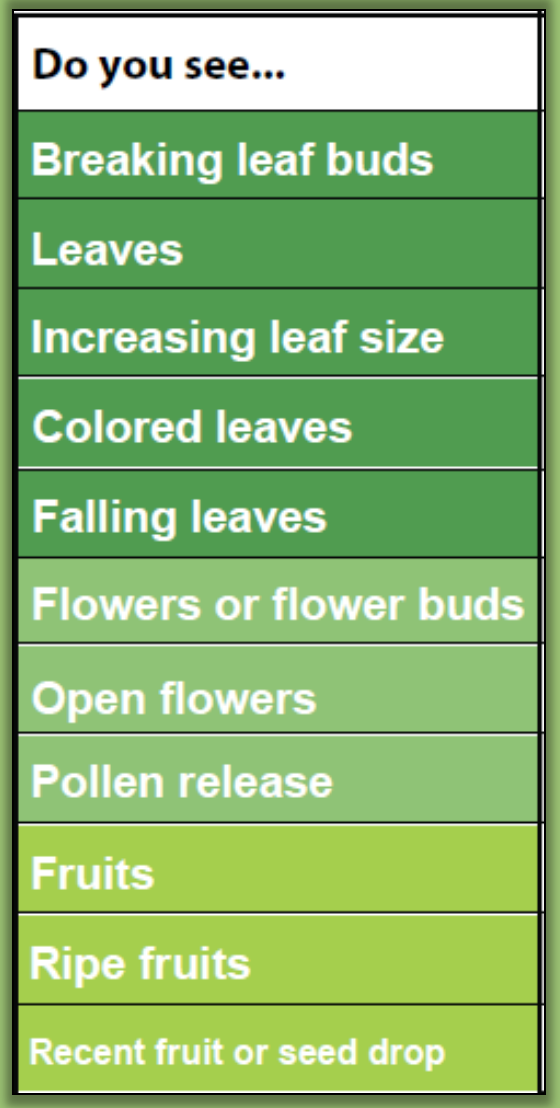
Basic Botany Review

Vegetative structures

- Leaf buds
- Leaves & stems

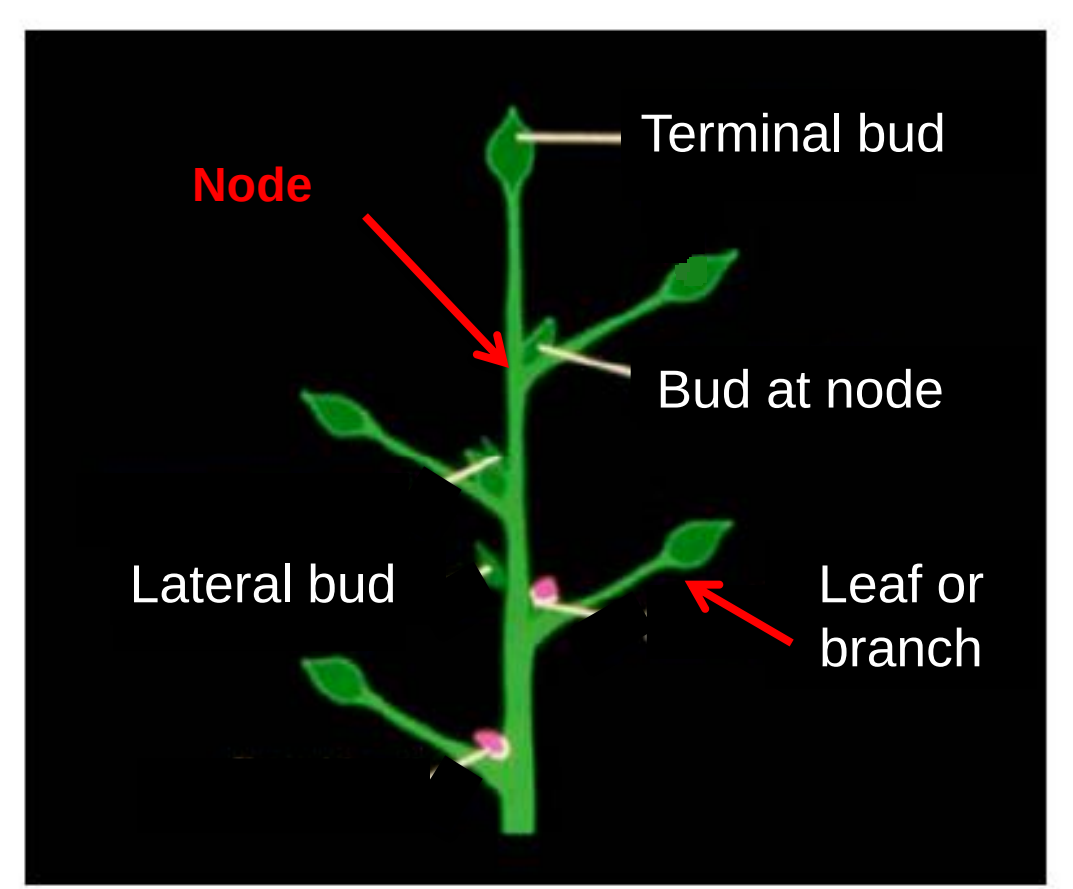
Reproductive structures

- Flower buds
- Flowers
- Fruits & seeds



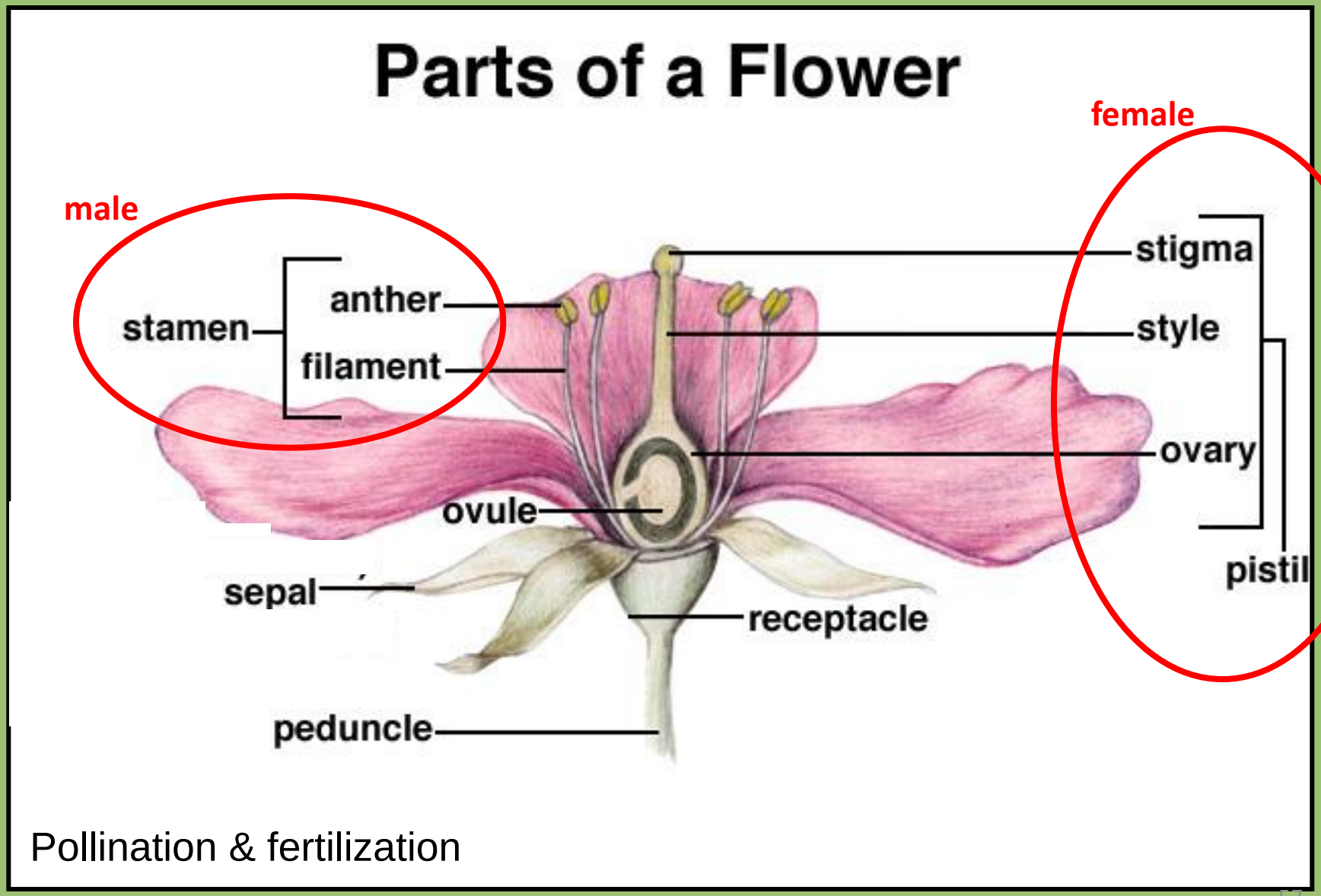
Pollination → Fertilization → Seeds & Fruits develop

Basic Botany Review



Buds may be found in several locations relative to leaves and stems. Generally, leaves ALWAYS have a bud in their axil, even though it may be very small

Reproductive structures: flower buds, flowers, fruits & seeds



Pollination & fertilization

Vegetative structures: breaking leaf buds, expanding leaves, and full-sized leaves

Common Lilac

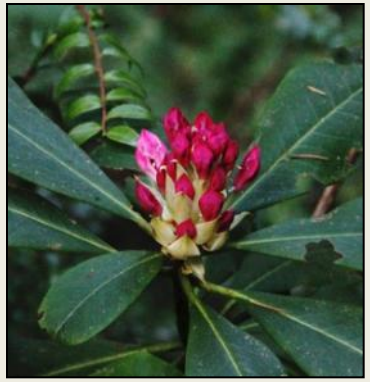


Red Elderberry



Pacific Rhododendron





CPP: phenophase descriptions

Reproductive structures: flower buds, open flowers, and fruits

Joshua Tree

Red elderberry

California Buckeye phenophases



Let’s go observe!!