WORKSHOP REPORT
SCIENTIFIC FRAMEWORK FOR CALIFORNIA PHENOLOGY PROJECT (CPP)

November 2, 2010

Berkeley, California

Background

The National Park Service (NPS) funded a 2.5-year project to facilitate the design and implementation of a research and education program to assess climate change response in California parks, with the aim of developing protocols and tools to support an integrated phenological monitoring program. The project incorporates public education and outreach with sound scientific practices and outcomes to inform natural resource management within and among the 19 National Park Service (NPS) units in California. Project activities are being initiated in six pilot parks representing five park networks that encompass desert, coastal and mountain areas of California. Pilot parks will serve as the 'seeds' to inform the development of future phenological monitoring projects at the other parks in each network. The design and implementation of this initial, integrated set of project activities is referred to as the California Phenology Project (CPP). Principle partners in this project are the University of California, Santa Barbara (UCSB), the National Coordinating Office of the USA National Phenology Network (USA-NPN) and the Pacific West Region of the National Park Service through the Californian Cooperative Ecosystem Studies Unit and Research Learning Center Network.

In addition to focusing on national parks, the project seeks to network with a variety of natural resource education and resource communities in California, including University of California Natural Reserves and federal and state lands managed for natural resources. As the CPP develops, we expect it to become the nucleus of a continually growing California Phenology Network.

To advise the initiation of the project and the development of a scientifically based framework for network-wide phenology monitoring, a group of scientists and the project core planning team was convened on November 2, 2010 to discuss the scientific needs and goals of the CPP and to begin to design a conceptual framework (see Appendix A for list of the participants).

Workshop Goals

The specific goals of the workshop (See Agenda, Appendix B) were to solicit ideas and recommendations that would enable the CPP core planning team to achieve the following objectives.

1. Identify how the California Phenology Project can best use plant phenology to monitor the response of natural resources to climate change <u>across</u> national parks and reserves in California (and beyond?).

2. For the approaches suggested in #1, <u>identify scientific questions or hypotheses</u> that will be both interesting scientifically AND relevant to resource managers.

3. Develop and agree to a set of prioritized recommendations for alternative approaches to California plant phenological monitoring and for the scientific questions to be addressed (Goals 1 & 2 above).

4. Define an initial scientific framework for California Phenology Project based on #3 (e.g. how to organize the sampling effort across bioregions, landscapes, altitudinal gradients, communities, co-location with environmental monitoring stations etc.).

5. Identify criteria for selecting monitoring targets (species, guilds, habitats etc) that are amenable to monitoring and vulnerable to climate change.

6. Identify a clear plan of action with assignments (for those who have time and interest in participating) to move forward on project design and species/community selection. Identify how to best engage university and other agency partners in the project and identify possible participants.

To facilitate group discussion two powerpoint presentations were delivered. Dr. Susan Mazer, UCSB provided an overview of the categories of questions that workshop participants were asked to consider and the kinds of ideas and recommendations that the workshop aimed to solicit. She also outlined a few of the challenges that are anticipated in executing the CPP (Appendix C). Drs. Jake Weltzin, Kathryn Thomas and Kathy Gerst of the USA-NPN presented an overview of the National Phenology Network, and an introduction to how phenology is being used as a tool in science, decision-support and education. They also presented initial ideas on an implementation framework for the CPP (Appendix D).

In general, workshop participants identified desirable characteristics of a framework for the design and implementation of the CPP and focused on key elements that structure the relationship between management needs, science questions, and the operational choices of field observations. The relationships between: (a) prospective plant species to be targeted; (b) scientific questions that the CPP could address; and (c) management needs of the NPS were of special interest and concern.

Report Organization

The primary outcomes of the workshop discussions on four topics are summarized below:

I. **Tractable ecological questions** and their relevance to natural resource management. This section includes ideas regarding the spatial sampling of populations, species, or communities across abiotic and biotic gradients.

II. **Criteria for selecting species** in each national park, UC Reserve, or other site where long-term phenological monitoring will occur.

III. **Measures of success** by which to evaluate the California Phenology Project's (CPP) impact and influence

IV. **Upcoming tasks and processes** by which species will be selected and the CPP's components will be implemented.

The main purposes of the summaries below are to record the primary ideas and suggestions about which most participants seemed to agree, and to identify the next steps necessary for project implementation (as discussed by workshop participants).

In addition to the ideas summarized below, workshop attendees discussed ideas that were either beyond the scope of the current project or that touched on the broad scientific framework of regional phenology monitoring. A summary of these ideas is presented in Appendix E.

I. Tractable ecological questions and their relevance to natural resource management

The workshop participants aimed to identify a range of scientific questions that can be addressed by a long-term, California-wide phenological monitoring program. Participants in this discussion recognized that articulating the hypotheses or questions underlying a proposed long term monitoring effort is key to a successful outcome (i.e., providing results that are informative to both scientists and managers). Although long-term research often leads to new and unanticipated discoveries (and ultimately should generate new hypotheses), formal hypothesis testing can focus the question(s) being asked and allow for a more robust study design. In the context of phenological monitoring, asking the following over-arching questions may help frame the process of selecting species or communities of interest and help lead to the development of testable hypotheses that can be addressed by monitoring phenology.

- What do observers, managers, and scientists think is going to happen? What changes in temperature and precipitation do climate change models predict for each park or reserve?
- How do observers, managers, and scientists anticipate that the populations, species, or communities being monitored will respond to the predicted changes?
- Which components of the systems of interest are most vulnerable to changes in climate?
- What can phenological monitoring tell scientists and the public about the biology of the species and systems of interest?
- How can the results of phenological monitoring inform land and resource management?

With these over-arching questions in mind, the workshop participants proposed that to fulfill the educational, management-related, and scientific goals of the currently funded project, the CPP should focus on ecological questions that:

- provide information on species-specific and community-wide responses to climate change;
- are appealing to and conceptually engaging to the public, and;
- inform natural resource management practices that are vital to the National Park Service mission of maintaining the biological diversity and ecosystem function of its lands.

In addition, although the primary mission of the CPP is to design and to implement a phenological monitoring program that will detect potential *long-term* resource responses to climate change in California, workshop participants also aimed to identify questions that could be informed by phenological data recorded over the duration of this project (i.e., over the next 2-3 years).

The ecological questions below were identified during the workshop as being scientifically interesting, high-priority, tractable given the resources currently allocated to the CPP, and relevant to species and land use management. Additional questions (see **Appendix E**) were articulated that are of great scientific interest but would rely on resources that are beyond the scope of this project and its current personnel, including the use of satellite data, large-scale imaging software, climate modeling, and common garden installation.

The following ecological questions and suggested approaches may be addressed by a phenological monitoring design that encourages *both* the replicated monitoring of focal taxa over local and large-scale environmental gradients *and* the geographically-limited monitoring of species of special interest (e.g., highly charismatic species or species exhibiting highly specialized interactions with other taxa). Phenophases of special attention are the timing of vegetative budburst; the onset, duration, and termination of flowering; the appearance of ripe fruits; and fall leaf-color change. Although the examples below are all botanical, each of them could be modified to apply to birds, butterflies, bees, herbivorous insects, vector- or wind-borne diseases, mammals, amphibians, fish, and reptiles.

1. **How do iconic, widespread, and ecologically important species of the California flora respond to variation in climate (and, by extension, to alternative scenarios of climate change)?**

<u>Approach</u>: Use data obtained from *current* phenological patterns observed over local, regional, and state-wide environmental gradients to measure intra-specific phenological variation associated with spatial variation in light, slope, aspect, temperature, and moisture. Species or populations sampled over *local* gradients can be assessed for phenological responses to these *microclimatic* variables. Species sampled over *broad* geographic gradients (e.g., across large gradients of latitude and elevation within or across biogeographic zones [coastal, montane and desert]) will provide information on their responses to larger variation in climate. Widespread and common species can be sampled across local, regional, *and* California-wide gradients representing variation in elevation, latitude, longitude, photoperiod, soil moisture, and soil type.

Over extended periods of time, individuals and populations that are repeatedly monitored can be evaluated for their species-specific phenological responses to climate change (and to other changing aspects of the environment). With such long-term data, future scientists will be able to determine which phenological events and phenophases are most sensitive and responsive to climate change.

<u>Relevance to management</u>: Understanding the degree to which the most common and widespread California plant species exhibit phenological variation related to current *spatial* variation in climate is a first step toward predicting their responses to future *temporal* variation in climate. For example, if across many species, the duration of flowering consistently becomes compressed

in environments or elevations subject to the earliest onset of late-spring drought, then it may be predicted that, where climate change results in lower soil moisture earlier in the spring, the flowering durations of many species may also become shorter. Given that the length of the flowering and fruiting season of many species determines the diversity and abundance of the pollinators, herbivores, and seed dispersers that they can support, shorter flowering seasons of affected species can alert managers to the risks faced by the animal species that depend on them. In sum, changes in plant phenology may serve as a signal for management actions that could promote or preserve plant-animal interactions that are at risk.

2. **Which plant species in California are most sensitive to climate (and, by extension, to climate change)?**

Approach: As data accumulate on multiple species, scientists and land managers can compare the relationships observed between: (a) phenological events or phenophase lengths and (b) abiotic conditions across *current* environmental gradients to identify the species that are most sensitive vs. least sensitive to geographic variation in light, temperature and moisture (*local gradients that could be evaluated include*: elevation, aspect, slope, shade, insolation, soil texture; *regional or California-wide gradients that could be evaluated include*: elevation, latitude, photoperiod). These comparisons will allow scientists to identify those species that are most strongly programmed to flower at a particular time, regardless of climatic conditions (i.e., those that are *least* responsive to local environmental conditions, potentially controlled by photoperiod). These species, in turn, may be those that are *most* vulnerable to negative demographic responses to climate change simply because they are less able to acclimate phenologically to inter-annual or long-term climate variation or to sustained climate change.

Over the long-term, species that are repeatedly monitored can be evaluated for their species-specific phenological responses to climate change (and to other changing aspects of the environment). With such long-term data, future scientists will be able to determine which species are most sensitive and responsive to climate change.

Relevance to management: Understanding the degree to which species differ in their response to current spatial variation in climate is a first step toward predicting their responses to future temporal variation in climate. We predict, for example, that species whose flowering time is determined primarily by photoperiod will be more buffered against climatic variables than species whose flowering is initiated by seasonal increases in temperature or by declines in late-spring soil moisture. Rigidly programmed species may also be less able to adapt such that their reproductive cycles become optimally timed for temperature and moisture conditions, and park management should be aware of which species may fall into this category. Such species, in turn, may be candidates for management actions (e.g., assisted migrations, breeding programs, etc.) that promote their persistence.

3. **Are relationships between inter-dependent plant and animal mutualists at risk due to climate change? For example, are pollinators and their floral resources tracking climate change at the same pace?**

Approach: By targeting particular plant-animal interactions for phenological monitoring, the CPP can monitor the degree of phenological synchrony exhibited over time and space in association with climate. For example, where the pollinators of monitored species can be identified (and are not too diverse; this would work best in highly specialized plant-pollinator relationships), participants in the CPP may record the presence/absence of pollinators that are observed each time the plants are monitored. (NPN data sheets have "Notes" sections where this can be indicated.) Observed deviations from synchrony associated with particular current climatic conditions (detected over the short-term) can inform predictions about whether these deviations may become more severe under different scenarios of climate change. For example, under current climatic conditions where a species' flowering phenophases are relatively short, the window of overlap between a plant population's flowering time and its visitation by pollinators may also be shorter than where flowering phenophases are long. This kind of pattern would suggest that where climate change induces a shortening of the flowering season, plant populations may be at risk of becoming pollen-limited while their pollinators may be at risk of facing a reduced food resource. Alternatively, changes in the timing and duration of plant and animal phenophases may result in new species interactions.

Relevance to management: The risks faced by plants and animals that depend on mutualistic interactions that may be disrupted due to asynchronous responses to climate change can only be detected if both members of the interaction are monitored. Comparing the short-term and long-term phenological patterns of the members of mutualistic interactions may help National Park resource managers in California predict the conditions under which such interactions risk the greatest ecological disruption and demographic declines and design management approaches to minimize species loss.

4. How do particular communities or vegetation types differ in their phenological response to climate change? Are some communities more buffered against climate change?

Approach: One option for selecting species for monitoring is to choose *assemblages* or communities of sympatric species that consistently co-occur within each biogeographic zone (coastal, montane or arid) and to monitor these assemblages in a replicated fashion. One prediction, for example, might be that coastal assemblages or assemblages in mesic sites will be more highly buffered against short-term and long-term climate change because of the mitigating influences of coastal fog, and of airborne and soil moisture. It is also possible that species adapted to relatively stable sites are less tolerant of variable conditions, and thus they may be more negatively affected by small or sustained changes in climate.

Relevance to management: Comparing spatial variation in phenology among plant communities, as well as their short-term and long-term phenological responses to climate change may help National Park resource managers in California predict the relative rates at which different community types may become disrupted by climate change.

5. How do species or populations behave at their range margins or at ecotones?

Approach: Among widespread species, compare phenological patterns exhibited at the centers vs. the edges of their geographic ranges to identify the phenological signals and environmental conditions that are associated with species or population shifts and or demographic changes. More locally, within parks, species that are observed on transects that reach their geographic limit (e.g., along elevation gradients) may provide phenological signals near their limit (e.g., shortened flowering or failure to flower) that help to explain their geographic range. For example, the failure to flower regularly at range margins would reduce seed production and dispersal ability.

<u>Relevance to management</u>: The identification of phenological signals and environmental conditions that are associated with a species' vital signs (reduced density, failure to flower, or seed production as conditions become drier along a transect) may alert land managers of species or habitats that show signs of vulnerability to future environmental conditions. These signals may, in turn, allow managers to prioritize species and populations for preservation or restoration actions.

6. **How do plant reproductive schedules respond to invasions of competitors or diseases?** Do invasions or diseases accelerate or delay the flowering of focal or host species, and does this altered flowering schedule promote or suppress their reproductive success? Does the presence of competing invasive species compress the flowering time of natives?

<u>Approach</u>: Compare the phenology of targeted species across gradients where the presence or abundance of invasive species or plant diseases varies and is recorded (examples of invasive candidate species include yellow star thistle or pine bark beetle). This approach would allow the CPP to detect species-specific phenological responses to the abundance of disruptive or highly competitive species or diseases.

Relevance to management: These quantitative responses may be used to predict the response of monitored species to climate-mediated invasions or diseases and to target the most disruptive antagonists for management efforts or eradication.

7. **How do species respond to abiotic <u>disturbance</u>?**

<u>Approach</u>: Use phenological observations in disturbed vs. undisturbed sites (e.g., burned vs. unburned sites, or flooded vs. unflooded sites) to detect species-specific or community-specific phenological responses to disturbance. For example, does the timing or duration of a species' or plant community's flowering period increase when it occurs in both disturbed and undisturbed sites? Does disturbance (e.g., nutrient release in post-fire communities) promote or suppress reproductive success or the timing of fruit and seed production?

<u>Relevance to management</u>: Understanding the effects of disturbance on the phenological schedules of focal species and plant communities may help managers to predict the effects of intended (e.g., proscribed burns) or unintended (e.g., wildfires or disease) disturbance on plant reproduction. Such comparative studies of disturbed vs. undisturbed sites can thereby inform effective restoration or management of disturbed sites under future climate scenarios.

8. **What are the earliest indicators of spring?** What are the first-flowering taxa (herbs, shrubs, trees monitored separately) at each site?

Approach: At parks with hiking trails that are heavily used by visitors, establish public competitions to identify (and to photograph) the first-flowering taxa in each growth form and to record sightings on NPN database.

Relevance to management: Attracting attention and visitors the parks at the very beginning of spring may improve public awareness of inter-annual variation in climate and of the environmental conditions associated with the first-flowering species and habitats. In addition, targeting early-spring species may be an effective way of monitoring how rapidly winter may be warming (or shortening) in response to climate change.

9. **How are end-of-season phenological events and patterns affected by long-term climate change?** How are phenological events associated with the end of spring and the beginning of fall influenced by climate change?

Approach: Targeting a few taxa known to flower in late spring (e.g., *Clarkia*, farewell-to-spring) and deciduous taxa that change leaf color in response to colder temperatures in the early fall will shed light on whether the duration of flowering conditions is compressed due to late-spring drought and whether (given sufficient soil moisture) the duration of vegetative growth in some species may be extended due to a delayed onset of winter conditions.

Relevance to management: The length of the flowering and vegetative seasons are important for park visitors interested in wildflower viewing or the onset of fall foliage season. How these resources change over the short-term and long-term may affect park visitation rates. Ecologically, the length of the flowering season (across all flowering species) will affect the window of availability of floral resources for pollinators and floral herbivores, which are important ecological guilds under NPS stewardship.

10. **Can we link phenological signals to population vital signs?** For example, are directional changes in phenological patterns over time (e.g., shorter flowering periods or earlier flowering onset) associated with lower population growth, lower seed production, or lower population densities in subsequent years?

Approach: Where populations that monitored in the CPP are co-located with plots monitored by the I & M program, scientists may be able to find quantitative relationships between phenological patterns and population and community vital signs that are already under observation.

Relevance to management: If phenological changes can be used to predict future population vigor or other vital signs, then phenological responses and behaviors (of at least some species) may be used as an "early warning signal" for other biological features of a species or community.

11. **Across all species and habitats, what is the relationship between: (a) the onset and the duration of phenological events and phenophases and (b) current and long-term climatic conditions?**

Approach: Once the CPP has recorded data for multiple species across many climatic conditions (sampled spatially and over time), scientists will be able to assess the general associations between abiotic conditions and phenological behavior. Multivariate statistical analyses should be able to detect likely causal relationships between rainfall, elevation, slope, aspect, latitude, soil type and the timing and duration of phenological events.

12. Across all species and habitat types, are certain functional groups (e.g., winter annuals, perennial herbs, evergreen shrubs) more sensitive to climate and to climate change than others?

Approach: Once the CPP has recorded data for multiple species across many climatic conditions (sampled spatially and over time), scientists will be able to assess the general associations between growth from and life history vs. phenological sensitivity to abiotic conditions.

II. Criteria for selecting species in each national park or UC Reserve

As background for the discussion on species selection criteria, participants were provided with preliminary floristic information for 19 California NPS units and 26 of the 36 University of California Natural Reserves. These floristic summaries were compiled by USA-NPN and UCSB partners (Appendix F). Discussions at the workshop did not focus on specific species but rather the broader criteria for selecting species for monitoring.

There was general agreement among workshop participants that there is value to monitoring widespread species *as well as* carefully chosen or highly charismatic endemic or geographically limited flora. There was also the recognition that it may not be realistic to expect frequent and consistent monitoring of more than 3-4 plant species and 3-4 animal species at a given site (e.g., a National Park or UC Natural Reserve). The following criteria were generated to help participants at each site select a small group of species to be monitored that would provide data that could address one or more of the questions cited above. The criteria are divided into two groups; the first group encourages participants at each site to agree on the selection of species that represent a range of clear categories and that are likely to be recognizable to local observers. The second group of criteria provide *added value* that will facilitate and extend the range of scientific questions that may be addressed with the data from a particular species.

Guiding Principles: Limit the number of species to be monitored at each location to 3-4 species, with each species representing one (or more) of the following categories:

Group 1

- *dominant species* that represent the most common or "characteristic" local or regional vegetation type (e.g., coast live oak, redwood trees, giant sequoias);
- *widely distributed taxa* (widely distributed within or across coastal, montane, and arid regions and National Parks)
- *indicator species* for habitats, or *transitions between habitats*, of particular interest (e.g., desert scrub, vernal pools, bogs, maritime chaparral, oak woodland, pinyon pine-juniper, riparian, snowmelt edges, evergreen forest)

- *species (rare or abundant) of local ecological or management concern, including keystone or highly charismatic taxa, and/or species involved in highly inter-dependent plant-animal interactions* (e.g., Joshua Trees, fall-deciduous taxa that change leaf color; locally endangered species; highly invasive species; critical food sources for endangered pollinators or butterfly larvae)

The criteria below may also be used justify the choice of species (based on the criteria above) and can help to explain their selection to scientists and to members of the public involved in monitoring:

<u>Group 2</u>

- *ease of identification* – it's important that each selected species and its phenophases are relatively easy to identify
- *accessibility* for monitoring across an abiotic or biotic gradient, such as: elevation, aspect, soil moisture, gradients of invasive species abundance, gradients of disturbance (e.g., across a wildfire boundary); gradients of coastal fog;
- *proximity to other monitoring efforts*: e.g., co-location with I & M plots that provide demographic and abundance information, and proximity to meteorological stations
- *species for which there are legacy data* to which current phenological behavior can be compared (e.g., Clausen, Keck & Heisey data, PhD dissertations, published primary literature, etc.)
- *benchmark species*: e.g., species that are "first-responders" to spring warming; species that are last-to-flower; species that provide dramatic spring flowering or fall foliage displays
- *taxa that occur in the largest number of National Parks* (and UC reserves) *within* biogeographic regions (coastal, montane, or arid) and *across* biogeographic regions (including more than one of the following: coastal, montane, or arid).

Note: the species monitored at each location could represent any number of these categories, and not all categories would need to be represented at a given park or reserve. Collectively, across the CPP, species should include a variety of families, genera, and **functional groups**, which may include distinct phenological schedules (e.g., mast-flowering, multi-season flowering, early spring and fall flowering) and life forms.

III. Prospective Measures of Success to evaluate CPP's impact and influence

This discussion was aimed at identifying ways to keep the CPP on track towards fulfilling the public outreach and scientific goals of the project while exploring options to sustain the CPP beyond the 2.5 years of funding that is currently available. Workshop participants suggested the following measures of success for the CPP. The project core planning team will work to refine these ideas into a cohesive set of measures of success to guide the project.

<u>Participation/Engagement</u>

- Number of parks contributing data to NPN Nature's Notebook database
- Implementation of "Bridges to the Classroom" programs between Parks and public or charter schools (including Rangers in the Classroom, visits engaging Marin Headlands Institute, Field Centers, Outdoors Schools, etc.)
- Number of NPS and Natural Reserve System (NRS) staff trained to use NPN protocols
- Number of staff and members of the public registered on the USA-NPN website.
- Endorsement of activities by Park superintendents and/or I&M
- Maintain list of stakeholders by category (science, education, herbaria, conservation, restoration)
- Integration of phenological monitoring into visits of school classes to parks
- Creation of new monitoring and education partnerships: California Native Plant Society, Americorps, SCA & Reserves or Parks
- UC Reserve participation: Number of UC undergraduates earning research credits, number of reserves participating, number of reserve docents/staff involved, etc.

<u>Demonstrate value to land managers</u>

- For species selected for monitoring, link I & M data to phenological patterns (to assess whether population performance is related to phenological patterns)
- Discover and report conceptual connections between phenological signals (e.g., shortening flowering periods or failure to flower), environmental conditions, population failure, and natural resource management decisions
- Identify phenological indicators of population instability or decline (e.g., near range margins, or amid disruptive invasives or diseases)
- Identify species that are "most" and "least" responsive to climate, and link this to mean plant performance (e.g., flowering duration, or quantity of fruit or seed production)

<u>Document preparation (to be accessible on-line or disseminated electronically)</u>

- Creation of Standard Operating Procedures for place-based phenological monitoring: SOPs would address species selection; spatial sampling of species; how to establish phenology trails; label plants; train volunteers or staff; provide data sheets; collect completed data sheets; institutionalize data uploading to NPN website
- Create products that are compatible with agency reports and metrics (e.g., USFS Score Cards, NPS I&M Vital Signs)
- Creation of decision-making tools to facilitate design of an on-ground phenology project including species selection

<u>Identification/collation of legacy data</u>

- Collation of legacy data from UC NRS reserves, parks, and Center for Forest Genetics so that future researchers can compare historical with current/future phenological patterns; focus *particularly on species selected for monitoring* so that we can compare current phenology to historical "baseline" data
- Identify species with particularly rich herbarium records to promote for specimen-based analyses and for future phenological monitoring efforts (if not included in focal taxon list).

<u>Use of data</u>

- Download existing data from USA-NPN database & create synopsis report.
- Identify phenological indicators of population viability or growth: general or species-specific phenological signals that are associated with high plant population density, high pollinator abundances or diversity, or high seed production.
- Demonstrate quantitative relationships between phenological events or phenophase duration and climatic or environmental conditions

<u>Funding</u>

- Establish linkages between the CPP and national planning efforts to identify vulnerable species and communities (e.g., see the USDA Forest Service' *National Roadmap for Responding to Climate Change*: detecting vulnerable species and communities)
- Solicit and obtain additional funding by leveraging current NPS support: matching funds from foundations, federal agency support, UCOP support

IV. Upcoming tasks

The workshop attendees participated in a brief discussion to identify actions that would enhance the value or efficiency of the tasks that the core NPS, USA-NPN, and UCSB collaborators are planning for the near future. Workshop participants indicated that they would be willing to suggest the names of stakeholders, invitees, and participants in those upcoming activities for which we want to reach out to all interested parties. Following are the ideas generated by this short discussion.

(1) Schedule webinars to inform maximum number of stakeholders and participants of the goals and the educational and research opportunities to be provided by the CPP.

(2) Schedule briefing webinars to:

a) inform National Park representatives of each region about the project

b) inform education and outreach staff of project goals

c) solicit and answer questions about scientific and outreach goals

d) gather ideas and solicit participation for project implementation

(3) Schedule biogeographic conference calls (desert, coastal, and mountain) to:

a) Select species (at conference call with regional scientists)

b) Schedule late winter training trips to southernmost pilot National Parks (Mojave, Joshua Tree, Santa Monica Mountains), to which we invite staff from nearby UC Natural Reserves (Stunt Ranch Reserve, Granite Mountains, Deep Canyon, Burns Piñon Ridge, Box Springs, Boyd Deep Canyon Desert, James San Jacinto)

c) Query NPS staff at pilot parks to obtain descriptions of their current educational programs and format (e.g., one-hour presentations and demos in the field; outreach to schools; participation of volunteers or docents)

Note: these calls could include faculty directors, field researchers, and/or on-site staff directors of nearby UC Natural Reserves

(4) Learn what kinds of data (or metadata) are accessible or available from Inventory and Monitoring (I & M) Networks

(5) Create a one-page briefing or fact sheet for widespread distribution to NPS staff, educators, researchers, and users of national parks and UC natural reserves.

(6) Continue to build list of contacts and stakeholders, and invite them to Project Briefing Webinars. These include representatives of climate change consortia (contacts available through Connie Millar), vegetation specialists (contacts through Todd Keeler-Wolf), Friends of UC Reserves (contacts through Mark Stromberg and individual UC Reserve directors and managers).

(7) Think about one-day campaigns to draw attention to phenological monitoring in parks and reserves (July 4th: Flowering Independence Day! February 14th: Flowers for Valentine's Day! Labor Day: Flowers Work for Us Day! June 21st: Flowers for the First Day of Summer!)

(8) Design a brief survey for park contacts to get a sense of: (a) what are the most important management issues of concern to the park, particularly those that concern particular plants and/or plant-animal interactions; and (b) what are the formats of the parks educational products: are they most interested in running programs for one-time (one-hour) visitors, for independent hikers, or for long-term programs involving school children or repeat visitors?

Note: A .pdf version of this report is available at the following URL: http://www.usanpn.org/CPP

LIST OF APPENDICES

Appendix A. List of workshop participants.

Appendix B. Workshop Agenda

Appendix C. *California Phenology Network: Goals & Goblins*, a powerpoint presentation provided by Susan Mazer.

Appendix D. *Phenology as a tool for science, decision-support and education/interpretation*, a powerpoint presentation provided by Jake Weltzin, Kathryn Thomas and Kathy Gerst.

Appendix E: Record of Workshop Discussion Not Captured in Main Report

Appendix F. Preliminary Floristic Summaries of National Park and UC Natural Reserves.

Appendix A: List of Workshop Participants

National Park Service:
Dr. Angie Evenden, NPS Californian CESU, Berkeley, CA
Dr. Ben Becker, NPS Pacific Coast Science and Learning Center
Dr. Christy Brigham, Santa Monica Mountains NRA
Sylvia Haultain, Sequoia and Kings Canyon National Parks
Stassia Samuels, Redwood National and State Parks
Sue Fritzke, Golden Gate NRA

University of California:
Dr. Susan Mazer, UC Santa Barbara
Brian Haggerty, UC Santa Barbara, Ph.D. Student
Liz Matthews, Incoming UCSB Post-Doc
Dr. Peggy Fiedler, UC Reserve System
Dr. David Ackerly, faculty UC Berkeley
Dr. Susan Harrison, faculty UC Davis
Dr. Mark Schwartz, faculty UC Davis
Dr. Mark Stromberg, UC Hastings Natural History Reserve
Dr. Elsa Cleland, faculty UC San Diego
Margot Higgins, UC Berkeley Ph.D. Student

USA-National Phenology Network:
Dr. Jake Weltzin, National Phenology Network
Dr. Kathryn Thomas, National Phenology Network
Kathy Gerst, National Phenology Network, Ph.D. Student

Other:
Dr. Connie Millar, paleoecologist USFS Pacific Southwest Research Station, Albany, CA
Dr. Todd Keeler-Wolf, California Dept of Fish & Game, Natural Diversity Database

Appendix B. Workshop Agenda

WORKSHOP TO DEVELOP SCIENTIFIC FRAMEWORK FOR CALIFORNIA PLANT PHENOLOGY PROJECT (CPP)

Tuesday, November 2, 2010, 9:00 am – 5:00 pm
UC Berkeley Campus, 103 Mulford Hall

9:00 – 9:15 Brief introductions of workshop participants (name, interest in phenology)

9:15 – 9:30 Overview of CA Phenology Project goals –Susan Mazer

- What we are committed to doing from funding proposal & timeline
- Desired outcomes of the project.

9:30 – 9:45 Park manager perspective – Christy Brigham and Sylvia Haultain

- Scientific information needs to support resource management in the face of climate change

9:45 – 10:00 USA-NPN, Nature's Notebook and Climate Change – Jake Weltzin and /Kathryn Thomas

10:00 – 12:00 (w/short break incorporated)
Participants share ideas and discuss the first two workshop goals:

1. Identify and discuss how we can best use plant phenology to monitor resource response to climate change across national parks and reserves in California (and beyond?).
2. For the approaches suggested in #1, identify and discuss scientific questions or hypotheses that will be both interesting scientifically AND relevant to resource managers.

12:00 – 12:30 LUNCH (we will order in or bring your own)

12:30 – 13:45 Develop set of prioritized recommendations on California Phenology Project monitoring approaches and the scientific questions to focus on

13:45 – 14:45 Define initial scientific framework for project

14:45 – 15:00 BREAK

15:00 – 16:00 Identify criteria for selecting plant phenology monitoring targets

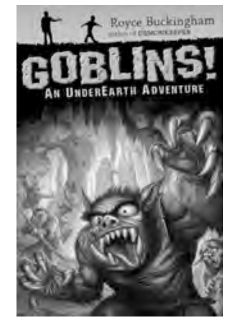
16:00 – 17:00 Next Steps: Action Plan, Workgroups and Assignments

17:00 ADJOURN

California Phenology Network: Goals & Goblins

Collaborators:
National Park Service
UCSB
National Phenology Network

California Phenology Network: Goals & Goblins



California Phenology Network: Goals

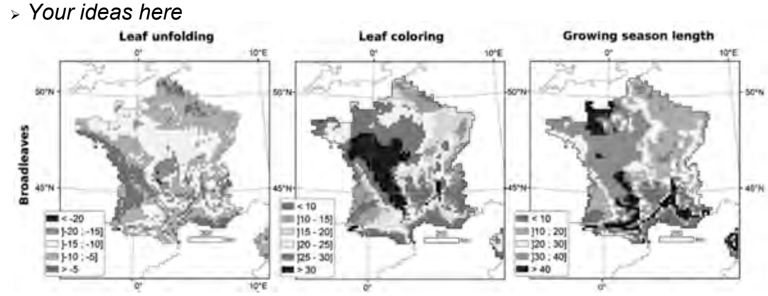
Identification of specific, tractable questions that:

- enable forecasts of biological responses to climate change

California Phenology Network: Goals

Identification of specific, tractable questions that:

- enable forecasts of biological responses to climate change
  - Will the flowering season becoming compressed or extended?
  - Can climate predict phenophase onset, events, duration, or synchrony?
  - *Your ideas here*



Lebourgeois, et al. 2010. *Int J Biometeorol* 54:563–581

Predicted changes (in days) by 2100 in spring leaf unfolding, autumn leaf coloring, and growing season length. Each map shows the predicted difference between the mean values from 1991–2000 and the predicted values for 2071–2100.

California Phenology Network: Goals

Identification of specific, tractable questions that:

- enable forecasts of biological responses to climate change
- inform land management decisions
  - Which kinds of species are most sensitive to climate change?
  - Which species' persistence is most threatened?
  - Which habitats or mutualisms will be most disrupted?



California Phenology Network: Goals

Identification of specific, tractable questions that:

- enable forecasts of biological responses to climate change
- inform land management decisions
- use historical data: e.g. herbaria, journals, archives
  - **Herbarium sheets**: species with the most long-term collection records
  - **Herbarium sheets**: species with most wide-spread geographic range (elevation, latitude)
  - **Informal phenological records**: museum or botanical garden archives
  - Individual professional or amateur journals
  - *Your ideas here*



California Phenology Network: Goals

Determine criteria for species selection:

- Distribution across…….largest number of parks and reserves
  ...largest number of biomes (to be defined)
  …widest elevation or latitudinal ranges
- Include natives and aliens/invasives
- Include representatives all growth forms
- Include keystone species: consider pollinators and seed-dispersers
- Include charismatic or historically important taxa: e.g., Joshua trees, redwoods, perennial grasses
- Include species that are accessible to the public outside of parks?
- *Taxa must be accessible to park and reserve staff and visitors*
- *Your ideas most definitively here!*

California Phenology Network: Goals

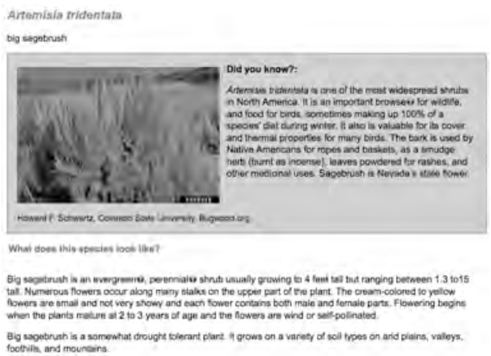
Choose species for initial and future monitoring:

- 2011: Focus on six pilot parks
  - Identify species for monitoring in southernmost parks ASAP
  - Select species to monitor in remaining parks and UC Reserves


California Phenology Network: Goals

Develop species profiles and protocols for selected taxa that aren't on the current NPN list

- Photos and descriptions of phenophases
- Include species in NPN interface



Artemisia tridentata

big sagebrush

Did you know?:

Artemisia tridentata is one of the most widespread shrubs in North America. It is an important browse for wildlife, and food for birds, sometimes making up 100% of a species' diet during winter. It also is valuable for its cover and thermal properties for many birds. The bark is used by Native Americans for ropes and baskets, as a smudge herb (burnt as incense), leaves powdered for rashes, and other medicinal uses. Sagebrush is Nevada's state flower.

Howard F. Schwartz, Colorado State University, Bugwood.org

What does this species look like?

Big sagebrush is an evergreen, perennial shrub usually growing to 4 feet tall but ranging between 1.3 to15 tall. Numerous flowers occur along many stalks on the upper part of the plant. The cream-colored to yellow flowers are small and not very showy and each flower contains both male and female parts. Flowering begins when the plants mature at 2 to 3 years of age and the flowers are wind or self-pollinated.

Big sagebrush is a somewhat drought tolerant plant. It grows on a variety of soil types on arid plains, valleys, foothills, and mountains.

California Phenology Network: Goals

Develop species profiles and protocols for selected taxa that aren't on the current NPN list

- Photos and descriptions of phenophases
- Include species in NPN interface

Which phenophases should I observe?

Leaves

Do you see...?

Emerging leaves
In at least 3 locations on the plant, an emerging leaf is visible. A leaf is considered "emerging" once the green tip is visible at the end of the leaf bud, but before it has fully unfolded to expose the petiole (leaf stalk) or leaf base. For *Artemisia tridentata*, primary new leaves develop along the main stem.

Young unfolded leaves
In at least 3 locations on the plant, a young unfolded leaf is visible. A leaf is considered "young" and "unfolded" once the petiole (leaf stalk) 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. The leaf may need to be bent backwards to see whether the petiole or leaf base is visible.

Flowers

Do you see...?

Open flowers
In at least 3 locations on the plant, an open fresh flower is visible. Flowers are considered "open" when the reproductive parts are visible between unfolded or open flower parts. Do not include spent (wilted) flowers that remain on the plant.

Full flowering
For the whole plant, at least half (50%) of the flowers are open and still fresh.

Fruits

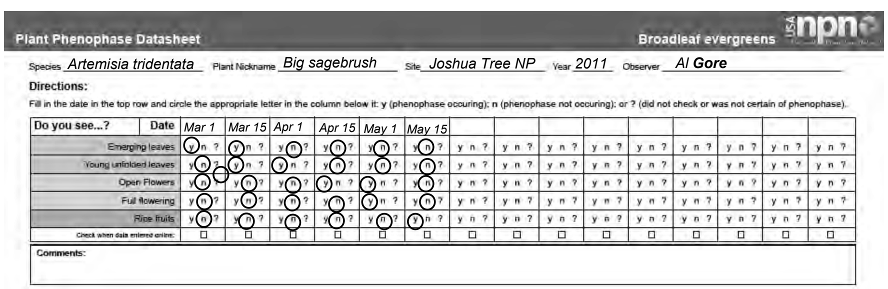
Do you see...?

Ripe fruits
In at least 3 locations on the plant, a ripe fruit is visible. For *Artemisia tridentata*, a fruit is considered ripe when it has turned dark brown in color.

California Phenology Network: Goals

Develop species profiles and protocols for selected taxa that aren't on the current NPN list

- Photos and descriptions of phenophases
- Include species in NPN interface



Plant Phenophase Datasheet — **Broadleaf evergreens** — USA npn

Species *Artemisia tridentata* Plant Nickname *Big sagebrush* Site *Joshua Tree NP* Year *2011* Observer *Al Gore*

Directions:

Fill in the date in the top row and circle the appropriate letter in the column below it: y (phenophase occuring); n (phenophase not occuring); or ? (did not check or was not certain of phenophase).

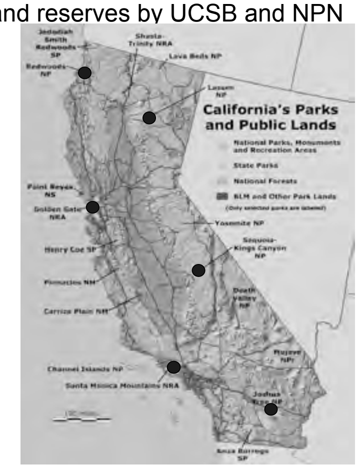
Do you see...? Date	Mar 1	Mar 15	Apr 1	Apr 15	May 1	May 15									
Emerging leaves	(y) n ?	(y) n ?	y (n) ?	y (n) ?	y (n) ?	y (n) ?	y n ?	y n ?	y n ?	y n ?	y n ?	y n ?	y n ?	y n ?	y n ?
Young unfolded leaves	y (n) ?	(y) n ?	(y) n ?	y (n) ?	y (n) ?	y (n) ?	y n ?	y n ?	y n ?	y n ?	y n ?	y n ?	y n ?	y n ?	y n ?
Open Flowers	y (n) ?	y (n) ?	y (n) ?	(y) n ?	(y) n ?	y (n) ?	y n ?	y n ?	y n ?	y n ?	y n ?	y n ?	y n ?	y n ?	y n ?
Full flowering	y (n) ?	y (n) ?	y (n) ?	y (n) ?	(y) n ?	y (n) ?	y n ?	y n ?	y n ?	y n ?	y n ?	y n ?	y n ?	y n ?	y n ?
Ripe fruits	y (n) ?	y (n) ?	y (n) ?	y (n) ?	y (n) ?	(y) n ?	y n ?	y n ?	y n ?	y n ?	y n ?	y n ?	y n ?	y n ?	y n ?
Check when data entered online:	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Comments:

California Phenology Network: Goals

Train NPS and UCNRS staff in NPN protocols

- 2011-2012: Rotating visits to parks and reserves by UCSB and NPN collaborators
  - ✓ NPS and UCNRS scientists
  - ✓ NPS interpreters
  - ✓ NPS and UCNRS docents



California Phenology Network: Goals

Train NPS and UCNRS staff in NPN protocols

- 2011-2012: Rotating visits to parks and reserves by UCSB and NPN collaborators
  - ✓ NPS and UCNRS scientists
  - ✓ NPS interpreters
  - ✓ NPS and UCNRS docents
- Conduct webinars and workshops for these groups

Planting the Seed for Citizen Science

Santa Monica Mountains National Recreation Area
January 30, 2010

Brian Haggerty, M.S.
Susan Mazer, PhD
Department of Ecology, Evolution & Marine Biology
University of California, Santa Barbara

UCSB Phenology Stewardship Program

USA npn National Phenology Network

California Phenology Network: Goals

Outreach and Education

- Develop activities for park rangers to provide to supervised visitors
- Develop opportunities for monitoring by independent visitors: e.g., design signs, phenology trails, data sheets
- Create on-line materials for teachers whose classes visit a park
- Create on-line materials for teachers who cannot visit parks

California Phenology Network: Goals

Outreach and Education

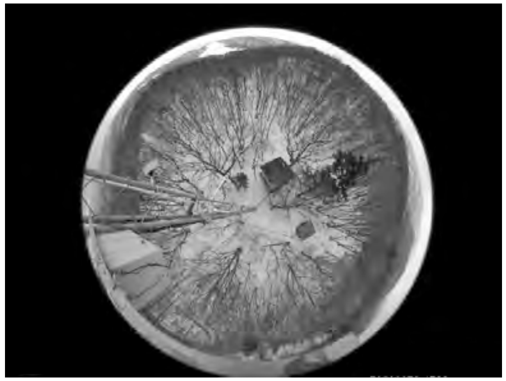
- Use of new technologies for phenological monitoring
  - ➢ smart phones

Ceci n'est pas un smartphone

California Phenology Network: Goals

Outreach and Education

- Use of new technologies for phenological monitoring
  - ➢ smart phones
  - ➢ phenocams
  - ➢ on-line data entry to NPN



The Phenology Handbook

A guide to phenological monitoring for students, teachers, families, and nature enthusiasts

Brian P Haggerty and Susan J Mazer
University of California, Santa Barbara

California Phenology Network: lessons learned at UCSB

Outreach and Education: current programs at UCSB

- Phenological education is integrated into year-round *Kids In Nature* Program for 5th-graders
  - ✓ 4 native plant phenology gardens are installed + 1 under construction
- *KIN* now includes three 5th-grade classes + 1 after-school Boys & Girls Club program
- Phenology trail established at Coal Oil Point Natural Reserve
- Undergraduate course: **four teams of students are preparing phenology lesson plans that cover California science standards**
- Delivery of 2- to 6-hour workshops for teachers, docents, and park staff

Outline

- Phenology for science, decision-support, and interpretation
- The USA National Phenology Network
- Phenology monitoring
- Framework for collaboration and implementation

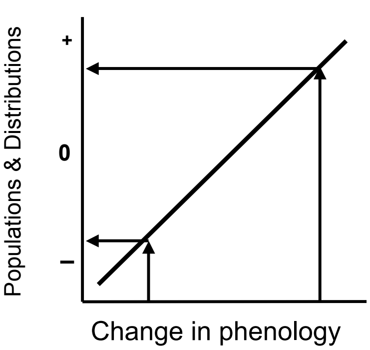

"Phenology…is perhaps the simplest process in which to track changes in the ecology of species in response to climate change."
(IPCC 2007)


Phenology – Timing is Everything!

- Primary productivity
- Trophic relationships
- Species interactions
- Species movements
- Human activities

Photo David Inouye

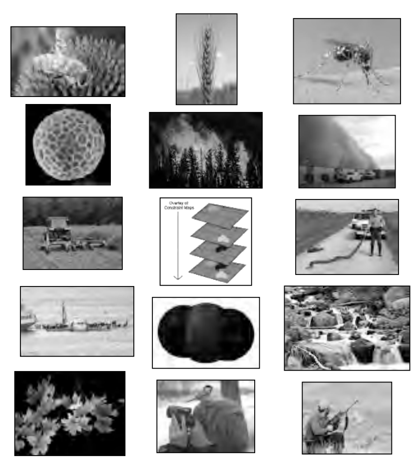
Predicting vulnerability, invasions and distributions



Willis et al. 2008 PNAS
Moller et al. 2008 PNAS
Willis et al. 2010 PLOS Biology
Hulme 2010 New Phyt.
Ozgul et al. 2010 Nature

Applications and decision-support tools

- Science
- Predictive services
- Health
- Resource mgmt
- Conservation
- Agriculture
- Ecosystem services
- Recreation



Education and Interpretation through Engagement

Outline

- Phenology for science, decision-support, and interpretation
- **The USA National Phenology Network**
- Phenology monitoring
- Framework for collaboration and implementation

USA npn National Phenology Network

A new data resource—*a national network of integrated phenological observations across space and time*

Key Goal

Understand how plants, animals and landscapes respond to environmental variation and climate change

USA-NPN in a nutshell

- A national biological science and monitoring program
- Agencies, NGOs, academia, the public
- Standard protocols for plants, animals & landscapes
- Facilitate scaling from 'leaf to globe'
- Integrate with other monitoring networks
- Business to Business and Business to Customer

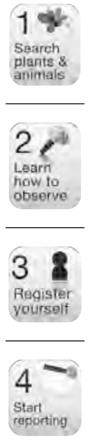
What we do…

- Develop a national phenology information management system
- Develop partnerships for implementation
- Conduct and facilitate education and outreach
- Facilitate phenology science and research
- Facilitate development of decision support tools
- Develop a national phenology monitoring system

Outline

- Phenology for science, decision-support, and interpretation
- The USA National Phenology Network
- **Phenology monitoring**
- Collaboration and implementation

nature's notebook
a project of the USA-NPN



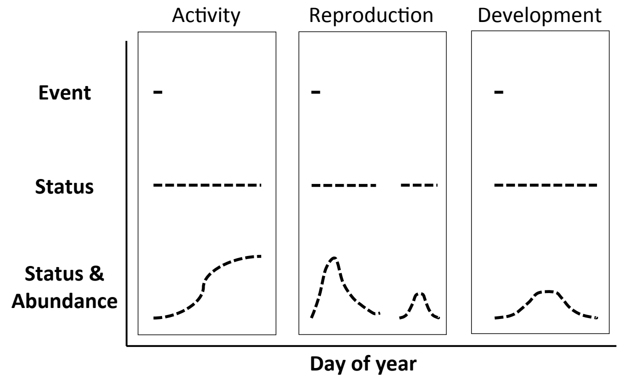
- Go to www.usanpn.org
  - · 253+ plant species
  - · 158+ animal species
  - · Status monitoring
  - · Core protocols

Coming soon

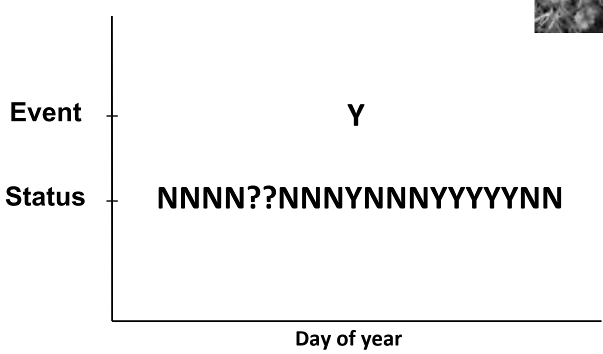
- Species on demand
- Abundance reporting
- User profiles

Metadata: method used, effort reporting, condition of site & organism

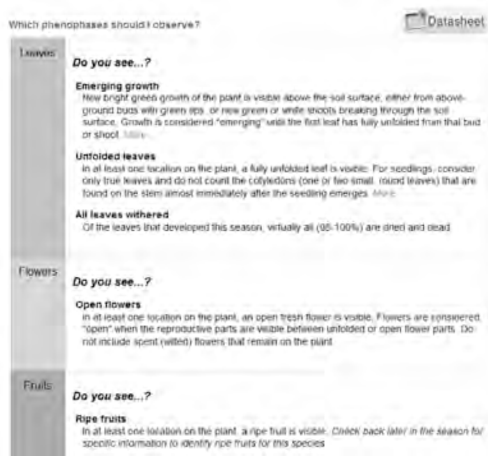
Phenology Monitoring Methods



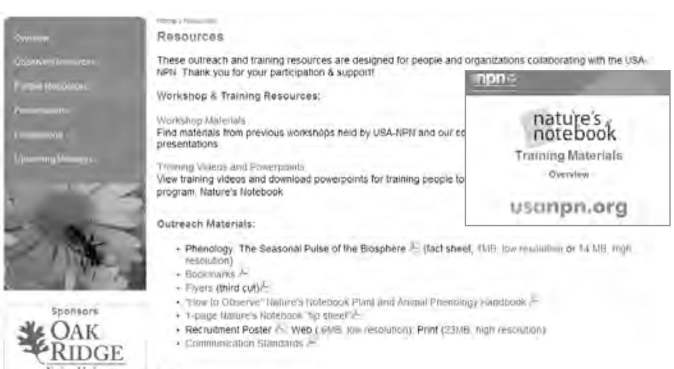
Event vs Status Monitoring
e.g., flowering



On-line observation protocols



Training resources



www.usanpn.org/resources/resources

Outline

- Phenology for science, decision-support, and interpretation
- The USA National Phenology Network
- Phenology monitoring
- **Framework for collaboration and implementation**

The Collaboration

Five Park Networks

Two Research Learning Centers

CA-CESU

An integrated scientific framework

Framework Questions

↕

Indicators

↕

Phenology Observations

The implementation framework

- **Target species**
- **Protocols: phenophase definitions and sampling design**
- **Supporting services: species profiles, registration into NPDb**
- **Observer training and support**

Appendix E: Record of Workshop Discussion Not Captured in Main Report

Compiled by Kathy Gerst, Ph.D. Student USA-NPN

I. Suggestions for potential species selection criteria
II. Compilation of questions and methodology for potential research ideas
III. Additional ideas related to developing selection criteria and a project scientific framework

I. Suggestions for potential species selection criteria:

- Choose species for which we have older published demographic studies to get earlier data to see population/demographic/phenological patterns for which to compare new data.

- Focus on broadly distributed species (i.e. *Artemesia californica*), and/or narrowly endemic species (i.e. *Lessingia franciscana*), and/or charismatic megaflora (i.e. *Sequoia sempervirens*).

- Choose species that are common and widespread, as well as species that are rare.

- Choose select species interactions (e.g. plant/pollinators) to bring in animal monitoring.

- Choose keystone species, as they are important links in regional food webs.

- One approach could be for each park/reserve to choose 3 plants, 3 animals. I.e. One animal/plant that is the characteristic dominant on landscape, one that is a legacy species on landscape, and a last species which is whatever you want. This approach would allow researchers to ask different questions. Driven by ability to ask a diversity of management questions, not necessarily specific criteria.

- Link phenology project to the inventory and monitoring program in the NPS. I&M monitors selected vital signs- phenology was not on the radar when this program was established. Emphasis on the importance of building around nodes where we have data to monitor climate.

- Need to come up with a balance between a top-down vs bottom up model for species selection. NEON is top-down; they dictate what everyone has to monitor. Their approach is using three species- one that is abundant, one that is locally important, and one that they choose based on interest.

- There is a benefit of using the new "indicators of climate change in California" publication in driving our selection and approach.

- Choose species that occur over *smaller*-scale topographic gradients and develop phenology trails that capture these gradients. Examples of small scale gradients could be fog on the coast, or elevation in the desert. Recognize that California plant distributions and communities are patchy- so small scale makes more sense logistically.

- Utilize the NVC community classifications for each park; use the indicator or dominant species that were identified in the community classifications as monitoring species.

- Stratify choices of taxa to include (1) locally interesting, (2) rare species, (3) broad species that occur across many parks.

- Consider iconic species animal interactions for guiding final taxon choices (yucca moth, checkerspot butterfly, etc…). Many citizens may be more interested in animal spotting.

- Think in terms of functional groups rather than species to incorporate taxa across all parks. If there is phylogenetic conservatism of sensitivity (meaning there is a strongly conserved relationship between closely related taxa) it may not be necessary to choose a single variety of an oak, for example, as the monitored taxon. Then, identify evolutionary conservative traits that are easy to follow in the type of monitoring we expect to carry out.

- Study of phenology of whole communities. Determine if there is a bell curve of phenology of the whole community. We can pick key communities from the NVC. It might be easier to compare across gradient observations at the community level. Community-level information might tell you something about synchrony in a community and this could guide when managers would use different management treatments.

II. Compilation of questions and methodology for potential research ideas

(a) Species distributions, demography, and phenology

- Do phenology changes predict species loss?
- Is invasive species establishment responding directly to climate variation and change?
- Monitor along a gradient of the competitor abundance of invasive species. Are invasives compressing the growing season of the natives?
- Are certain plant traits (life form, maturity, etc) associated with taxa that do respond to environmental variation/climate change? Do some of these traits explain patterns of invasion?
- Which environments in California are most/least climate-sensitive, based on factors like elevation, soils, distance from coast, dominant species, and their traits? Are any habitats exceptionally 'safe' or 'at risk' compared to others?
- Link long term phenology monitoring with existing vegetation plots and monitoring.
- What is happening at the edge of species ranges? We might be able to identify phenological signals of species failures by using margins of species distributions and to address questions related to species distributions and range limits. Might be useful to identify species whose range edge occurs near the parks, or at least ID where range edges of potential species choices are located relative to park spatial boundaries. This could help answer the question: which species ranges are expected to shrink? Must remember that *climatic edge of a species range is not necessarily its geographic edge.*
- Can we identify phenological signals that indicate impending species failure?
- What is relationship between growing and flowering season length and climate? If we know what this looks like now, we might be able to make projections.

(b) Trophic structures:

- As phenology of oak leaf development in spring predicts fall acorn production, how does this subsequently affect feral pig populations the next year? (Has major management implications).
- What is relationship between phenology of organisms and their pathogens? (e.g. sudden oak death)
- Are pollinators tracking climate the same as plants?
- When does phenological change have ecological impacts? Particularly, how do shifts in phenology change predator-prey relationships, pollination, etc.
- Test hypotheses around ecological/multitrophic impacts of phenology changes.

(c) Gradients, phenology and climate:

- Can we detect phenological responses to microclimatic gradients?
- Utilize large and small elevational and latitudinal gradients within California to understand role of climate in determining phenology
- Identify biophysical gradients (e.g. temperature and precipitation on elevational gradients) and choose ecologically-relevant species (dominant species). Biophysical gradients provide: current environmental spectrum that can be used to forecast future scenarios.
- Potential for common garden experiments on gradient
- Use fine scale montane phenological monitoring in order to validate (or not) climate downscaling info.
- How can we stratify across vegetation types/habitats to identify communities most threatened by climate change (due to changing mutualisms, effects on demography, etc)?
- Look at ecotones in parks—what is the relationship of phenology to treeline? Is there some threshold that changes at the treeline ecotone?
- Identify species that span a habitat boundary—how they behave at that boundary? How do they behave across these boundaries?

(d) Historical Context

- Establish selected temporal baselines on selected species abundance (with phenology) to allow future comparisons, measure of change.
- Mine common garden studies for data. Particularly, conifers and broad-leaved trees along elevational gradients. Through the Institute of Forest Genetics there are resources available for this kind of data.
- Utilize herbaria and long term data sets to choose species with differing phenological responses over time/ responses to climate.

(e) Integrating technology with on-the-ground monitoring

- Infrastructure: identify overlap of existing remotely-sensed capabilities, on the ground monitoring, and climate towers. Satellites, webcams, climate towers, on-the-ground measurement, and eddy-flux towers all interact in this context.
- Leverage existing networks for co-location (e.g. climate stations, other monitoring plots) especially long term stable administrators and funds
- Develop and use remote observation technologies- webcams, security camera options
- Link observations to climate-monitoring stations; Monitoring could be done close to weather stations or we could use the mini-thermocrons near monitoring sites.

- Can we do solar modeling in the parks? May not be able to have the microclimate observations at each phenology trail, but solar modeling could fill this gap if necessary.

(f) Education

- Use NRS K-12 public outreach to tap into high school and retirement communities; engage and thus teach. Gather data!
- Choose species that exist inside and outside parks to further engage public. Challenge false boundaries of 'protected' land.
- Integrate school properties with phenology observations—pass out seeds to school to develop their own projects. E.g. the Great Sunflower project

(g) Social aspects

- Connect phenology monitoring with sense of place. Will answer local's questions about what is happening 'here' with regard to climate change and conservation issues.
- Look for disparate and divergent interests in participants. E.g. Mountain peak 'baggers' can monitor elevational extremes. Gardeners can discuss when their roses are blooming.
- Engage NPS interpretive specialists ASAP in order to (a) incorporate their expertise, and (b) excite them into making this a priority.
- Use volunteers to collect data.
- Survey parks about what their most current management issues are, most vulnerable habitats, charismatic species. Design species and community to be based on that survey. Let's generate engagement and interest based on response to survey.

III. Additional ideas related to developing selection criteria and a project scientific framework:

Climate sensitivity: Recognize that some species we may choose may not be sensitive to climate. Additionally, an evolutionary phenology indicator may be different from a plastic phenology indicator. By getting lots of spatial data on a specific species through time, we get more info on whether it's responding to local climate, or climate change in general.

Issue of scale: Address the problem of multiple scales- individual park level, network level, can we develop a framework that applies to whole state. Our scientific framework could have different scaling factor applied to it.

Long vs Short term success: Connection between what happens in long term vs. short term: If we can show that we can detect climatological signal in one year, and integrate different technologies, we will show success. This gives leverage to show we can do this for a long-term monitoring project. Species decisions can be based on short term goals to prove we can do this, and not species that already have long term data. Provides adaptive management approach, new stakeholders in future, relaying this type of science and information to policy makers and public.

Phenological Sensitivity: Developing a broader network for understanding sensitivity would be interesting for choosing species and questions. *What is phenological sensitivity?* Is it due to demography, or distributions? Or are we talking about phenological sensitivity to environment? Some groups are currently developing vulnerability assessment tools. NCEAS group is using inter-annual variability to look at phenological sensitivity and phylogenic sensitivities.

Green vs brown: Focus on autumn phenology in addition to spring phenology. There is a tendency to focus on spring phenology- green-up (east coast/snow melt focus). But green-up in California is totally dependent on rainfall timing which is variable. Spring phenology signals very clear- but autumn phenology is much more unclear for determining long term trends. Green-up and brown-up are Mediterranean climate specific issues that may be more important for our climate than other sites. Regionally and locally let's think about what are most valuable and most attractive for Californians to do. Less important to find the perfect species that are indicators of all of North America climate change.

Growing season length: Rainfall is the big driver here (compared to temperature on the east coast), more difficult here than in other places to make linkages with climate change (as opposed to adaptation to variation). We need to recognize that many California plants have adaptive bet hedging strategies to natural variation in rainfall and climate. One theme that links the rainfall/temperature dichotomy is the issue is of length of the growing season- how to predict length of growing season (resource availability for animals) as you go up in elevation- drought doesn't cut things off earlier like lower in elevation. Growing season here always starts with rainfall. This is an open question. We could model this and let models drive questions. Need to find way to get grad students interested in modeling and participating, next generation of scientists taking on these issues.

Life form: Phenology and life form stratification: population-level observations of perennial plants rather than single year observations of individual annual plants. In perennial species—could ask rank order questions within a site; such as, is the rank order the same every year? If you are first to leaf out in year one, are you always the first to leaf out in a population? Is rank-order conserved?

Predictions: Choose key indicators for entities that are likely to be changing in California (e.g. hot summer temps will move towards the coast, with the warmest temps at coast, but warmest summers inland). Species (or guilds, or vegetation types, etc) that are most strongly tied to climate might be most likely to change—*how* are they going to change? Then, we can look for new weeds, broadening niches.

Disturbance: another potential important question to address: how does phenology interact with ecological disturbance to effect landscape conversion, human health, etc.. Fires as a disturbance (build-up of fuels, invasion of annual grasses, etc…). How can we answer questions about disturbance, when building from a framework beginning with single species, across environmental gradients, across space.

Restoration: Given that observation will take place across parks, we could connect this work to restoration in the state; some species are commonly planted for restoration; perhaps observing these species, in many places, could help inform where restoration practitioners might want to choose source populations; identify places/populations that are most or least responsive to climate change (depending upon the need). This brings up the issue of plasticity vs underlying genetic variability, and from where we supply restoration propagules. This can be utilized to justify habitats and areas that need to be conserved for future restoration projects (areas that can also be used for preservation)

Appendix F. Preliminary Floristic Summaries of National Park and UC Natural Reserves.

Compiled species lists for 19 California NPS Units (draft analysis)

Prepared by Kathryn Thomas, US Geological Survey and USA-NPN Project Scientist,
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Background

Plant species lists were obtained from 19 California National Park units in the fall of 2010 in order to develop supporting materials for the NPS-California Phenology Project. The species lists obtained represent different levels of completion and verification and, in some cases, different currency of nomenclature.

The species lists was compiled into an Access database, with 15,392 total records. The database contains the original imported park species list and a compiled species table currently with six fields (described below). The two important fields are LatinName_Original and LatinName_SppOnly. The former is the original species record from each park and the latter the species name with varieties, subspecies, and forms removed and with partial update of nomenclature.

The summary presented below represents initial analysis of the floras of 19 National Park units within California. The summaries were obtained through querying the Access database. Additional refinements and queries are expected. The data will ultimately be linked with habitat data from each park and data from NatureServe on dominant and associate species in Californian ecological systems.

Summary Results

Number of species reported for each park (excluding spp, var. and forma except where all parks reported the same subgroup, many parks report multiple ssp., var. and/or form for each species)

Park Name	ParkCode	Num Spp
Cabrillo National Monument	CABR	414
Channel Islands National Park	CHIS	766
Devil's Postpile National Monument	DEPO	363
Death Valley National Park	DEVA	1087
Golden Gate National Recreation Area	GOGA	718
John Muir NHS	JOMU	455
Joshua Tree National Park	JOTR	749
Lava Beds National Monument	LABE	347
Lassen Volcanic National Park	LAVO	876
Mojave National Preserve	MOJA	865
Muir Woods National Monument	MUWO	262
Pinnacles National Monument	PINN	651
Point Reyes National Seashore	PORE	755
Redwood National and State Parks	RNSP	908
Santa Monica Mountains National Recreation Area	SAMO	1115
Sequoia & Kings Canyon National Parks	SEKI	1450
Whiskeytown National Recreation Area	WHIS	903
Yosemite National Park	YOSE	1582

Total number of unique species among all parks: 4861

Number of shared species among parks

Number of parks	Number of species
1	1911
2	923
3	717
4	425
5	264
6	155
7	105
8	100
9	84
10	57
11	35
12	26
13	21
14	16
15	11
16	7
17	4
18	1

121 species occurring in 11 or more parks, sorted by number of parks in which the species occurs; N= native, NN = non-native; F=forb, FA=Forb-annual, FP=Forb perennial; G?=Graminoid (duration TBD), GA=graminoid-annual, GP=graminoid-perennial, S=shrub, T=Tree

LatinName_SppOnly	Num	Family	CommonName	Nativity	LifeForm
Sambucus mexicana	18	Caprifoliaceae	blue elderberry	N	S
Bromus carinatus	17	Poaceae	California brome	N	GA
Erodium cicutarium	17	Geraniaceae	red-stem filaree	NN	FA
Galium aparine	17	Rubiaceae	annual bedstraw	N	FA
Sonchus asper	17	Asteraceae	spiny sowthistle	NN	FA
Amsinckia menziesii	16	Boraginaceae	fiddleneck	N	FA
Conyza canadensis	16	Asteraceae	horseweed	N	FA
Hordeum murinum	16	Poaceae	smooth barley	NN	G?
Pentagramma triangularis	16	Pteridaceae	goldback fern	N	FP-fern
Rumex crispus	16	Polygonaceae	curly dock	NN	FP
Sonchus oleraceus	16	Asteraceae	common sow thistle	NN	FA
Taraxacum officinale	16	Asteraceae	dandelion	NN	FP
Bromus diandrus	15	Poaceae	ripgut grass	NN	G?
Cirsium vulgare	15	Asteraceae	bull thistle	NN	F
Claytonia perfoliata	15	Portulacaceae	miner's lettuce	N	FA
Elymus glaucus	15	Poaceae	blue wildrye	N	G?
Gnaphalium palustre	15	Asteraceae	lowland cudweed	N	FA

LatinName_SppOnly	Num	Family	CommonName	Nativity	LifeForm
Juncus bufonius	15	Juncaceae	toad rush	N	GA
Lactuca serriola	15	Asteraceae	prickly lettuce	NN	FA
Mimulus guttatus	15	Scrophulariaceae	creek monkey flower	N	FA
Polypogon monspeliensis	15	Poaceae	rabbitsfoot grass	NN	G?
Salix lasiolepis	15	Salicaceae	arroyo willow	N	T/S
Urtica dioica	15	Urticaceae	American stinging nettle	N	FP
Achillea millefolium	14	Asteraceae	yarrow	N	F
Anagallis arvensis	14	Primulaceae	scarlet pimpernel	NN	FA
Artemisia douglasiana	14	Asteraceae	mugwort	N	FP
Avena fatua	14	Poaceae	wild oat	NN	GA
Capsella bursa-pastoris	14	Brassicaceae	shepherd's purse	NN	FA
Convolvulus arvensis	14	Convolvulaceae	field bindweed	NN	FP
Dichelostemma capitatum	14	Liliaceae	blue dicks	N	FP
Epilobium ciliatum	14	Onagraceae	slender willow-herb	N	FP
Erysimum capitatum	14	Brassicaceae	western wallflower	N	FP
Eschscholzia californica	14	Papaveraceae	California poppy	N	FA
Hirschfeldia incana	14	Brassicaceae	shortpod mustard	NN	FP
Juncus balticus	14	Juncaceae	Baltic rush	N	GP
Marrubium vulgare	14	Lamiaceae	horehound	NN	GP
Plantago lanceolata	14	Plantaginaceae	English plantain	NN	FP
Plantago major	14	Plantaginaceae	common plantain	NN	F
Pseudognaphalium californicum	14	Asteraceae	ladies' tobacco	N	F-biennial
Vulpia bromoides	14	Poaceae	brome fescue	NN	GA
Agrostis exarata	13	Poaceae	spike bentgrass	N	GP
Bromus hordeaceus	13	Poaceae	soft brome	NN	GA
Bromus madritensis	13	Poaceae	compact brome	NN	GA
Centaurea melitensis	13	Asteraceae	napa thistle	NN	FA
Centaurea solstitialis	13	Asteraceae	yellow star thistle	NN	FA
Eleocharis macrostachya	13	Cyperaceae	spikerush	N	GP
Epilobium canum	13	Onagraceae	hummingbird trumpet	N	FP
Eriogonum nudum	13	Polygonaceae	naked buckwheat	N	FP
Hordeum brachyantherum	13	Poaceae	meadow barley	N	G?
Leymus triticoides	13	Poaceae	beardless wildrye	N	GP
Lolium multiflorum	13	Poaceae	Italian ryegrass	NN	GA
Madia gracilis	13	Asteraceae	slender tarweed	N	F
Poa secunda	13	Poaceae	Sandberg bluegrass	N	GP
Pteridium aquilinum	13	Dennstaedtiaceae	western bracken fern	N	FP-fern
Raphanus sativus	13	Brassicaceae	cultivated radish	NN	FA
Rumex salicifolius	13	Polygonaceae	willow dock	N	FP
Scrophularia californica	13	Scrophulariaceae	California figwort	N	FP
Solanum americanum	13	Solanaceae	small-flowered	N	S

LatinName_SppOnly	Num	Family	CommonName	Nativity	LifeForm
			nightshade		
Stellaria media	13	Caryophyllaceae	common chickweed	NN	F
Thysanocarpus curvipes	13	Brassicaceae	lace pod	N	FA
Vulpia myuros	13	Poaceae	rat-tail fescue	NN	G?
Agoseris grandiflora	12	Asteraceae	California dandelion	N	F
Amaranthus blitoides	12	Amaranthaceae	prostrate amaranth	NN	FA
Chenopodium album	12	Chenopodiaceae	lambsquarters	NN	FA
Cuscuta californica	12	Cuscataceae	chaparral dodder	N	FP
Cynodon dactylon	12	Poaceae	Bermuda grass	NN	GP
Daucus pusillus	12	Apiaceae	American wild carrot	N	F
Distichlis spicata	12	Poaceae	saltgrass	N	GP
Dryopteris arguta	12	Dryopteridaceae	coastal woodfern	N	FP-fern
Epilobium brachycarpum	12	Onagraceae	Willowherb	N	F
Holodiscus discolor	12	Rosaceae	oceanspray	N	S
Hypochaeris glabra	12	Asteraceae	smooth cat's-ear	NN	F
Koeleria macrantha	12	Poaceae	junegrass	N	FP
Lotus unifoliatus var. unifoliatatus	12	Fabaceae	American bird's-foot trefoil	N	FA
Lupinus bicolor	12	Fabaceae	bicolored lupine	N	FA
Medicago polymorpha	12	Fabaceae	burclover	NN	F
Orobanche fasciculata	12	Orobanchaceae	clustered broomrape	N	FA
Poa annua	12	Poaceae	annual bluegrass	NN	G?
Rorippa nasturtium-aquaticum	12	Brassicaceae	watercress	N	FP
Sisyrinchium bellum	12	Iridaceae	western blue-eyed-grass	N	FP
Trifolium microcephalum	12	Fabaceae	smallhead clover	N	F
Typha latifolia	12	Typhaceae	broadleaf cattail	N	FP
Uropappus lindleyi	12	Asteraceae	Lindley's silverpuffs	N	FA
Vicia americana	12	Fabaceae	American vetch	N	FP
Vinca major	12	Apocynaceae	greater periwinkle	NN	FP
Vulpia microstachys	12	Poaceae	Pacific fescue	N	GA
Agrostis stolonifera	11	Poaceae	creeping bent grass	NN	G?
Amaranthus albus	11	Amaranthaceae	tumbleweed	NN	FA
Aquilegia formosa	11	Ranunculaceae	western columbine	N	FP
Asclepias fascicularis	11	Asclepiadaceae	narrow-leaved milkweed	N	FP
Avena barbata	11	Poaceae	slender wild oat	NN	GA
Brassica nigra	11	Brassicaceae	black mustard	NN	F
Bromus tectorum	11	Poaceae	cheat grass	NN	GA
Calandrinia ciliata	11	Portulaceae	fringed redmaids	N	FA
Cardamine californica	11	Brassicaceae	milk maids	N	F
Chlorogalum pomeridianum	11	Liliaceae	wavyleaf soap plant	N	F

LatinName_SppOnly	Num	Family	CommonName	Nativity	LifeForm
Cirsium occidentale	11	Asteraceae	California thistle	N	FP
Clematis ligusticifolia	11	Ranunculaceae	western white clematis	N	Vine
Cyperus eragrostis	11	Cyperaceae	tall flatsedge	N	G?
Elymus multisetus	11	Poaceae	big squirreltail	N	GP
Equisetum laevigatum	11	Equisetaceae	smooth scouring-rush	N	FP
Erodium botrys	11	Geraniaceae	long-beaked filaree	NN	F
Gnaphalium canescens	11	Asteraceae	everlasting cudweed	N	F
Juncus xiphioides	11	Juncaceae	iris-leaf rush	N	GP
Madia elegans	11	Asteraceae	common madia	N	FA
Oenothera elata	11	Onagraceae	Hooker's eveningprimrose	N	FP
Polygonum arenastrum	11	Polygonaceae	knotweed	NN	F
Quercus chrysolepis	11	Fagaceae	canyon live oak	N	T/S
Rosa californica	11	Rosaceae	California wildrose	N	S
Rumex acetosella	11	Polygonaceae	common sheep sorrel	NN	FP
Salix laevigata	11	Salicaceae	red willow	N	S
Salix lucida	11	Salicaceae	shining willow	N	T/S
Senecio vulgaris	11	Asteraceae	common groundsel	NN	F
Silene gallica	11	Caryophyllaceae	common catchfly	NN	F
Stachys ajugoides	11	Lamiaceae	bugle hedgenettle	N	GP
Symphoricarpos mollis	11	Caprifoliaceae	creeping snowberry	N	S
Torilis arvensis	11	Apiaceae	spreading hedgeparsley	NN	F
Toxicodendron diversilobum	11	Anacardiaceae	western poison-oak	N	Shrub
Trifolium variegatum	11	Fabaceae	whitetip clover	N	FP
Vicia sativa	11	Fabaceae	common vetch	NN	FA
Xanthium strumarium	11	Asteraceae	rough cocklebur	N	FA

121 species occurring in 11 or more parks, sorted by family in which the species occurs

LatinName_SppOnly	Num	Family	CommonName
Amaranthus albus	11	Amaranthaceae	tumbleweed
Amaranthus blitoides	12	Amaranthaceae	prostrate amaranth
Toxicodendron diversilobum	11	Anacardiaceae	western poison-oak
Daucus pusillus	12	Apiaceae	American wild carrot
Torilis arvensis	11	Apiaceae	spreading hedgeparsley
Vinca major	12	Apocynaceae	greater periwinkle
Asclepias fascicularis	11	Asclepiadaceae	narrow-leaved milkweed
Achillea millefolium	14	Asteraceae	yarrow
Agoseris grandiflora	12	Asteraceae	California dandelion
Artemisia douglasiana	14	Asteraceae	mugwort
Centaurea melitensis	13	Asteraceae	napa thistle
Centaurea solstitialis	13	Asteraceae	yellow star thistle

LatinName_SppOnly	**Num**	**Family**	**CommonName**
Cirsium occidentale	11	Asteraceae	California thistle
Cirsium vulgare	15	Asteraceae	bull thistle
Conyza canadensis	16	Asteraceae	horseweed
Gnaphalium canescens	11	Asteraceae	everlasting cudweed
Gnaphalium palustre	15	Asteraceae	lowland cudweed
Hypochaeris glabra	12	Asteraceae	smooth cat's-ear
Lactuca serriola	15	Asteraceae	prickly lettuce
Madia elegans	11	Asteraceae	common madia
Madia gracilis	13	Asteraceae	slender tarweed
Pseudognaphalium californicum	14	Asteraceae	ladies' tobacco
Senecio vulgaris	11	Asteraceae	common groundsel
Sonchus asper	17	Asteraceae	spiny sowthistle
Sonchus oleraceus	16	Asteraceae	common sow thistle
Taraxacum officinale	16	Asteraceae	dandelion
Uropappus lindleyi	12	Asteraceae	Lindley's silverpuffs
Xanthium strumarium	11	Asteraceae	rough cocklebur
Amsinckia menziesii	16	Boraginaceae	fiddleneck
Brassica nigra	11	Brassicaceae	black mustard
Capsella bursa-pastoris	14	Brassicaceae	shepherd's purse
Cardamine californica	11	Brassicaceae	milk maids
Erysimum capitatum	14	Brassicaceae	western wallflower
Hirschfeldia incana	14	Brassicaceae	shortpod mustard
Raphanus sativus	13	Brassicaceae	cultivated radish
Rorippa nasturtium-aquaticum	12	Brassicaceae	watercress
Thysanocarpus curvipes	13	Brassicaceae	lace pod
Sambucus mexicana	18	Caprifoliaceae	blue elderberry
Symphoricarpos mollis	11	Caprifoliaceae	creeping snowberry
Silene gallica	11	Caryophyllaceae	common catchfly
Stellaria media	13	Caryophyllaceae	common chickweed
Chenopodium album	12	Chenopodiaceae	lambsquarters
Convolvulus arvensis	14	Convolvulaceae	field bindweed
Cuscuta californica	12	Cuscataceae	chaparral dodder
Cyperus eragrostis	11	Cyperaceae	tall flatsedge
Eleocharis macrostachya	13	Cyperaceae	spikerush
Pteridium aquilinum	13	Dennstaedtiaceae	western bracken fern
Dryopteris arguta	12	Dryopteridaceae	coastal woodfern
Equisetum laevigatum	11	Equisetaceae	smooth scouring-rush
Lotus unifoliatus var. unifoliatatus	12	Fabaceae	American bird's-foot trefoil
Lupinus bicolor	12	Fabaceae	bicolored lupine
Medicago polymorpha	12	Fabaceae	burclover
Trifolium microcephalum	12	Fabaceae	smallhead clover
Trifolium variegatum	11	Fabaceae	whitetip clover
Vicia americana	12	Fabaceae	American vetch
Vicia sativa	11	Fabaceae	common vetch
Quercus chrysolepis	11	Fagaceae	canyon live oak
Erodium botrys	11	Geraniaceae	long-beaked filaree
Erodium cicutarium	17	Geraniaceae	red-stem filaree
Sisyrinchium bellum	12	Iridaceae	western blue-eyed-grass
Juncus balticus	14	Juncaceae	Baltic rush
Juncus bufonius	15	Juncaceae	toad rush
Juncus xiphioides	11	Juncaceae	iris-leaf rush

LatinName_SppOnly	**Num**	**Family**	**CommonName**
Marrubium vulgare	14	Lamiaceae	horehound
Stachys ajugoides	11	Lamiaceae	bugle hedgenettle
Chlorogalum pomeridianum	11	Liliaceae	wavyleaf soap plant
Dichelostemma capitatum	14	Liliaceae	blue dicks
Epilobium brachycarpum	12	Onagraceae	Willowherb
Epilobium canum	13	Onagraceae	hummingbird trumpet
Epilobium ciliatum	14	Onagraceae	slender willow-herb
Oenothera elata	11	Onagraceae	Hooker's eveningprimrose
Orobanche fasciculata	12	Orobanchaceae	clustered broomrape
Eschscholzia californica	14	Papaveraceae	California poppy
Plantago lanceolata	14	Plantaginaceae	English plantain
Plantago major	14	Plantaginaceae	common plantain
Agrostis exarata	13	Poaceae	spike bentgrass
Agrostis stolonifera	11	Poaceae	creeping bent grass
Avena barbata	11	Poaceae	slender wild oat
Avena fatua	14	Poaceae	wild oat
Bromus carinatus	17	Poaceae	California brome
Bromus diandrus	15	Poaceae	ripgut grass
Bromus hordeaceus	13	Poaceae	soft brome
Bromus madritensis	13	Poaceae	compact brome
Bromus tectorum	11	Poaceae	cheat grass
Cynodon dactylon	12	Poaceae	Bermuda grass
Distichlis spicata	12	Poaceae	saltgrass
Elymus glaucus	15	Poaceae	blue wildrye
Elymus multisetus	11	Poaceae	big squirreltail
Hordeum brachyantherum	13	Poaceae	meadow barley
Hordeum murinum	16	Poaceae	smooth barley
Koeleria macrantha	12	Poaceae	junegrass
Leymus triticoides	13	Poaceae	beardless wildrye
Lolium multiflorum	13	Poaceae	Italian ryegrass
Poa annua	12	Poaceae	annual bluegrass
Poa secunda	13	Poaceae	Sandberg bluegrass
Polypogon monspeliensis	15	Poaceae	rabbitsfoot grass
Vulpia bromoides	14	Poaceae	brome fescue
Vulpia microstachys	12	Poaceae	Pacific fescue
Vulpia myuros	13	Poaceae	rat-tail fescue
Eriogonum nudum	13	Polygonaceae	naked buckwheat
Polygonum arenastrum	11	Polygonaceae	knotweed
Rumex acetosella	11	Polygonaceae	common sheep sorrel
Rumex crispus	16	Polygonaceae	curly dock
Rumex salicifolius	13	Polygonaceae	willow dock
Claytonia perfoliata	15	Portulacaceae	miner's lettuce
Calandrinia ciliata	11	Portulaceae	fringed redmaids
Anagallis arvensis	14	Primulaceae	scarlet pimpernel
Pentagramma triangularis	16	Pteridaceae	goldback Fern
Aquilegia formosa	11	Ranunculaceae	western columbine
Clematis ligusticifolia	11	Ranunculaceae	western white clematis
Holodiscus discolor	12	Rosaceae	oceanspray
Rosa californica	11	Rosaceae	California wildrose
Galium aparine	17	Rubiaceae	annual bedstraw
Salix laevigata	11	Salicaceae	red willow
Salix lasiolepis	15	Salicaceae	arroyo willow

LatinName_SppOnly	**Num**	**Family**	**CommonName**
Salix lucida	11	Salicaceae	shining willow
Mimulus guttatus	15	Scrophulariaceae	creek monkey flower
Scrophularia californica	13	Scrophulariaceae	California figwort
Solanum americanum	13	Solanaceae	small-flowered nightshade
Typha latifolia	12	Typhaceae	broadleaf cattail
Urtica dioica	15	Urticaceae	American stinging nettle

The Flora of the UC Natural Reserve System: preliminary summaries

Prepared by Brian Haggerty & Susan Mazer, UC Santa Barbara
October 28, 2010

This is a work in progress…

To date, 8876 species occurrences in 26 of the 36 UC Natural Reserves have been included in the “global” UC Reserve Species List that we’re compiling. Three reserves will be added in the near future (Stunt Ranch, Burns, San Joaquin Freshwater Marsh). For some reserves, plant lists are unavailable; we expect that our global list will ultimately include the relatively up-to-date floras of ~30 reserves.

Our first goal has been simply to identify the species that occur at the largest number of reserves; for this purpose, subspecies designations have been ignored. Note that the nomenclature may not always be up to date, and if you’re aware of any inaccuracies in the attached lists, please let us know.

As we revise our summaries, we will be adding the following information for each of the most widely distributed species:

Growth form/habit: Tree, shrub, perennial herb, annual herb, vine
Status: Native vs. Exotic
Number of climatic regions in it occurs: Regions to be defined

Prospective criteria for selecting species for the California Phenology Network:

- Species distributed among the largest number of Reserves, Parks, and other landholdings
- Species distributed among the largest number of Regions (e.g., North Coast, South Coast, North Foothills/Mtns, Southern Foothills/Mtns, Northern Deserts, Southern Deserts)
- Species distributed across wide latitudinal range
- Species distributed across the widest elevation range
- Representation of both native and exotic/invasive species
- Representation of wide range of families and growth forms
- Include winter-, spring-, summer-, and fall-flowering species
- Include endangered species
- Include keystone species (e.g., food sources for pollinators, seed-dispersers, etc.)
- Include charismatic species (e.g., Redwoods, Joshua trees)

Below appear two lists, each with the same 115 species. These are the species that have been recorded at more than 11 of the 26 reserves for which we have floras. In the first list, species are sorted alphabetically by family. In the second list, species are sorted on the basis of the number of reserves at which they’ve been recorded, with the most widespread species listed first.

Most widespread 115 species, sorted by family and by species
Each species has been recorded at >10 UC Natural Reserves
# of reserves = # out of 26 floras available

Count	# of reserves	Genus-Species	Common Name	Family	Bloom Time
1	14	*Toxicodendron diversilobum*	Poison oak	Anacardiaceae	Apr-May
2	11	*Apiastrum angustifolium*	Wild celery	Apiaceae	Mar-April
3	11	*Daucus pusillus*	Rattlesnake weed	Apiaceae	Apr-June
4	12	*Sanicula crassicaulis*	Gamble weed	Apiaceae	Mar-May
5	11	*Asclepias fascicularis*	Narrow-leaved milkweed	Asclepiadaceae	Jun-Sept
6	15	*Achillea millefolium*	Yarrow	Asteraceae	
7	11	*Artemisia douglasiana*	Douglas' Mugwort	Asteraceae	
8	12	*Centaurea melitensis*	Tocalote	Asteraceae	Apr-June
9	11	*Chamomilla suaveolens*	pineapple weed	Asteraceae	
10	11	*Cirsium occidentale*	western thistle	Asteraceae	
11	14	*Cirsium vulgare*	bull thistle	Asteraceae	
12	13	*Conyza canadensis*	horseweed	Asteraceae	
13	16	*Eriophyllum confertiflorum*	golden yarrow	Asteraceae	
14	12	*Filago gallica*	Narrow-leaved filago	Asteraceae	Apr-June
15	16	*Gnaphalium palustre*	lowland cudweed, western marsh cudweed	Asteraceae	
16	12	*Gnaphalium stramineum*	cotton-batting plant	Asteraceae	
17	11	*Hemizonia congesta*	Field tarweed	Asteraceae	Sept-Oct
18	12	*Hypochaeris glabra*	Smooth cat's-ear	Asteraceae	May-June
19	13	*Lactuca serriola*	Prickly lettuce	Asteraceae	Sept-Oct
20	14	*Sonchus asper*	prickly sow-thistle	Asteraceae	
21	14	*Sonchus oleraceus*	common sow-thistle	Asteraceae	
22	13	*Stephanomeria virgata*	Twiggy wreath plant	Asteraceae	July-Nov
23	11	*Uropappus lindleyi*	silver puffs	Asteraceae	
24	17	*Baccharis pilularis*	Coyote Brush	Asteraceae	
25	17	*Gnaphalium californicum*	California Cudweed	Asteraceae	
26	11	*Gnaphalium luteo-album*	Pearly Everlastings	Asteraceae	
27	18	*Amsinckia menziesii*	Fiddleneck	Boraginaceae	Mar-June
28	12	*Brassica nigra*	Black mustard	Brassicaceae	April-Jun
29	14	*Capsella bursa-pastoris*	shepherd's purse	Brassicaceae	
30	11	*Cardamine californica*	California toothwort	Brassicaceae	Feb-April
31	11	*Hirschfeldia incana*	Mediterranean mustard	Brassicaceae	
32	11	*Thysanocarpus curvipes*	narrow-leaved fringe pod	Brassicaceae	
33	11	*Sambucus mexicana*	Blue elderberry	Caprifoliaceae	March-Sept

Count	# of reserves	Genus-Species	Common Name	Family	Bloom Time
34	13	*Cerastium glomeratum*	Mouse-ear chickweed	Caryophyllaceae	Feb-May
35	15	*Silene gallica*	Common catchfly	Caryophyllaceae	Feb-June
36	13	*Stellaria media*	Common chickweed	Caryophyllaceae	Mar-Jun
37	11	*Chenopodium californicum*	Perennial goosefoot	Chenopodiaceae	Mar-Jun
38	12	*Calystegia macrostegia*	island morning glory	Convolvulaceae	
39	16	*Crassula connata*	Sand pygmy	Crassulaceae	Feb-May
40	12	*Cuscuta californica*	California dodder	Cuscutaceae	
41	11	*Cyperus eragrostis*	Tall Cyperus	Cyperaceae	
42	14	*Arctostaphylos glandulosa*	Eastwood manzanita	Ericaceae	Jan-April
43	12	*Eremocarpus setigerus*	turkey mullein	Euphorbiaceae	
44	12	*Lathyrus vestitus*	Pacific peavine	Fabaceae	April-Jun
45	13	*Lotus purshianus*	Spanish lotus	Fabaceae	June
46	15	*Lotus scoparius*	California broom, deerweed	Fabaceae	Mar-Aug
47	11	*Lotus strigosus*	strigose lotus	Fabaceae	
48	16	*Lupinus bicolor*	Miniature lupine	Fabaceae	Mar-Jun
49	11	*Lupinus microcarpus*	chick lupine	Fabaceae	
50	14	*Medicago polymorpha*	Bur clover	Fabaceae	Mar-Jun
51	11	*Trifolium albopurpureum*	Rancheria clover	Fabaceae	Mar-Apr
52	15	*Trifolium microcephalum*	Small-headed clover	Fabaceae	March
53	11	*Vicia sativa*	Common vetch	Fabaceae	Apr-May
54	11	*Erodium botrys*	Long-beaked filaree	Geraniaceae	Mar-May
55	24	*Erodium cicutarium*	red-stemmed filaree	Geraniaceae	
56	12	*Eucrypta chrysanthemifolia*	small-flowered eucrypta	Hydrophyllaceae	
57	16	*Sisyrinchium bellum*	Blue Eyed Grass	Iridaceae	
58	21	*Juncus bufonius*	common toad rush	Juncaceae	
59	11	*Juncus xiphioides*	iris leaved rush	Juncaceae	
60	12	*Marrubium vulgare*	Horehound	Lamiaceae	Mar-Aug
61	13	*Salvia columbariae*	chia	Lamiaceae	
62	12	*Stachys ajugoides*	Hedge nettle	Lamiaceae	July-Aug
63	13	*Chlorogalum pomeridianum*	Soap Plant	Liliaceae	
64	19	*Dichelostemma capitatum*	desert blue-dicks	Liliaceae	
65	12	*Malva parviflora*	Cheeseweed	Malvaceae	Most of year
66	12	*Clarkia purpurea*	Four-spot	Onagraceae	April-July
67	11	*Epilobium brachycarpum*	annual fireweed, panicled willowherb	Onagraceae	
68	18	*Epilobium canum*	California fushia	Onagraceae	
69	14	*Epilobium ciliatum*	willowherb	Onagraceae	

Count	# of reserves	Genus-Species	Common Name	Family	Bloom Time
70	15	*Eschscholzia californica*	California Poppy	Papaveraceae	
71	13	*Plantago erecta*	Annual plantain	Plantaginaceae	April
72	11	*Plantago lanceolata*	English plantain	Plantaginaceae	
73	15	*Avena barbata*	Slender wild oat	Poaceae	Mar-June
74	14	*Avena fatua*	Broad-leaved wild oat	Poaceae	Apr-June
75	11	*Briza minor*	Little quaking grass	Poaceae	Apr-June
76	16	*Bromus carinatus*	California brome grass	Poaceae	
77	18	*Bromus diandrus*	Ripgut grass	Poaceae	Apr-June
78	14	*Bromus hordeaceus*	soft brome	Poaceae	
79	17	*Bromus madritensis*	Red brome	Poaceae	Mar-June
80	13	*Bromus tectorum*	cheat grass	Poaceae	
81	13	*Distichlis spicata*	Saltgrass	Poaceae	
82	18	*Elymus glaucus*	Blue Wild Rye	Poaceae	
83	14	*Gastridium ventricosum*	Nit grass	Poaceae	May-Sept
84	16	*Hordeum murinum*	Farmer's foxtail	Poaceae	Apr-June
85	14	*Lolium multiflorum*	Italian ryegrass	Poaceae	Mar-May
86	11	*Lolium perenne*	English rye grass, perennial rye grass	Poaceae	
87	17	*Melica imperfecta*	small-flowered melica	Poaceae	
88	13	*Nassella pulchra*	Purple Needlegrass	Poaceae	
89	14	*Poa annua*	annual bluegrass	Poaceae	
90	15	*Poa secunda*	one-sided bluegrass	Poaceae	
91	21	*Polypogon monspeliensis*	annual beard grass	Poaceae	
92	24	*Vulpia microstachys*	awned fescue	Poaceae	
93	19	*Vulpia myuros*	rattail fescue	Poaceae	
94	11	*Hordeum brachyantherum*	Meadow Barley	Poaceae	
95	13	*Leymus triticoides*	Alkali Rye Grass	Poaceae	
96	13	*Eriogonum fasciculatum*	California Buckwheat	Polygonaceae	
97	13	*Pterostegia drymarioides*	pterostegia	Polygonaceae	
98	12	*Rumex crispus*	Curly dock	Polygonaceae	Most of year
99	14	*Rumex salicifolius*	Willow-Leaved Dock	Polygonaceae	
100	14	*Calandrinia ciliata*	Red maids	Portulacaceae	February-May
101	13	*Claytonia parviflora*	linear-leaved miner's lettuce	Portulacaceae	
102	17	*Claytonia perfoliata*	Miner's lettuce	Portulacaceae	Febr-May
103	16	*Anagallis arvensis*	Scarlet pimpernel	Primulaceae	March-July
104	11	*Pellaea mucronata*	bird's-foot fern	Pteridaceae	

Count	# of reserves	Genus-Species	Common Name	Family	Bloom Time
105	14	*Pentagramma triangularis*	Maxon's goldback fern	Pteridaceae	
106	13	*Adenostoma fasciculatum*	Chamise	Rosaceae	May-June
107	12	*Heteromeles arbutifolia*	Toyon	Rosaceae	April-July
108	13	*Potentilla glandulosa*	common cinquefoil	Rosaceae	
109	11	*Rosa californica*	California Wild Rose	Rosaceae	
110	17	*Galium aparine*	Goose grass	Rubiaceae	
111	18	*Salix lasiolepis*	Arroyo Willow	Salicaceae	
112	15	*Mimulus aurantiacus*	Bush monkey flower	Scrophulariaceae	Mar-Aug
113	20	*Mimulus guttatus*	seep monkeyflower	Scrophulariaceae	
114	16	*Scrophularia californica*	Bee Plant	Scrophulariaceae	
115	11	*Urtica dioica*	stinging nettle	Urticaceae	

Most widespread 115 species, sorted by the number of reserves at which they occur

Count	# of reserves	Genus-Species	Common Name	Family	Bloom Time
1	24	*Erodium cicutarium*	red-stemmed filaree	Geraniaceae	
2	24	*Vulpia microstachys*	awned fescue	Poaceae	
3	21	*Juncus bufonius*	common toad rush	Juncaceae	
4	21	*Polypogon monspeliensis*	annual beard grass	Poaceae	
5	20	*Mimulus guttatus*	seep monkeyflower	Scrophulariaceae	
6	19	*Dichelostemma capitatum*	desert blue-dicks	Liliaceae	
7	19	*Vulpia myuros*	rattail fescue	Poaceae	
8	18	*Amsinckia menziesii*	Fiddleneck	Boraginaceae	Mar-June
9	18	*Epilobium canum*	California fushia	Onagraceae	
10	18	*Elymus glaucus*	Blue Wild Rye	Poaceae	
11	18	*Bromus diandrus*	Ripgut grass	Poaceae	Apr-June
12	18	*Salix lasiolepis*	Arroyo Willow	Salicaceae	
13	17	*Gnaphalium californicum*	California Cudweed	Asteraceae	
14	17	*Baccharis pilularis*	Coyote Brush	Asteraceae	
15	17	*Melica imperfecta*	small-flowered melica	Poaceae	
16	17	*Bromus madritensis*	Red brome	Poaceae	Mar-June
17	17	*Claytonia perfoliata*	Miner's lettuce	Portulacaceae	Feb-May
18	17	*Galium aparine*	Goose grass	Rubiaceae	
19	16	*Gnaphalium palustre*	lowland cudweed, western marsh cudweed	Asteraceae	
20	16	*Eriophyllum confertiflorum*	golden yarrow	Asteraceae	
21	16	*Crassula connata*	Sand pygmy	Crassulaceae	Feb-May
22	16	*Lupinus bicolor*	Miniature lupine	Fabaceae	Mar-June
23	16	*Sisyrinchium bellum*	Blue Eyed Grass	Iridaceae	
24	16	*Hordeum murinum*	Farmer's foxtail	Poaceae	Apr-June

Count	# of reserves	Genus-Species	Common Name	Family	Bloom Time
25	16	*Bromus carinatus*	California brome grass	Poaceae	
26	16	*Anagallis arvensis*	Scarlet pimpernel	Primulaceae	Mar-July
27	16	*Scrophularia californica*	Bee Plant	Scrophulariaceae	
28	15	*Achillea millefolium*	Yarrow	Asteraceae	
29	15	*Silene gallica*	Common catchfly	Caryophyllaceae	Feb-June
30	15	*Trifolium microcephalum*	Small-headed clover	Fabaceae	March
31	15	*Lotus scoparius*	California broom, deerweed	Fabaceae	Mar-Aug
32	15	*Eschscholzia californica*	California Poppy	Papaveraceae	
33	15	*Poa secunda*	one-sided bluegrass	Poaceae	
34	15	*Avena barbata*	Slender wild oat	Poaceae	March-June
35	15	*Mimulus aurantiacus*	Bush monkey flower	Scrophulariaceae	Mar-Aug
36	14	*Toxicodendron diversilobum*	Poison oak	Anacardiaceae	Apr-May
37	14	*Sonchus oleraceus*	common sow-thistle	Asteraceae	
38	14	*Sonchus asper*	prickly sow-thistle	Asteraceae	
39	14	*Cirsium vulgare*	bull thistle	Asteraceae	
40	14	*Capsella bursa-pastoris*	shepherd's purse	Brassicaceae	
41	14	*Arctostaphylos glandulosa*	Eastwood manzanita	Ericaceae	Jan-April
42	14	*Medicago polymorpha*	Bur clover	Fabaceae	Mar-June
43	14	*Epilobium ciliatum*	willowherb	Onagraceae	
44	14	*Poa annua*	annual bluegrass	Poaceae	
45	14	*Lolium multiflorum*	Italian ryegrass	Poaceae	Mar-May
46	14	*Gastridium ventricosum*	Nit grass	Poaceae	May-Sept
47	14	*Bromus hordeaceus*	soft brome	Poaceae	
48	14	*Avena fatua*	Broad-leaved wild oat	Poaceae	Apr-June
49	14	*Rumex salicifolius*	Willow-Leaved Dock	Polygonaceae	
50	14	*Calandrinia ciliata*	Red maids	Portulacaceae	Feb-May
51	14	*Pentagramma triangularis*	Maxon’s goldback fern	Pteridaceae	
52	13	*Stephanomeria virgata*	Twiggy wreath plant	Asteraceae	July-Nov
53	13	*Lactuca serriola*	Prickly lettuce	Asteraceae	Sept-Oct
54	13	*Conyza canadensis*	horseweed	Asteraceae	
55	13	*Stellaria media*	Common chickweed	Caryophyllaceae	Mar-June
56	13	*Cerastium glomeratum*	Mouse-ear chickweed	Caryophyllaceae	Feb-May
57	13	*Lotus purshianus*	Spanish lotus	Fabaceae	June
58	13	*Salvia columbariae*	chia	Lamiaceae	
59	13	*Chlorogalum pomeridianum*	Soap Plant	Liliaceae	
60	13	*Plantago erecta*	Annual plantain	Plantaginaceae	April
61	13	*Nassella pulchra*	Purple Needlegrass	Poaceae	
62	13	*Distichlis spicata*	Saltgrass	Poaceae	
63	13	*Bromus tectorum*	cheat grass	Poaceae	
64	13	*Leymus triticoides*	Alkali Rye Grass	Poaceae	
65	13	*Pterostegia drymarioides*	pterostegia	Polygonaceae	

Count	# of reserves	Genus-Species	Common Name	Family	Bloom Time
66	13	*Eriogonum fasciculatum*	California Buckwheat	Polygonaceae	
67	13	*Claytonia parviflora*	linear-leaved miner's lettuce	Portulacaceae	
68	13	*Potentilla glandulosa*	common cinquefoil	Rosaceae	
69	13	*Adenostoma fasciculatum*	Chamise	Rosaceae	May-June
70	12	*Sanicula crassicaulis*	Gamble weed	Apiaceae	Mar-May
71	12	*Hypochaeris glabra*	Smooth cat's-ear	Asteraceae	May-June
72	12	*Gnaphalium stramineum*	cotton-batting plant	Asteraceae	
73	12	*Filago gallica*	Narrow-leaved filago	Asteraceae	Apr-June
74	12	*Centaurea melitensis*	Tocalote	Asteraceae	Apr-June
75	12	*Brassica nigra*	Black mustard	Brassicaceae	Apr-June
76	12	*Calystegia macrostegia*	island morning glory	Convolvulaceae	
77	12	*Cuscuta californica*	California dodder	Cuscutaceae	
78	12	*Eremocarpus setigerus*	turkey mullein	Euphorbiaceae	
79	12	*Lathyrus vestitus*	Pacific peavine	Fabaceae	Apr-June
80	12	*Eucrypta chrysanthemifolia*	small-flowered eucrypta	Hydrophyllaceae	
81	12	*Stachys ajugoides*	Hedge nettle	Lamiaceae	July-Aug
82	12	*Marrubium vulgare*	Horehound	Lamiaceae	Mar-Aug
83	12	*Malva parviflora*	Cheeseweed	Malvaceae	Most of year
84	12	*Clarkia purpurea*	Four-spot	Onagraceae	April-July
85	12	*Rumex crispus*	Curly dock	Polygonaceae	Most of year
86	12	*Heteromeles arbutifolia*	Toyon	Rosaceae	April-July
87	11	*Daucus pusillus*	Rattlesnake weed	Apiaceae	Apr-June
88	11	*Apiastrum angustifolium*	Wild celery	Apiaceae	Mar-April
89	11	*Asclepias fascicularis*	Narrow-leaved milkweed	Asclepiadaceae	Jun-Sept
90	11	*Uropappus lindleyi*	silver puffs	Asteraceae	
91	11	*Hemizonia congesta*	Field tarweed	Asteraceae	Sept-Oct
92	11	*Cirsium occidentale*	western thistle	Asteraceae	
93	11	*Chamomilla suaveolens*	pineapple weed	Asteraceae	
94	11	*Artemisia douglasiana*	Douglas' Mugwort	Asteraceae	
95	11	*Gnaphalium luteo-album*	Pearly Everlastings	Asteraceae	
96	11	*Thysanocarpus curvipes*	narrow-leaved fringe pod	Brassicaceae	
97	11	*Hirschfeldia incana*	Mediterranean mustard	Brassicaceae	
98	11	*Cardamine californica*	California toothwort, milkmaids	Brassicaceae	Febr-Apr
99	11	*Sambucus mexicana*	Blue elderberry	Caprifoliaceae	Mar-Sept
100	11	*Chenopodium californicum*	Perennial goosefoot	Chenopodiaceae	Mar-June
101	11	*Cyperus eragrostis*	Tall Cyperus	Cyperaceae	
102	11	*Vicia sativa*	Common vetch	Fabaceae	Apr-May

Count	# of reserves	Genus-Species	Common Name	Family	Bloom Time
103	11	*Trifolium albopurpureum*	Rancheria clover	Fabaceae	Mar-April
104	11	*Lupinus microcarpus*	chick lupine	Fabaceae	
105	11	*Lotus strigosus*	strigose lotus	Fabaceae	
106	11	*Erodium botrys*	Long-beaked filaree	Geraniaceae	Mar-May
107	11	*Juncus xiphioides*	iris leaved rush	Juncaceae	
108	11	*Epilobium brachycarpum*	annual fireweed, panicled willowherb	Onagraceae	
109	11	*Plantago lanceolata*	English plantain	Plantaginaceae	
110	11	*Lolium perenne*	English rye grass, perennial rye grass	Poaceae	
111	11	*Briza minor*	Little quaking grass	Poaceae	Apr-June
112	11	*Hordeum brachyantherum*	Meadow Barley	Poaceae	
113	11	*Pellaea mucronata*	bird's-foot fern	Pteridaceae	
114	11	*Rosa californica*	California Wild Rose	Rosaceae	
115	11	*Urtica dioica*	stinging nettle	Urticaceae	