National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

# California Phenology Project

## *Report on Pilot Phase Activities, 2010-2013*

Natural Resource Report NPS/PWRO/NRR—2013/743

**ON THE COVER:**
NPS staff, interns, and volunteers working together to teach, learn, and collect phenological data along a trail at Joshua Tree NP.

# California Phenology Project

*Report on Pilot Phase Activities, 2010-2013*

Natural Resource Report NPS/PWRO/NRR—2013/743

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This report received formal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data, and whose background and expertise put them on par technically and scientifically with the authors of the information.



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# Executive Summary

In 2010, the Pacific West Region of the National Park Service (NPS) partnered with the University of California, Santa Barbara (UCSB) and the National Coordinating Office of the USA National Phenology Network (USA-NPN) to develop a coordinated phenological monitoring network in National Park units across California. The NPS Climate Change Response Program (CCRP) at the national level provided funding for the three-year (2010-2013) pilot phase of the project. The CCRP was particularly interested in supporting development of climate change monitoring efforts that encourage public participation in scientific research and that could serve as a model for broader implementation service-wide.

The purpose of this report is to document the development, implementation, and accomplishments of the California Phenology Project (CPP; www.usanpn.org/cpp) during the pilot phase. It is intended to provide guidance for National Parks and other management agencies, institutions, and organizations that would like to join the CPP or implement a similar phenological monitoring program in other geographic areas. The primary goals of the CPP are to:

1. Establish a framework for long-term phenological monitoring in California so that phenology can be linked to climate conditions that vary over time and space.
2. Collect and analyze phenological data to address a number of research questions related to phenology, climate change, conservation, and resource management.
3. Engage and educate people of all backgrounds and ages in the study of phenology and in understanding climate change.

Specific objectives of the pilot phase of the project were to:

1. Work with NPS staff at pilot parks and with expert scientists across California to develop a scientific framework to guide the development of a CPP monitoring network and the selection of target plant species for the core monitoring program.
2. Use the USA-NPN online platform, *Nature's Notebook* (www.npn.usanpn.org; Schwartz et al. 2012; Rosemartin et al. 2013), as the basis for developing and testing standardized phenological monitoring protocols for CPP target plant taxa.
3. Develop and test analytical and reporting tools for interpreting phenological data and communicating results.
4. Provide training in phenological monitoring and in phenology-focused educational activities for NPS staff, volunteers, teacher-ranger-teachers, and other interested parties.
5. Develop approaches and tools for public engagement and education.
6. Create a website to provide access to monitoring tools and educational materials developed by the CPP.
7. Communicate the results and successes of CPP pilot phase activities.

The design and implementation of the CPP pilot activities has been directed by the CPP Core Team, which includes representatives from each institutional and agency collaborator: UCSB, USA-NPN, the Californian Cooperative Ecosystem Studies Unit, and each of seven NPS pilot park units, including: Golden Gate National Recreation Area (GOGA), John Muir National Historic Site (JOMU), Joshua Tree National Park (JOTR), Lassen Volcanic National Park (LAVO), Redwood National and State Parks (REDW), Santa Monica Mountains National Recreation Area (SAMO), and Sequoia and Kings Canyon National Parks (SEKI). The CPP Core Team worked closely with NPS managers, educators, and interpreters at each park and with a broad variety of partner organizations to implement phenological monitoring and public outreach activities in the pilot park units.

The core elements of the CPP pilot phase activities are documented in this report, and include:

1. Development of a scientific framework to guide all CPP pilot activities.
2. Selection of target species for monitoring.
3. Development, testing, and implementation of monitoring protocols.
4. Initiation of outreach and partnership activities at each pilot park.
5. Creation of educational materials.

The CPP pilot phase achieved many of its objectives. The CPP hosted >25 training workshops, attended by >900 members of the public and NPS staff. Across the pilot parks, the CPP is now monitoring the phenology of 30 plant species, for which observers have submitted >435,000 records to the USA-NPN's National Phenology Database (NPDb). In addition to this report, the CPP developed a *Plant Phenological Monitoring Protocol* (Matthews et al. *In review*), which is available for download as a draft on the CPP website. The protocol includes 11 Standard Operating Procedures (SOPs) that provide comprehensive instructions for designing and implementing a phenological monitoring program (e.g., instructions for: selecting focal species, developing a sampling design, establishing monitoring sites, recording phenological observations, and training observers) and detailed park-specific monitoring guides for each of the pilot parks. The protocol is expected to be a valuable resource for parks that want to join the CPP network or to design their own phenological monitoring program. Finally, analysis of CPP data is underway, with data summaries, peer-reviewed publications, and a report expected in 2014.

## Acknowledgments

The authors of this report represent the California Phenology Project Core Team and the partnership among the University of California, Santa Barbara (UCSB); the USA National Phenology Network (USA-NPN); and the National Park Service (NPS) for the 2010-2013 pilot phase of the project.

A project of this size and scope is only successful with the participation and contributions of many individuals. We wish here to acknowledge project participants beyond the Core Team of project collaborators. Dr. John Gross, an ecologist with the NPS Inventory and Monitoring Program and a big supporter of phenological monitoring, provided valuable guidance and encouragement throughout the project. Dr. Kathryn Thomas, USGS ecologist with the USA-NPN National Coordinating Office (NCO) participated in the early stages of the project and was instrumental in compiling species lists for NPS units in California and assisting with the selection of CPP target taxa. We are also grateful for the participation of other USA-NPN NCO staff in the project including: Dr. Jake Weltzin, Director and USGS scientist who provided expert counsel throughout the project; Alyssa Rosemartin, assistant director; Ellen Denny, monitoring design and data coordinator; and Lee Marsh, applications programmer, for providing administrative and technical support. Margot Higgins, Ph.D. Candidate at UC Berkeley, assembled information on existing park-based education and outreach programs, thereby providing a basis for integrating phenological monitoring and climate change education activities with existing programs. We thank Dr. Carolyn Enquist (USA-NPN), Dr. Jana Newman (US Fish and Wildlife Service), and Stephanie Sutton (NPS), who provided comments on an earlier draft of this report. We also thank our review manager, Dr. Robert Steers (NPS) for providing thoughtful feedback and guidance during the review process, and Suzanne Gucciardo (NPS) for serving as a peer reviewer of this report.

We would like to thank additional NPS staff who participated in the CPP pilot phase planning and implementation including Sue Fritzke, Janet Coles, Will Elder, Annie Esperanza, Erik Meyer, Denise Roberston, Danielle Cessna, Stephanie Sutton, Mitzi Harding, Alysia Schmidt, and Martin Hutten. Lisa Okazaki and Barbara Applebaum assisted in the organization and funding of professional development workshops at Santa Monica Mountain National Recreation Area, where UCSB collaborators trained middle and high school teachers in the methods and educational applications of phenological monitoring.  Finally, we thank the many intrepid individuals who helped conduct the pilot testing of monitoring protocols and outreach tools on the ground in the pilot parks including:  Ruby Kwan, Margo Wallace, Jess Gambel, Steven Krause, Steve Musch, Kipp Callahan, Crystal Anderson, Sarah Felts, Ann Huber, Jay Johnson, Hannah Schwalbe, and April Shackleford.

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# I. Introduction: the California Phenology Project (CPP)

The California Phenology Project (CPP) was launched in 2010 as a three-year pilot project to develop and test protocols for a long-term phenological monitoring program across National Parks and other protected areas in California. The core mission of the CPP effort is to build a plant phenology dataset that represents California's diverse landscapes and to analyze and interpret these data to help understand the effects of climate change on natural resources. The project also emphasizes public participation in scientific research, providing opportunities for citizen scientists to gain first-hand experience in, and a deeper understanding of, biological responses to climate change.

The goals of the California Phenology Project (CPP) are to:

1. Establish a framework for long-term phenological monitoring of wild plant species in California in order to detect whether and how the phenological timing of targeted species is linked to climatic conditions that vary over time and space.
2. Provide baseline data and analytical results to address a number of research questions and to support stewardship of wildland ecosystems.
3. Engage and educate people of all backgrounds and ages in the study of phenology and in understanding climate change.

Specific objectives of the pilot phase of the project were to:

1. Work with NPS staff at pilot parks and with expert scientists across California to develop a scientific framework to guide the development of a CPP monitoring network and the selection of target plant species for the core monitoring program.
2. Use the USA-NPN online platform, *Nature's Notebook,* (www.nn.usanpn.org; Schwartz et al. 2012; Rosemartin et al. 2013), as the basis for developing and testing phenological monitoring protocols for CPP target plant taxa,
3. Develop and test analytical and reporting tools for interpreting phenological data and communicating results.
4. Provide training in phenological monitoring and in phenology-focused educational activities for NPS staff, volunteers, teacher-rangers, and other interested parties.
5. Develop approaches and tools for public engagement and education.
6. Create a website to provide access to monitoring tools and educational materials developed by the CPP.
7. Communicate the results and successes of CPP pilot phase activities.

The CPP pilot phase was implemented through a three-way partnership between the Pacific West Region of the National Park Service (NPS), the University of California, Santa Barbara (UCSB) and the US Geological Survey's National Coordinating Office of the USA National Phenology Network (USA-NPN). The NPS Climate Change Response Program (CCRP) provided funding for the pilot phase and was particularly interested in supporting development of climate change monitoring efforts that encourage public participation and that could serve as models for broader implementation service-wide and in other natural areas (such as state parks, private preserves, and the University of California Natural Reserve System). With completion of the pilot phase, protocols and infrastructure are now in place to support an evolving California Phenology Network. The products resulting from the CPP pilot phase are available to encourage broader engagement across California and in turn to support the collection of a robust phenological dataset that will be useful for assessing plant responses to climate change. The purpose of this report is to document CPP project activities and successes during the three-year pilot phase of the project (2010 to 2013).

### 1.1 Phenology and Climate Change

Phenology is the study of seasonal life cycle events such as the flowering and fruiting of plants; the migration of birds and mammals; and the annual emergence of insect pollinators and pests. Shifts in the timing of plant and animal phenology are a well-documented biological response to climate change and thus, phenology is now recognized as a leading indicator of climate change impacts on ecosystems and society (IPCC 2007, EPA 2012, Janetos et al. 2012). Indeed, recent warming trends are associated with an earlier onset of phenological activity in the spring and a longer active growing season (Richardson et al. 2013). Ecological processes and species interactions are strongly influenced by phenology (e.g. Both et al. 2006, Ozgul et al. 2010, Richardson et al. 2010, McKinney et al. 2012), and disruptions or shifts in phenology can have profound effects on ecosystem function and species abundance and distribution (Chuine 2010, Miller-Rushing et al. 2010, Willis et al 2010, Cleland et al. 2012).

Land management agencies are increasingly tasked with planning and managing for climate change impacts (Enquist et al. *In Press*), and phenological monitoring provides a straight-forward way for managers to track biological responses to climate change. As a land management agency, the NPS is well poised to contribute to a national-scale phenological monitoring effort from which the parks can ultimately benefit. Phenological monitoring is also a tangible activity that can be useful for engaging the public in climate change research and for incorporating climate change concepts into educational, interpretive, and natural resource programming. In short, the establishment and sustained implementation of phenological monitoring programs in the national parks can be used to meet the goals of many of the suggested actions described in Director Jon Jarvis' 2011 *A Call to Actio*n (http://www.nps.gov/calltoaction/PDF/Directors_Call_to_Action_Report.pdf)

### 1.2 The CPP Pilot Phase (2010-2013)

Eighteen NPS units across California were identified as potentially suitable locations for phenological monitoring (Figure 1; Table 1). CPP pilot phase activities were concentrated in seven pilot park units including: Joshua Tree National Park (JOTR), Santa Monica Mountains National Recreation Area (SAMO), Golden Gate National Recreation Area (GOGA), John Muir National Historic Site (JOMU), Redwood National Park (REDW), Sequoia and Kings Canyon National Parks (SEKI), and Lassen Volcanic National Park (LAVO). These parks encompass the varied landscape of California and are distributed across biogeographic regions that include desert, coastal, and montane habitats. Throughout the pilot phase, the 11 non-pilot park units had opportunities to participate in pilot phase activities, such as the selection of focal species for monitoring and training events held at pilot parks, with the hope that the CPP pilot phase products will be useful for and adopted by all NPS units in California.

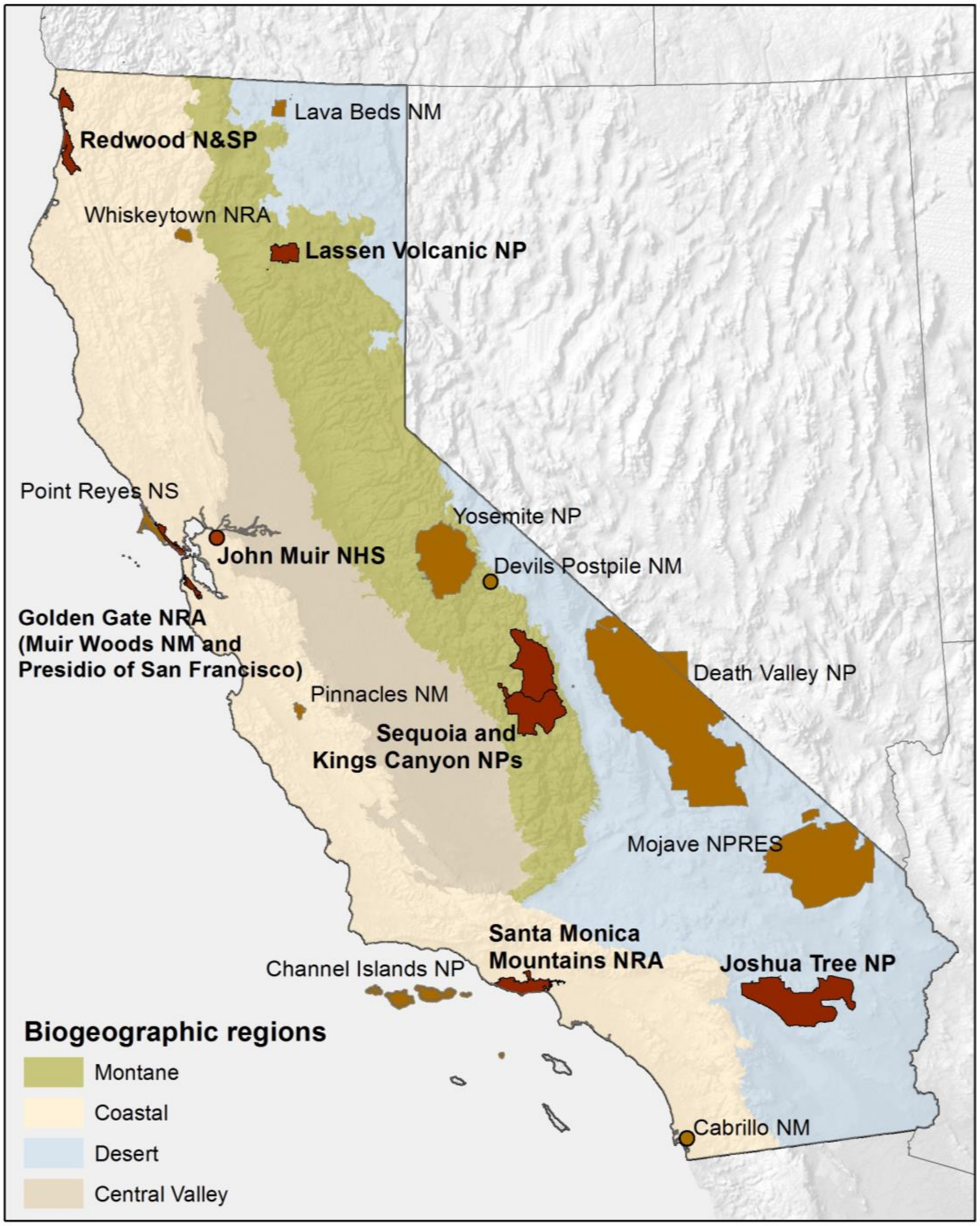


**Figure 1.** National Park Service units in California, with biogeographical areas overlaid. The seven California Phenology Project pilot parks are shown in dark red.

**Table 1.** National Park Service units in California. Bold text indicates parks where California Phenology Project pilot phase activities occurred.

| Park | Park Code | Area (ha) | Biogeographic Area |
|---|---|---|---|
| Cabrillo National Monument | CABR | 67 | Coastal |
| Channel Islands National Park | CHIS | 100,994 | Coastal |
| Death Valley National Park | DEVA | 1,362,860 | Desert |
| Devils Postpile National Monument | DEPO | 320 | Montane |
| **Golden Gate National Recreation Area** | **GOGA** | **32,376** | **Coastal** |
| **John Muir National Historic Site** | **JOMU** | **140** | **Coastal** |
| **Joshua Tree National Park** | **JOTR** | **320,713** | **Desert** |
| Lava Beds National Monument | LABE | 18,896 | Desert |
| **Lassen Volcanic National Park** | **LAVO** | **42,896** | **Montane** |
| Mojave National Preserve | MOJA | 587,250 | Desert |
| Muir Woods National Monument | MUIR | 224 | Coastal |
| Pinnacles National Park | PINN | 10,767 | Coastal |
| Presidio of San Francisco | PRES | 603 | Coastal |
| **Redwood National Park** | **REDW** | **53,411** | **Coastal** |
| **Santa Monica Mountains National Recreation Area** | **SAMO** | **61,947** | **Coastal** |
| **Sequoia and Kings Canyon National Parks** | **SEKI** | **350,443** | **Montane** |
| Yosemite National Park | YOSE | 302,687 | Montane |
| Whiskeytown National Recreation Area | WHIS | 17,197 | Montane |

The design and implementation of the CPP pilot phase has been directed by the CPP Core Team, which includes representatives from each institutional and agency collaborator (UCSB, USA-NPN, and each of seven NPS pilot park units) as well as the NPS Research Coordinator at the Californian Cooperative Ecosystem Studies Unit. Throughout the pilot phase, the CPP Core Team sought to network and build relationships with the environmental education, natural resource management, and conservation communities in California. As part of this broader effort, the CPP is currently developing a complementary network of monitoring sites in the University of California Natural Reserve System and has supported the development of phenological monitoring programs at non-pilot NPS units in California (e.g., Lava Beds National Monument, Death Valley National Park, and Yosemite National Park). As the CPP network continues to expand, it is hoped that the pilot parks will function as a nucleus of a continually growing California Phenology Network.

The CPP Core Team, facilitated by the UCSB team, implemented a suite of activities during the pilot phase (Table 2). The Core Team developed and tested phenological monitoring protocols at each of the pilot parks; created tools and infrastructure to support long-term phenological monitoring and public education activities; established a core sampling design to capture phenological variation within and among monitoring locations; and trained a network of citizen scientists and NPS staff to participate in the collection and interpretation of phenological data. The achievements — and the operational challenges encountered — at each pilot park are meant to inform the future development of phenological monitoring projects at other national parks and beyond.

**Table 2.** Schedule of California Phenology Project pilot phase activities and milestones (2010-2013).

| Timeframe | Activity | Milestone |
|---|---|---|
| Fall 2010 – Winter 2010 | Developed CPP Scientific Framework | Conducted November 2010 workshop with NPS staff & scientific experts to develop CPP scientific and research framework. A report was completed in Winter 2010 (Mazer et al. 2010) |
| Winter 2010 – Spring 2011 | Selected CPP target plant species with expert input. | Compiled species lists for all California NPS units and convened 4 working groups, based on biogeographic regions, to identify target taxa. |
| Winter 2010 – Spring 2011 | Conducted outreach to 18 California NPS units via webinars and direct dialogue to obtain input on framing CPP direction | Results of these conversations documented in an outreach report (Higgins et al. 2011). |
| Spring – Summer 2011 | Established monitoring infrastructure and conducted training workshops and protocol development and testing activities in pilot parks | Trained NPS staff, volunteers, and partner institutions at each of the pilot parks and worked with NPS staff to select and establish monitoring sites. |
| Summer – Winter 2011 | Collaborated with USA-NPN to revise phenological monitoring protocols | Monitoring protocols for most of the species targeted for monitoring by the CPP were revised to conform to the phenological details that characterize plant species adapted to Mediterranean and arid climates. |
| Summer – Winter 2011 | Developed CPP website and monitoring tools (e.g., CPP species profiles, maps, and education and training materials) | CPP website went online in July 2011. Monitoring tools uploaded and made available on the website in Fall 2011. |
| Spring – Summer 2012 | Conducted CPP training workshops and protocol development and testing activities in pilot parks | Trained NPS staff, volunteers, and partner institutions at pilot parks and UC Natural Reserves. |
| Spring – Summer 2011 & 2012 | Submitted phenological observations to the National Phenology Database (NPDb) | As of October 2013, CPP observers had contributed >435,000 observation records to the NPDb. |
| Winter 2012 – Spring 2013 | Documented CPP monitoring protocols, including data analysis and project reporting | Completed CPP Plant Phenological Monitoring Protocol manuscript for peer-review (Matthews et al. *In review*). Published summary of CPP objectives and design in Madroño (Haggerty et al. 2013). |
| On-going | Communicate outcomes of CPP activities | Developed various project briefs, newsletters, and articles to report on CPP pilot phase activities. |

As mentioned previously, the purpose of this report is to document the development, implementation, and accomplishments of the CPP during the pilot phase. Additionally, this report is intended to provide guidance for parks and other management agencies, institutions, and organizations that would like to join the CPP or implement a similar phenological monitoring program in other geographic areas. As such, the following sections describe the core elements of the CPP pilot phase activities, including the:

1. Development of a scientific framework to guide all CPP pilot activities.
2. Selection of target species for monitoring.
3. Development, testing, and implementation of monitoring protocols.

4. Initiation and implementation of outreach and partnership activities at each pilot park.
5. Creation of educational materials.

# II. CPP Scientific Framework

## 2.1 Development of the Scientific Framework

An important step in launching the CPP was the development of a scientific framework and associated set of approaches to guide project design and implementation. In November 2010, the CPP hosted a workshop at the University of California, Berkeley for all project partners. Agency and academic scientists from across California were also invited to attend (see Appendix A for a list of attendees). The primary goals of the workshop were to: (1) identify how the CPP can best use plant phenology to monitor the response of natural resources to climate change across National Parks in California; (2) identify research questions that could be addressed by a long-term, state-wide monitoring program, and that are scientifically interesting and relevant to resource managers; (3) develop a set of recommendations for implementing plant phenological monitoring and for addressing research questions (e.g. how to organize the sampling effort across bioregions, landscapes, altitudinal gradients, biological communities, and in association with co-located environmental monitoring stations); (4) identify criteria for selecting target plant taxa; and (5) develop a plan of action to move forward on project design and implementation. The results of the scientific framework workshop are documented in a report by Mazer et al. 2010; much of the content of this report is presented in this document, including the phenology-focused research questions and their relevance to management (section 2.2 and Appendix B) and the CPP species selection guidelines (section III).

## 2.2 CPP Research Questions

Articulating the hypotheses or questions underlying any long-term monitoring effort is an important first step for maximizing successful project outcomes. As such, participants in the November 2010 workshop identified research questions that they considered to be scientifically interesting and relevant to resource management (Mazer et al. 2010). These questions were refined and expanded during the pilot phase to include a total of 15 research questions that collectively evaluate the causes and consequences of phenological variation at different ecological levels and that may be addressed by a monitoring scheme 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. The full list of CPP research questions is presented in Appendix B, along with a recommended approach for addressing each question and each question's link to resource management issues.

Although a core goal of the CPP is to design and implement a phenological monitoring program that can detect *long-term* responses to climate change, the CPP also aims to address research questions that can be informed by phenological data recorded during the funded period of activity (i.e., 2-3 years). Among the larger set of research questions, the CPP identified high-priority questions that can be addressed using the CPP pilot phase data. These included the following questions: *Among conspecific individuals, is there spatial variation in phenological parameters (e.g., onset and duration of targeted phenophases) that is associated with geographic gradients (e.g., elevation, latitude, or longitude)? Which phenophases are most sensitive to variation in geographic gradients that also correspond with climatic gradients (e.g., changes in mean monthly or annual temperature along an elevational gradient)?* Because the CPP monitoring approach includes the observation of phenological patterns over local and regional geographic gradients, intra-specific phenological variation associated with spatial variation can be quantified. Some of the CPP focal species, for example, were observed across numerous sites, allowing the CPP to assess correlations between phenological behavior and geographic parameters (e.g., elevation). Understanding the degree to which common and widespread plant species exhibit phenological variation related to *spatial* variation in climate is a first step toward predicting their responses to *temporal* variation in climate. A better understanding of the climate sensitivity of focal species, in turn, can provide valuable information for climate change vulnerability assessments and the subsequent prioritization of management actions.

Analysis of CPP data to address high-priority research questions is currently underway, with final results and reports anticipated in 2014. Preliminary results suggest that the CPP has been successful in detecting spatial variation in phenology. Spatial variation in the onset date of phenophases, for example, has been detected at Sandstone Peak in Santa Monica Mountains NRA. *Adenostoma fasciculatum* (Chamise) is now monitored at 8 sites (with multiple plants monitored at each site) along an elevation gradient at Sandstone Peak, and data collected in 2013 reveal that the timing of the onset of the open flowers phenophase is related to variation in elevation (Figure 2).

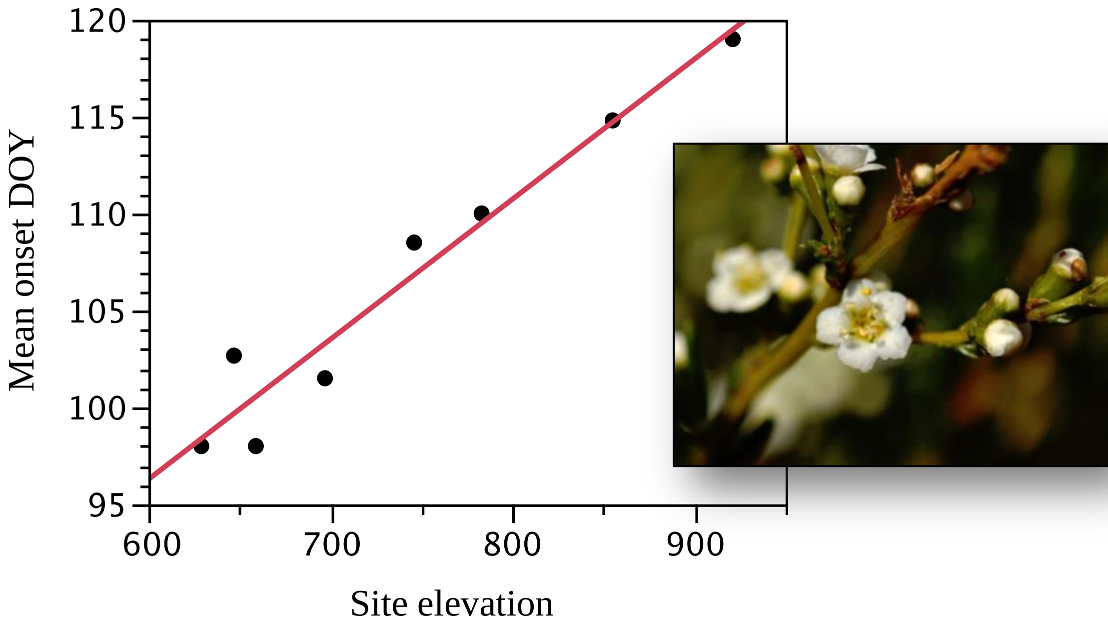


**Figure 2.** The mean onset date (the mean day of year [DOY] on which a phenophase is first observed) of the open flowers phenophase recorded for *Adenostoma fasciculatum* individuals at SAMO's Sandstone Peak monitoring sites varies with the monitoring sites' elevation: the first DOY on which open flowers are observed is earlier at low elevation sites and later at high elevation sites ($y= .072x+ 52.91$, $r^2$=0.948, P<0001). Inset: Open flowers phenophase observed on an *Adenostoma fasciculatum* individual.

# III. CPP Target Species Selection Process

## 3.1 Criteria for Species Selection

Eleven criteria to guide the selection of CPP target plant species were identified at the November 2010 Workshop. Target species selected for monitoring at each pilot park were chosen to fulfill one or more of these criteria (although all workshop participants agreed that it was unlikely that all criteria would be fulfilled at a given park or by any single target species). Each selection criterion was weighted differently at a given park, depending on the park's goals and objectives and on the knowledge and skill set of the park's staff and observer network. Across the pilot parks, the aim was to include and test a variety of families, genera, and functional groups that represent a range of phenological schedules (e.g., mast-flowering, multi-season flowering, early spring and fall flowering) and life forms. Pilot parks decided to limit the number of species to be monitored at each location to 3 or 4 taxa (although this number was generally exceeded in response to local enthusiasm for monitoring additional taxa), and where possible, target species were replicated across multiple pilot parks to strengthen resulting datasets.

The species selection criteria identified during the November 2010 workshop gave highest priority to species representing the following attributes:

1. *Dominant species:* species that represent the most common or "characteristic" local or regional vegetation type (e.g., coast live oak, Joshua tree).

2. *Widely distributed taxa*: species that are widely distributed within or across biogeographical regions and parks.

3. *Indicator species* for particular habitats or for transitions between habitats.

4. *Species 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 and yucca moths; locally endangered species; highly invasive species; critical food sources for endangered pollinators or butterfly larvae).

5. *Ease of identification*: selected species and its phenophases should be relatively easy to identify.

6. *Accessibility for monitoring across gradients*, including elevation, aspect, soil moisture, gradients of invasive species abundance, or disturbance gradients.

7. *Proximity to other monitoring efforts*, including co-location with Inventory and Monitoring vegetation plots that provide demographic and abundance information, proximity to meteorological stations, etc.

8. *Species for which there are legacy data* to which current phenological behavior can be compared.

9. *Benchmark species*, including species that are "first-responders" to spring warming, species that are last-to-flower, species that provide dramatic spring flowering or fall foliage displays, etc.

10. *Ability to engage Citizen Scientists:* this includes species that are easy to propagate or cultivate for use in native plant or school gardens, species with phenological activity occurring at different periods throughout the year that allow for interaction with citizen scientist observers across many seasons, etc.

11. *Species that occur in known and accessible locations* in a given park.

Note that "climate sensitivity" was not an explicit species-selection criterion, primarily because there is little known about the climate sensitivity of most California taxa. As such, the CPP recognized that the phenology of some of the selected species might not be sensitive to climatic variation.

### 3.2 Selection of Target Species for Monitoring

In early 2011, the CPP began selecting species for monitoring in each of the pilot park units. This process was carried out by four working groups, representing each of four biogeographic regions in the state: Northern Coast, Southern Coast, Mountains, and Desert (Figure 1). Each park unit was assigned to one of the four working groups (Table 1). Working groups were composed of NPS botanists, vegetation ecologists, and others with botanical expertise relevant to the specific biogeographic area. During a series of discussions conducted via webinar, email, and conference calls, working groups developed target species lists and a set of recommended taxa for each park (Appendix C presents the schedule of working group discussions and participants). The set of recommended taxa were further refined at the individual park level, incorporating on-the-ground knowledge of each species' abundance, distribution, ease of identification, and accessibility. Each step in the species selection process is described in detail below.

1. The CPP Core Team consolidated the vascular plant lists for the 18 park units in California and created a floristic database that, for each species, included a variety of botanical attributes obtained from the online USDA PLANTS database (e.g., nativity, life form, and taxonomic family) and from NatureServe's Terrestrial Ecological Systems Classification (e.g., as an indication of dominant, characteristic, and indicator species for California's ecological systems). The database allowed the CPP to determine the frequency of each species' presence across all California park units and across park units within a given biogeographic region. For each of the four biogeographic regions, an initial candidate species list was exported from the database in a spreadsheet format; the spreadsheets included the 100 most frequent species in the focal bioregion, all of the dominant, characteristic, and indicator species for the NatureServe ecological systems in the focal bioregion, and botanical attribute information for each species on the list.

2. A series of webinars (one for each biogeographic region) was scheduled in early 2011. The initial candidate species lists were distributed to the working groups prior to the webinars, and the working groups were asked to assess each of the candidate species based on whether it was well-suited to address the CPP research questions (described in section 2.2) and the species-selection criteria (described in section 3.1). Species were considered to be strong candidates for monitoring if they could be used to address many of the research questions and if they fulfilled many of the species-selection criteria. Species that are widespread in California and/or that are found in multiple biogeographic

regions were given higher priority than narrowly distributed taxa (except where parks desired to focus on a locally important species). A few days before the webinar, working group participants submitted a list of their top candidates, along with a justification for each candidate taxon (i.e., how the taxon addresses a focal ecological questions and/or fulfills species-selection criteria).

3. Each species selection webinar began with a presentation that provided an overview of the CPP's goals and a summary of the initial candidate species lists, with each species ranked by the number of times it was proposed as a candidate by working group members. The working group then reviewed the initial, ranked species list and discussed additional justification for each of the ranked species. Working group members also had an opportunity to propose additional candidate taxa that were not included in the preliminary rankings. Based on the webinar discussions, the working groups identified a short list (5-15 taxa) of high-priority species for monitoring in each of the California park units and a comprehensive list of target taxa for each of the focal biogeographic region.

4. Following each webinar, the short list of high priority species and an annotated list of all species discussed during the webinar were distributed via email to working group participants for a second round of comment. This feedback resulted in a comprehensive, high-priority species list consisting of 57 taxa (Table 3). These species were submitted to the USA-NPN for the development of species-specific phenophase protocols and species profiles on *Nature's Notebook* .

5. Ultimately, the high priority species list was further constrained through the application of practical criteria that were determined to be important in the field; these criteria required detailed on-the-ground knowledge of the distribution, habit, and abundance of focal taxa in the area of interest. The list of 57 species was reduced to 30 target species that were monitored during the CPP pilot phase (Table 3). The reduced list came about during multi-day visits by the UCSB field team to each of the pilot parks, with assistance from park staff who were knowledgeable of the ecology, distribution, and abundance of the taxa.

**Table 3.** List of high-priority species recommended for phenological monitoring in California. Thirty are actively monitored by the California Phenology Project (these species are identified by bold text). Nomenclature follows the Jepson Manual, Second Edition (Baldwin et al. 2012).

| | Species (Common name) | Justification summary: identified by CPP Core Team and participants of species selection working groups | Desert | Southern Coast | Northern Coast | Mountain | Actively monitored |
|---|---|---|---|---|---|---|---|
| 1 | *Acer macrophyllum* (Big leaf maple) | Easy to identify, linked to stream ecology. | | | X | | |
| 2 | ***Adenostoma fasciculatum*** **(Chamise)** | Indicator species for chaparral habitat, broadly distributed, fire management concerns, showy flowers, late season bloom. Occurs on many slope and elevation zones. | | X | X | | X |

**Table 3.** List of high-priority species recommended for phenological monitoring in California. Thirty are actively monitored by the California Phenology Project (these species are identified by bold text). Nomenclature follows the Jepson Manual, Second Edition (Baldwin et al. 2012). (continued)

| | Species (Common name) | Justification summary: identified by CPP Core Team and participants of species selection working groups | Desert | Southern Coast | Northern Coast | Mountain | Actively monitored |
|---|---|---|---|---|---|---|---|
| 3 | ***Aesculus californica*** **(California buckeye)** | Broadly distributed and common, engaging for public. Indicator of Mediterranean climate. Early indicator of spring in Sierra foothills. Showy flowers. Drought deciduous. | | | X | X | X |
| 4 | ***Arctostaphylos patula*** **(Greenleaf manzanita)** | Easily identified and widely distributed in Sierra Nevada. Found in accessible locations and habitats. Early season flowers. Bee pollinated, fruits are important for wildlife. | | | | X | X |
| 5 | *Atriplex hymenelytra* (Desert holly) | Fall bloomer, strongly affected by changes in ground water. | X | | | | |
| 6 | ***Baccharis pilularis*** **(Coyotebrush)** | Widespread and common. Flowers in late summer and Fall. Important winter pollen source for insects. Flowers for an extended period. | | X | X | | X |
| 7 | *Cardamine californica* (Milkmaids) | One of earliest blooming species along the coast of California. Easy to identify. | | X | X | | |
| 8 | *Ceanothus cordulatus* (Whitethorn ceonothus) | Occurs in large patches and showy when in bloom. | | | | X | |
| 9 | *Ceanothus cuneatus* (Buckbrush) | Common species; could easily be linked to vegetation related interpretation programs. | | X | | | |
| 10 | *Cirsium occidentale* (Western thistle) | Good comparison with invasive congener (*C. vulgare*). Easy to find on landscape. Insect-pollinated, and birds eat the seeds. | | | X | | |
| 11 | *Cirsium vulgare* (Bull thistle) | Broadly distributed and easy to identify. Invasive species with native congener (*C. occidentale*) for comparison. | | | X | | |
| 12 | ***Coleogyne ramosissima*** **(Blackbrush)** | Drought deciduous. Individuals lose most of their leaves during hot summer months so this is an easy phenophase to track. Rodents cache seeds. Indicator of upper Mojave transition zone and sensitive to environmental change and fire. | X | | | | X |
| 13 | *Cornus nuttallii* (Mountain dogwood) | Showy and found along roadsides. Iconic. | | | | X | |
| 14 | ***Mimulus aurantiacus*** **(Sticky monkeyflower)** | Common and charismatic species. | X | X | X | X | X |
| 15 | *Epilobium canum* (California fuchsia) | Late flowering species with showy, easily identified flowers. Accessible locations and habitats. Flowers during hot, dry periods of year. Easy to grow so would be good for phenology demonstration gardens for schools. | | | | X | |

**Table 3.** List of high-priority species recommended for phenological monitoring in California. Thirty are actively monitored by the California Phenology Project (these species are identified by bold text). Nomenclature follows the Jepson Manual, Second Edition (Baldwin et al. 2012). (continued)

| | Species (Common name) | Justification summary: identified by CPP Core Team and participants of species selection working groups | Desert | Southern Coast | Northern Coast | Mountain | Actively monitored |
|---|---|---|---|---|---|---|---|
| 16 | *Ericameria nauseosa* (Rubber rabbitbrush) | Fall blooming species, found along roads. | | | | X | |
| 17 | ***Eriogonum fasciculatum*** **(California buckwheat)** | Abundant at multiple parks across Southern California. Phenological variation of sub-specific taxa may be of interest. | X | X | | | X |
| 18 | ***Eschscholzia californica*** **(California poppy)** | Widespread and charismatic species, one of the first to bloom in the winter. Coastal and inland populations have a lot of variation in phenology. State wildflower. Insect pollinated. Variation in life form (annual vs. perennial) throughout state. | | X | X | | X |
| 19 | ***Heracleum maximum*** **(Common cowparsnip)** | Common and showy, found in 9 total NPS park units in CA. Easy to identify with early bloom times. Wetland species. | | | X | X | X |
| 20 | *Heteromeles arbutifolia* (Toyon) | Iconic with noticeable flowers and fruits. Widespread and abundant. | | X | | | |
| 21 | ***Larrea tridentata*** **(Creosote)** | Most common and widespread native shrub in the Mojave region. Indicator of warm deserts and found throughout all four major North American desert regions. Responsive to precipitation and accessible. | X | | | | X |
| 22 | ***Lathyrus littoralis*** **(Silky beach pea)** | Species of management concern at REDW. | | | X | | X |
| 23 | *Lessingia germanorum* (San Francisco lessingia) | Species of management concern at GOGA. Rare taxon that is endemic to CA. | | | X | | |
| 24 | *Lithophragma bolanderi* (Bolander's woodland star) | Short flowering season. Widely distributed genus. Close relationship with pollinators. Previous studies focused on reproductive phenology of congeners. | | | | X | |
| 25 | *Lupinus latifolius* (Bigleaf lupine) | Widespread, in and outside of California. | | X | X | X | |
| 26 | ***Lupinus obtusilobus*** **(Bluntlobe lupine)** | Charismatic, iconic species of the subalpine. Very sensitive to amount and timing of precipitation. | | | | X | X |
| 27 | *Malacothrix glabrata* (Desert dandelion) | Widespread showy annual. Early indicator of Spring. Early colonizer of roads. | X | | | | |
| 28 | ***Mimulus guttatus*** **(Common yellow monkeyflower)** | Widespread and found in a majority of parks. Found along many elevations, in wetlands, deserts- huge range of habitats. | X | X | X | X | X |
| 29 | ***Penstemon newberyii*** **(Mountain pride)** | Showy and frequent in Mountain parks. | | | | X | X |

**Table 3.** List of high-priority species recommended for phenological monitoring in California. Thirty are actively monitored by the California Phenology Project (these species are identified by bold text). Nomenclature follows the Jepson Manual, Second Edition (Baldwin et al. 2012). (continued)

| | Species (Common name) | Justification summary: identified by CPP Core Team and participants of species selection working groups | Desert | Southern Coast | Northern Coast | Mountain | Actively monitored |
|---|---|---|---|---|---|---|---|
| 30 | ***Pinus contorta*** **(Lodgepole pine)** | Ecologically important responses to hydrological and climate change. Found along gradients (e.g., dry to saturated soils) and a variety of habitats. Widespread and easy to recognize. | | | | X | X |
| 31 | ***Pinus ponderosa*** **(Ponderosa pine)** | Easy to identify and widely distributed in the Sierra Nevada (and throughout the west). Iconic and charismatic species. Historic decline and changes in community composition and structure due to fire suppression. Susceptible to ozone damage. | | | | X | X |
| 32 | *Polemonium eximium* (Skypilot) | Iconic species. Occurs on a few peaks in YOSE, (e.g., Mt Excelsior and Mt. Dana) and in SEKI (e.g., Mt. Whitney and Mt Langley), which are popular peak-bagging hikes and thus could be prime candidate locations for citizen science participation in monitoring if photo-points were established and online submission format deployed. Skypilot monitoring could be a terrific way to raise public awareness of alpine ecosystems. | | | | X | |
| 33 | ***Populus tremuloides*** **(Aspen)** | Iconic mountain species. There are concerns that it appears to be declining at some parks. Dramatic fall foliage display. Widely distributed. Notable variation in timing of Spring leaf-out and Fall color change. | | | | X | X |
| 34 | ***Prosopis glandulosa*** **(Honey locust)** | A long-flowering species that is important for pollinators. Important tree for migratory birds. Widespread, associated with mesic areas sensitive to climate change, such as riparian zones. Very sensitive to changes in hydrology. | X | | | | X |
| 35 | *Prunus emarginata* (Bitter cherry) | Easily identified, widely distributed in Sierra Nevada. Accessible locations and habitats. Distributed along moisture and fire severity gradients. | | | | X | |
| 36 | ***Quercus agrifolia*** **(California live oak)** | Dominant tree in mixed evergreen woodlands. Species of management concern and public interest. Iconic. Many interactions with animals. | | X | X | | X |
| 37 | ***Quercus douglasii*** **(Blue oak)** | Easily accessible and integral to the SPROUTS program at SEKI. | | | | X | X |
| 38 | *Quercus garryana* (Oregon oak) | Dominant species in oak woodlands. | | | X | | |

**Table 3.** List of high-priority species recommended for phenological monitoring in California. Thirty are actively monitored by the California Phenology Project (these species are identified by bold text). Nomenclature follows the Jepson Manual, Second Edition (Baldwin et al. 2012). (continued)

| | **Species (Common name)** | **Justification summary: identified by CPP Core Team and participants of species selection working groups** | **Desert** | **Southern Coast** | **Northern Coast** | **Mountain** | **Actively monitored** |
|---|---|---|---|---|---|---|---|
| 39 | *Quercus kelloggii* (California black oak) | Indicator species. Widely distributed, with broad elevation range. Easily identified. Culturally important, and in accessible locations and habitats. Charismatic. Has shown declines in the mixed conifer zone associated with fire suppression. Important to wildlife habitat. Dramatic fall foliage display. | | | | X | |
| 40 | ***Quercus lobata*** **(Valley oak)** | A keystone species throughout California. Important food resources. Known to be experiencing reproductive and recruitment issues. Large and charismatic. | | X | | | X |
| 41 | ***Rhododendron macrophyllum*** **(Coast rhododendron)** | Charismatic. Huge interest in blooming times among public. | | | X | | X |
| 42 | *Rhododendron occidentale* (Western azalea) | Iconic. Distinct bloom season. Good candidate for phenology gardens, since it is a showy, easily recognizable species. | | | | X | |
| 43 | ***Rosa californica*** **(California wild rose)** | Very common and easy to identify. | | X | X | X | X |
| 44 | *Rubus spectabilis* (Salmonberry) | Common in Northern Coast region, with showy fruit. Many congeners on the USA-NPN species list. | | | X | | |
| 45 | *Salix lasiolepis* (Arroyo willow) | Common; many congeners on the USA-NPN list. | X | X | X | X | |
| 46 | *Salvia columbariae* (Chia) | Important food plant or native tribes. Occurs in many habitats and widespread. | X | X | | | |
| 47 | ***Sambucus nigra* ssp *cerulea*** **(Blue elderberry)** | Easy to identify and determine leaf and flower buds, narrow range of time when it flowers, accessible, found along coast- widespread, connected to other monitoring efforts. | | X | X | X | X |
| 48 | ***Sambucus racemosa*** **(Red elderberry)** | Abundant at REDW and GOGA. A good candidate for comparative study with other *Sambucus* spp. | | | X | X | X |
| 49 | ***Senegalia greggii*** **(Catclaw acacia)** | Interesting late season phenology, thought to respond closely to temperature variation. Important species for birds. | X | | | | X |
| 50 | *Sisyrinchium bellum* (Western blue-eyed grass) | Abundant and showy flowers. Easy to identify. John Muir's favorite plant. Occurs across multiple ecosystems and broad latitudinal range. Indicator species for grasslands and oak woodlands. | | X | X | | |
| 51 | ***Symphoricarpos albus*** **(Snowberry)** | Abundant and accessible at John Muir NHS. Showy fruits good for interpretation. | | X | X | X | X |

**Table 3.** List of high-priority species recommended for phenological monitoring in California. Thirty are actively monitored by the California Phenology Project (these species are identified by bold text). Nomenclature follows the Jepson Manual, Second Edition (Baldwin et al. 2012). (continued)

| | **Species (Common name)** | **Justification summary: identified by CPP Core Team and participants of species selection working groups** | **Desert** | **Southern Coast** | **Northern Coast** | **Mountain** | **Actively monitored** |
|---|---|---|---|---|---|---|---|
| 52 | *Taraxacum officinale* (Dandelion) | Calibration species for USA-NPN. Invasive in wetlands, competes with native species for pollinators. High risk of being a widespread weed in alpine areas. | | | | X | |
| 53 | ***Trillium ovatum*** **(Pacific trillium)** | Charismatic. Pollinated by beetles. | | | X | | X |
| 54 | ***Umbellularia californica*** **(California bay)** | Common and widespread. Early bloomer. | | | X | | X |
| 55 | *Wyethia mollis* (Woolly mule ears) | A keystone species in habitats found on the south side of LAVO, a pilot park. Good candidate for a comparative study: the flowering phenology of closely related species (in CO) has been shown to vary across elevation and this phenological variation is related to seed predation (early flowering plants have been shown to be more susceptible to predation). | | | | X | |
| 56 | ***Yucca brevifolia*** **(Joshua Tree)** | Iconic Mojave desert species, at risk from the effects of climate change. Ideal citizen science focus because it is a symbol of the desert and an indicator of Mojave desert ecosystems. Has elevation limitations within California NPS units. Coevolved with moth pollinator. | X | | | | X |
| 57 | **Yucca schidigera (Mojave yucca)** | Indicator species of mid and upper elevations of the Mojave desert. Tolerant of multiple disturbance regimes. Potentially more resilient to climate change than Joshua Trees. Reliable spring bloomer. | X | | | | X |

For each CPP target species, descriptive species profile guides were developed to assist with monitoring efforts. CPP species profiles include customized phenophase descriptions (i.e. species-specific descriptions of each phenophase, as opposed to the generic phenophase definitions included on all USA-NPN datasheets), practical pointers for monitoring phenophases in the field, phenophase photos, and a general description of the taxon. The CPP species profile may be a useful model for parks and partner institutions who are interested in monitoring taxa not currently targeted by the CPP (CPP species profiles for actively monitored species can be found at www.usanpn.org/cpp/AllSpecies). Additional information about selection of CPP target species can be found in the *CPP Plant Phenological Monitoring Protocol* (Matthews et al. *In review*).

# IV. Development and Implementation of the Monitoring Program

## 4.1 Identification of Opportunities to Link CPP Monitoring with Park Interpretive, Education, and Outreach Programs

In an effort to identify ways to integrate climate change education and phenological monitoring into current and prospective education and interpretive activities at each park, the CPP Core Team invited each of the 18 California NPS units (Table 1) to describe its existing education, interpretive, and volunteer programs. A total of 41 conversations (1 to 2 hours each) were held with NPS interpretation and/or resource management staff at these parks between February and May 2011. Many of the park contacts already had some familiarity with the CPP through previously scheduled briefing webinars offered by the CPP Core Team.

The aim of these conversations was to gain an understanding of the following for each park:

1. The type and scope of existing education, outreach, volunteer, and interpretive programs, as well as each park's previous experience with climate change education programs or programs related to natural resource monitoring or natural history.

2. The park staff who are active in interpretation or outreach.

3. Current interpretive programs or activities that may integrate phenological education and monitoring.

4. The level of interest in phenological monitoring and associated citizen engagement.

5. Opportunities to connect phenology with existing park efforts and to hear from each park about how the CPP pilot project could best meet long-term needs for climate change related education/outreach activities.

6. Existing citizen science and volunteer programs and activities.

7. Education and outreach staff motivations, needs, preferences, opportunities and constraints.

8. Relevant physical locations for phenological monitoring.

9. The relationship with local communities and the general characteristics of park visitors.

Information obtained through the conversations with parks was compiled and summarized in a report (Higgins et al. 2011). This information was used in a variety of ways during the development and implementation of the monitoring program at each park. For example, the physical location of interpretive and education programs that were identified in the report as the most likely candidates for integrating phenological monitoring were later targeted as candidate CPP phenological monitoring sites. Additionally, NPS staff and organizations that facilitate these interpretive and education programs were invited to brainstorming sessions at each pilot park, during which the UCSB field team worked closely with participants to develop creative approaches for incorporating phenological monitoring into ongoing programs.

### 4.2 Pilot Park Visits to Train CPP Observers and to Establish Monitoring Locations

Following the selection of candidate species and the initial outreach to the California parks, the UCSB field team visited each pilot park several (2-4) times in 2011 and 2012. During these visits, the UCSB field team and the NPS pilot park led scheduled and implemented training workshops that provided an introduction to the CPP's goals, hands-on practice using the USA-NPN monitoring protocols, and instructions for entering data online using *Nature's Notebook* (see section V for details of the training workshop content). The primary goal of the initial workshop(s) at each park was to train and prepare NPS staff for participation in the CPP activities at their park and to discuss in detail how to implement a phenological monitoring program so that it could be incorporated into ongoing park activities and programs. During these discussions, the UCSB field team worked with NPS staff in all divisions (e.g., interpretation, education, and resources), with representatives of potential partner institutions (e.g., NatureBridge, the California Native Plant Society, local schools and universities), and with NPS volunteers to select monitoring locations.

Trainings and brainstorming sessions were followed by 1-4 field days focused on establishing monitoring sites at which species and individual plants were selected, tagged, and geo-referenced. Note that CPP monitoring occurs at *sites* where individual plants have been selected and labeled with unique identifiers; these monitoring *sites* are nested within *locations*, which are larger areas generally named for a nearby landmark, such as a trail, visitor center, or road. The guidelines for selecting monitoring locations and the instructions for establishing and documenting sites are described in detail in the *CPP Plant Phenological Monitoring Protocol* and associated Standard Operating Procedures (Matthews et al. *In review*); the documentation for CPP monitoring sites at each park is found in the park-specific monitoring guides, which are included in the *CPP Plant Phenological Monitoring Protocol* as appendices and available on the CPP website. At each National Park, 2-6 monitoring locations were established, each of which is comprised of several sites at which multiple individuals of 1-5 focal species were tagged for monitoring (Figures 3 and 4). Table 4 presents a list of pilot park monitoring locations, along with the number of sites and the targeted plant species at each location.

**Figure 3.** NatureBridge staff assists California Phenology Project scientists in establishing monitoring sites at Sandstone Peak trail in Santa Monica Mountains National Recreation Area.


**Figure 4.** A California buckeye (*Aesculus californica*) tagged at a monitoring site near the Foothills Visitor Center in Sequoia and Kings Canyon National Parks.

**Table 4.** California Phenology Project pilot park monitoring locations, with year established number of sites, and scientific name of target plant species.

| Park Code | Location (CODE) | Year Established | # of sites | Target Plant Species |
|---|---|---|---|---|
| GOGA | Crissy Marsh Overlook (MAOV) | 2012 | 1 | *Baccharis pilularis* |
| | Mori Point (MORI) | 2011 | 6 | *Baccharis pilularis*<br>*Mimulus aurantiacus*<br>*Heracleum maximum*<br>*Eschscholzia californica* |
| | Old Bunker Road (OLBU) | 2011 | 6 | *Baccharis pilularis*<br>*Mimulus aurantiacus*<br>*Heracleum maximum* |
| | Presidio- Lobos Dunes/Mountain Lake (LDML) | 2011 | 9 | *Baccharis pilularis*<br>*Mimulus aurantiacus*<br>*Heracleum maximum*<br>*Eschscholzia californica*<br>*Quercus agrifolia* |
| JOMU | Mount Wanda (WAND) | 2011-2012 | 1 | *Aesculus californica*<br>*Baccharis pilularis*<br>*Quercus agrifolia*<br>*Quercus douglasii*<br>*Umbellularia californica* |
| | Strentzel Meadow (STME) | 2012 | 1 | *Aesculus californica*<br>*Baccharis pilularis*<br>*Rosa californica*<br>*Sambucus nigra*<br>*Symphoricarpos albus* |
| JOTR | High View Trail (HIVI) | 2011 | 8 | *Coleogyne ramosissima*<br>*Eriogonum fasciculatum*<br>*Yucca brevifolia*<br>*Yucca schidigera* |
| | Oasis Visitor Center (OAVC) | 2011 | 1 | *Larrea tridentata*<br>*Prosopis glandulosa* |
| | Ryan Mountain Trail (RYAN) | 2011 | 7 | *Coleogyne ramosissima*<br>*Eriogonum fasciculatum*<br>*Larrea tridentata*<br>*Yucca schidgera* |
| | Park Boulevard (PABO) | 2011 | 3 | *Larrea tridentata*<br>*Senegalia greggii*<br>*Yucca schidigera* |
| LAVO | Hot Rock (HORO) | 2011 | 1 | *Lupinus obtusilobus*<br>*Pinus contorta* |
| | Sunflower Flats (SNFL) | 2011 | 1 | *Arctostaphylos patula*<br>*Penstemon newberryi* |
| | Emigrant Trail (EMIG) | 2011 | 4 | *Arctostaphylos patula*<br>*Penstemon newberryi*<br>*Pinus ponderosa*<br>*Populus tremuloides* |
| | Lake Manzanita (MANZ) | 2011 | 4 | *Arctostaphylos patula*<br>*Penstemon newberryi*<br>*Pinus contorta*<br>*Pinus ponderosa* |
| | Devastated Area (DEVA) | 2011 | 1 | *Populus tremuloides* |

**Table 4.** California Phenology Project pilot park monitoring locations, with year established, number of sites, and scientific name of target plant species (continued).

| Park Code | Location (CODE) | Year Established | # of sites | Target Plant Species |
|---|---|---|---|---|
| SAMO | Zuma Canyon (ZUMA) | 2011 | 7 | *Adenostoma fasciculatum*<br>*Baccharis pilularis*<br>*Eriogonum fasciculatum*<br>*Quercus agrifolia*<br>*Quercus lobata*<br>*Sambucus nigra* |
| | Sandstone Peak Trail (SAPE) | 2011 | 9 | *Adenostoma fasciculatum*<br>*Eriogonum fasciculatum* |
| | Paramount Ranch (PARA) | 2011 | 9 | *Adenostoma fasciculatum*<br>*Baccharis pilularis*<br>*Eriogonum fasciculatum*<br>*Quercus agrifolia*<br>*Quercus lobata*<br>*Sambucus nigra* |
| | Cheesebro Canyon (CHCA) | 2011 | 11 | *Baccharis pilularis*<br>*Eriogonum fasciculatum*<br>*Quercus agrifolia*<br>*Quercus lobata*<br>*Sambucus nigra* |
| | Rancho Sierra Vista/ Satwiwa (RSVS) | 2011 | 6 | *Adenostoma fasciculatum*<br>*Baccharis pilularis*<br>*Eriogonum fasciculatum*<br>*Quercus agrifolia*<br>*Sambucus nigra* |
| SEKI | Foothills Visitor Center (FHVC) | 2011 | 4 | *Aesculus californica*<br>*Quercus douglasii* |
| | Lower Kaweah Air Quality Monitoring Site (LKAQ) | 2011 | 1 | *Arctostaphylos patula*<br>*Penstemon newberyii* |
| REDW | Kuchel Visitor Center (KVC) | 2011 | 5 | *Baccharis pilularis*<br>*Lathyrus littoralis* |
| | Lady Bird Johnson Grove (LBJ) | 2011 | 6 | *Rhododendron macrophyllum*<br>*Trillium ovatum* |
| | Crescent Beach Overlook (CBO) | 2011 | 6 | *Baccharis pilularis*<br>*Heracleum maximum*<br>*Sambucus racemosa* |

In subsequent park visits, the UCSB field team met with CPP participants (including both NPS staff and volunteers) to discuss overall project progress; to provide additional training opportunities; to obtain feedback about the monitoring protocols, volunteer recruitment efforts, and selected sampling design and approach; to establish additional monitoring sites, if desired; and to share monitoring tools, phenophase photos, and field experiences from other pilot parks.

## 4.3 Testing and Revising Monitoring Protocols

Throughout the first monitoring season, the UCSB partners communicated extensively with NPS staff and CPP observers to compile feedback on the monitoring protocols, to develop solutions to problematic phenophase descriptions, and to create monitoring tools to support field observations (e.g., CPP species profiles with phenophase photos). Having obtained observer feedback, UCSB partners worked closely with the USA-NPN staff to adjust species-specific monitoring protocols, to revise and clarify phenophase definitions, and to create monitoring tools intended to increase observer confidence and to reduce errors.

For instance, a common point of confusion cited by CPP observers in desert and Mediterranean ecosystems related to plant responses to sporadic precipitation events: after a flush of new leaf production, if water subsequently becomes unavailable, leaf expansion may be arrested, resulting in many small leaves on the plant. These responses to water availability (initiation of growth followed by arrested growth when the resources give out) were confusing for observers, as it is difficult to differentiate between small young leaves and small old leaves. In order to reduce observer confusion, the CPP include additional guidance and instructions on the species profiles created for these taxa (e.g., *Eriogonum fasciculatum* and *Adenostoma fasciculatum*). The CPP species profiles remind observers that with additional monitoring experience, observers may begin to feel confident in distinguishing between newly produced, small leaves and older small leaves based on differences in color, texture, size, and location on the plant. The species profile developed for each target species is available for download on the CPP website (www.usanpn.org/cpp/AllSpecies).

### 4.4 Protocol Documentation

The field testing and the subsequently revised phenological monitoring and outreach protocols are documented in the *CPP Plant Phenological Monitoring Protocol* (which is compliant with NPS Inventory and Monitoring Program guidelines, following Oakley et al. 2003). The CPP Core Team completed the first draft of the protocol and the associated SOPs in early 2013 (Matthews et al. *In review*), and the protocol was submitted for peer review through the NPS Natural Resources Publications Management System in June 2013. It will be made available for download after the peer-review process is complete.

The protocol and SOPs provide detailed instructions for developing and implementing a phenological monitoring program. The SOPs include:

- SOP1: Guidelines for Designing a Phenological Monitoring Program at New California Phenology Project National Parks
- SOP2: Steps for Selecting and Documenting New Species (non-CPP taxa)
- SOP3: Selecting and Establishing Monitoring Sites
- SOP4: Field Season Preparation and Equipment and Materials Needed
- SOP5: Recruiting and Training Phenology Observers
- SOP6: Safety Procedures
- SOP7: Phenology Site and Trail Monitoring
- SOP8: Data Entry and Data Management
- SOP9: Post Field Season Activities
- SOP10: Data Summary, Analysis, and Reporting
- SOP11: Revision Process

### 4.5 Status of Monitoring Efforts

The CPP has been successful in its data collection efforts. In both 2011 and 2012, the CPP observer network contributed >20% of the total observations submitted to the USA-NPN's National Phenology Database (NPDb), and as of October 2013, the CPP network had submitted

>435,000 observation records representing the 30 target species to the NPDb (Table 5). These figures highlight the substantial contribution the CPP has made to the nation-wide effort to collect baseline phenological data. Preliminary analysis of these data have already been used to demonstrate how phenological patterns vary across elevation and latitude in California and suggest the important and less-often studied role of sporadic rainfall events in driving phenology in precipitation-limited systems. Preliminary results were presented at the Ecological Society of America's annual meeting and at the International Phenology meeting in 2012, and the George Wright Society meeting in 2013 (download PDFs of these presentations here: https://www.usanpn.org/cpp/resources). In addition, presentation of the quantitative geographical patterns observed by the CPP have been incorporated into training workshops and were shared with workshop attendees at GOGA, YOSE, the Botanical Society Meetings of America (New Orleans, LA), the Pepperwood Preserve (Santa Rosa, CA), and the Oxnard Union High School District in July – September 2013. Rigorous analysis of the pilot data is underway, and the CPP expects to complete a manuscript for peer-reviewed publication by early 2014. In addition, the CPP is continuing to develop new approaches for summarizing phenological data for clear communication to participants, partners, and the general public.

**Table 5.** Total number of observation records collected during 2011 and 2012 by the California Phenology Project, arranged by species and pilot park.

| Species | # of observation records | GOGA | | JOMU | JOTR | | LAVO | | REDW | | SAMO | | SEKI | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2011 | 2012 | 2012 | 2011 | 2012 | 2011 | 2012 | 2011 | 2012 | 2011 | 2012 | 2011 | 2012 |
| *Adenostoma fasciculatum* | 8394 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2384 | 6010 | 0 | 0 |
| *Aesculus californica* | 6643 | 0 | 0 | 2523 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 290 | 3830 |
| *Arctostaphylos patula* | 10184 | 0 | 0 | 0 | 0 | 0 | 4338 | 2807 | 0 | 0 | 0 | 0 | 392 | 2647 |
| *Baccharis pilularis* | 35881 | 11456 | 7711 | 882 | 0 | 0 | 0 | 0 | 2160 | 3844 | 1138 | 8690 | 0 | 0 |
| *Coleogyne ramosissima* | 13855 | 0 | 0 | 0 | 6740 | 7115 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Eriogonum fasciculatum* | 17667 | 0 | 0 | 0 | 0 | 4906 | 0 | 0 | 0 | 0 | 2887 | 9874 | 0 | 0 |
| *Eschscholzia californica* | 2596 | 1596 | 1000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Heracleum maximum* | 10709 | 1458 | 961 | 0 | 0 | 0 | 0 | 0 | 2513 | 5777 | 0 | 0 | 0 | 0 |
| *Larrea tridentata* | 10992 | 0 | 0 | 0 | 4911 | 6081 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Lathyrus littoralis* | 9640 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3130 | 6510 | 0 | 0 | 0 | 0 |
| *Lupinus obtusilobus* | 3290 | 0 | 0 | 0 | 0 | 0 | 1750 | 1540 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Mimulus aurantiacus* | 3873 | 573 | 3300 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Penstemon newberryii* | 8791 | 0 | 0 | 0 | 0 | 0 | 3247 | 2810 | 0 | 0 | 0 | 0 | 392 | 2342 |
| *Pinus contorta* | 4096 | 0 | 0 | 0 | 0 | 0 | 2368 | 1728 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Pinus ponderosa* | 2768 | 0 | 0 | 0 | 0 | 0 | 1688 | 1080 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Populus tremuloides* | 3190 | 0 | 0 | 0 | 0 | 0 | 2860 | 330 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Prosopis glandulosa* | 2520 | 0 | 0 | 0 | 1060 | 1460 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Quercus agrifolia* | 12530 | 1465 | 1265 | 385 | 0 | 0 | 0 | 0 | 0 | 0 | 1340 | 8075 | 0 | 0 |
| *Quercus douglasii* | 9789 | 0 | 0 | 550 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 759 | 8480 |
| *Quercus lobata* | 19337 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2459 | 16876 | 0 | 0 |
| *Rhododendron macrophyllum* | 7906 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1889 | 6017 | 0 | 0 | 0 | 0 |
| *Rosa californica* | 1560 | 0 | 0 | 1560 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Sambucus nigra ssp cerulea* | 19232 | 0 | 0 | 1210 | 0 | 0 | 140 | 0 | 0 | 0 | 2895 | 14987 | 0 | 0 |
| *Sambucus racemosa* | 4781 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1379 | 3402 | 0 | 0 | 0 | 0 |
| *Senegalia greggii* | 3092 | 0 | 0 | 0 | 0 | 3092 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Symphoricarpos albus* | 1890 | 0 | 0 | 1890 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Table 5.** Total number of observation records collected during 2011 and 2012 by the California Phenology Project, arranged by species and pilot park (continued).

| Species | # of observation records | GOGA | | JOMU | JOTR | | LAVO | | REDW | | SAMO | | SEKI | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **2011** | **2012** | **2012** | **2011** | **2012** | **2011** | **2012** | **2011** | **2012** | **2011** | **2012** | **2011** | **2012** |
| *Trillium ovatum* | 7530 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2336 | 5194 | 0 | 0 | 0 | 0 |
| *Umbellularia californica* | 112 | 0 | 0 | 112 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Yucca brevifolia* | 9084 | 0 | 0 | 0 | 3635 | 5449 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Yucca schidigera* | 8332 | 0 | 0 | 0 | 4244 | 4088 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total by Park by Year | 260152 | 16548 | 14237 | 9112 | 20590 | 32191 | 16391 | 10295 | 13407 | 30744 | 13103 | 64512 | 1833 | 17299 |
| Total by Park | | 30785 | | 9112 | 52781 | | 26686 | | 44151 | | 77615 | | 19132 | |
| **2011 Total** | **81872** | | | | | | | | | | | | | |
| **2012 Total** | **178278** | | | | | | | | | | | | | |

# V. Outreach and Partnership Development

### 5.1 Building an Observer Network

Because many of the pilot parks relied on volunteer observers for data collection, much of the CPP pilot phase focused on building and retaining a widespread network of professional and citizen scientist observers. This required an investment of time and energy on the front end, but volunteer network-building efforts can result in a dedicated and knowledgeable group of "local experts" who are able to train new recruits, and who, collectively, can record more frequent phenological observations at a larger spatial extent than would be possible by relying solely on NPS employees.

As a first step towards building an observer network, the UCSB field team led training workshops for NPS staff, representatives of local partner organizations (e.g., botanical gardens docents, California Native Plant Society members, conservation non-governmental organization staff), and volunteers during the visits to each pilot park. Prior to each training event, the UCSB team created flyers to promote the workshops and to recruit participants; flyers were distributed by the CPP Core Team and pilot park staff to the intended audience (Figure 2). As a general rule, public and staff participation in training workshops were greatly increased when flyers and public announcements were distributed through multiple outlets (e.g., park newsletters, visitor center bulletin boards, local newspapers, garden clubs, and NPS campground activity notices) and to multiple organizations (e.g., the Desert Institute at JOTR, botanic gardens, local community colleges, California Native Plant Society chapters, etc.). In addition, many of the workshop participants claimed that they made the decision to attend the workshop only after having received an announcement multiple times.

CPP training workshops provided instruction in, practice with, and reinforcement of the observational skills and in the core ecological and botanical concepts needed for accurate and sustained long-term recording and interpretation of phenological data. After attending one of these workshops, participants were prepared to record accurate phenological data and to contribute these data to the USA-NPN online database (via the *Nature's Notebook* web interface). In order to provide the background information and hands-on training necessary for successful use of the USA-NPN monitoring protocols, CPP workshops typically required at least a 4-hour window, which included a well-illustrated lecture, hands-on activities, and discussion. The lecture session typically required at least 90 minutes to cover: the background and goals of the CPP; ecological concepts needed to understand the CPP's goals; examples of scientific studies demonstrating the link between variation in climate and phenology; botanical terms needed to monitor plant phenology (e.g., bud, flower, fruit); mechanics of monitoring (including a demonstration of the monitoring protocols and hands-on practice using the protocols during longer workshops); and, finally, data-entry methods and tools used by participating parks. The lecture slides from all workshops are available on the CPP website as PDFs (http://www.usanpn.org/cpp/resources/presentations).

## *A California Phenology Project workshop:*

### *Using phenology to detect plant responses to climate change*

***Who:** professional scientists, educators, citizen scientists, and nature enthusiasts*
***Where:** Lassen Volcanic National Park, Loomis Ranger Station (see detailed directions below)*
***When:** Thursday, June 14th, 9am-3pm*
***CPP website:** www.usanpn.org/cpp*

*Note: we recommend that you explore the CPP website prior to the workshop to learn a bit about this project!*

**Workshop Agenda**

| | |
|---|---|
| 8:45am: | Arrive at Loomis Ranger Station, Lassen Volcanic National Park (*directions below*) |
| 9:00am: | Introductions & What to Expect |
| 9:15am-12:00pm: | Presentation, hands-on practice, and discussion:<br>• The link between climate change and phenology<br>• Introduction to the California Phenology Project (CPP) and the USA National Phenology Network (USA-NPN)<br>• Move outside: hands-on practice monitoring plant phenology!<br>• Demonstration of Nature's Notebook: the user-friendly USA-NPN interface for contributing phenological data |
| 12:00am – 1:00pm: | LUNCH BREAK (everyone should bring a bag lunch!) |
| 1:00- 3:00pm: | Wrap-up morning content, discussion, and opportunity for Q&A<br>• Logistics of implementing phenological monitoring at natural areas (e.g., learn how to establish monitoring sites, label plants, and record important field information)<br>• How to get involved in the CPP, as an educator, scientist, student, or natural area representative<br>• Developing educational and interpretive activities around phenological monitoring |

**Workshop Facilitators:** *Dr. Susan Mazer and Dr. Liz Matthews, CPP Field Coordinators, University of California, Santa Barbara; email: phenology@eemb.ucsb.edu*

**Directions to Lassen Volcanic National Park, Loomis Ranger Station:** *The ranger station is near Manzanita Lake, on the right just past the Northwest entrance station (park in the lot near the Loomis Museum). Download directions to the Northwest entrance here: http://www.nps.gov/lavo/planyourvisit/directions.htm (maps of the park and surrounding area can be downloaded here: http://www.nps.gov/lavo/planyourvisit/maps.htm).*

USA npn National Phenology Network

NATIONAL PARK SERVICE

UCSB Phenology Stewardship Program

UNIVERSITY OF CALIFORNIA Natural Reserve System

**Figure 5.** Sample promotional flyer for California Phenology Project training events, this one held in at Lassen Volcanic National Park (July 2012).

**Figure 6.** California Phenology Project observers monitor *Mimulus aurantiacus* at sites in Golden Gate National Recreation Area.

CPP training materials can be tailored to meet the needs of diverse audiences, including NPS resource management and interpretation staff, citizen scientist volunteers, formal and informal educators, partner organizations, and the general public. The CPP encourages experienced observers to modify and use these materials when training new observers. During the pilot period, the CPP provided >25 training workshops at pilot parks, which were attended by ~ 435 participants (Table 6). The CPP also offered training workshops and public presentations at a variety of non-NPS venues to a total of > 470 participants and attendees in an effort to recruit a broader network of volunteers and to support the long-term goal of expanding the CPP network (Table 7). The CPP also compiled information about the CPP, the USA-NPN, and other phenological monitoring and citizen science programs across the U.S. as part of an "online toolkit" (Appendix D).

**Table 6.** List of California Phenology Project training workshops and outreach events held during 2011, 2012, and 2013 at California parks units indicating date, park name, focal audience, participants and total number of attendees.

| Date (Month, Year) | NPS unit | Brief Description | Focal Audience | Other Participating Parks, Organizations, and Agencies | Total # Attendees |
|---|---|---|---|---|---|
| April 2011 | JOTR | 3 half-day training workshops | JOTR resources, interpretation, and education staff | Desert Institute | 27 |

**Table 6.** List of California Phenology Project training workshops and outreach events held during 2011, 2012, and 2013 at California parks units indicating date, park name, focal audience, participants and total number of attendees (continued).

| Date (Month, Year) | NPS unit | Brief Description | Focal Audience | Other Participating Parks, Organizations, and Agencies | Total # Attendees |
|---|---|---|---|---|---|
| May 2011 | SAMO | 3 full-day training workshops | SAMO interpretation and resources staff, RLC, local organizations, and teachers (e.g. NatureBridge) | NatureBridge | 24 |
| June 2011 | GOGA | 1 full-day training workshop | NPS and Presidio staff | Presidio, USFWS | 16 |
| June 2011 | REDW | 1 full-day training workshop | NPS and partner agency staff | Oregon Caves NM, Humboldt State University (HSU) | 19 |
| July 2011 | SEKI | 1 full-day training workshop | SEKI interpretation staff | Sequoia Natural History Association (SNHA) | 29 |
| July 2011 | LAVO | 1 full-day training workshop | NPS staff | Lava Beds NM, Whiskeytown NRA | 12 |
| September 2011 | SAMO | 1 half-day field training event at SAMO's Sandstone Peak monitoring sites | volunteers and local educators | NatureBridge | 10 |
| October 2011 | JOTR | 1 evening lecture with the Desert Institute | JOTR volunteers and the general public | Desert Institute, Death Valley NP | 10 |
| November 2011 | JOMU | 1 full-day training workshop | NPS staff, volunteers, and local high school students | Friends of Alhambra Creek, New Leaf Collaborative | 14 |
| January 2012 | JOTR | 1 full-day training workshop for JOTR interpretation staff and evening lecture and field training event coordinated with Desert Institute | NPS staff and volunteers | Desert Institute | 40 |
| March 2012 | REDW | 3 half-day training workshops | NPS staff, volunteers, and the general public | HSU students, Wiyot Tribe Environmental Dept., Burea of Land Management (BLM), CA State Parks | 45 |
| June 2012 | LABE[1] | 1 full-day training workshop | NPS staff and volunteers | BLM | 16 |
| June 2012 | LAVO | 1 full-day training workshop | NPS staff, volunteers, and the public | US Forest Service, CA Department of Fish and Game, CNPS Mt Lassen Chapter, Western Shasta Resource Conservation District, Shasta College, Simpson University | 19 |
| July 2012 | SEKI | 1 full-day training workshop | NPS staff, volunteers, and partner organizations | Yosemite NP, Tulare County educators, local land trusts, local artist | 25 |

**Table 6.** List of California Phenology Project training workshops and outreach events held during 2011, 2012, and 2013 at California parks units indicating date, park name, focal audience, participants and total number of attendees (continued).

| Date (Month, Year) | NPS unit | Brief Description | Focal Audience | Other Participating Parks, Organizations, and Agencies | Total # Attendees |
|---|---|---|---|---|---|
| July 2012 | GOGA | 3 half-day training workshops | NPS staff and volunteers | CA College of the Arts, San Francisco Chronicle, PRBO Conservation Science, Marin Municipal Water District | 35 |
| July 2012 | JOMU | 1 evening presentation and 1 full-day training workshop | NPS staff and volunteers | Friends of Alhambra Creek, New Leaf Collaborative, Solano Land Trust, East Bay regional parks | 25 |
| September 2013 | YOSE[1] | 1 lecture and 1 full-day workshop | NPS staff and volunteers | NatureBridge | 60 |

[1]Lava Beds National Monument and Yosemite National Park are not CPP pilot parks

**Table 7.** California Phenology Project training events and outreach activities at non-NPS venues, with date, location, description of event, and approximate number of attendees.

| Date (Month, Year) | Location | Description | Approximate # of attendees |
|---|---|---|---|
| September 2011 | San Diego, CA | presentation at California Native Plant Society (CNPS) Chapter Council meeting | 40 |
| October 2011 | Santa Ynez, CA | presentation at Sedgwick Reserve for the UC Natural Reserve System's managers meeting | 40 |
| January 2012 | San Diego, CA | presentation at CNPS 2012 Conservation Conference | 50 |
| April 2012 | Malibu, CA | 2 half-day workshops at the Association for Environmental and Outdoor Education’s Spring Conference | 30 |
| August 2012 | Portland, OR | 2 oral papers at the Ecological Society of America's annual meeting | 50 |
| October 2012 | Oakland, CA | 1 full-day training workshop and a lecture at the North American Association for Environmental Education's annual meeting | 50 |
| December 2012 | Los Angeles, CA | 1 evening presentation and 1 half-day training workshop with the Los Angeles County CNPS Chapter and UC’s Stunt Ranch Reserve | 40 |
| February 2013 | Chico, CA | presentation at CSU-Chico biology seminar series | 50 |
| February 2013 | Carmel Valley, CA | Training workshop at Hastings Reserve | 40 |
| March 2013 | Santa Barbara, CA | Training workshop at Santa Barbara Botanic Garden | 30 |
| July 2013 | New Orleans, LA | Workshop at Botanical Society of America Annual Meeting | 15 |

**Table 7.** California Phenology Project training events and outreach activities at non-NPS venues, with date, location, description of event, and approximate number of attendees (continued).

| Date (Month, Year) | Location | Description | Approximate # of attendees |
|---|---|---|---|
| August 2013 | Camarillo, CA | Professional development workshop for high school teachers at Adolfo Camarillo High School | 10 |
| August 2013 | Sausalito, CA | Workshop with NatureBridge at Marin Headlands campus | 23 |
| August 2013 | Santa Rosa, CA | Workshop with Pepperwood Preserve staff and volunteers | 4 |

Providing training opportunities is the first step in building an observer network, but sustained participation and volunteer retention often require follow-up and additional interaction. As such, the CPP created infrastructure to support continued interaction among observers and trainers and information exchange among the observer network, including a listserv (http://www.usanpn.org/cpp/news/listserv) and a Facebook page (https://www.facebook.com/CaliforniaPhenologyProject). These resources were invaluable for sustaining participant enthusiasm and for building a sense of a community among observers. These tools are expected to support sustained growth of the network, to maximize volunteer retention, and to promote continued learning. A variety of other communication and support tools were developed by the pilot parks, which included recurring training events and community field days, where observers work together at established monitoring sites; distribution of newsletters with data summaries or project updates; online calendars to facilitate scheduling monitoring with other observers; and participant appreciation events (e.g., botanical walks, pot-luck events, etc.).

One of the most successful models for recruiting CPP observers is to build partnerships with local organizations, particularly those that have an ongoing relationship with the NPS unit. Potential partner organizations include schools, land trusts, local and regional parks, environmental education programs, conservation organizations, botanical gardens, and natural history museums, among others. Focused outreach to these groups (e.g., inviting them to attend CPP training workshops, public lectures, or field events) was often effective in earning their attendance and participation. Many CPP pilot parks have been successful in recruiting observers from organizations that have ongoing relationships with the park, particularly conservation and education-focused organizations. For example, Santa Monica Mountains NRA and Golden Gate NRA have an ongoing relationship with NatureBridge, a residential environmental education program with campuses at these parks (as well as other NPS units in California and Washington). NatureBridge staff participated in CPP training workshops at these two pilot parks, and subsequently incorporated phenological monitoring into their local environmental education programs by monitoring designated CPP sites with student groups. Other pilot parks have successfully recruited volunteers from local conservation and restoration groups with well-established ties to a park (e.g., Friends of Alhambra Creek at John Muir National Historic Site) and local universities (e.g., Humboldt State University students at Redwood National Park).

### 5.2 Outreach and Partnership-development Activities at the Pilot Parks

Each pilot park employed a different approach to building a local network of observers and partners. These approaches were based upon each park's capacity for recruiting, training, and coordinating volunteers; the local community setting (i.e., the size and make-up of the volunteer pool); proximity to volunteers who have their own transportation and can visit monitoring locations; and the ongoing relationships with volunteer groups and partner organizations. As part of the pilot phase, each park was provided with funding to hire field support staff (e.g., student interns or seasonal biological technicians) to assist with coordination and implementation of on-the-ground phenological monitoring activities. Some parks secured additional resources to augment the funding provided by the CPP; for example, GOGA received funding through the NPS George Melendez Wright internship program to hire an intern to support the monitoring efforts. Successful implementation of CPP protocols required staff with a sufficient portion of their position dedicated to monitoring and outreach activities. Because the permanent park staff in most parks did not have time available to oversee phenological monitoring activities on a day-to-day or week-to-week basis, the field support positions were critical to the success of CPP pilot phase activities.

Brief descriptions of the network-building and outreach activities at each pilot park are provided below as potential models for other parks that are interested in implementing a citizen science-driven phenological monitoring program. In addition, due to the regular turnover of both seasonal and permanent staff at all parks, these descriptions may facilitate the sustainability of phenological monitoring at the pilot parks should cognizant staff members leave due to retirement and transfers.

#### *5.2.1 Golden Gate National Recreation Area (GOGA)*

Pilot activities: GOGA's outreach focused on individual volunteers, local schools, and partner groups. Much of the partnership development, volunteer recruitment, and observer training were directed by three interns: one funded by the CPP, one funded by the Presidio Trust, and a third funded through the George Melendez Wright Climate Change internship program. The interns developed a program with the Golden Gate National Parks Conservancy (GGNPC) to train and coordinate volunteer efforts at the CPP monitoring sites near GGNPC plant nurseries, including the nurseries in the Presidio and at Mori Point. CPP interns also worked with teachers at Oceana High, a local high school near Mori Point, to develop a program that will train students to conduct phenological monitoring at the Mori Point sites. Finally, the CPP interns worked with the Alcatraz Garden Club to establish a monitoring trail on Alcatraz (see a recent article about this effort at this URL: http://alcatrazgardens.org/blog/index.php/2013/02/science-of-the-seasons/) and initiated a nascent partnership with faculty at Skyline Community College, who are developing a curriculum that includes monitoring CPP plants at Mori Point.

One of the strongest partnerships developed at GOGA is with NatureBridge (www.naturebridge.org), which operates an environmental education program in the Marin Headlands portion of GOGA. NatureBridge staff at the GOGA campus developed teaching materials that introduce core ecological, botanical, and phenological concepts to younger students and that prepare students to identify CPP target species and their phenophases. Field instructors introduce the students to the target species and the USA-NPN monitoring protocols at the Marin Headlands nursery (also operated by GGNPC) and then students observe the CPP plants at the Old Bunker Road sites (Table 4). Senior NatureBridge staff review the data and upload the records to the NPDb via *Nature's Notebook.* NatureBridge staff also collaborated with the UCSB field team to offer training workshops at the North American Association for

Environmental Education (NAAEE) meetings held in Oakland, California in October, 2012 (Table 7). In August 2013, UCSB collaborators delivered a half-day workshop to NatureBridge staff during their one-week staff training period at the beginning of the school year.

Lessons Learned: GOGA was very successful in building partnerships with well-established local organizations during the pilot phase. The partnership with NatureBridge successfully taps into local expertise in environmental education and engages students who are already visiting the Marin Headlands for NatureBridge programming; this partnership has the potential to expand to other NatureBridge campuses, such as those in Yosemite NP and Olympic NP. The NatureBridge model has also been successful in overcoming a common hurdle cited in developing partnerships with school groups: follow-through in entering data online (e.g., see the section describing SAMO's experience with school groups below).

### *5.2.2 John Muir National Historic Site (JOMU)*

Pilot Activities: JOMU developed a graduated phenology internship program in partnership with *New Leaf: A Sustainable Collaborative*, a place-based high school program within the Martinez United School District. JOMU recruits and trains student interns who participate over several years. The program provides long-term mentorship, career exploration opportunities, and a pathway to careers in the NPS for the interns. The internship program is structured around four tiers that have graduated degrees of responsibility and compensation:

1. *Tier 1:* Interns complete comprehensive training in phenological monitoring, data management, safety, professionalism, and NPS operations and career options. Interns receive academic credit with no financial compensation.

2. *Tier 2:* Interns have successfully completed the initial phase of training and are expected to conduct monitoring independently and assist with education and outreach efforts. Interns receive academic credit and are compensated $5 per hour.

3. *Tier 3:* Interns have displayed a high level of knowledge and fluency in core phenological, ecological, and botanical concepts, in the USA-NPN phenological monitoring protocols, and in NPS operations and outreach efforts. Interns are expected to help train and mentor Tier 1 and 2 interns and to play a bigger role in outreach and education activities. Interns receive academic credit and are compensated $10 per hour.

4. *Tier 4:* Once interns meet all the internship standards and qualifications, they will have the opportunity to compete for a student hire position. As student hires, they will be expected to help with the management of the phenology program, among other programs. Compensation will be at a GS-1 or GS-2, depending on the qualifications of each student.

Martinez Unified School District has committed to paying for the interns in Tiers 1, 2, and 3, and JOMU has committed to paying for the students who graduate to Tier 4 using NPS Youth Program funding.

In addition to the high school internship program, JOMU is continually recruiting and training volunteers from the local community and partner groups, such as Friends of Alhambra Creek, who currently monitor a site at JOMU, interact with student interns, and assist in outreach and training of new volunteers. Local college students and instructors have also contacted the park and expressed interest in developing a monitoring program on or near their campuses.

Lessons Learned: The internship program with New Leaf has been successful thus far, but if budget projections change in the future, the sustainability of the internship program may be jeopardized. One of the biggest challenges in coordinating the internship program has been managing student schedules and commitments. A potential solution to this logistical issue could be requiring a regular schedule of each intern and having NPS staff check-in with them periodically. Patience is important when training and managing younger interns. Also, providing an opportunity for students to transition slowly into the program (e.g., the Tier 1 level) has served the students well. For adult volunteers, matching each group with a monitoring site has made logistics easier  which has increased each group's commitment and ownership of the program.

#### *5.2.3 Joshua Tree National Park (JOTR)*

Pilot Activities: Outreach, volunteer recruitment, and partnership development at JOTR were conducted in stages, successively reaching wider audiences. The CPP-funded intern initially conducted outreach to conservation and botanical organizations in the local area, which was followed by recruitment efforts directed towards the broader community. The JOTR intern reached out to conservation organizations whose missions are in line with the CPP's goals. These organizations included the Mojave Desert Land Trust (MDLT), the Morongo Basin Conservation Association (MBCA), Master Composter's group, the Mojave Desert Branch of the California Native Plant Society (CNPS), and the Desert Studies Club at the local community college, Copper Mountain College (CMC). More than 700 members of these organizations were contacted, either in person or via email, with varying degrees of success. Outreach to the MDLT and the MBCA was the most successful, resulting in several inquiries from people interested in volunteering with the CPP. JOTR organized a training session, and approximately 7 participants remained engaged with the project and participated in CPP data collection following the training. Some of these participants lost interest over time, and eventually the group shrunk to 3 committed observers. Initial outreach efforts were also successful in building partnerships with local educational organizations. CMC has created a 100-hour volunteer internship program for academic credit, and the Joshua Tree National Park Association's adult education program, the Desert Institute (http://www.joshuatree.org/desert-institute/), hosted three CPP lectures and training events during the pilot phase. Unfortunately, none of the Desert Institute program participants subsequently volunteered with the CPP, perhaps because many are not from the local area.

During the second phase of volunteer recruitment, JOTR staff reached out to a more diverse audience and publicized the CPP to the broader Morongo Basin community (which includes the gateway cities surrounding JOTR: Twentynine Palms, Joshua Tree, and Yucca Valley). Civic groups were strategically selected and approached, and JOTR staff presented a seminar at the Basin Wide Foundation (BWF) Breakfast, a monthly gathering of representatives from nonprofits in the Morongo Basin. JOTR staff attended the Yucca Valley Earth Day Fair to present a CPP poster and to engage visitors, answer their questions, and recruit volunteers.

Overall, these efforts were met with little success: more than 200 people were approached, but no volunteers were recruited.

Lessons Learned: Recruiting volunteers at a rural park such as JOTR can be difficult. Almost 1000 members of the local community were targeted for outreach activities, and JOTR successfully recruited about 10 long-term volunteers. Despite the low investment to return ratio, the experiences of the pilot phase recruitment efforts will help to refine future outreach. First, persistence and follow through on the part of JOTR staff are very important; for example, a follow-up email to the Basin Wide Breakfast community may have engaged people who were initially interested in volunteering, but were unsure of how to proceed. Similarly, some volunteers who expressed interest in the CPP were traveling or out of touch over the summer months; it was only through regular, persistent email and phone contact that these volunteers eventually participated in the program.

Second, there is a lot of power in publicizing the CPP in the local community. The word "phenology" may be foreign to the general public, but once the local community was repeatedly exposed to the terms and concepts related to phenological monitoring, the park was more successful in recruiting volunteers. Through outreach to the Morongo Basin community, for example, a few members of the public learned of the CPP by word of mouth; they approached JOTR staff about participating, and these volunteers are now regularly monitoring CPP plants at the park. Much of this messaging to the public was a result of staff at the visitor centers and people in the community spreading the word. Using a variety of media can also help in successfully reaching out to the community (e.g., creating and distributing informational signs and pamphlets at the JOTR visitor centers; creating advertisements on the JOTR website; recruiting through the Desert Institute mailing list or class handouts; including a description CPP volunteer opportunities on the park's website: http://www.volunteer.gov/gov/results.cfm?ID=12421).

Beyond the initial hurdle of recruiting volunteers, there are many challenges related to retaining, training, and coordinating volunteers. Only a handful of volunteers who had gone through a training subsequently made a commitment to monitor on a regular basis. There are several factors which may contribute to the difficulty in retaining trained volunteers, including the timing of follow-up trainings, the high cost of using personal transportation to reach relatively distant sites, inclement weather conditions, the required frequency of observation, frustration related to observing difficult phenophases, and the lack of social interaction when monitoring. In order to mitigate these factors, JOTR may identify a shorter period of time for observation, reducing the period of volunteer participation to the phenologically active season (i.e., excluding the months of the year when focal species are more likely to be dormant). By concentrating volunteer efforts during the phenologically active period, pre-season training can be restricted to specific time periods and volunteers can be better trained before they begin monitoring. Clustering trainings will also allow JOTR to effectively utilize limited staff and volunteer time and may allow observers to partner with other volunteers and increase social interaction. Overall, JOTR's experience reveals that a lot of effort and planning is required up front to build a volunteer-based monitoring program. JOTR will continue to explore ways to make the CPP program sustainable, including limiting the active period of volunteer observation, increasing the number of training and social opportunities, and staying in regular contact with active volunteers during the “off-season.”

#### *5.2.4 Lassen Volcanic National Park (LAVO)*

Pilot Activities: LAVO is a remote park with a small local community, which has constrained the growth of a volunteer observer network. Furthermore, most of LAVO’s staff is seasonal, which limits the period in each year during which staff can participate in monitoring activities. Despite these challenges, LAVO has been successful in monitoring most of its CPP sites by engaging NPS staff from both the resources and interpretation divisions and by recruiting a small number of dedicated volunteers.

In 2011, NPS natural resources staff, a volunteer, and a seasonal interpreter conducted the bulk of the CPP monitoring. The seasonal interpreter also designed and led programs to introduce the idea of seasonal, phenological changes to the public. These programs were piloted at two of the CPP sites near the Loomis Museum. Although the programs were popular with park visitors, the interpreter found that it was not realistic to attempt to deliver educational programming *and* collect data in these short interactions with visitors.

In 2012, the monitoring season began early due to an unusually light winter snow pack, and seasonal natural resources staff began monitoring CPP sites in late May. A CPP-dedicated Student Conservation Association (SCA) intern began his season in mid-June, first attending the 2012 CPP training led by the UCSB field team and then serving as the CPP volunteer point of contact. The SCA intern was stationed at Manzanita Lake, which is near LAVO’s monitoring sites but far from LAVO’s resources staff, who are stationed in Mineral. As such, the intern worked independently to train student volunteers from local colleges (e.g., Shasta Community College and Simpson College) and to coordinate volunteer efforts so that data were regularly and accurately recorded. Because LAVO volunteers typically have a long commute to the park (e.g., a >1 hour drive from Redding to the CPP sites at LAVO), volunteers sometimes were not able to fulfill their regular monitoring commitments, requiring the intern to fill in for them. Unfortunately, several fires in the park impacted the 2012 monitoring season due to extensive and lengthy park closures. Luckily, the CPP monitoring sites were not directly affected by the fire, and after the park reopened to the public, volunteers resumed monitoring until the park closed for the season in early November.

Under the supervision of interpretation and education, the SCA intern developed a phenology display at LAVO’s Discovery Center to inform the public about the CPP. The intern interacted with many members of the public throughout the season, providing them with information about the project and about climate change in general. These outreach efforts fulfilled a major need in the park, but at the cost of completing data entry for the 2012 season. (The complications and closures resulting from the wildfire at the end of the season further limited the park’s ability to complete data entry in 2012).

Lessons Learned: There is a high level of support for the CPP at Lassen Volcanic National Park. However, without a nearby population base from which to recruit long-term volunteers and without a stable source of funding, the long-term viability of the CPP at LAVO is limited. A professor at Simpson College, who had been a major supporter of the project and who provided travel expense reimbursements to student volunteers, transferred out of state during the 2012 monitoring season and efforts to maintain a relationship with local universities and colleges have not been successful since then. The selection of gorgeous but remote monitoring sites complicates logistics. At remote parks such LAVO, the goals and viability of the CPP would likely be better served by selecting monitoring sites that are readily accessible by volunteers and park staff (see example from SEKI below) even though this may compromise the selection of species and the number of replicate sites. Because of the high level of enthusiasm for the CPP at LAVO, there is the possibility of dedicated funding for CPP activities, but without this funding, LAVO will likely need to decrease the number of active monitoring sites or adjust its model of participation.

#### *5.2.5 Redwood National Park (REDW)*

Pilot Activities: REDW is located in the remote northwestern corner of coastal California, spanning two sparsely populated counties and distant from major population centers. Park headquarters are in Crescent City (population of <5,000), near the northern extent of the park, and the Resource Management offices are located in Orick (population of <400), near the southern extent of the park. The CPP pilot efforts at REDW focused on establishing, maintaining, and troubleshooting phenological monitoring at three locations, recruiting observers, collecting data, and developing and delivering interpretive materials.

Three REDW monitoring locations were established in June 2011. Sites were selected with three high-priority criteria in mind: sites must be easily accessible to park staff and volunteers; they must be protected from in-house operational activities such as trail clearing; and they must have an appropriate number of target species. Two of the monitoring locations, the Crescent Beach Overlook (CBO) and Kuchel Visitor Center (KVC) were located in coastal areas near park facilities in Crescent City and Orick, respectively. The third location, Ladybird Johnson Trail (LBJ), was established along a popular trail in an old growth redwood forest, within a 15-minute drive from KVC and Orick.

In 2011, the CPP funding was used to augment the salary of a student seasonal interpreter, who photo-documented and mapped the monitoring sites and carried out most of the monitoring and data entry in 2011 (from June – September). This interpreter also developed an interpretive program focused on phenological monitoring, wrote a feature article for the park's annual Visitor Guide (to be used in 2012 and 2013), and introduced park visitors to phenological monitoring in both formal programs and in informal interactions with visitors on the trails. The park media specialist identified several options for highlighting the CPP on the park's website; unfortunately, the position is vacant and has lapsed for 2013 due to federal budgetary reductions. Ideas for promoting the CPP on the REDW website will be implemented once this position is filled.

In 2012, a local community member with an advanced degree in environmental science, who started as a volunteer observer, carried out some paid volunteer coordination. In the spring, REDW hosted four recruiting workshops offered by the UCSB field team in the local communities of Crescent City, Orick, and Arcata; these were advertised in a newspaper article, news releases, and flyers posted in and emailed to the natural resource related departments at Humboldt State University (HSU) and College of the Redwoods. Only one out of 75 attendees of the workshops eventually participated in monitoring. However, of the five volunteer observers who participated in 2012, four were from HSU and heard of the CPP through the workshop press releases (although they did not attend a workshop).

In 2013, phenological monitoring was included in a newly-developed internship program funded (for one year) by the Save-the-Redwoods-League education program, and designed to provide mentoring and hands-on learning to HSU students. This program yielded two dedicated interns for the spring semester. Phenological monitoring has also been featured as a job-shadowing activity for local high school students, and a local elementary school is interested in setting up a phenology garden to complement activities in the park. Several meetings with school administrators have been held, but time and funding limitations have prevented this from moving forward to date.

Lessons Learned: The CPP pilot phase has been successful at REDW, but there are challenges to implementing what is essentially an unfunded monitoring program over the long term. Some of the challenges include:

*Lack of dedicated project coordinator:* Currently the CPP effort is being managed entirely by the REDW plant ecologist. This is not sustainable over the long-term, as the ecologist oversees several other programs. One alternative would be to recruit a dedicated long-term volunteer to help recruit, train, and coordinate volunteers in the CPP data collection and data entry activities.

*Difficulty in recruiting volunteers:* Because of REDW's remote location, the program has had to rely on a small group of dedicated volunteer observers. Although the Crescent Beach Overlook (CBO) site is within a couple of miles of Crescent City, the volunteer population base in Crescent City already has many projects to choose from and only one individual has chosen to monitor CPP plants at the CBO sites. The southern sites are located 35 – 50 miles from the McKinleyville/Arcata/Eureka population hubs, a significant distance for volunteers to drive; with current local gasoline prices over $4.00/gallon, the cost of driving has been a significant deterrent for volunteers. Compounding the recruitment difficulty is the fact that there is a large amount of land under management by public and non-profit entities around the Humboldt Bay region, all of which offer many volunteer opportunities. However, a small group of HSU students has monitored the southern sites throughout 2012, and it is likely that HSU students will continue to be the major volunteer pool for this project.

*Monitoring season length:* Originally, REDW expected that park visitors could collect phenological data on ranger-guided or self-guided phenology walks, and that it would be beneficial to choose a suite of species exhibiting a wide temporal span of phenological activity. However, it has turned out to be difficult to recruit observers throughout a long monitoring season (essentially extending from February through October/November). One solution would be to limit the monitoring season length (e.g., April through June, during the flowering season of charismatic species) and/or to reduce the number of species or phenophases targeted.

*Trail maintenance and public vandalism:* The northern sites have been subject to excessive trail clearing activities and resource management staff are working with maintenance staff to ensure that monitoring locations are protected from trail maintenance activities. Park staff suspect that a few plants have been vandalized by the public (e.g., sprayed with herbicide), which makes a good case for locating plants in locations that are not obvious to trails and parking areas.

#### *5.2.6 Santa Monica Mountains National Recreation Area (SAMO)*

Pilot Activities: SAMO explored three approaches to monitoring during the pilot phase: (1) hiring an intern to coordinate data collection and volunteer training and to participate in data collection, (2) recruiting a group of adult volunteers, who were trained to collect data on their own, and (3) engaging elementary, high school, and middle school students, who visit the park on school field trips and who may collect data with an adult guide (e.g., a trained college student). A recent college graduate was hired in a paid internship position to lead phenological data collection, volunteer training and recruitment, and coordination efforts. The SAMO education specialist partnered with California State University Channel Islands, a George Melendez Wright Climate Change Intern, and the U.S. Fish and Wildlife Service to develop a phenology-based curriculum and to recruit and train college level students to observe CPP plants.

SAMO also hoped to develop a strong relationship with NatureBridge (similar to the partnership at GOGA). NatureBridge works with short-term, residential student groups (primarily fifth grade through high school) at their Circle X campus at SAMO. Because they are close to the Sandstone Peak monitoring site (Table 4), they focused data collection efforts on this trail. However, because NatureBridge only provides residential programming during the spring semester, the time period during which they are able to collect data is very short. Overall, the contribution of NatureBridge students to the data collection effort at SAMO is limited due to time and location constraints.

Lessons Learned: Of the three approaches, SAMO found that the intern coordinator role and training adult volunteers were the most viable models for implementing phenological monitoring. Although working with high school students and college students has been successful at other parks, it did not work well at SAMO. Both college students and younger school groups had difficulty identifying phenophases and made many mistakes in the field. Additionally, the students and teachers rarely followed-through to submit their observations to the NPDb via *Nature's Notebook.*

Alternatively, having a botanically knowledgeable and enthusiastic post-graduate intern worked well. Through the efforts of this intern, the CPP gained momentum and resulted in the recruitment and retention of approximately 5 dedicated, adult volunteers (most of whom are botanically-oriented and retired). Each SAMO volunteer selected a different monitoring location and visited the plants at their monitoring sites once a week. These volunteers entered their own data and participated in quarterly botanical training hikes. As such, SAMO is currently focused on maintaining a small core group of adult volunteers. In the future, the park may revisit using phenology as a teaching and climate change education tool, without expecting students to be a part of the core data collection effort.

#### *5.2.7 Sequoia and Kings Canyon National Parks (SEKI)*

Pilot Activities: Unlike the urban parks (SAMO, GOGA, and JOMU), SEKI is a large, remote wilderness park surrounded by small rural enclaves, and the local communities provide a relatively limited source of volunteers. As an alternative to the volunteer-focused monitoring model, SEKI engaged NPS staff whose jobs included tasks that occur in close proximity to the plants monitored at CPP sites, allowing these staff members to participate in monitoring with a relatively low time investment. For example, the plants at the Lower Kaweah Air Quality monitoring site are regularly monitored by NPS air quality technicians, and the plants outside the Foothills Visitor Center are monitored by interpretation staff stationed at the visitor center. Between these two locations, SEKI monitors four species (Table 4). Both of the monitoring sites are co-located with weather stations, are relatively easy to access, and lend themselves to sustained long-term monitoring. This approach also allowed SEKI to depart from the phenology trail model and thus to mitigate potential trampling impacts and avoid issues associated with establishing installations within wilderness.

In 2011, the Sequoia District Interpreter secured funding to support a summer intern who was dedicated to developing and testing a phenology-themed interpretive program delivered at the Foothills Visitor Center and nearby monitoring sites. The resulting program, *Pulse of the Planet*, is described in section VI of this report. SEKI also has two phenocams at headquarters, which complement these educational materials. The phenocams broadcast time-delayed photos of a blue oak and a buckeye on the SEKI website. Originally broadcast as static images without context, CPP funds were used to develop an associated time-lapse video to help students understand the role that climate and weather play in determining the timing of phenological events by integrating temperature and precipitation data into the online display. This video engages audiences visiting the park's website, as well as students viewing the webcam images as part of the classroom-based SPROUTS curriculum (also described in Section VI below).

CPP funds were also used to hire a part time ecologist to train park staff, develop monitoring materials, and serve as an intermediary among the CPP Core Team, USA-NPN, and park observers. In 2013, the ecologist explored the potential for a 'picture-post' approach to monitoring (http://picturepost.unh.edu/). Park visitors that are climbing Mt. Whitney, for example, could capture images of the showy sky pilot (*Polemonium eximium*) at remote, high elevation sites; park visitors would then post their images on the existing Picture Post website. This approach, which would not require the installation of markers in wilderness (relying instead on an easily identifiable location, such as a prominent trail sign), has the potential to capture multiple observations of a single point and to engage large numbers of park visitors, many of whom are carrying smartphones and are already engaged in sharing images via social media. Although data captured this way would not be directly compatible with *Nature's Notebook*, repeat photography of this alpine perennial could be used to document changes in flowering period and the persistence of the population, information that is often difficult to obtain for remote sites.

Lessons Learned: From the outset, the intention at SEKI was to establish a program that could be sustained over the long term. As such, SEKI developed a relatively small, staff-based monitoring program. Although SEKI did not monitor a large number of plants, and thus made relatively modest contributions to the development of species profiles and the collection of pilot data, the SEKI monitoring program is well poised to continue beyond the pilot funding period. This would not have been possible without the dedication and enthusiasm of the Sequoia District interpretive staff, which early on recognized the potential of phenology as a teaching and outreach tool and which took the lead on the monitoring of the Foothills Visitor Center sites. Similarly, field support from the air quality monitoring program led to the co-location and continued monitoring of two species at an existing air quality monitoring location, which is subject to weekly visits on a year-round basis. From the outset, NPS staff at SEKI recognized that capturing observations more than once per week would be challenging; this remains an issue at the Lower Kaweah Air Quality site, where the park will be looking closely at baseline data to identify key periods of the year in which to focus the monitoring effort, should resources be available.

Having trained staff collect phenological observations is expected to result in cleaner, more accurate data than those collected by a diverse group of volunteers. Even so, it is critical to spend at least one season refining protocols and species-specific phenophase descriptions, as phenophases often proved difficult to identify and clarification of phenophase definitions was needed to ensure data consistency across years and observers. Lacking an on-site CPP project coordinator or dedicated intern during the first year of data collection meant that field observers were on their own when questions came up. To reduce observer error and facilitate consistent responses and data collection, it is very important to have at least one part time staff person dedicated to answering questions and trouble-shooting protocols issues. NPS staff, as a rule, are over extended; having clear protocols and a park-specific monitoring guide should make it easier to continue the CPP effort and to generate useful data over the long term. At SEKI, monitoring is anticipated to continue at the two sites described above. If staffing levels allow, pilot data will be used to identify key times where it would be most profitable to increase the frequency of observation at the Lower Kaweah sites. SEKI's plant ecologist intends to continue overseeing the CPP program; however, this commitment will be subject to management review and may not be sustainable without some level of additional support.

### 5.3 Alternative Approaches to Outreach and Partnership Development

In addition to the models implemented by the CPP pilot parks, there are other approaches for engaging volunteer observers that may be successful at NPS units or other CPP partner institutions. Conservation organizations and land trusts are promising partners, since they often have a strong volunteer base. These organizations may be interested in contributing to the broader effort by monitoring on their own properties, which can complement monitoring in the National Parks. In the Bay Area, for example, PRBO Conservation Science has established monitoring sites that complement the observations recorded at GOGA, since both groups monitor many of the same species. Botanic gardens and nature reserves often have trained docent groups that can lead volunteer training and monitoring efforts. For example, Sedgwick Reserve, near Santa Barbara, is monitoring CPP target taxa with the help of a docent group who received training from the UCSB field team (http://sedgwick.nrs.ucsb.edu/phenology). Other NPS phenology efforts, such as the Northeast Temperate Inventory and Monitoring Network (NETN), have developed citizen science-focused phenology monitoring programs in collaboration with local hiking clubs, such as the Appalachian Mountain Club.

# VI. Education

In addition to outreach and partnership-building activities, pilot parks and collaborators developed phenology-based educational materials and programs that engage and educate the public, including: phenology-focused lesson plans; interactive activities appropriate for indoor and outdoor learning environments; and university-level seminar modules. The phenology-focused educational materials described below are available for download on the CPP website's education page (http://www.usanpn.org/cpp/education).

## 6.1 Phenology Literacy: Understanding through Science and Stewardship (PLUSS)

With funding from the USGS and the USA-NPN, UCSB Professor Susan Mazer, Dr. Alisa Hove (former UCSB PhD student), and Brian Haggerty (UCSB PhD student) developed educational curricula and supporting materials for a variety of age groups over a two-year period (2010-2011). Two lesson plans were created and tested in each of three $5^{th}$ grade classrooms in two Santa Barbara public schools (the Adelante School and the Franklin School). These lesson plans include complete instructions so that they may be used by informal science education teachers, pre-service teachers, and experienced teachers alike. The lessons prepare participants to use USA-NPN protocols and datasheets and to record phenological data throughout the year in schoolyard phenology gardens in which species targeted by the CPP and the USA-NPN have been cultivated. Because of the dynamic nature of plant phenology, these lesson plans have their greatest value when repeated throughout the year to reinforce the concepts they introduce; to sensitize students to seasonal cycles; and to enable students to compare the life cycles of different plant species. Compilation of the California State Standards that are fulfilled by these lessons are included in both of the lesson plans. While these two lesson plans were initially designed for fifth-graders, they may be easily modified for use by interpretive park rangers who lead 20- to 50-minute walks or presentations for mixed-age groups.

In addition to these fifth-grade lesson plans, the PLUSS program developed three interactive games and activities that are targeted to groups representing a wider age range. One activity, "Flight of the Pollinators," introduces participants to the importance of plant phenology to pollinators. Another activity, "Ethnophenology," demonstrates that the usefulness of plants in traditional medicine and for other practical uses depends on an understanding of the phenology of the particular plant organs sought (e.g., roots, stems, bark, seeds, and fruits). Participants in this activity learn to search for seasonally-available plant structures needed to treat common health ailments. The third activity, the "Phenology Relay Race," provides a workout while promoting cooperation among students who must review and reinforce their knowledge of plant phenology while they are "on the run."

To assist schools, parks, botanic gardens, and communities in designing or encouraging phenological monitoring activities, PLUSS materials include a guide to developing and installing phenology gardens in schools and in private or public parks. This guide includes planning tables, details on aligning phenology gardens with the USA-NPN standards, and several case studies of successful phenology gardens.

Other educational materials produced as part of the PLUSS project supported the phenology-based *Nature Sleuths* program, which provided afternoon activities (once a week during the

2010-2011 academic year and summer) for eight- to twelve-year-old students who attend the Santa Barbara Westside Boys & Girls Club on a near-daily basis. These materials include: (1) a "Phenology Scavenger Hunt," in which participants search phenology gardens or outdoor habitats for seasonally-available plant structures, and then photograph, illustrate, describe, or collect the plant phenophases; and (2) a "Secret Observations Game," in which students provide verbal descriptions of hidden objects to their peers, highlighting the importance of careful observation and scientific communication.

For university students with an interest in nature education, the UCSB group participated in teaching an upper division course in science education, in collaboration with UCSB's Cheadle Center for Biodiversity and Ecological Restoration (CCBER) and its *Kids in Nature* program. UCSB undergraduates were enrolled in this course throughout the 2010-2011 academic year, and they assisted in the implementation of the phenology-themed lesson plans (described above) at the Adelante and Franklin Schools. These undergraduates were also trained to use USA-NPN phenological monitoring protocols and used these protocols with elementary school students.

Finally, a university-level seminar and phenology journal club was designed and made available on-line to provide instructors with several 90-minute powerpoint presentations and scripts to introduce the topic of plant phenology and its link to climate change.

### 6.2 CPP Interpretive Guide

The UCSB collaborators created the CPP Interpretive Guide to assist park-based staff in describing the CPP's goals and activities to park visitors. The guide was specifically designed for staff members who had attended a CPP workshop and who regularly engage with park visitors in formal or informal settings. To maximize relevance and usability for NPS interpreters, the guide was reviewed by NPS interpretive staff and reflects substantial input provided by these reviewers. The guide covers a wide variety of topics, including: the geographic coverage of the CPP activities; the species being monitored; the reasons for monitoring plant phenology; a brief introduction to botanical concepts, with illustrative figures; a description of interactive activities and discussion topics to promote visitor learning; and real-world stories of phenology and its link to climate. The CPP Interpretive Guide is available for download from the CPP website.

### 6.3 *SPROUTS* and *Pulse of the Planet* at SEKI

NPS interpretive staff at SEKI created a range of phenology-themed programs that have been implemented at the park and with park-partners. SPROUTS is a phenology-focused lesson plan that was developed for 5$^{th}$ and 6$^{th}$ grade students. It is part of SEKI's *Rangers in the Classroom* program, which offers 1-hour classroom visits by park rangers to elementary schools in Tulare County and whose objective is to connect students to the park through a series of programs that build on each other and cover a variety of ecological themes (e.g., life zones, watersheds, climate change). SPROUTS uses a methodology called *Understanding by Design* to help students discover what phenology is and how they can detect plant phenological changes. Participating students observe the phenophases of valley oaks (*Quercus lobata*) in their schoolyard and compare their phenological status with blue oaks (*Quercus douglasii*) in the park via webcams (http://www.nps.gov/seki/photosmultimedia/webcams.htm). The SPROUTS program has been aligned with California's 6$^{th}$ grade education standards, and the program was piloted in the 2010-2011 school year in a single 6th grade classroom at Cottonwood Creek Elementary school (Visalia, CA). It is currently being expanded to additional schools in the area. SEKI interpretive staff also developed a 45-minute interpretive program, *Pulse of the Planet*, for park visitors of all ages. This program uses hands-on activities and real-life examples to demonstrate the relevance of phenology in a changing world. The program was developed to be appropriate for indoor or outdoor settings, and it has also been aligned with California education standards.

# VII. Conclusion: The California Phenology Project beyond the Pilot Phase

As the pilot phase concludes, the CPP has made substantial progress towards achieving the three goals described in this report: (1) establishing a framework for long-term phenological monitoring in California; (2) providing baseline data and analytical results to address a number of research questions and to support stewardship of wildland ecosystems; and (3) engaging and educating people of all backgrounds and ages in the study of phenology and in understanding climate change.

Over 435 individuals participated in CPP trainings, workshops, and monitoring efforts at the national parks during the CPP pilot phase (Table 6), with an additional 470 Californian teachers, informal educators, naturalists, botanic garden staff, Audubon Society members, and docents participating at events outside the parks (Table 7). The seven pilot parks are committed to maintaining their monitoring programs to varying degrees, and the CPP network has already begun to expand into the University of California Natural Reserve System (UCNRS), where CPP species are being monitored at six reserves. Similar to the NPS model described in this report, the monitoring in the UCNRS will be carried out by a combination of students, staff, and volunteers, and some reserves will be working with nearby National Parks in order to monitor overlapping species and carry out joint training workshops.

With >435,000 records submitted to the NPDb, the CPP is well on its way to building a robust phenological dataset that can be used to address the focal research questions described in this report. The phenological patterns displayed by most of the CPP focal species were generally unknown prior to the start of this project, and in many cases, the data collected during the pilot phase will be the first empirical data sets for these species. Evidence for an environmental trigger of Joshua Tree flowering, for example, is anecdotal at best; with phenological data recorded at multiple locations across key environmental gradients, the CPP should be able to quantify the correlations between flowering phenophase metrics (e.g., onset, peak, and duration of flowering) and their potential environmental cues. Statistically rigorous analysis of the pilot data is an essential next step for the CPP. Preliminary analysis is currently underway, and a report addressing a subset of the CPP research questions will be completed and submitted to a peer-reviewed journal by 2014.

The biggest challenges facing the CPP monitoring program are limited funding, staff, and volunteer capacity at the National Parks. In light of these challenges, the CPP Core Team is actively pursuing opportunities to obtain continued funding, and the parks are exploring ways to maintain the momentum of the past three years without dedicated funding. Joshua Tree National Park, for example, has been awarded funding to work with a medical clinic within the local community to promote phenology trails as a component of an active, healthy lifestyle. The Core Team is also exploring ways to creatively leverage resources to continue monitoring and outreach activities. The collaboration with the UCNRS, in conjunction with nascent partnerships with land trusts and conservation organizations, should strengthen the long-term sustainability of CPP activities by allowing partners to leverage and share resources. In the future, the CPP hopes to continue building partnerships across the state, with informal education organizations, herbaria, and public gardens.

In sum, the CPP's successes to date have laid the foundation for a long-term phenological monitoring network in California. In the coming years, the CPP network expects to continue creating opportunities for the public to learn about phenology and climate change and to participate in a state-wide monitoring program, with the hope that they gain a lifelong interest in observing the natural world. Finally, it is hoped that the CPP pilot phase outcomes may provide a model for implementation in other regions of the country, thereby contributing to the nation-wide effort to document the phenology of wildland plants and its relationship to climate change.

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# Appendix A. List of participants in the California Phenology Project Scientific Framework workshop held at UC Berkeley, November 2010.

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

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

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

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

# Appendix B. Scientific research questions.

As part of the pilot phase, the CPP identified focal research questions to provide a framework for the collection, analysis, and interpretation of CPP data. Many of these research questions require a dataset that is beyond the scope of the CPP pilot phase (e.g., requiring longer time series, climate data, or other biological data). Regardless, the full list of research questions is presented here to illustrate the potential applications of CPP data (and their relevance to resource management). The questions are categorized by ecological level (e.g., questions addressing variation within species, across species, and among communities). It is hoped that these questions provide guidance for future data collection efforts in California.

## Phenological Variation within Species

*1. Among conspecific individuals, is there spatial variation in phenological parameters (e.g., the onset and duration of phenophases) that is associated with geographic gradients (e.g., elevation, latitude, or longitude)? What phenological parameters are most sensitive to variation in geographic gradients?*

Approach: Observe contemporary phenological patterns over local and regional geographic gradients to measure intra-specific phenological variation associated with spatial variation. Once phenological data have been recorded across many sites, researchers will be able to assess the general associations between phenological behavior and geographic parameters (e.g., latitude). Multivariate statistical analyses should be able to detect relationships between the timing and duration of phenological events and geographic parameters such as elevation, latitude, and longitude. With high-resolution climatic data now available online (e.g., http://www.prism.oregonstate.edu/), phenological variation among georeferenced plants may be linked quantitatively to variation in seasonal variables such as mean monthly minimum tempurature, maximum temperature, and cumulative precipitation. Where geographic variation in climate can be used as a proxy for temporal variation in climate, CPP data may be used to predict temporal changes in phenology of well-monitored species.

Relevance to management: Understanding the degree to which common and widespread plant species exhibit phenological variation related to *spatial* variation in climate is a first step toward predicting their responses to *temporal* variation in climate. Understanding the climate sensitivity of focal species can provide valuable information for climate change vulnerability assessments and the subsequent prioritization of management actions.

*2. At what ecological level do we observe most of the variance in phenological parameters: (a) among individuals at a site? (b) among sites across latitudes? (c) among sites across elevations? Do phenological traits differ in the magnitude of each source of variance? For example, is the timing of the onset of new leaf production more likely to vary with latitude and elevation than the timing of the onset of open flowers?*

Approach: Phenological traits that are most sensitive to environmental variation may also be those that are most responsive to climate change. Replicated monitoring allows for the measurement of population-level parameters (such as the mean and variance of the onset dates of phenological events), which can be calculated at a variety of ecological levels (e.g., among individuals at a site, among sites across latitude, among sites across elevation). Data obtained from the replicated monitoring of focal taxa over local and regional environmental gradients may allow the CPP to identify the scale at which the greatest magnitude of variation in each phenological metric is observed.

Relevance to management: If, within a species, distinct phenophases consistently exhibit more geographic variation in their timing than others, we may be able to predict which traits (in a given species) are most likely to change in response to changes in climate. This will help managers understand the inherent sensitivity and adaptive capacity of focal species (which may have a variety of management applications, including vulnerability assessment). For plant species in which a given phenophase is an important resource for an animal species (e.g. Joshua tree flowers and Yucca moths), phenological changes may have strong effects on the maintenance of plant-animal interactions, including pollination, herbivory, and seed dispersal. Understanding the phenology of species interactions can help managers plan for the potential consequences of a trophic mismatch, such as population declines and local extirpations.

*3. Can phenological signals be linked to population success? 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 plant populations monitored by the CPP are co-located with other monitoring efforts (e.g., NPS Inventory & Monitoring vegetation plots), scientists may be able to detect quantitative relationships between phenological patterns and population vital signs that are under observation.

Relevance to management: If phenological changes in a given species can be used to predict its future population vigor, then phenological responses and behaviors (of at least some species) may be used as an "early warning signal". The identification of such signals will facilitate future monitoring and adaptive management efforts.

*4. How do species respond to abiotic disturbance?*

Approach: Phenological observations in disturbed vs. undisturbed sites (e.g., burned vs. unburned sites or flooded vs. unflooded sites) may allow for the detection of species-specific phenological responses to disturbance. For example, do disturbances free up resources for early-successional species, resulting in advances or increased durations of their growth- or reproduction-related phenophases relative to conspecific populations in less disturbed sites? Do disturbances create sufficient environmental heterogeneity that they increase the cross-site duration of phenophases in species that occur in both disturbed and undisturbed sites? Does disturbance (e.g., nutrient release in post-fire communities) promote or suppress reproductive success and does it advance or delay the timing of fruit and seed production?

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

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

Approach: Within widespread species, comparing phenological patterns exhibited at the centers versus the edges of their geographic ranges may reveal the phenological signals and environmental conditions that are associated with demographic changes that limit species' distributions. Within parks, species that are observed on transects that reach their elevation range limit may display phenological signals (e.g., shortened flowering or failure to flower) that help to explain their geographic range. The failure to flower regularly at range margins, for example, would reduce seed production and dispersal ability.

Relevance to management: The identification of phenological signals and environmental conditions that are associated with a taxon's reproductive success (e.g., reduced density, failure to flower, or decreased seed production as environmental conditions become drier) 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 conservation and climate adaptation actions.

*6. Within species, what is the relationship between phenological parameters (e.g., the onset or duration of phenophases) and long-term climatic conditions?*

Approach: Once the CPP has recorded phenological data across many year (e.g., 10 or more), researchers 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 seasonal or annual cumulative rainfall, monthly or seasonal mean minimum and maximum temperatures, soil type, and the timing and duration of phenological events. Using CPP data collected in association with precipitation data, for example, may allow scientists to quantify the delay (length in days) between precipitation events and phenological responses, and the relationship between the magnitude of a rainfall event and the magnitude or timing of the phenological response.

Relevance to management: With sufficient data that reveal the effects of climatic events or patterns on the phenological behavior of individual species, managers can use model predictions of shifts in climatic regimes to predict quantitative shifts in species' phenologies. This process will help managers to prepare for scenarios in which novel interactions between species occur and in which novel communities may form. Managers may need to adjust practices based on predicted shifts in ecosystem, community, and population dynamics that are heavily influenced by phenological patterns.

## Phenological Variation among Species

*7. 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) or late summer (e.g., *Baccharis pilularis*, coyote brush) and deciduous taxa that change leaf color in response to colder temperatures in the 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 species) will affect the window of availability of floral resources for pollinators and floral herbivores, which are important ecological guilds under NPS stewardship.

*8. Can we identify distinct categories of phenological behavior among well-sampled taxa?*

Approach: Some woody taxa appear to respond to recurrent or sporadic environmental conditions with renewed and indeterminate episodes of leaf production (e.g., *Adenostoma, Baccharis, Coleogyne*) while others present a more consistent, determinate, step-wise sequence of discrete phenological stages over the course of the growing season (e.g., *Aesculus, Heracleum, Quercus*). Identifying species that clearly fall into one of these categories may inform predictions of their responses to future climate change. We may expect, for example, that species that respond to short-term changes in weather with altered phenological activity may also be those that respond most strongly to unpredictable climate change.

Relevance to management: Taxa with indeterminate growth and flowering (e.g., those that respond to sporadic precipitation in arid environments) may provide resources (for herbivores and pollinators) over longer periods within a season than taxa with highly determinate growth and flowering. Depending on weather or climatic conditions, this plasticity may result in a resource base that either promotes or suppresses pests, invasive organisms, or pollinators, with cascading trophic effects on interacting species.

*9. Does the timing of phenophases (e.g., flowering or leaf emergence) differ intra- and inter-specifically?*

Approach: The variance among individuals in the onset or duration of a given phenophase reflects a combination of both genetic variation and environmentally induced variation. Long-term observational studies of long-lived individuals sampled across heterogeneous environments cannot provide quantitative measures of the relative magnitude of genetic vs. environmental variance. However, the estimation of variance among individuals within sites and of variance among site means (for a given species)— and the comparison of these variance components across species — may reveal taxa that are consistently phenologically inflexible vs. those that are highly phenologically responsive to environmental variation.

Relevance to management: Recent studies suggest that phenologically unresponsive species are more vulnerable to climate change (Cleland et al 2012). If so, quantifying the magnitude of phenological variation that is related to geographic parameters that co-vary with climate may allow the CPP to identify focal species that are more vulnerable to future climate change.

*10. Which plant species in California are most sensitive to climate change?*

Approach: 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). This approach requires that *many* species are targeted for monitoring and that climate data be collected at or near phenological monitoring sites. With long-term phenological and climatic records, researchers will be able to determine which species, which phenological events, and which phenophases are most sensitive and responsive to climate change.

Relevance to management: The sensitivity of a phenophase to climate is often measured by examining the linear relationship — among >10 years at a given site — between the day of the year (DOY) on which a phenophase is observed (on the y-axis) and some estimate of that year's annual temperature [on the x-axis; e.g., the Growing Degree Days (GDD) accumulated over some interval in the spring]. The slope of this relationship estimates the number of days of phenological advancement (if the slope is negative) or delay (if the slope is positive) in response to a unit increase in GDD (Cook et al. 2012; Mazer et al. 2013). As noted above, recent studies suggest that phenologically unresponsive species are more vulnerable to climate change (Cleland et al 2012), and this type of analysis, therefore, may alert land managers of species that show signs of vulnerability to future environmental conditions.

*11. What are the earliest phenological 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 USA-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.

## Phenological Variation among Interacting Species

*12. Are relationships between plant and animal mutualists at risk due to climate change? For example, are pollinators and their floral resources responding to climate change in the same direction and at the same pace?*

Approach: By targeting particular plant-animal interactions for phenological monitoring, the CPP can monitor whether phenological synchrony changes over time and space in association with climate. For example, where the pollinators of monitored species can be identified, CPP observers may record the presence/absence of pollinators that are observed each time the plants are monitored. Observed deviations from synchrony associated with particular 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, such as the exposure of a plant to a flower predator or herbivore not previously encountered.

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 resource managers to predict the conditions under which such interactions risk the greatest ecological disruption and to design management approaches to minimize species loss.

*13. 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?*

Approach: Compare the phenology of targeted species across gradients where the presence or abundance of invasive species or plant diseases varies and is recorded (note: monitoring sites selected for this type of approach would require minimizing variation in other factors that influence phenology, such as climatic and edaphic conditions, which would need to be consistent across sites). Examples of invasive candidate species include yellow star thistle or pine bark beetle. This approach would allow researchers to detect species-specific phenological patterns that are related 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.

## Community-level Phenology

*14. How do particular communities or vegetation types differ in their phenological response to climate change?*

Approach: The CPP might choose assemblages or communities of sympatric species that consistently co-occur within selected biogeographic zones (e.g., coastal or arid zones) and monitor these assemblages in a replicated fashion. Community-level information might be used to describe phenological synchrony in a community or to identify habitats that may be more buffered by climate change (e.g., coastal or island habitats might be more buffered against climate change because of the mitigating influences of the coastal environment).

Relevance to management: Phenological synchrony may guide the timing of different management treatments (e.g., when exotic plant management will have the greatest effect on a large number of exotic species). Comparing spatial variation in phenology among plant communities, as well as their 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.

*15. 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 form and life history vs. phenological sensitivity to abiotic conditions.

Relevance to management: The ability to predict a species' phenological sensitivity or responsiveness based on its life history may inform restoration efforts by identifying species or combinations of species that appear to adapt most readily to changes in climate. Observations of multiple species may also contribute to predictions of future community composition and ecosystem function in response to climate change. Such an approach can help managers prepare for composition shifts that may alter landscape dynamics.

# Appendix C. California Phenology Project species-selection biogeographic working group meeting schedule and participants.

Desert working group (discussions convened on January 25th, 2011):
Alice Corrine Newton, Vegetation Lead, Lake Mead National Recreation Area
Todd Keeler-Wolf, Ecologist, California Department of Fish & Wildlife
Cameron Barrows, Professor, University of California, Riverside
Neal Darby, Biologist, Mojave National Preserve
Jane Cipra, Botanist, Death Valley National Park
Tasha LaDoux, Botanist and Assistant Manager University of California, Sweeney Granite Mountains Desert Research Center
Jim Andre, Botanist and Manager, University of California Sweeney Granite Mountains Desert Research Center)
Jeanne Taylor, Vegetation Coordinator, NPS Mojave Inventory and Monitoring Network
Jean Pan, Ecologist, NPS Mojave Inventory and Monitoring Network
Fred Edwards, Botanist, Bureau of Land Management, Las Vegas
Lesley DeFalco, Research Ecologist, US Geological Survey, Las Vegas
Todd Esque, Research Ecologist, US Geological Survey, Las Vegas
Vicky Chang, Science Coordinator, Joshua Tree National Park
Susan Mazer, CPP Core Team and Professor, University of California, Santa Barbara
Josh Hoines, CPP Core Team and Vegetation Program Manager, Joshua Tree National Park
Angie Evenden, CPP Core Team and NPS Research Coordinator, Californian Cooperative Ecosystem Studies Unit
Janet Coles, former CPP Core Team and Ecologist, Lassen Volcanic National Park
Kathryn Thomas, former CPP Core Team and Ecologist, US Geological Survey, Tucson, AZ
Liz Matthews, CPP Core Team and Postdoctoral Associate, University of California, Santa Barbara
Kathy Gerst, CPP Core Team and Biologist, USA-NPN National Coordinating Office
Brian Haggerty, CPP Core Team and Ph.D. student, University of California, Santa Barbara

Northern Coast working group (discussions convened on February 10th, 2011):
Janet Klein, Vegetation Ecologist, Marin Municipal Water District
Michael Chasse, Rare Plant Botanist, Golden Gate National Recreation Area
Allison Forrestel, former Fire Ecologist, Point Reyes NS; current Supervisory Vegetation Ecologist at Golden Gate National Recreation Area
Ellen Hamingson, Restoration Biologist, Point Reyes National Seashore
Sue Fritzke, former CPP Core Team and Vegetation Program Manager, Golden Gate National Recreation Area
Stassia Samuels, Botanist, Redwood National Park
Andrea Pickart, Botanist, Humboldt Bay National Wildlife Refuge
Marie Denn, Aquatic Ecologist, NPS Pacific West Region
Tood Keeler Wolf, Vegetation Ecologist, CA Department of Fish and Wildlife
Fernando Villalba, Natural Resource Specialist, John Muir National Historic Site
Andrea Williams, Vegetation Ecologist, Marin Municipal Water District
Robert Steers, Vegetation Ecologist, NPS San Francisco Bay I&M Network

Angie Evenden, CPP Core Team and NPS Research Coordinator, Californian Cooperative Ecosystem Studies Unit
Susan Mazer, CPP Core Team and Professor, University of California, Santa Barbara
Liz Matthews, CPP Core Team and Postdoctoral Associate, University of California, Santa Barbara
Kathy Gerst, CPP Core Team and Biologist, USA-NPN National Coordinating Office

Southern Coast working group (discussions convened on February 17th, 2011):
Arlee Montalvo, Restoration Ecologist, Riverside-Corona Resource Conservation District
Brent Johnson, Botanist, Pinnacles National Monument
Tessa Christensen, Intern, NPS Pinnacles National Monument
Dirk Rodriguez, Botanist, Channel Islands National Park
Dieter Wilken, Director of Conservation, Santa Barbara Botanic Garden
Steve Junak, Herbarium Curator, Santa Barbara Botanic Garden
Marti Witter, Fire Ecologist, Santa Monica Mountains National Recreation Area
Irina Irvine, Restoration Ecologist, Santa Monica Mountains National Recreation Area
John Tiszler, Plant Ecologist, Santa Monica Mountains National Recreation Area
Tarja Sagar, Botanist, Santa Monica Mountains National Recreation Area
Keith Lombardo, Biologist, Cabrillo National Monument
Kathryn McEachern, Ecologist, USGS Western Ecological Research Center
Layla Hains, Herbarium Collections Manager, San Diego Natural History Museum
Paul Wilson, Professor, California State University-Northridge
Stacey Ostermann-Kelm, Program Manager, NPS Mediterranean Coast Inventory and Monitoring Network
Victoria Sork, Professor, University of California, Los Angeles
Christy Brigham, CPP Core Team and Chief of Resources and Science at Santa Monica Mountains National Recreation Area
Angie Evenden, CPP Core Team and NPS Research Coordinator, Californian Cooperative Ecosystem Studies Unit
Susan Mazer, CPP Core Team and Professor, University of California, Santa Barbara
Liz Matthews, CPP Core Team and Postdoctoral Associate, University of California, Santa Barbara
Kathy Gerst, CPP Core Team and Biologist, USA-NPN National Coordinating Office
Brian Haggerty, CPP Core Team and Ph.D. student, University of California, Santa Barbara

Mountains working group (discussions convened on March 1st, 2011):
Alison Colwell, Botanist, Yosemite National Park
Janet Coles, former CPP Core Team and Ecologist, Lassen Volcanic National Park
Jennifer Gibson, Ecologist, Whiskeytown National Recreation Area
Kaitlin Lubetkin, Graduate student, University of California-Merced
Marie Denn, Aquatic Ecologist, NPS Pacific West Region
Peggy Moore, Botanist, US Geological Survey, Yosemite Field Station
Sylvia Haultain, CPP Core Team and Ecologist, Sequoia and Kings Canyon National Parks
Giselle Block, Inventory and Monitoring Specialist, National Wildlife Refuge System, Sacramento
Jason Mateljak, Natural Resources Specialist, Lava Beds National Monument

Connie Millar, Research Scientist, USDA Forest Service, Pacific Southwest Research Station
Angie Evenden, CPP Core Team and NPS Research Coordinator, Californian Cooperative Ecosystem Studies Unit
Susan Mazer, CPP Core Team and Professor, University of California, Santa Barbara
Liz Matthews, CPP Core Team and Postdoctoral Associate, University of California, Santa Barbara
Kathy Gerst, CPP Core Team and Biologist, USA-NPN National Coordinating Office

# Appendix D. Phenology Toolkit of Online Resources.

There are many online resources to help implement a successful phenological monitoring program. If you have suggestions of additional resources to add to this list, please send an email to phenology@eemb.ucsb.edu with your ideas.

1. Resources for recruiting and engaging volunteer observers:

- the CPP Plant Phenological Monitoring Protocol and Standard Operating Procedures (to be available online in early 2014)
- USA-NPN Technical Series 2012-002: An Evaluation of Observer Engagement Strategies for *Nature's Notebook* (available at: http://www.usanpn.org/files/shared/files/USA-NPN_Engagement_Strategies_DRAFT_5-2012.pdf)
- Chapter 4 (Recruiting, Training, and Retaining Volunteers) of the *EPA's Volunteer Estuary Monitoring Manual, A Methods Manual, Second Edition* for great tips: http://water.epa.gov/type/oceb/nep/upload/2009_03_13_estuaries_monitor_chap4.pdf

2. Resources for developing phenological training opportunities:

- PDF versions of powerpoint presentations from past CPP training events (http://www.usanpn.org/cpp/resources/presentations)
- CPP Plant Phenological Monitoring Protocol and Standard Operating Procedures (to be available online in Spring 2014)
- USA-NPN website, which has many tips for monitoring plant and animal phenology: http://www.usanpn.org/resources/resources, http://www.usanpn.org/how-observe, http://www.usanpn.org/participate/guidelines, and http://www.usanpn.org/participate/faq
- USA-NPN's *How to Observe* Handbook: https://www.usanpn.org/files/shared/files/USA-NPN-HTOFull_8.27.13.pdf 3.

Other phenological monitoring programs:

- Picture post: From the picture post website, "Picture Post is a part of the Digital Earth Watch (DEW) network. DEW supports environmental monitoring by citizens, students and community organizations through digital photography and satellite imagery." Visit the website at this URL: http://picturepost.unh.edu/
- The NPS Northeast Temperate Network (NETN) Inventory and Monitoring program has identified phenology as a vital sign for long-term monitoring and has recently published its phenology monitoring protocol (available here: https://irma.nps.gov/App/Reference/Profile/2197242). The NETN's phenology program, which includes observational, acoustic, and photographic data collection by both citizen

and professional scientists, has initiated pilot monitoring in Acadia National Park and Boston Harbor Islands NRA. The NETN is using the USA-NPN monitoring protocols for observational data collection and is collaborating with other parks and organizations to establish phenological monitoring along the Appalachian National Scenic Trail. For more information about the NETN program, contact Brian Mitchell (Brian_Mitchell@nps.gov) or Abe Miller-Rushing (Abe_Miller-Rushing@nps.gov).

- Project BudBurst: This is a national scale phenology monitoring program, whose mission is to "Engage people from all walks of life in ecological research by asking them to share their observations of changes in plants through the seasons." Learn more about the program on their website: http://budburst.org

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**National Park Service**
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