National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

California Phenology Project (CPP) Plant Phenological Monitoring Protocol

Version 1

Natural Resource Report NPS/PWR/NRR—2014/763




ON THE COVER
Clockwise from top left: (1) NPS staff monitor greenleaf manzanita (*Arctostaphylos patula*) at Lassen Volcanic National Park; (2) CPP focal species, California buckeye (*Aesculus californica*); (3) CPP focal species, California poppy (*Eschscholzia californica*); (4) CPP participants monitoring at Sandstone Peak Trail in Santa Monica Mountains National Recreation Area. Photographs by: Brian Haggerty (1,4) and Liz Matthews (2,3)

California Phenology Project (CPP) Plant Phenological Monitoring Protocol

Version 1

Natural Resource Report NPS/PWR/NRR—2014/763

Elizabeth R. Matthews[1,3], Katharine L. Gerst[2], Susan J. Mazer[1], Christy Brigham[3], Angie Evenden[3], Alison Forrestel[3], Brian Haggerty[1], Sylvia Haultain[3], Josh Hoines[3], Stassia Samuels[3], Fernando Villalba[3]

[1] Department of Ecology, Evolution, and Marine Biology, University of California, Santa Barbara

[2] USA National Phenology Network National Coordinating Office

[3] National Park Service

February 2014

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado, publishes a range of reports that address natural resource topics. These reports are of interest and relevance to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Report Series is used to disseminate high-priority, current natural resource management information with managerial application. The series targets a general, diverse audience, and may contain NPS policy considerations or address sensitive issues of management applicability.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner.

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.

This report is available from www.usanpn.org/cpp and the Natural Resource Publications Management website (http://www.nature.nps.gov/publications/nrpm/). To receive this report in a format optimized for screen readers, please email irma@nps.gov.

Please cite this publication as:

Matthews, E. R., Gerst, K. L., Mazer, S. J., Brigham, C., Evenden, A., Forrestel, A., Haggerty, B., Haultain, S., Hoines, J., Samuels, S., F. Villalba. 2014. California Phenology Project (CPP) plant phenological monitoring protocol: Version 1. Natural Resource Report NPS/PWR/NRR—2014/763. National Park Service, Fort Collins, Colorado.

NPS 963/123655, February 2014

Contents

Contents (continued)

Page

Figures

Page

Tables

Page

Standard Operating Procedures

Online Appendices

Executive Summary

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, so much so that phenology is widely recognized as an indicator of climate change impacts on ecosystems. Phenological monitoring is a tangible activity that can be useful for incorporating climate change concepts into educational, interpretive, and natural resource programming and for engaging the public in climate change research. Data collected from phenological monitoring can be analyzed and interpreted to make inferences about the magnitude and direction of phenological responses to variation in climate, and this information can be used to guide climate change response planning, to optimize implementation of climate-informed monitoring for adaptive management, and to inform climate change vulnerability assessments.

In 2010, the Pacific West Region of the National Park Service (NPS) received funding from the NPS Climate Change Response Program (CCRP) to conduct a 3-year pilot project to develop a phenological monitoring network in California's National Park units. 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 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 tools and infrastructure to support a coordinated phenological monitoring effort, and pilot activities were implemented in seven 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 Park (REDW), Santa Monica Mountains National Recreation Area (SAMO), and Sequoia and Kings Canyon National Parks (SEKI). This project is now known as the California Phenology Project (CPP; www.usanpn.org/cpp), and this protocol is a direct result of the CPP pilot phase.

The purpose of this protocol is to describe the goals of the California Phenology Project and to provide detailed instructions to carry out plant phenological monitoring within the established framework of the CPP. The protocol was designed to support the goals of the USA-NPN: to provide a platform for the standardized recording of phenological data and for the contribution of these data to a national database. The specific objectives of the CPP are to:

1. Establish a framework for long-term phenological monitoring of plant species in California and to contribute phenological data to a nationwide dataset that may be used to detect whether and how the phenological timing of targeted species is linked to climatic conditions that vary over time and space.
2. Determine the status and trends in onset and duration of key phenophases for focal plant species.
3. Develop methods and tools to engage people of all backgrounds and ages in the study of phenology and in understanding climate change.

Over time, the CPP hopes to build a widespread, standardized, and accessible long-term dataset that can be used to better understand how individual plant species and communities are responding to climate change in California.

In late 2010, species selection criteria and priority research questions were established during a workshop attended by agency and academic scientists. The CPP then identified a set of plant taxa for focused phenological monitoring and established monitoring locations that reflect environmental gradients within and across landscapes in California. Members of the public were recruited to participate in data collection at the pilot parks, thereby increasing the geographic distribution, number, and frequency of phenological observations recorded throughout California. The monitoring methods presented in this protocol are based upon the standardized protocols developed by the USA-NPN, but these were field tested in the pilot parks and adapted so that they accurately reflect the phenological progression of targeted California plant species. The phenological data collected using this protocol are contributed to the National Phenology Database [NPDb] curated by the USA-NPN.

This protocol includes eleven Standard Operating Procedures (SOPs) that describe the sampling framework, including information on optimal frequency of data collection and sample size, and how to: select target taxa, select and establish monitoring locations, recruit and train observers, prepare for the field season, record phenological data, submit phenological observations to the NPDb, and report CPP activities and results at each park on an annual basis. These are designed for use by parks that participated in phenological monitoring during the pilot phase, as well as parks or other land management agencies that may wish to join the CPP network in the future. 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

Ultimately this phenological monitoring protocol and other similar efforts (e.g. NETN) will allow the NPS to adopt a standardized, integrated approach to understanding how species are responding to climate change and to use phenological information in management decision-making.

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.

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. Thanks to John Gross and Tom Phillipi for helpful comments, discussion and ideas about sampling design and data management. Additional thanks go to the USGS and USA-NPN National Coordinating Office staff for project support and guidance, particularly Kathryn Thomas, Jake Weltzin, Alyssa Rosemartin, and Lee Marsh. We also appreciate contributions to the education and outreach component of the project by UC Berkeley Ph.D. candidate, Margot Higgins, and helpful reviews of early drafts of this document by Jherime Kellerman (USA-NPN), Ellen Denny (USA-NPN), and Geri Tierney (NETN).

We would like to thank the California botanical specialists that assisted the CPP team in the target species selection process and the science advisory group that participated in the November 2010 meeting in Berkeley, CA (participant list can be found online at http://www.usanpn.org/cpp/resources).

Finally, this project would not have been possible without the enthusiastic group of park-based seasonal technicians, interns, park project coordinators, and volunteers that worked to implement and test and ultimately improve these protocols. This group includes Crystal Anderson, Kipp Callahan, Sarah Felts, Jess Gambel, Mitzi Harding, Ann Huber, Jay Johnson, Steven Krause, Ruby Kwan, Steve Musch, Hannah Schwalbe, April Shackleford, and Margo Wallace – we are very grateful for their contributions.

Primary financial support for this project was provided by the National Park Service, Climate Change Response Program with supplemental funds provided by the USGS. The project was implemented through financial assistance agreements administered by the Californian Cooperative Ecosystem Studies Unit (TA # J8C07100014) with UC Santa Barbara and the Desert Southwest Cooperative Ecosystem Studies Unit (TA # P11AT10435) with University of Arizona, USA-NPN.

1. Background and Objectives

The core mission of the National Park Service (NPS) is to preserve and protect natural and cultural resources for the enjoyment of future generations. The NPS Climate Change Response Program (CCRP) was established to foster communication and to provide guidance, scientific information, and recommendations that support stewardship actions to effectively manage natural and cultural heritage in light of a rapidly changing climate. In 2010, the NPS Pacific West Region received funding from the CCRP to conduct a 3-year pilot project to develop tools and protocols to support long-term plant phenological monitoring across parks in California, with an emphasis on public participation and education. The project is now known as the California Phenology Project (CPP; www.usanpn.org/cpp). This protocol is a direct result of the CPP pilot phase and is designed for use by parks that participated in phenological monitoring during the pilot phase as well as parks or other land management agencies that may wish to join the CPP network in the future. Monitoring methods in this protocol are based on the USA National Phenology Network (USA-NPN; www.usanpn.org) standardized protocols and *Nature's Notebook* interface.

The purpose of this protocol is to provide instructions and details concerning the human and material resources necessary to carry out plant phenological monitoring within the established framework of the CPP, both at parks that are currently monitoring plant phenology and at parks that wish to join the CPP. Seven NPS park units currently implement the CPP plant phenological monitoring protocol, 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 Park (REDW), Santa Monica Mountains National Recreation Area (SAMO), and Sequoia and Kings Canyon National Parks (SEKI).

1.1 Phenology as a Focus for Monitoring

Phenology is the study of the timing of seasonal biological events such as the flowering and fruiting of plants; the annual emergence of insect pollinators and pests; and the migration of birds and mammals. Long-term observational studies have documented that both the onset and duration of phenological phases are sensitive to environmental variation and climate change, and that the alteration of plant and animal phenology by climate change has strong effects on ecological processes including primary productivity, species interactions, resource availability, and population growth (Both et al. 2006, Ozgul et al. 2010, Richardson et al. 2010, Willis et al. 2010, Aldridge et al. 2011, Primack and Miller-Rushing 2012). The links between phenology, climate, and climate change are so well documented that changes in the phenology of plant and animal species have been identified as a "fingerprint" and key "indicator" of climate change (Parmesan and Yohe 2003; IPCC 2007; U.S. EPA 2010).

Plant phenology is monitored by documenting the timing of individual life history stages, also known as *phenophases*. The duration and productivity of these phenophases may be altered where the timing of phenophases such as budbreak, leaf production, flowering, pollen release, and seed dispersal advances or delays in response to changes in temperature or rainfall. In addition, the degree to which an individual plant's phenophases overlap temporally with those of its natural enemies (e.g., leaf and floral herbivores) and its mutualists (e.g., pollinators and seed dispersers) will determine the frequency of its encounters with: competitors for pollination, herbivores, sexually transmitted diseases, pollen vectors, seed predators, and fruit dispersers. Consequently, the timing of the interacting phenophases of sympatric species — and the degree to which they are altered by climate change — can have strong effects on individual fitness and population dynamics (Harrington et al. 1999; Durant et al. 2007; Bertin 2008; Forrest and Miller-Rushing 2010; Gilman et al. 2012; Johansson et al. 2012).

Recent studies suggest that accurate predictions of the effects of climate change on wild species require observational data from unmanipulated systems (Wolkovich et al. 2012). However, few long-term observational datasets exist, and of those available, most are spatially limited, comprising data collected in a geographically restricted region (e.g., Rocky Mountain Biological Station in Gothic, CO; Hubbard Brook, NH; and Harvard Forest, MA). Moreover, many existing datasets do not provide records that allow the characterization of variation in phenological responses among individuals within populations, nor do they represent observations of many taxa, necessary for detecting and describing biologically significant variation among species (for examples of variation in phenological sensitivity to climate between species, within taxonomic families, and among families, see Cook et al. 2012; Diez et al. 2012; Mazer et al. 2013).

Given the current scientific and management interest in documenting and understanding climate change impacts on natural ecosystems and the concurrent lack of phenological data necessary to understand and predict ecosystem responses to climate change, the development of large-scale phenological monitoring efforts is timely. The USA-NPN was initiated in 2007 to address the shortage of spatially extensive and temporally frequent phenological observations by developing standardized monitoring protocols for a diverse group of plant and animal species and by providing online tools that enable the broad-scale observation of phenological events by both professional and citizen scientists. The CPP takes advantage of this resource and integrates seamlessly into the national effort by working closely with USA-NPN staff, by implementing monitoring that is consistent with USA-NPN protocols, and by contributing data to the National Phenology Database (NPDb) managed by the USA-NPN.

Furthermore, phenological information has been increasingly recognized as a valuable resource for managers and decision-makers. For example, Enquist et al. (2014) outline how phenological data can facilitate resource management by (1) informing climate change response planning, (2) optimizing implementation of climate-informed monitoring in the context of adaptive management, and (3) supporting climate change vulnerability assessment. Over the short-term, phenological monitoring by the CPP will firmly establish baseline patterns and the relationship between plant phenology and spatial variation in climatic conditions in California. Continued monitoring will enable researchers and land managers to track long-term trends, to document the effects of climate change on plants, to identify taxa that are phenologically sensitive (or insensitive) to climate change, and to guide adaptive management of natural resources. Long-term monitoring will enable resource managers to better predict the biological effects of a changing climate and to address essential science and management questions, such as whether earlier bloom time causes susceptibility to frost damage or when to apply invasive plant species control measures (e.g., herbicide application or mechanical removal).

1.2 Biogeographic Distribution of California National Parks

California is well known for its rich array of ecosystems and biological diversity. Park units in the state occur in three biogeographic regions: coastal, montane and desert (Figure 1; Table 1).

1.2.1 Coastal

Coastal California can be divided into two ecological zones, which the Environmental Protection Agency classifies as *Mediterranean California* in the south and *Marine West Coast Forests* in the north (CEC 1997). The southern coast is characterized by a Mediterranean climate, with hot, dry summers, and mild winters; the majority of precipitation in this region occurs during winter storms. The northern coast's maritime climate is cooler, but also characterized by dry summers and mild, wet winters. Linear mountain ranges parallel to the Pacific Coast are primarily oriented north-south, with numerous valleys interspersed among the ridges; this complex coastal topography results in highly variable local climate regimes and a strong inland-coastal gradient, with substantially higher summer temperatures occurring in the low-lying inland valleys (Ornduff et al. 2003). One CPP pilot park is located in the southern zone (SAMO) and three pilot parks are located in the northern zone (REDW, GOGA, and JOMU).

1.2.2 Montane

Most park units in California's high elevation regions are found in the Sierra Nevada and Cascade Ranges, where elevation frequently exceeds 3000m (~10,000ft). These landscapes are heavily vegetated, with alpine vegetation in the highest elevation zones (Ornduff et al 2003). The montane climate is characterized by warm summers and cold winters, although temperatures can be much warmer in the lower-elevation foothills (<1000m), where the dominant vegetation is oak woodlands. Two CPP pilot parks are found in this ecoregion: LAVO and SEKI.

1.2.3 Desert

California's desert ecoregion includes portions of the Sonoran, Great Basin, and Mojave Deserts, all of which are characterized by low rainfall (although the distribution of precipitation throughout the year varies among these regions) and seasonal temperature extremes (CEC 1997). Joshua Tree National Park, the only pilot park in the desert ecoregion, is in the Mojave Desert, which ranges in elevation from almost 100m (~300ft) below sea level to 3344m (~11,000ft).

Figure 1. Distribution of the National Park Service units in California. The seven California Phenology Project pilot parks are shown in dark red.

Table 1. National Park Service units in California. Bold text indicates units currently implementing the California Phenology Project Plant Phenological Monitoring Protocol.

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 Monument	PINN	10,767	Coastal

Table 1. National Park Service units in California. Bold text indicates units currently implementing the California Phenology Project Plant Phenological Monitoring Protocol (continued).

Park	Park Code	Area (ha)	Biogeographic Area
Presidio of San Francisco	PRES	603	Coastal
Redwood National and State Parks	**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

1.3 California Phenology Project Monitoring Goals and Objectives

The CPP was designed to support the goals of the USA-NPN — to provide a platform for the standardized recording of phenological data and for the contribution of these data to a national database. Over the long-term, these data can be analyzed, modeled, and interpreted to make inferences about the magnitude and direction of phenological responses to spatial and temporal variation in climate. To assess plant responses to climate and climate change, the CPP has identified a set of taxa for focused phenological monitoring and has selected monitoring locations that reflect environmental gradients within and across park landscapes (e.g., latitude and elevation gradients representing variation in temperature and precipitation). With the goal of building a geographically expansive dataset, the CPP has recruited and engaged the public in data collection, increasing the geographic distribution, number, and frequency of phenological observations recorded throughout California. Over time, the CPP hopes to increase the number of monitoring locations for focal plant taxa (see section 2), both in National Parks and on lands managed by other agencies and institutions (e.g., the University of California Natural Reserves), in order to build a widespread, standardized, and accessible long-term data set that can be used to better understand how individual plant species (and their communities) are responding to climate change in California. In sum, the specific objectives of the CPP monitoring effort are to:

1. Establish a framework for long-term phenological monitoring of wild plant species in California and contribute phenological data to a nationwide dataset (the NPDb) 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. Determine the status and trends in onset and duration of key phenophases (those included in the USA-NPN’s standardized monitoring protocol) for 30 focal plant species (Table 2).
3. Develop methods and tools to engage people of all backgrounds and ages in the study of phenology and in understanding climate change.

2. CPP Research Questions and Focal Species

At the onset of the project, expert taxonomists, plant ecologists, and conservation biologists participated in a workshop to define the CPP scientific framework and in subsequent focus groups (representing each of three biogeographic regions described in section 1.2) to select focal species. The process of identifying research questions and selecting focal species is described in detail in a Natural Resources Report documenting the CPP pilot activities (Matthews et al. 2013); a list of workshop and focus group participants is also included in the report.

Workshop participants identified 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 research questions is presented in Matthews et al. (2013). Among the larger set of research questions, the CPP identified 5 high-priority questions to guide the implementation of the pilot project. Four of these questions can be addressed with the sampling approach and infrastructure developed during the CPP pilot phase, while the fifth question will require both longer-term phenological monitoring (e.g., >10 years of data) and co-located climate data (e.g., collected at climate stations adjacent to CPP monitoring sites). The high-priority research questions include:

1. Among conspecific individuals, is there spatial variation in phenological parameters (e.g., the onset and duration of phenophases)? If so, is this phenological variation correlated with geographic gradients known to be associated with climate (e.g., elevation, latitude, or longitude)? Which phenological parameters or phenophases are most sensitive to these geographic gradients?

2. At what ecological level do we observe most of the variance in phenological metrics: (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 appearance of open flowers?

3. Are there distinct categories of phenological behavior among well-sampled taxa?

4. Within and across sites, do species differ in the magnitude of variation among individuals in the timing of flowering or leaf emergence (or other phenophases)? Across a similar ecological range of sites, do species differ in the magnitude of variation among site means, and is this phenological variation related to variation in geographic parameters?

5. Within and across species, what is the relationship between: (a) the onset of phenological events and the duration of phenophases and (b) current and long-term climatic conditions?

A description of an analytical approach that may be used to address each question is presented in SOP 10.

After developing research questions, focus groups representing each of the biogeographic regions (Figure 1; Table 1) identified target species for monitoring. Focus groups assessed species based on whether they were suited to address the CPP research questions and a series of additional criteria, including:

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.

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 with broad geographic ranges were given higher priority than narrowly distributed taxa to allow for sampling across multiple national parks and environmental settings. Many pilot parks, however, were interested in monitoring narrowly distributed species due to local ecological or management concerns; this resulted in a large portion of the focal species being monitored in only a single park. The primary limitation of monitoring in a narrower geographic area (e.g., a single park) is capturing less environmental variation. The focus groups identified 57 high-priority species for monitoring; the full list, and a justification for the selection of each species, is presented in Matthews et al. (2013)**.** During the pilot period, the high-priority species list was constrained through the application of practical criteria that were determined to be important in the field, including: accessibility, abundance, ease of delineating a single individual, and ease of identifying phenophases. 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 focal species that were monitored during the CPP pilot phase (Table 2).

Table 2. California Phenology Project species monitored in the seven pilot National Park Service Units. An 'X' indicates that a given species is monitored at the CPP pilot park indicated.

	Scientific name	**Common name**	**JOTR**	**SAMO**	**GOGA**	**REDW**	**LAVO**	**SEKI**	**JOMU**	**Total # of parks**
1	*Adenostoma fasiculatum*	chamise		X						1
2	*Aesculus californica*	California buckeye						X	X	2
3	*Arctostaphylos patula*	greenleaf manzanita					X	X		2
4	*Baccharis pilularis*	coyotebrush		X	X	X			X	4
5	*Coleogyne ramosissima*	blackbrush	X							1
6	*Eriogonum fasciculatum*	California buckwheat	X	X						2
7	*Eschscholzia californica*	California poppy			X					1
8	*Heracleum maximum*	common cowparsnip			X	X				2
9	*Larrea tridentata*	creosote	X							1
10	*Lathryus littoralis*	beach pea				X				1
11	*Lupinus obtusilobus*	satin lupine					X			1
12	*Mimulus (Diplacus) aurantiacus*	sticky monkeyflower			X					1
13	*Penstemon newberryi*	mountain pride					X	X		2
14	*Pinus contorta* ssp *murrayana*	lodgepole pine					X			1
15	*Pinus ponderosa*	ponderosa pine					X			1
16	*Populus tremuloides*	aspen					X			1
17	*Prosopis glandulosa*	honey mesquite	X							1
18	*Quercus agrifolia*	coast live oak		X	X				X	3
19	*Quercus douglasii*	blue oak						X	X	2
20	*Quercus lobata*	valley oak		X						1
21	*Rhododendron macrophyllum*	coast rhododendron				X				1
22	*Rosa californica*	California wild rose							X	1
23	*Sambucus nigra* ssp *cerulea*	blue elderberry		X			X		X	3
24	*Sambucus racemosa*	red elderberry				X				1
25	*Senegalia greggii*	catclaw acacia	X							1
26	*Symphoricarpos albus*	common snowberry							X	1
27	*Trillium ovatum*	pacific trillium				X				1
28	*Umbellularia californica*	California bay							X	1
29	*Yucca brevifolia*	Joshua tree	X							1
30	*Yucca schidigera*	Mojave yucca	X							1

Parks interested in joining the CPP are encouraged to monitor focal CPP species, where feasible, and to contribute to expanding the overall monitoring effort. Standard Operating Procedure 1 (SOP1) provides guidelines for designing a phenological monitoring program at national parks that have not yet become part of the CPP. Recognizing that there are circumstances where parks will want to select species for monitoring that are not currently on the CPP species list, SOP2 provides instructions for selecting and documenting new CPP species (e.g., criteria for species selection and detailed instructions for assembling species profiles and phenophase information to support monitoring efforts).

3. Monitoring Approach

3.1 USA-NPN monitoring protocols

This protocol employs the USA-NPN monitoring protocols (Denny et al. 2014), which are supported long-term by the USA-NPN National Coordinating Office (NCO) staff and infrastructure. The USA-NPN has carefully designed protocols and phenophase definitions for over 800 plant and animal species distributed throughout the nation, including those specifically targeted by the CPP for phenological monitoring in California. Phenophases are observable stages in the annual life cycle of plants or animals that can be defined by a start and end point, and recording the presence or absence of phenophases is the primary focus of the USA-NPN monitoring protocols. Based upon the results of CPP field testing during the pilot period, the USA-NPN and the CPP have collaboratively revised the USA-NPN phenophase definitions to better represent the phenological progression of the CPP target taxa and the USA-NPN has incorporated these revisions in their monitoring protocols.

The USA-NPN monitoring approach is based upon a "status monitoring" model rather than an "event monitoring" model. Status monitoring refers to the recording — every time a plant is observed — of the presence, absence, and intensity of each of several phenophases carefully selected to represent the key life cycle events for a species' particular life form or growth habit. In other words, the complete phenological "status" of an individual plant is recorded any time the plant is observed. By contrast, event-based monitoring aims to record the precise date of onset of key phenophases (e.g., the opening of the first flower), which must be directly observed in order for a record to be reliable. Status monitoring allows for year-round phenophase monitoring since participants are asked to respond "yes", "no", or "uncertain" for a given phenophase at *every* observation. When conducted with sufficient frequency, this procedure can provide accurate estimates of the onset and duration of phenophases and keep participants engaged in monitoring activities year-round. Additionally, given that the USA-NPN's status monitoring protocols allow the observer to estimate an abundance associated with each phenophase (e.g., the proportion of flowers that are open or the number of breaking leaf buds), this procedure provides data that can be used to determine the change in abundance (or intensity) of a phenophase across observation events (e.g., throughout the growing season). These abundance data can then be used to identify, for example, the peak intensity of a phenophase (Figure 2).

CPP observations are uploaded to the NPDb, which serves as the data repository for the CPP. Data are uploaded via *Nature's Notebook*, an online program designed for use by both professional and citizen scientists. *Nature's Notebook* mobile applications for data entry are available for iPhone and Android mobile devices.

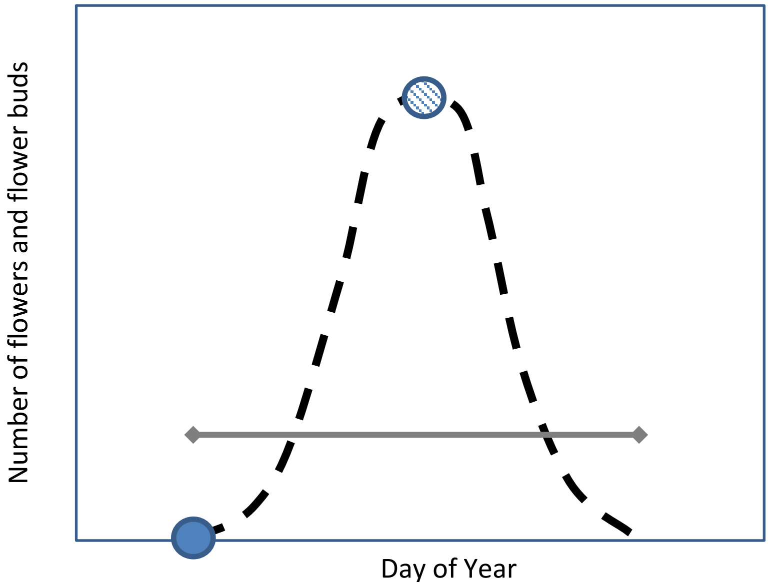


Figure 2. Graphical representation of USA-NPN status monitoring data (with abundance observations) for an individual plant. The dashed line represents the number of flowers or flower buds observed on a given day (each dash represents a "Yes" response to the question, "Do you see flowers or flower buds?" and its vertical position represents the numerical response to the question "How many flower and flower buds are present?"). The filled blue circle represents the onset of flowering (the first day a "Yes" response is recorded) and the gray bar represents the duration of flowering. To report intensity of the phenophase, the observer responds to the question, "How many flowers or flower buds are present?" Peak intensity of phenophases can be identified based on intensity responses: the shaded circle represents the date on which the greatest number of flowers were observed.

3.2 CPP observers

The CPP relies on both NPS staff and volunteer observers. During the pilot period, the CPP focused on engaging the public in data collection in three ways: by offering training workshops for park visitors and volunteers at most of the pilot parks; by posting instructional materials online at the CPP website; and by creating interpretive materials that park rangers could use to inform park visitors of the CPP's activities and objectives at their park. Four factors motivated this focus on public engagement. First, by enlisting volunteers in data collection, the number and frequency of phenological observations recorded throughout California might greatly exceed what is possible by park staff alone. Having numerous and frequent observations will contribute to the parks' needs for evidence-based early indicators of climate change response and climate sensitivity. Second, the CPP aims to educate the public about the ways in which biologists assess climate change impacts and about the need to address climate change in the management of natural resources. The third reason for emphasizing and encouraging the engagement of volunteers in data collection is that many parks face staff turnover, staff shortages, and limited resources for field research. Consequently, by encouraging participation by invested volunteers and creating a wide range of volunteer recruitment and training materials, the burden of data collection on park staff can be reduced. Finally, inclusion of and focus on volunteer data collection also engages the public and builds understanding, stewardship, and engagement around climate change issues and national parks. However, parks without large populations of prospective volunteers to draw from (i.e., those far from urban areas, such as Sequoia and Kings Canyon National Parks and Lassen Volcanic National Park) have primarily relied upon park staff and interns for data collection.

4. Sampling Framework

By observing plant phenology over a broad geographic area, the CPP sampling framework takes advantage of California's diverse landscape and large size to better understand how plant species respond to environmental variation and climate change. To this end, CPP monitoring locations are distributed across the three biogeographic regions (Figure 1), as well as across environmental gradients within park units. The core CPP sampling locations are listed in Table 3.

4.1 Frequency

In order to increase the precision of phenophase onset and duration estimates, the CPP aims to monitor targeted plants at a high frequency. Directional changes in phenology, such as a progression towards earlier flowering dates, can take many years to detect and species differ enormously both in their sensitivity to climate and in the direction of their response to inter-annual increases in temperature. The more frequently the phenological status of an individual or population is recorded, the smaller the magnitude of phenological change that can be detected, and the sooner it will be detected. Determining the optimal frequency of data collection relative to the sample size of individuals and the number of species studied will be highly dependent on how much variation in phenology is detected and how strongly species respond to climate; these relationships will vary within species and ecosystems (e.g. Morellato et al. 2010). A detailed discussion of the trade-offs between the frequency of monitoring and the rapidity with which statistically significant inter-annual changes in the onset of phenological events can be detected is found in SOP1. Once baseline data have been collected over multiple years, power analyses may be used to determine the optimal frequency and sample size for detecting phenological trends for a given species. Parks will then be able to make refinements to their sampling design in order to best allocate monitoring resources.

Ideally, the CPP and the USA-NPN recommend that observers monitor individual plants twice weekly, and at a minimum of once per week. In addition, observers are encouraged to monitor more intensively during periods of peak activity (e.g., every other day), preferably starting just before anticipated phenophases begin. By establishing monitoring sites in accessible locations, the time investment (e.g., for travel to the monitoring sites and for locating individual plants) per observer is minimized.

4.2 Sampling locations

Because the CPP aims to achieve high-frequency monitoring at accessible sites, sampling sites were subjectively selected and established along trails, near visitor centers, or in other locations that could be easily accessed and monitored at least twice per week. The convenience of these locations was necessary to facilitate outreach by park staff who wished to offer short presentations and demonstrations to inform visitors and volunteers of the parks' efforts to understand the effects of climate change on the natural resources that they are charged to protect. A limitation of this non-random design is that the data collected only apply to the specific locations of the plants sampled at each park. However, these data can be included in larger analyses of plants across California and the nation, where post-hoc statistical analyses can be used to investigate patterns among phenological events and abiotic variables including latitude, elevation, slope, aspect, and soil type. A detailed discussion of the trade-offs between subjectively and randomly sampled sites can be found in SOP1. CPP monitoring complies with the USA-NPN recommended guidelines of monitoring a minimum of three conspecific individuals per site, where individual sites are distributed at regular intervals along a trail or across environmental gradients (e.g., elevation).

Generally, at a given monitoring *location* at a park, four to eight *sites* are distributed along a trail that is two to six kilometers long, ideally spanning an environmental gradient across which factors such as temperature, precipitation, or soil moisture vary (sites are nested within locations). At each park unit where the CPP has implemented phenological monitoring, 2-6 monitoring locations have been established, each of which is comprised of several sites at which multiple individuals of multiple species are monitored (Table 3; see Appendices A-G for park-specific site information). Each site is relatively uniform with respect to habitat type, ground cover, species composition, and canopy cover and generally occupies no more than 100 m^2 (although some are larger). Instructions for establishing new monitoring locations are found in SOP3.

Table 3. California Phenology Project National Park sampling locations, target species, and approximate phenological active season. See Appendices A-G for maps, information about each monitoring site, and for detailed discussion of phenologically active season at each park and monitoring location.

Park Code	Location (CODE) and number of sites at location	Target Species	Phenologically Active Season
JOMU	Mount Wanda (WAND) 1 site	*Aesculus californica* *Baccharis pilularis* *Quercus agrifolia* *Quercus douglasii* *Umbellularia californica*	TBD TBD TBD TBD TBD
	Strentzel Meadow (STME) 1 site	*Aesculus californica* *Baccharis pilularis* *Rosa californica* *Sambucus nigra* *Symphoricarpos albus*	TBD TBD TBD TBD TBD
JOTR	High View Trail (HIVI) 8 sites	*Coleogyne ramosissima* *Eriogonum fasciculatum* *Yucca brevifolia* *Yucca schidigera*	sporadic, year round TBD March-August TBD
	Oasis Visitor Center (OAVC) 1 site	*Larrea tridentata* *Prosopis glandulosa*	year round[1] year round[1]
	Ryan Mountain Trail (RYAN) 7 sites	*Coleogyne ramosissima* *Eriogonum fasciculatum* *Larrea tridentata* *Yucca schidgera*	sporadic, year round TBD year round[1] TBD
	Park Boulevard (PABO) 3 sites	*Acacia greggii* *Larrea tridentata* *Yucca brevifolia*	TBD year round[1] February-July
GOGA	Mori Point (MORI) 6 sites	*Baccharis pilularis* *Mimulus aurantiacus* *Heracleum maximum* *Eschscholzia californica*	TBD TBD TBD TBD
	Old Bunker Road (OLBU) 6 sites	*Baccharis pilularis* *Mimulus aurantiacus* *Heracleum maximum*	year round TBD year round
	Presidio- Lobos Dunes/Mountain Lake (LDML) 9 sites	*Baccharis pilularis* *Mimulus aurantiacus* *Heracleum maximum* *Eschscholzia californica* *Quercus agrifolia*	year round TBD TBD TBD year round

Table 3. California Phenology Project National Park sampling locations, target species, and approximate phenological active season. See Appendices A-G for maps, information about each monitoring site, and for detailed discussion of phenologically active season at each park and monitoring location (continued).

Park Code	Location (CODE) and number of sites at location	Target Species	Phenologically Active Season
GOGA (continued)	Crissy Marsh Overlook (MAOV) 1 site	*Baccharis pilularis*	TBD
LAVO	Hot Rock (HORO) 1 site	*Lupinus obtusilobus* *Pinus contorta*	TBD TBD
	Sunflower Flats (SNFL) 1 site	*Arctostaphylos patula* *Penstemon newberryi*	TBD TBD
	Emigrant Trail (EMIG) 4 sites	*Arctostaphylos patula* *Penstemon newberryi* *Pinus ponderosa* *Populus tremuloides*	TBD TBD TBD TBD
	Lake Manzanita (MANZ) 4 sites	*Arctostaphylos patula* *Penstemon newberryi* *Pinus contorta* *Pinus ponderosa*	TBD TBD TBD TBD
	Devastated Area (DEVA) 1 site	*Populus tremuloides*	TBD
SAMO	Zuma Canyon (ZUMA) 7 sites	*Baccharis pilularis* *Eriogonum fasciculatum* *Quercus agrifolia* *Sambucus nigra*	year round[1] year round[1] year round[1] year round[1]
	Sandstone Peak Trail (SAPE) 9 sites	*Adenostoma fasciculatum* *Eriogonum fasciculatum*	TBD[2] TBD[2]
	Paramount Ranch (PARA) 9 sites	*Adenostoma fasciculatum* *Baccharis pilularis* *Eriogonum fasciculatum* *Quercus agrifolia* *Quercus lobata* *Sambucus nigra*	year round[1] year round[1] year round[1] year round[1] year round[1] year round[1]
	Cheesebro Canyon (CHCA) 11 sites	*Baccharis pilularis* *Eriogonum fasciculatum* *Quercus agrifolia* *Quercus lobata* *Sambucus nigra*	year round[1] year round[1] year round[1] year round[1] year round[1]
	Rancho Sierra Vista/ Satwiwa (RSVS) 6 sites	*Adenostoma fasciculatum* *Baccharis pilularis* *Eriogonum fasciculatum* *Quercus agrifolia* *Sambucus nigra*	year round[1] year round[1] year round[1] March-December year round[1]
SEKI	Foothills Visitor Center (FHVC) 4 sites	*Aesculus californica* *Quercus douglasii*	year round[1] year round[1]
	Lower Kaweah Air Quality Monitoring Site (LKAQ) 1 site	*Penstemon newberyii* *Arctostaphylos patula*	year round[1] year round[1]
REDW	Kuchel Visitor Center (KVC) 5 sites	*Baccharis pilularis* *Lathyrus littoralis*	year round[1] year round[1]
	Lady Bird Johnson Grove (LBJ) 6 sites	*Rhododendron macrophyllum* *Trillium ovatum*	March-December/January TBD
	Crescent Beach Overlook (CBO) 6 sites	*Baccharis pilularis* *Heracleum maximum* *Sambucus racemosa*	TBD TBD TBD

[1]the *phenologically active season* is considered year round if at least 1 phenophase was observed in each month of the calendar year. The *phenologically active season* for specific phenophases may be more restricted.

[2]the *phenologically active season* of species for which a full calendar year of observations were not available are labeled as TBD (to be determined).

5. Field Methods

5.1 Establishing New Monitoring Sites

SOP 3, Selecting and Establishing Monitoring Sites, describes how to choose locations, sites, and individual plants for monitoring. These instructions are intended for use by parks that are not currently participating in the CPP (but where staff are interested in establishing a monitoring program) and by participating parks that are interested in establishing additional monitoring sites. SOP3 also describes how to create visual tools to support monitoring (e.g., maps that document monitoring site position along trails).

5.2 Field Season Preparations for Established Monitoring Sites

Phenological monitoring occurs throughout the season of plant growth and reproduction, defined as the *phenologically active season*, which varies in length and timing in California depending on the prevailing climatic regime (e.g., in desert and Mediterranean ecosystems the phenologically active season will begin days or weeks after winter rains begin, whereas in mountain ecosystems the phenologically active season will begin in early spring as temperatures warm). As discussed above, the timing and duration of the phenologically active season may also be highly species-specific. Detailed instructions for field season preparation can be found in SOP4, Preparations for the Field Season and Equipment and Materials Needed. All observers should review the FAQ section on the *Nature's Notebook* website to ensure that they are familiar with revisions to the monitoring protocols (protocol updates are posted in January or February). Observers should also download the most recent *Nature's Notebook* datasheets and CPP species profiles for each focal species. All observers should attend a pre-season training event. Because many CPP parks rely on volunteer observers, SOP5, Recruiting and Training Phenology Observers, describes guidelines and materials for recruiting and training phenology volunteer observers (and for training new NPS staff that are participating in CPP monitoring). Safety procedures (described in detail in SOP6) should be reviewed by all CPP observers (volunteers and staff) prior to participation in any CPP activity.

5.3 Sampling Procedures

5.3.1. Sequence of Events during the Field Season

CPP observers record plant phenology throughout the phenologically active growing season. Since many CPP species are phenologically active year-round (Table 3), it may be useful to identify an arbitrary time period in which pre-field season activities and post-field season activities are completed. For example, many CPP species are active year-round at SAMO. To ensure that pre-season and post-season activities are completed every year at SAMO, pre-season activities could be scheduled every year during late summer or early fall (e.g., August and September), whereas post-season activities could be completed in early summer (e.g., June and July).

For parks that rely heavily on volunteer observers, the volunteer coordinator organizes volunteer monitoring efforts during the field season to ensure that: tagged plants are monitored at the suggested frequency, observations are uploaded to the NPDb, and observers have opportunities to ask questions and get feedback from the CPP participant network (e.g., via mid-season training sessions or via digital communication infrastructure, such as email listservs or message boards).

5.3.2 Measurement Details
To record phenological observations, CPP participants follow the status-based, species-specific protocols and phenophase definitions as defined by the USA-NPN and described in detail in SOP7, Phenology Site and Trail Monitoring. Most CPP observers will use *Nature's Notebook* datasheets to record their phenological observations, although some parks may choose to collect data using a handheld electronic device (e.g., tablet or phone) that has the *Nature's Notebook* mobile application installed. Locating established monitoring locations and sites is facilitated by the creation, maintenance, and use of map resources, which are described in detail in SOP3 and found in the park-specific monitoring guides (Appendices A-G).

5.3.3 Post-collection Processing
All phenological observations should be reviewed according to quality control criteria by both observers and the data manager or park coordinator, and should be submitted to the NPDb via methods described in SOP8, Data Entry and Data Management. Data can be uploaded via the *Nature's Notebook* online interface, by bulk upload procedures, or via applications on mobile devices (e.g., tablets and smartphones).

5.3.4 End-of-season Procedures
Although the phenologically active season may be year-round for some parks and/or species, other parks may cease observation or greatly decrease observation frequency during relatively inactive phenological periods (e.g., the late summer and early fall months in the desert and the winter months at higher elevation sites that are covered with snow). During this dormant (or phenologically "slow") period, each park should conduct an annual close-out and end-of-season documentation, described in detail in SOP9, Post-Field Season. The inactive period is an opportune time for CPP participants to catch-up on data entry, update maps and other monitoring materials, confirm the monitoring schedules of volunteers and other participants, and replace equipment, as needed.

6. Data Management

6.1 Overview of Data and Database Design

The structure of the NPDb is such that each observation represents an observer's recorded observations of the phenological status of a particular individual plant on a particular day. The data are comprised of the observers' responses (Y, N, or ?) to a query ("Do you see…?") regarding each targeted phenophase of the individual plant (Table 4). Observers may also estimate a categorical abundance measure for many of the phenophases. Each observation is associated with the observer, the date and time of the observation, the species, the site (and its geo-coordinates), and any additional notes made by the observer. Data on a single phenophase for an individual on a given day and time by a single observer is referred to as a "phenophase status record", whereas data for a suite of phenophases on one individual on a given day and time is considered an "observation".

Table 4. Example datasheet for a monitoring site at Joshua Tree National Park.

Observer: Mary Smith, VIP
Date: October 20, 2012

Plant ID	Northing	Easting	Common Name	Notes	Young Leaves? QNTY	Leaves? %	Flwr buds? QNTY	Open flwrs? %	Fruits? QNTY	Ripe Frts? %
HIVI1-CORA1	3770362	555950	Blackbrush		y n ? ___	y n ? ___	y n ? ___	y n ? ___	y n ? ___	y n ? ___
HIVI1-CORA2	3770366	555945	Blackbrush	Plant is closer to trail than YUSC2	y n ? ___	y n ? ___	y n ? ___	y n ? ___	y n ? ___	y n ? ___
HIVI1-CORA3	3770367	555937	Blackbrush	Plant is downslope from YUSC3	y n ? ___	y n ? ___	y n ? ___	y n ? ___	y n ? ___	y n ? ___
HIVI1-YUBR1	3770362	555950	Joshua Tree		N/A	N/A	y n ? ___	y n ? ___	y n ? ___	y n ? ___
HIVI1-YUBR2	3770366	555945	Joshua Tree		N/A	N/A	y n ? ___	y n ? ___	y n ? ___	y n ? ___
HIVI1-YUBR3	3770367	555939	Joshua Tree		N/A	N/A	y n ? ___	y n ? ___	y n ? ___	y n ? ___

6.2 Data Archival Procedures

CPP data will be archived in the NPDb automatically when they are entered in *Nature's Notebook*, as described in SOP8. Data stored in the NPDb are available for download using the USA-NPN data download tool (http://www.usanpn.org/results/data) and using filters to select data of interest (e.g., geographic area, species, timeframe, partner affiliation, and phenophases). In addition, each park is expected to download their data from the NPDb on an annual basis and archive the resulting .csv files according to their park-specific procedures for data management and storage.

6.3 Data Entry, Quality Assurance, and Quality Control

As described in SOP8, Data Entry and Data Management, data may be recorded on the datasheets that are provided through *Nature's Notebook* or on customized datasheets, which may be designed so that observations for many individuals (e.g., >10) can fit on a small number of datasheets in order to reduce the number of datasheets that are needed in the field on a given day and to streamline the data collection process (Table 4; see additional examples of datasheets in SOP8).

There are three ways in which data may be submitted to the NPDb. First, data may be uploaded directly to *Nature's Notebook* by setting up a user account and adding the affiliated CPP network and associated sites to a user's profile. Second, in circumstances where large numbers of observations are being entered at once or where internet access is poor, data may be bulk uploaded using an Excel-based data entry form that mimics custom datasheets. Bulk uploading provides the opportunity for an extra step of quality assurance/quality control (QA/QC), since the project coordinator or data manager can review all observations before the data are uploaded. Finally, observations may also be entered directly into the NPDb via the *Nature's Notebook* application on hand-held mobile devices (https://www.usanpn.org/nn/mobile-apps).

Edits to already-submitted data (e.g., observations, individuals, or sites need to be modified or deleted due to observer error) can be accomplished directly through *Nature's Notebook* or through communication with the USA-NPN National Coordinating Office.

A variety of quality control and quality assurance measures are implemented by the USA-NPN, as described in SOP 8. However, three additional processes can contribute to CPP data quality assurance: consistent observer training, using uniform training materials, and data collection by multiple observers. All CPP volunteers must be carefully trained to identify each individual plant and targeted phenophase. Training is designed to provide calibration among observers (particularly for abundance measures, if these are being recorded) and must occur before the phenologically active season begins. Follow-up field trainings, email reminders, or other communications should continue throughout the phenologically active season to ensure that observers are correctly identifying phenophases and estimating abundances. Quality assurance can also be addressed by having participants record phenology at the same location during a short time period (e.g., a one to two week period); any inconsistencies among observers can be identified and corrected.

Quality control measures include simple, timely reviews of data (before or after they are submitted to the NPDb). The CPP project coordinator or data manager will review the observations recorded by volunteers and staff, ideally on a weekly basis, in order to check for anomalies. Alternatively, this duty might be delegated to a trained and experienced CPP volunteer. If inconsistent observations are identified, the project coordinator will need to follow up with the observers and may need to visit the targeted individual plants to verify their phenological status. Quality control may also be augmented by digital photography (e.g., by suggesting that observers photograph phenophases or plants representing unclear phenological stages).

7. Data Summary, Analysis, and Reporting

7.1 Recommended Reporting Schedule

The CPP project coordinator and data manager will work together to summarize the data that were collected at the park on an annual schedule; longer-term trend analyses will be carried out every 3-5 years. SOP10, Data Summary, Analysis, and Reporting, describes the steps for downloading data from *Nature's Notebook*, summarizing the data collection effort, summarizing phenological records, and creating an annual summary report. It also includes suggested approaches for analyzing long-term data to address focal research questions. The methods described in SOP10 conform to the guidelines developed by the USA-NPN.

7.2 Downloading Data from *Nature's Notebook*

Parks should download their raw data annually from *Nature's Notebook.* Data are downloaded as a .csv file using the USA-NPN Data Download Tool (http://www.usanpn.org/results/data); the raw data file should be reviewed by the data manager to check for outliers, errors, etc. Instructions for downloading data are described in SOP10; these data will be used to create annual summary reports.

7.3 Data Summary

Annual summary reports created by the project coordinator at each park will include the following components: (1) a summary of climate data, including monthly temperature and precipitation records, (2) a summary of the monitoring effort in a given year, including the total number of unique phenophase status records, number of observers, days on which plants were monitored, and the total number of species, sites, and individual plants that were monitored; (3) phenological activity tables and figures, summarizing the onset and duration of each phenophase, created using the USA-NPN visualization tool and Excel pivot tables; and (4) graphs displaying the timing of peak phenophase intensity. Detailed directions for creating each section of the annual report are found in SOP10.

7.4 Long-term Research Objectives and Statistical Analyses

The CPP has identified research questions that can be addressed with the sampling approach and infrastructure established during the pilot phase of the project. These questions examine the sources of phenological variation and ask how geographic, climatic, and biological parameters affect the timing and duration of phenophases. Because some of the questions require climate data, park staff should communicate with their inventory and monitoring coordinator to assess the availability of local climate data. A set of high-priority research questions is presented in section 2 of this document, and the full suite of CPP research questions is presented in SOP10, along with a description of the analytical approach that will be used to address each question. Most of these questions can be addressed solely with data collected during the CPP pilot phase, but others require longer-term phenological datasets and co-located climate data; these questions will be addressed when the CPP has collected 10 years of phenological data.

8. Personnel Requirements and Training

8.1 Roles and Responsibilities

Implementation of the CPP plant phenological monitoring protocol requires a ***project coordinator*** at each park, as well as ***CPP participants*** (e.g., NPS seasonal staff, volunteer observers, student interns, education partners) who fulfill a variety of roles. These roles may be assigned to a single CPP participant or divided among several participants (e.g., staff members and committed volunteers), depending upon park resources. A summary of the key roles needed at each park include:

- ***project coordinator***, to manage program implementation, oversee site maintenance (e.g., replacing tags), and data collection, entry, summary, analysis, and reporting (e.g., preparing annual reports and coordinating analyses and report preparation on 3-5 year cycle); the coordinator should assign roles and delegate tasks to the CPP participants.
- ***observers***, to record phenological observations during the growing season and upload these data to *Nature's Notebook.* Observers may be NPS staff or volunteers, who will be trained by park staff or by other experienced CPP participants. (Note: data uploading may be delegated to the data manager role in some parks.)
- ***volunteer coordinator***, to recruit and train volunteers, foster volunteer retention, organize volunteer efforts to ensure targeted plants are monitored at the appropriate frequency, and ensure that volunteer observations are uploaded to *Nature's Notebook*. If resources are not available for a volunteer coordinator, these duties would fall under the project coordinator's role.
- ***data manager,*** to confirm the uploading of data to the NPDb**.** Because all CPP observations are submitted to the NPDb, the data management role for park staff is substantially reduced. The data manager may, however, need to oversee the following tasks: organize datasheets before data are uploaded; archive paper datasheets after the data have been entered in *Nature's Notebook;* and/or prepare spreadsheets for bulk uploading, if a park chooses this method for contributing data to the NPDb. These duties may be accomplished by a single individual or this role may be assigned to a few CPP participants. The data manager is also responsible for implementing data quality control procedures during data entry (See SOP6). If resources are not available for a data manager, these duties would fall under the role of project coordinator.

8.2 Qualifications

The *project coordinator* at each park must have a good working knowledge of park habitats and the CPP focal species targeted for monitoring at their park. Ideally, the project coordinator should have botanical training and experience working with the public, organizing volunteers, training park staff and volunteers to use standardized protocols, and managing data. *Observers* will be responsible for the bulk of data collection, and volunteer observer effort is organized by the volunteer coordinator. Because the *volunteer coordinator* will need to work with a diverse group of volunteers, the coordinator must be highly organized and comfortable working with the public. The volunteer coordinator will arrange training opportunities at the start of each monitoring season and as needed throughout the field season to provide additional opportunities for observers to develop skills and to ask questions of other observers. Note that the volunteer coordinator does not necessarily need to lead and present training opportunities; instead, there may be a volunteer, a seasonal employee, or a permanent staff member at the park who is familiar with the USA-NPN protocols and who may be available to provide training opportunities (see SOP5, Recruiting and Training Volunteer Observers for details). During training events, observers are trained in the observational and quantitative skills needed to record the phenological status of individual tagged and geo-referenced plants and to submit these observations to the NPDb. At some parks, volunteer observers may be required to commit a minimum amount of monitoring time following attendance at a training event (e.g., 2 observations a month for 6 months); this commitment, plus familiarity with plant identification and the ability to keep careful records and detailed observations are important qualities for the volunteer observers. The *data manager* must be comfortable with computers, particularly with internet browsers (e.g., Microsoft Explorer, Mozilla Firefox, Google Chrome) and word-processing and spreadsheet software (e.g., Microsoft Word and Excel). The data manager should also become familiar with the USA-NPN online interface, *Nature's Notebook,* through which CPP data will be uploaded to the NPDb.

8.3 Training Procedures

CPP observers will attend at least one training session prior to each field season. Training sessions, described in SOP5, give new participants and experienced observers the tools they need to record phenological data successfully and with confidence. The subject matter covered in these sessions includes: the background and goals of the CPP and USA-NPN; a review of the botanical terms needed to monitor plant phenology; the mechanics of observing plants and entering data to the NPDb; and a review of the material in the *park-specific monitoring guides* (the locations of monitoring sites, the focal species and the identification of their phenophases, and directions for submitting data online; see Supplemental Material).

9. Operational Requirements

9.1 Annual Workload

To successfully implement a phenological monitoring program, parks must have at least one employee who will serve as the project coordinator; the coordinator will need to dedicate *at least* eight hours per week to monitoring, data entry, and coordinating volunteers. If resources permit, ideally a park can split duties between a project coordinator, a volunteer coordinator, and a data manager. Note that the time commitment will be higher during the initial months of project implementation, which requires additional personnel hours to select species, establish monitoring sites, prepare supplies and materials, and recruit and train volunteers. The total amount of time required of park personnel is related to the size of the program at a given park (e.g., the number of targeted plants, the number of volunteer observers, and the number of monitoring locations); by limiting the number of targeted plants, the number of monitoring sites (and their distance from park offices or other monitoring sites), or the number of observers, the weekly time commitment can be constrained to the eight hours/week estimate given above.

Most parks rely on volunteer observers, who record phenological data at monitoring sites. Once trained, an individual observer (whether a volunteer or park employee) can typically record phenological data on 12 – 15 plants per hour, not including time spent driving to a monitoring site, locating individuals, or hiking along a trail. Consequently, an experienced observer could monitor 30 plants (e.g., 2 species x 3 individuals per site x 5 sites) distributed along a one-mile trail in approximately two hours. Therefore, excluding travel time, monitoring a total of 60 plants along two separate trails twice a week would require a minimum of four field hours, with additional time necessary for data entry and project coordination. Once familiar with *Nature's Notebook*, the data recorded during a single 2-hour period takes approximately 15 minutes to enter online.

9.2 Equipment Needed

The equipment and supplies listed below are necessary for establishing and maintaining phenological monitoring sites and for recording phenological observations in accordance with the monitoring protocols of the USA National Phenology Network (USA-NPN). These equipment needs are also described in SOP2, Steps for Selecting and Documenting New Species; SOP3, Selecting and Establishing Monitoring Sites; SOP4, Field Season Preparation and Equipment and Materials Needed; SOP 6, Safety Procedures; and SOP7, Phenology Site and Trail Monitoring.

1. *camera* — used to photograph plant phenophases (SOP2) and newly established monitoring sites (SOP3)
2. *maps* of all potential monitoring locations — used to navigate to selected monitoring locations and sites (SOP3)
3. *site establishment datasheets* — used to record geo-coordinates, unique identifiers, and other information about each site (SOP3)
4. *plant tags* (or other marking materials) — for marking new plants or replacing damaged or missing tags (SOP3)
5. *GPS units* — used to record geo-coordinates of monitoring sites and tagged plants (SOP3) and to locate tagged plants (SOP7)

6. *species identification guides* — may include CPP species profiles (SOP2) and local botanical resources and field guides
7. *first aid kits* — should always be carried in the field (SOP6)
8. *CPP species profiles, maps of trails and plants, and park monitoring guides* — these printed materials are available online and provide detailed information about the targeted taxa, the phenophases to be observed for each taxon, and monitoring sites at each participating park (SOP2, SOP3, and SOP7)
9. *Nature's Notebook datasheets and phenophase descriptions* — available for download on the *Nature's Notebook* website and CPP website (SOP7)
10. *clipboards*

Optional equipment

1. *binoculars* — for observing phenophases on large trees;
2. *hand lens* — for detailed observation of plant phenophases;
3. *three-ring binders* — to organize datasheets and to facilitate recording observations in the field;
4. *tablet or smartphone,* with the USA-NPN *Nature's Notebook* App installed (http://www.usanpn.org/nn/mobile-apps)

10. Revising the Protocol

Revision to the protocol narrative and SOPs will occur every 3 years (the CPP is currently seeking funding to support the protocol revision process). One representative from each park will participate in a protocol revision workgroup, which will convene to discuss and agree upon updates and to assign tasks to the workgroup members. The *CPP Plant Phenological Monitoring Protocol* will be electronically available for download and stored in the NPS Integrated Resource Management Applications (IRMA) portal. Previous versions of the protocol will be archived on the CPP website: www.usanpn.org/cpp; updated versions of the protocol may be posted to the website by USA-NPN NCO staff.

The protocol narrative and all SOPs contain version numbers and include a *Revision History Log* which will document changes, revision dates, and authors of revisions. Park-specific monitoring guides will be updated annually at each park to account for changes in maps, individual plants monitored, and trail locations; up-to-date versions of the park-specific guides will be posted on the CPP website on the appropriate park page (updated versions of the guides may be posted to the CPP website by contacting USA-NPN NCO staff). A detailed description of the revision process is described in SOP11, Protocol Revisions.

11. References

Aldridge, G., D. W. Inouye, J. R. K. Forrest, W. A. Barr, and A. J. Miller-Rushing. 2011. Emergence of a mid-season period of low floral resources in a montane meadow ecosystem associated with climate change. *Journal of Ecology* 99: 905-913.

Bertin, R.I. 2008. Plant phenology and distribution in relation to recent climate change. *Journal of the Torrey Botanical Society* 135: 126-146.

Both, C., S. Bouwhuis, C. M. Lessells, and M. E. Visser. 2006. Climate change and population declines in a long-distance migratory bird. *Nature* 441: 81-83.

Commission for Environmental Cooperation Working Group (CEC). 1997. Ecological Regions of North America-- toward a common perspective. Montreal, Commission for Environmental Cooperation (CEC).

Cook, B. I., E. M. Wolkovich, T. J. Davies, T. R. Ault, J. L. Betancourt, J. M. Allen, K. Bolmgren, E. E. Cleland, T. M. Crimmins, N. J. B. Kraft, L. T. Lancaster, S. J. Mazer, G. J. McCabe, B. J. McGill, C. Parmesan, S. Pau, J. Regetz, N. Salamin, M. D. Schwartz, and S. E. Travers. 2012. Sensitivity of spring phenology to warming across temporal and spatial climate gradients in two independent databases. *Ecosystems* 15: 1283-1294.

Denny, E.G., K. L. Gerst, A. J. Miller-Rushing, G. L. Tierney, T. M. Crimmins, C. A. F. Enquist, P. Guertin, A. H. Rosemartin, M. D. Schwartz, K. A. Thomas, K.A. and J. F. Weltzin. 2014. Standardized phenology monitoring methods to track plant and animal activity for science and resource management applications**.** *International Journal of Biometeorology*.

Diez, J., I. Ibanez, S. J. Mazer, T. Crimmins, M. Crimmins, and A. Miller-Rushing. 2012. Forecasting phenology: from species variability to community patterns. *Ecology Letters* 15: 545-553.

Durant, J. M., D. Ø. Hjermann, G. Ottersen, and N.C. Stenseth. 2007. Climate and the match or mismatch between predator requirements and resource a vailability. *Climate Research* 33: 271–283.

Enquist, C.A.F., J.L. Kellermann, K.L. Gerst, and A.J. Miller-Rushing. 2014. Phenology research for natural resource management in the United States. *International Journal of Biometeorology*.

Forrest, J. and A. J. Miller-Rushing. 2010. Toward a synthetic understanding of the role of phenology in ecology and evolution. *Philosophical Transactions of the Royal Society B-Biological Sciences* 365: 3101-3112

Gilman, R.T., N. S. Fabina, K. C. Abbott, and N. E. Rafferty. 2012. Evolution of plant-pollinator mutualisms in response to climate change. *Evolutionary Applications* 5: 2 – 16.

Harrington, R., I. Woiwod, and T. Sparks. 1999. Climate change and trophic interactions. *Trends in Ecology and Evolution* 14: 146-150.

Intergovernmental Panel on Climate Change (IPCC). 2007. Climate change 2007: synthesis report. Contributions of Working Groups I, II, and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. IPCC, Geneva, Switzerland.

Johansson, J., K. Bolmgren, and N. Jonzén. 2012. Climate change and the optimal flowering time of annual plants in seasonal environments. *Global Change Biology* 19: 197-207.

Matthews, E. R., K. L. Gerst, S. J. Mazer, C. Brigham, A. Evenden, A. Forrestel, B. Haggerty, S. Haultain, J. Hoines, S. Samuels, and F. Villalba. 2013. California Phenology Project: Report on Pilot Phase Activities, 2010-2013. Natural Resource Report NPS/PWRO/NRR—2013/743. National Park Service. Fort Collins, Colorado.

Mazer, S. J., S. E. Travers, B. I. Cook, T. J. Davies, K. Bolmgren, N. J. B. Kraft, N. Salomin, and D. W. Inouye. 2013. Flowering date of taxonomic families predicts phenological sensitivity to temperature: implications for forecasting the effects of climate change on unstudied taxa. *American Journal of Botany* 100: 1-17.

Morellato L. P. C., M. G. G. Camargo, F. F. D'Eça Neves, B. G. Luize, A. Mantovani, I. L. Hudson. 2010. The influence of sampling method, sample size, and frequency of observations on plant phenological patterns and interpretation in tropical forest trees. Pages 99-121 *in*: I. L. Hudson and M. R. Keatley, editors. Phenological Research: Methods for Environmental and Climate Change Analysis. Springer, Netherlands.

Ornduff, R., P. M. Faber, and T. Keeler-Wolf. 2003. Introduction to California Plant Life. University of California Press, Berkeley, CA.

Ozgul, A., D. Z. Childs, M. K. Oli, K. B. Armitage, D. T. Blumstein, L. E. Olson, S. Tuljapurkar, and T. Coulson. 2010. Coupled dynamics of body mass and population growth in response to environmental change. *Nature* 466: 482-485.

Parmesan, C. and G. Yohe. 2003. A globally coherent fingerprint of climate change impacts across natural systems. *Nature* 421: 37-42.

Primack, R.B. and A. J. Miller-Rushing. 2012. Uncovering, collecting, and analyzing records to investigate the ecological impacts of climate change: a template from Thoreau's Concord. *Bioscience* 62: 170-181.

Richardson, A. D., T. A. Black, P. Ciais, N. Delbart, M. A. Friedl, N. Gobron, D. Y. Hollinger, W. L. Kutsch, B. Longdoz, S. Luyssaert, M. Migliavacca, L. Montagnani, J. W. Munger, E. Moors, S. L. Piao, C. Rebmann, M. Reichstein, N. Saigusa, E. Tomelleri, R. Vargas, and A. Varlagin. 2010. Influence of spring and autumn phenological transitions on forest ecosystem productivity. *Philosophical Transactions of the Royal Society B-Biological Sciences* 365: 3227-3246.

U.S. Environmental Protection Agency (U.S. EPA). 2010. Climate Change Indicators in the United States. EPA 430-R-10-007. www.epa.gov/climatechange/indicators.html.

Willis, C. G., B. R. Ruhfel, R. B. Primack, A. J. Miller-Rushing, J. B. Losos, and C. C. Davis. 2010. Favorable climate change response explains non-native species' success in Thoreau's Woods. *PLoS ONE* 5: 1-5.

Wolkovich, E. M., B. I. Cook, J. M. Allen, T. M. Crimmins, J. L. Betancourt, S. E. Travers, S. Pau, J. Regetz, T. J. Davies, N. J. B. Kraft, T. R. Ault, K. Bolmgren, S. J. Mazer, G. J. McCabe, B. J. McGill, C. Parmesan, N. Salamin, M. D. Schwartz, E. E. and Cleland. 2012. Warming experiments underpredict plant phenological responses to climate change. *Nature* 485: 494-497.

SOP1: Guidelines for Designing a Phenological Monitoring Program at New California Phenology Project National Parks

Version 1.0

Revision History Log:

Version #	Revision Date	Author	Changes Made	Reason for Change
1.0	June 2013	Matthews, Mazer, Gerst, Brigham		

Overview

This SOP provides guidelines for park units not currently participating in the project that wish to design a phenological monitoring program that will be fully integrated with the current CPP approach. (The active phenological monitoring programs at participating CPP parks were implemented in accordance with these guidelines.) Because each park has a unique set of opportunities, species, personnel, and resources with which to implement a phenological monitoring program, several alternative sampling design options and considerations are presented below, any of which might effectively meet the specific goals of a particular park. Each of these alternative designs is intended to provide flexibility and may be customized according to the constraints or opportunities encountered by a given park.

I. General guidelines

Parks that wish to implement a phenological monitoring program should first review the general guidelines described in this section. The steps for designing a program are outlined in the flowchart below and described in the sections that follow.

1. Convene a working group that includes representatives of each division that would like to participate in the phenological monitoring program (e.g., resources, interpretation, and education divisions). The working group should review the entire protocol, the report on the CPP pilot phase (Matthews et al. 2013), and materials on the CPP website (www.usanpn.org/cpp) in order to become familiar with the current CPP approach and infrastructure.

2. The working group will proceed through the steps outlined in the workflow diagram below, including: identifying goals for a given park's phenological monitoring program that fit within the scope of the CPP; identify resources that are available to support the implementation of a long-term phenological monitoring program; determining who will observe targeted plants (e.g., NPS staff, citizen science volunteers, student interns); selecting target species; and selecting monitoring locations and sample sites (these steps are described in detail in the sections that follow).

3. New parks should adopt and use the monitoring protocols developed by the USA-National Phenology Network (USA-NPN), as these provide a standardized approach to monitoring that allows the quantitative comparison of phenological events within and across species,

locations, and regions. Using the USA-NPN protocols also reduces the need for long-term data management, as all observations recorded with these protocols can be easily submitted to the National Phenology Database (NPDb) managed by the USA-NPN.

4. When selecting target species, carefully consider the list of species currently being monitored by the CPP (see the full list of CPP species here: http://www.usanpn.org/cpp/AllSpecies). By selecting a species from this list, parks will have access to species-specific monitoring tools (e.g., CPP species profiles) that have already been developed for the CPP species. Additionally, new monitoring sites will complement the data recorded at other park units, which collectively will contribute to the understanding of how California taxa respond to environmental and climatic variation. See section 2.4 and SOP2 for additional instructions for selecting focal species.

The steps for designing a phenological monitoring program are displayed in the flowchart below (Figure 1). The outcome of the initial steps (i.e., identifying park goals and resources) will inform the subsequent steps (e.g., selection of monitoring locations and focal species). Many of the decisions made during the later steps (most of which are related to sampling design) will have an effect on each other, and these steps may be best approached iteratively. For example, decisions about who will collect phenological data, what areas of the park are high priority for observation, and the frequency of data collection will lead to decisions regarding the best locations at which to collect data.

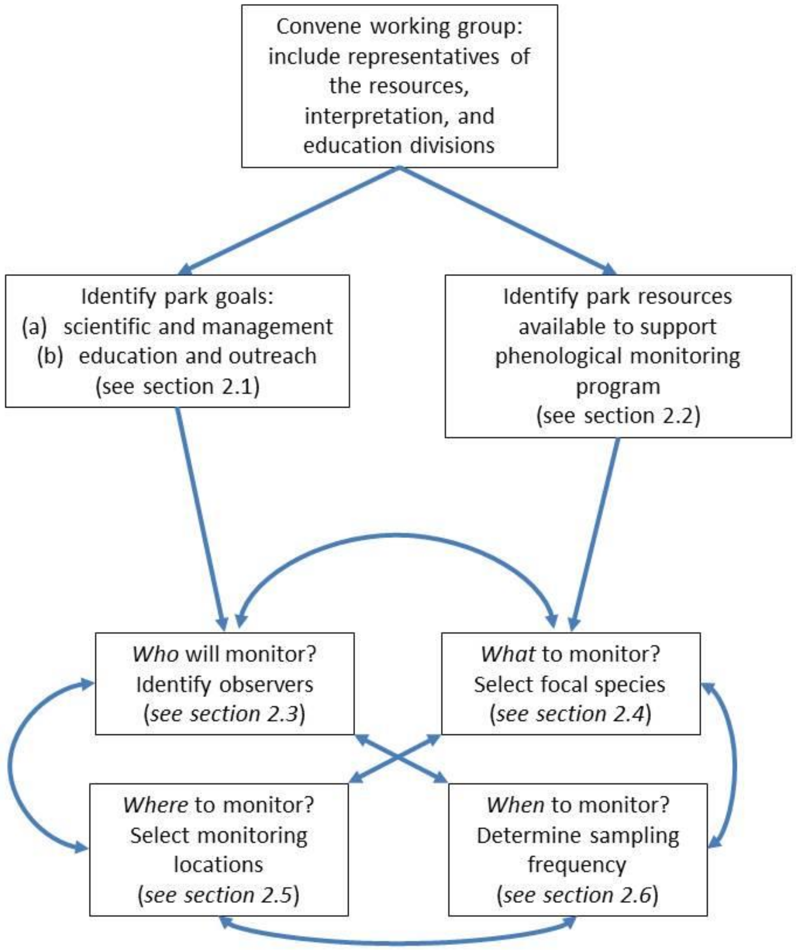


Figure 1. Flowchart displaying the steps for designing a phenological monitoring program.

II. Steps for designing a phenological monitoring program at a national park

The working group described in section I of this SOP will be responsible for implementing the following steps at each new park.

2.1 Identify park goals

Before developing a sampling design for a given park, the park must clearly identify the project goals, which may include scientific and management objectives, as well as education and outreach objectives.

2.1.1 Scientific questions and management needs

Identify the highest-priority research questions and management needs within the park. This will facilitate the identification of phenological data that would allow, for example, the detection of the effects of environmental conditions (e.g., temperature and soil moisture content) on the timing and duration of phenophases. A summary of a set of research questions that can be addressed by a sustained phenological monitoring program, and descriptions of their applicability to resource management, are presented in Matthews et al. (2013).

In particular, parks may consider the following questions:

1. Are there specific plant species (or plant communities or sensitive habitat types) that may be particularly vulnerable to climate change? If so, park staff may choose to focus the majority of their sampling and monitoring on these species or in these areas.

2. Are there particular mutualisms or other ecological relationships that may be at risk due to climate change? For example, are there cases in which plants may temporarily escape insect herbivores because climate-induced changes in the phenology of edible plant parts are not matched by the phenology of the herbivore? Alternatively, are there cases where plants may become exposed to particular herbivores for the first time because the plants' edible organs become available to herbivores during a new window of time? If so, park staff may wish to monitor the phenology of animals as well as plants.

3. Are there plant species for which phenological information could guide management action? For example, phenological data might be used to inform invasive plant management (e.g., timing pesticide application or manual removal to avoid periods of seed dispersal).

The questions posed above should help park staff to select species and populations that would provide the most value for the individual park's scientific or management needs. Ideally, the selected species will also contribute to the regional and national coverage of the USA-NPN's database, allowing other scientists or managers to compare phenological responses of widespread species distributed across California and the U.S.

<u>2.1.2 Education and outreach objectives</u>

Parks may be interested in engaging the public in scientific research or in educating park visitors about the biological impacts of climate change. Phenological monitoring programs offer may opportunities for park visitors, school groups, and citizen scientists to learn about the scientific process, local flora and fauna, and the effects of climate variability and climate change on biological systems. To reduce the time investment on the part of park staff and to reduce the need for financial support, park staff in the education and interpretation divisions may identify on-going outreach and education programs that provide opportunities for introducing phenological concepts to the public. For example, park staff may be able to introduce phenological monitoring during plant-focused interpretive programs that are active near visitor centers.

At the park level, the data collection effort is likely to benefit by the joint participation of staff in the resource, education and/or interpretation divisions. Indeed, CPP activities may offer a strong bridge and potential for collaboration between the staff in these divisions. Each park may benefit by evaluating the current interests and capacity of its rangers, interpreters, and resource managers to initiate or to sustain long-term phenological monitoring and to recruit and organize volunteers who may conduct most of the actual data-recording. The strongest and most sustainable phenological monitoring programs are likely to be those that engage park staff from multiple divisions.

2.2. Identify park resources available to support a phenological monitoring project

Consider the resources, including personnel, which are available for implementing and maintaining a long-term monitoring effort. In terms of personnel, parks must have at least one employee who will serve as the project coordinator; the coordinator will need to dedicate *at least* eight hours per week to monitoring, data entry, and coordinating volunteers. Note that the time commitment will be higher during the initial months of project implementation, during which additional personnel hours will be needed to select target species, establish monitoring sites, prepare supplies and materials, and recruit and train observers. The total amount of time required of park personnel will be related to many of the components described in other sections: the number and location of targeted plants, the number of volunteer observers, and the location and number of monitoring locations, etc. By limiting the size of a park's program (e.g., the number of targeted plants, monitoring or volunteer observers), the total personnel requirements can be constrained.

Parks should determine personnel availability based on the unique circumstances of their own permanent staff, seasonal employees, student interns, and volunteers. Optimally the roles described in the protocol narrative (e.g., project coordinator, volunteer coordinator, data manager) will be divided among park staff and committed volunteers, although these roles may be fulfilled by a single person, where staff size and park resources are limited.

2.3 Identify observers

The working group at each park should consider *who* will observe the plants targeted for phenological monitoring (e.g., seasonal staff, volunteer observers, student groups). If observers are comprised primarily of volunteers and park visitors, then monitoring sites must be easily accessible and capable of tolerating the foot traffic incurred by repeat visitation on a once or twice-weekly basis. If, by contrast, phenological observation is to be conducted by NPS staff, then co-locating monitoring sites with other locations that staff visit (e.g., visitor centers, a campsite near an evening program amphitheater, staff offices, trailheads, etc.) may be convenient and practical. Even with volunteer observation, significant staff time will be required to organize volunteer efforts, train volunteers and staff to use monitoring protocols, upload data, and summarize and analyze data.

Most parks rely on volunteer observers, who record phenological data at monitoring sites. Once trained, an individual observer (whether a volunteer or park employee) can typically record phenological data on 12 – 15 plants per hour, not including time spent driving to a monitoring site, locating individuals, or hiking along a trail. Consequently, an experienced observer could monitor 30 plants (e.g., 2 species x 3 individuals per site x 5 sites) distributed along a one-mile trail in approximately two hours. Therefore, excluding travel time, monitoring a total of 60 plants along two separate trails twice a week would require a minimum of four field hours, with additional time necessary for data entry and project coordination. (Note: travel time between monitoring locations is substantial at some parks, and will significantly add to the total time investment.) Using these estimates, along with knowledge of the travel and hiking time required to visit each tagged plant, the project coordinator at each park should be able to calculate the total number of person-hours necessary to record the phenological status of all individuals twice per week. Whether observers work alone or in pairs, and whether observers are assigned to particular species, to particular days of the week, or to particular trails or locations, will determine how many observers are necessary at a given park. Once familiar with *Nature's Notebook*, the data recorded during a single 2-hour period would take approximately 15 minutes to enter online.

2.4. Select focal species

Consider the entire list of species currently being monitored by the CPP (see the full list of CPP species here: http://www.usanpn.org/cpp/AllSpecies). By selecting a species from this list, parks will have access to species-specific monitoring tools (e.g., CPP species profiles) that have already been developed for the CPP species. Additionally, new monitoring sites will complement the data recorded at other park units, which collectively will contribute to our understanding of how California taxa respond to environmental and climatic variation. There may be some instances, however, when parks choose to monitor species not currently represented in the CPP; SOP2, Selecting and Documenting New CPP Species, provides guidance for the latter case. In general, the CPP recommends selecting a small number of species to allow for replication of individuals across many sites; additional species can always be added at a later time.

2.5 Select sampling locations

Factors such as who will collect phenological data, what areas of the park are high priority for observation, and the frequency of data collection (*see section 2.6*) will lead to decisions regarding the best locations at which to collect data. SOP3 provides detailed steps for selecting and establishing monitoring locations and sites; additional considerations are discussed here.

At CPP parks, phenological monitoring occurs at *sites* where individual plants have been selected and labeled with tags, each inscribed with unique identifiers. CPP monitoring *sites* are often nested within *locations*, which are generally named for a nearby trail, visitor center, or road. There is often more than one monitoring *site* at a monitoring *location* (e.g., four to eight *sites* might be distributed along a trail that is two to six kilometers long, ideally spanning an environmental gradient across which factors such as temperature, precipitation, or soil moisture vary.

At a new CPP park, the working group may first determine the capacity for monitoring and then decide on the number of locations, sites, and individual plants to target for monitoring. For example, the working group could assess the capacity for monitoring by multiplying the number of prospective observers (e.g., volunteers plus staff) by the number of hours that each has available to participate each week. The total number of person-hours available for monitoring per week must then be discounted by travel time and hiking time. If volunteers are to work in pairs, then the total number of hours must be halved. In any case, once the total number of available monitoring-hours per week is determined, this value may be used to determine the total number of plants that can be visited and monitored each week. In other words, if the human capacity for monitoring is known and fixed, then the number of locations, sites, and individual plants per species that can be reliably monitored twice weekly can be estimated before selecting locations.

Any effort to establish long-term phenological monitoring at a given park unit can contribute to statistically valid broad inferences concerning the effect of climate and climate change on phenology because an established site that contributes many years of data will be useful for comparison with data collected across the nation and submitted to the NPDb. However, to detect park-specific effects of climate variability on a smaller, regional scale, a sampling design should take advantage of gradients within parks, such as the inland- coastal gradient at Santa Monica Mountains National Recreation Area (see Appendix F for SAMO monitoring locations). Because the current CPP monitoring approach requires high-frequency observation (see discussion section VIII below), to date, all CPP monitoring locations have been selected to maximize accessibility and the ecological variation sampled (as opposed to random site selection methods). Additionally, the relationship between phenology and environmental conditions can be detected at a higher resolution using replicated trail-based gradients within a park, such as the elevation gradients covered by the sites established for monitoring along the Ryan Trail and the High View Trail at Joshua Tree National Park (see Appendix C for a description of JOTR's monitoring locations and SOP3 for a detailed discussion about selecting monitoring sites along a trail).

One limitation of a non-random design is that the analysis of the data collected in this way will only allow statistically valid inferences for the plants sampled at each park. However, these data will be able to be included in larger analyses of plants across California and the nation, and where statistical analyses allow the control of variables such as latitude, elevation, slope, aspect, and soil type, the responses of non-randomly selected plants to climate change will contribute to a broader understanding of the effects of local climate on the phenology of wild species.

In selecting monitoring locations, the working group might identify gaps in the ecological representation of species currently being monitoring by the CPP. For example, for a given species currently being monitored in one or more parks, gaps may exist with respect to its representation across geographic (e.g., latitude) or environmental (e.g., variation in soil moisture or temperature) gradients. Adding monitoring sites that capture previously unsampled ecological variation will provide more value than simply increasing the number of individuals or sites monitored across an ecologically homogeneous landscape.

Once monitoring locations are determined, park staff will face a range of choices regarding the particular sites and individuals to sample. The criteria for site selection are described in SOP3; for example, accessibility of individual plants representing targeted species has been a necessary criterion to ensure high-frequency phenological monitoring. Because observation is primarily accomplished through volunteer data collection at some parks, some sites have been established in heavily visited areas of the park, near trails or visitor centers. The main limitation to this approach is that it may introduce unintentional bias into the study, and therefore, the analyses of these data only allow statistically valid inference to the particular plants observed.

2.6 Determine sampling frequency

<u>2.6.1 Recommended approach: high-frequency phenological monitoring</u>

Greater frequency and consistency of observations allows for a higher likelihood of detecting phenological patterns and change, and twice-weekly monitoring will achieve a high likelihood of detecting statistically significant change across years and decades (Moussus et al. 2010). When resources are limited, it is more desirable to have frequent data (ideally twice weekly during phenologically active periods) recorded from fewer individual plants and species than infrequently recorded data from many individual plants. Because species phenological responses can be highly variable depending on the species and region of interest, there is no published recommended optimal frequency of data collection relative to sample size (but see Morellato et al. [2010] for an in-depth study on this trade-off in tropical tree communities). Once data have been analyzed for multiple years, a power analyses may help to determine the optimal frequency and sample size for detecting variation and change in phenology with climate for a given focal species. Parks will then be able to refine their sampling design in order to best allocate resources.

Once species have been selected for monitoring, then park staff may consider issues concerning: the degree of phenological change that may be detected by a given sampling intensity; the time frame over which phenological change may become apparent; and the spatial scale over which monitoring will occur. Directional changes in phenology, such as a progression towards earlier flowering dates, can take many years to detect and species differ enormously both in their sensitivity to climate and in the direction of their response to inter-annual increases in temperature. The more frequently the phenological status of an individual or population is recorded, the smaller the magnitude of phenological change that can be detected, and the sooner it will be detected. Sampling more frequently allows observers to detect smaller phenological changes from year to year, but takes more effort. In other words, there is a clear trade-off between the frequency of monitoring (and the number of individuals monitored) and the rapidity with which statistically significant inter-annual changes in the onset of phenological events can be detected. If climate change effects on the timing and duration of phenophases are sufficiently large and occur over sufficiently short time scales, however, this trade-off may be relatively weak.

However, this frequency can be difficult to achieve when sites are remote or personnel are limited, and several alternative sampling frequencies can also be informative. To maintain a high likelihood of detecting variation in the timing of particular phenophases, individuals should be monitored at a high frequency (e.g., at least 2 times per week) during the phenologically active period (i.e., when phenophases are known to occur or be in transition); they may then be observed less frequently (e.g., 1-2 times a month) during non-peak periods. Non-peak periods are a great opportunity for observers and park staff to "re-group" and prepare for the next growing season. This strategy, however, requires prior knowledge of phenological activity and several years of high-frequency sampling before being able to estimate the periods of high phenological activity.

One challenge of this approach is that where sites contain multiple species of interest, their periods of peak phenological activity may not overlap; in this case, it may be difficult to reduce travel costs and the time required for adequate monitoring. A second challenge is that, in regions with Mediterranean or desert climates, the timing of one or more phenophases may be highly sensitive to the frequency and intensity of rainfall. For example, in many species, the production of new leaves may occur multiple times during the growing season in response to rainfall events. In this case, there may be very high year-to-year variation in the timing of the onset of leaf production and in the number of times at which it occurs. In such cases, monitoring may be intensified during periods that follow rainfall events until the expected phenophases (such as leaf emergence) have been observed. Then, during subsequent dry periods (as they occur), monitoring may be conducted less frequently.

2.6.2 Alternatives to high-frequency phenological monitoring

Alternatives to a high frequency monitoring schedule include monitoring once weekly or monthly, while maintaining year to year consistency and revisiting the same individuals on the same dates every year. While long-term, frequent monitoring is required to detect the effects of climate change on phenological activity and allows for finer scale detection of the role of climate variability in triggering phenological activity, less frequent monitoring can be useful for determining broad phenological patterns and for addressing short-term management applications (note, however, that less frequent monitoring does not directly support the scientific goals of the

California Phenology Project). Lower frequency efforts may be appropriate if the goals of the monitoring program are, for example, to develop a phenological calendar of activity (e.g., to identify the months during which plants of a given species are commonly flowering) or to determine what month to spray herbicides on invasive species (e.g., before seed set).

Phenological monitoring may also be carried out less frequently when sites are remote and/or when phenological monitoring is done in conjunction with other monitoring efforts that take place on an annual or semi-annual basis, such as NPS Inventory and Monitoring vegetation sampling. In such circumstances, it is important that phenological monitoring is done as near as possible to the same date each year and on the same individuals or patches of individuals. For example, monitoring conducted on the same dates each year provides successive "snapshots" of the phenological status of the park that can be examined to detect long-term trends; if all monitored plants were recorded on the first of the month all year round, these data could be used to ask whether the proportions of flowering individuals and species on a given date were changing from year-to-year. In other words, is the month when the maximum number of individuals or species are flowering or leafing out becoming earlier over time? Similarly, these data could be used to address whether the phenological calendar within a park is advancing, exhibiting delays, or becoming shorter or longer from year-to-year. In sum, date-specific inter-annual sampling allows comparisons of the phenological status of individuals on the same date in successive years, leading to inferences concerning the role of inter-annual variation in climate (as opposed to, for example, plant age) in generating phenological variation among years. While this type of monitoring cannot capture the start or end of a phenophase, it can provide information regarding the presence and absence of a particular phenophase at a consistent time of year. When linked to other monitoring protocols, this kind of monitoring scheme can contribute to the understanding of how plant communities are changing through time, both demographically and phenologically.

Other alternatives to frequent in-situ monitoring are beyond the scope of this protocol, but include remote sensing of phenological activity by phenocams (http://phenocam.org/) or by picture posts (http://picturepost.unh.edu/). The NPS North East Temperate Network is currently developing a protocol that includes detailed information on the installation of phenocams and analysis of phenocam data (access the most recent version of the protocol here: http://science.nature.nps.gov/im/units/netn/monitor/programs/phenology/phenology.cfm).

References

Matthews, E.R., Gerst, K.L., Mazer, S.J., Brigham, C., Evenden, A., Forrestel, A., Haggerty, B., Haultain, S., Hoines, J., Samuels, S. and Villalba, F. 2013. California Phenology Project: Report on Pilot Phase Activities, 2010-2013. Natural Resource Report NPS/PWRO/NRR—2013/743. National Park Service. Fort Collins, Colorado.

Morellato L. P. C., M. G. G. Camargo, F. F. D'Eça Neves, B. G. Luize, A. Mantovani, I. L. Hudson. 2010. The influence of sampling method, sample size, and frequency of observations on plant phenological patterns and interpretation in tropical forest trees. Pages 99-121 *in*: I. L. Hudson and M. R. Keatley, editors. Phenological Research: Methods for Environmental and Climate Change Analysis. Springer, Netherlands.

Moussus, J.P., Julliard, R., and Jiguet, F. 2010. Featuring 10 phenological estimators using simulated data. Methods in Ecology and Evolution 1: 140-150.

SOP2: Steps for Selecting and Documenting New Species (non-CPP taxa)

Version 1.0

Revision History Log:

Version #	Revision Date	Author	Changes Made	Reason for Change
1.0	June 2013	Haultain, Gerst, Matthews		

Overview

Parks (and institutions that would like to contribute to the CPP effort, such as the UC Natural Reserves, botanic gardens, and schools) are encouraged to establish additional monitoring locations for CPP focal species. A greater number of monitoring locations will better enable the CPP to use these data to understand and predict species-specific response to future climate change. However, there may be some instances when parks may choose to monitor plant species not currently represented in the CPP. This SOP is intended to provide guidance for the latter case. In addition, this SOP provides instructions for developing species-specific profiles to aid observers in phenophase identification and monitoring. Section I provides guidance for selecting new species. Section II contains instructions for preparing information and materials to support monitoring.

I. Guidelines for selecting new target taxa

One of the first steps in setting up a phenological monitoring program is the selection of target taxa (the plants species to monitor). This is an important step and parks need to consider monitoring goals and objectives as well as the resources available to dedicate to monitoring. Parks should first consider the list of California plant species identified by the CPP as candidates for phenological monitoring: http://www.usanpn.org/cpp/CPPcandidatespecies (all of these species have profiles available on the USA-NPN website; search by scientific or common name here: http://www.usanpn.org/species_search).

In November 2010, the CPP developed species-selection criteria during a full-day workshop held in Berkeley, CA. A report describing the development of these criteria, as well as ecological questions of interest, can be found at the following URL: www.usanpn.org/cpp/sites/www.usanpn.org.cpp/files/u5109/CPPScientificFrameworkWorkshopReport.pdf. Regional subject matter experts then applied these criteria to species lists compiled for four biogeographic regions of California. This process resulted in lists of potential target taxa that fulfilled these criteria for the California park units. These same criteria should be applied to any new target taxa.

The criteria for species selection identified by the CPP include the following:

i. dominant species, representing the most common or “characteristic” local or regional vegetation type (e.g., coast live oak, redwood trees, giant sequoias)

ii. widely distributed taxa (e.g., taxa that occur in the largest number of National Parks (and UC reserves) within biogeographic regions (coastal, montane, or arid) and across biogeographic regions (including more than one of the following: coastal, montane, or arid).

iii. indicator species for habitats, or transitions between habitats, of particular interest (e.g., desert scrub, vernal pools, bogs, maritime chaparral, oak woodland, pinyon pine-juniper, riparian, snowmelt edges, evergreen forest or coastal dunes)

iv. 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, fall-deciduous taxa that change leaf color; locally endangered species; invasive species that are not targeted for control; critical food sources for endangered pollinators or butterfly larvae)

v. ease of identification – it's important that each selected species and its phenophases are relatively easy to identify (especially when closely related and morphologically similar taxa are sympatric with the target species)

vi. taxa which are accessible for monitoring across an abiotic or biotic gradient (e.g., elevation; aspect; soil moisture; gradients of invasive species abundance; gradients of disturbance, such as across a wildfire boundary; gradients of coastal fog)

vii. taxa which are present and abundant near other monitoring efforts (e.g., co-location with I & M plots that provide demographic and abundance information or proximity to meteorological stations)

viii. species for which there are legacy data to which current phenological behavior can be compared (e.g., PhD dissertations, primary literature, etc.)

ix. benchmark species (e.g., species that may be reliably phenologically sensitive to climate change, including taxa that are "first-responders" to spring warming; species that are last-to-flower; species that provide dramatic spring flowering or fall foliage displays)

x. ability to engage citizen scientists (e.g., species that are easy to propagate or cultivate for use in native plant or school gardens; species whose phenological activity occurs at different periods throughout the year, allowing for interaction with citizen scientists in many seasons; etc.)

xi. known and accessible locations of multiple individuals in park/unit

Once a list of viable target taxa has been identified, species selection may proceed based upon practical considerations. These include *accessibility* (i.e., plants adjacent to the phenology trails or other monitoring locations), which is especially important when members of the public will be involved in data-collection, and *abundance* (i.e., if 5-15 healthy individuals of a given taxon cannot easily be located in the target area, then it is inadvisable to sample the taxon in that location due to lack of replication; also, as plants die in the future, it will be hard to replace them). Exceptions to this "rule" would include plants that represent highly charismatic and long-lived species that may be integrated into a brief interpretive program or walk near a visitor center. In this case, hundreds of individuals per year could be introduced to the CPP and its goals, learn what the park is doing to learn about the effects of climate change on its natural resources, and practice observing and recording of data for one or a few very-well studied individuals.

It is best to select species at least 6 months before the monitoring program begins. Allowing time for discussion with other subject matter experts and potential stakeholders in the process will help to ensure that a park selects species that can be successfully monitored and that will contribute to broader regional and national data collection efforts. Including botanically knowledgeable volunteers and educators in the species selection process is also a good way to generate conversation, debate, and the exchange of knowledge, while promoting a sense of ownership that may lead to long-term commitments. This process can also help to promote phenological monitoring in general and to advertise to the public how and why the park is initiating phenological monitoring.

II. Preparation of species-specific materials to support monitoring

2.1 Adding a species to Nature's Notebook

When a park selects a species that is not already included on the USA-NPN species list (see http://www.usanpn.org/nn/species_search), the project coordinator should fill out the species request form on the USA-NPN website and include rationale for monitoring at http://www.usanpn.org/node/add/species-request (please note that this form can only be accessed while logged into a *Nature's Notebook* account). Within one year, the requested species will be researched by the National Coordinating Office staff, assigned a phenophase protocol and species profile page on *Nature's Notebook*, and added to the list of USA-NPN target species.

2.2 Creating CPP species-profiles

A CPP species profile should be created for each new focal species; the profile should include information about the species' geographic distribution, physical description (including information about size and life form, leaves, flowers, and mating systems), and interesting facts or ethnobotanical uses (see Figure 1 for an example CPP species profile). Park staff and volunteers will need to collect phenophase photos for the profiles or search online for non-copyrighted images (note that photos taken by NPS staff and volunteers who have confirmed the species' identity are preferable to those found on the internet, which may not have been correctly identified).

The steps for assembling a CPP species profile include:

1. Review current CPP species profiles and become familiar with the style, layout, and language (see example CPP species profiles on the individual species' pages, accessed at the following URL: http://www.usanpn.org/cpp/allspecies).
2. Based on protocol category assigned by the USA-NPN (e.g., *Deciduous Trees and Shrubs* or *Forbs*), download the correct CPP species profile powerpoint template(s) at the following URL: www.usanpn.org/cpp/meet-the-species. Adapt information available on the USA-NPN species webpages for the CPP profile (search species here: https://www.usanpn.org/nn/species_search).
3. If no supplementary species-specific information has been developed on the USA-NPN species webpages, explore online resources to find information for California plant species (e.g., Jepson Manual, USDA PLANTS, U.S. Forest Service species pages, scientific research papers).

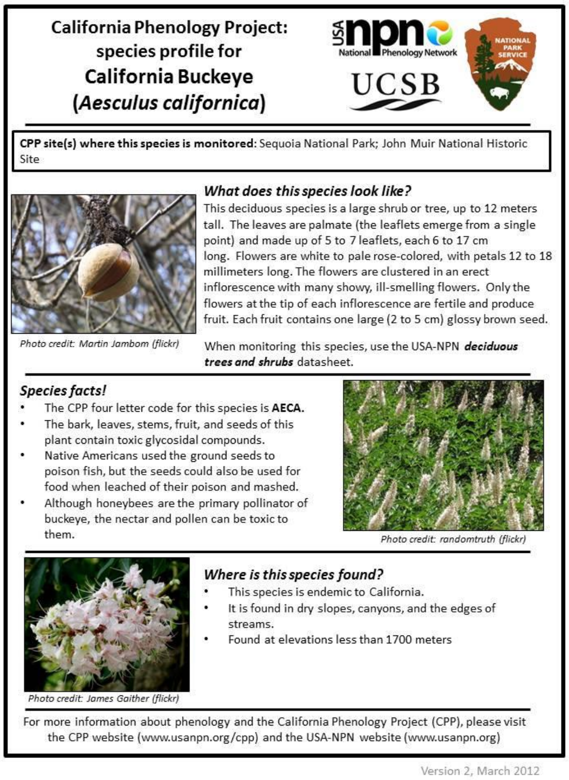
4. Collect high-resolution digital phenophase photos for each phenophase monitored on each focal taxon. If unable to obtain photos for every phenophase and species combination, search online for images, preferably using an open-access source such as Creative Commons (www.creativecommons.org); be sure to properly attribute photographers. Phenophase and species photographs are also available on CalFlora (www.calflora.org) and may be used after requesting permission from photographers.
5. As a general rule, attribute photos to their photographers, even when it is not required. This allows users to follow up with the photographer later, should questions or concerns regarding a particular photograph arise.
6. Customize the species profile layout depending on how many phenophases are monitored and the amount of text that is necessary to describe these phenophases. To maximize readability, density of text should be reduced to the minimum amount required to convey important information about the species and the tips for successful monitoring. Text should be written in a concise, simple, informative style.
7. Use a minimum font size of 11pt and maintain margins assigned in the templates. All photos are outlined with black borders measuring 0.75 pt.
8. Phenophase photos of hard-to-photograph but easy-to-identify phenophases, such as *falling leaves* and *recent seed or fruit drop*, may be excluded from the profile to allow for more space and greater emphasis on photos of more difficult-to-identify phenophases.
9. Crop phenophase photos and edit images in an image processing software in order to highlight the focal phenophase. For pages with 6 phenophase photos (e.g., *Pinus contorta*), phenophase photos should be cropped to 2.2 x 2.2 inches, and for pages with 8 phenophase photos (e.g., *Populus tremuloides*), photo dimensions should be 1.8 x 1.8 inches.
10. Include information on species specific monitoring instructions on the back side of the profile and borrow text from existing profiles when relevant (e.g., instructions for monitoring flowers within the Asteraceae). Include arrows and other photo annotations when necessary to highlight difficult anatomical features. See example profiles at the following URLs:

    a. *Eriogonum fasciculatum*
    https://www.usanpn.org/cpp/sites/www.usanpn.org.cpp/files/pdfs/ERFAv6_a.pdf

    b. *Baccharis pilularis*
    https://www.usanpn.org/cpp/sites/www.usanpn.org.cpp/files/pdfs/BAPIv7.pdf

11. If a phenophase is difficult to identify, problematic to observe, or not of interest for other reasons, it can be left out of the monitoring effort. For example, breaking leaf buds are difficult or impossible to detect in many Mediterranean and desert taxa (e.g., *Adenostoma fasciculatum* and *Baccharis pilularis*).
12. Before making species profiles available to a wide audience, they should be field tested by park staff and CPP volunteers.

Updated versions of species profiles are included in the park-specific monitoring guides and revised during updates to these guides (see SOP11).



California Phenology Project: species profile for California Buckeye (*Aesculus californica*)

USA npn National Phenology Network

UCSB

NATIONAL PARK SERVICE

CPP site(s) where this species is monitored: Sequoia National Park; John Muir National Historic Site

Photo credit: Martin Jambom (flickr)

What does this species look like?

This deciduous species is a large shrub or tree, up to 12 meters tall. The leaves are palmate (the leaflets emerge from a single point) and made up of 5 to 7 leaflets, each 6 to 17 cm long. Flowers are white to pale rose-colored, with petals 12 to 18 millimeters long. The flowers are clustered in an erect inflorescence with many showy, ill-smelling flowers. Only the flowers at the tip of each inflorescence are fertile and produce fruit. Each fruit contains one large (2 to 5 cm) glossy brown seed.

When monitoring this species, use the USA-NPN ***deciduous trees and shrubs*** datasheet.

Species facts!

- The CPP four letter code for this species is **AECA.**
- The bark, leaves, stems, fruit, and seeds of this plant contain toxic glycosidal compounds.
- Native Americans used the ground seeds to poison fish, but the seeds could also be used for food when leached of their poison and mashed.
- Although honeybees are the primary pollinator of buckeye, the nectar and pollen can be toxic to them.

Photo credit: randomtruth (flickr)

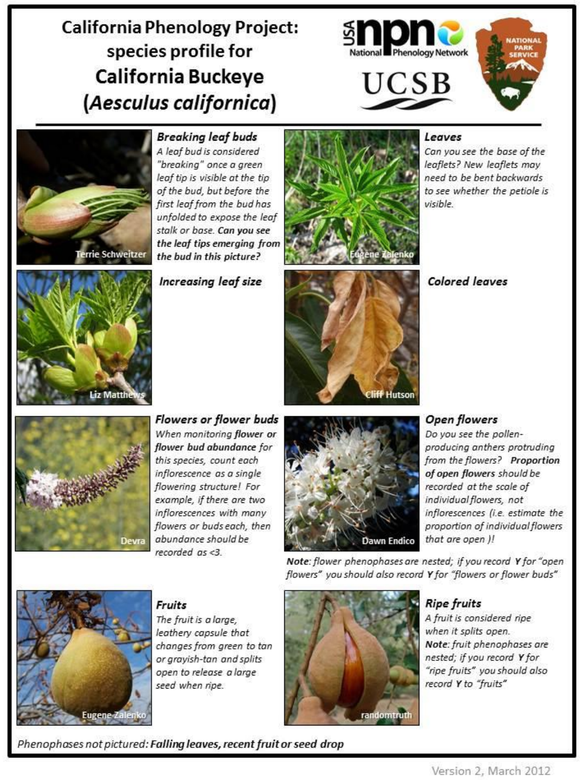
Where is this species found?

- This species is endemic to California.
- It is found in dry slopes, canyons, and the edges of streams.
- Found at elevations less than 1700 meters

Photo credit: James Gaither (flickr)

For more information about phenology and the California Phenology Project (CPP), please visit the CPP website (www.usanpn.org/cpp) and the USA-NPN website (www.usanpn.org)

Version 2, March 2012



California Phenology Project: species profile for California Buckeye (*Aesculus californica*)

USA npn National Phenology Network

UCSB

NATIONAL PARK SERVICE

Terrie Schweitzer

Breaking leaf buds

A leaf bud is considered "breaking" once a green leaf tip is visible at the tip of the bud, but before the first leaf from the bud has unfolded to expose the leaf stalk or base. ***Can you see the leaf tips emerging from the bud in this picture?***

Eugene Zalenko

Leaves

Can you see the base of the leaflets? New leaflets may need to be bent backwards to see whether the petiole is visible.

Liz Matthews

Increasing leaf size

Cliff Hutson

Colored leaves

Devra

Flowers or flower buds

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

Dawn Endico

Open flowers

Do you see the pollen-producing anthers protruding from the flowers? ***Proportion of open flowers*** *should be recorded at the scale of individual flowers, not inflorescences (i.e. estimate the proportion of individual flowers that are open)!*

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

Eugene Zalenko

Fruits

The fruit is a large, leathery capsule that changes from green to tan or grayish-tan and splits open to release a large seed when ripe.

randomtruth

Ripe fruits

A fruit is considered ripe when it splits open.
Note*: fruit phenophases are nested; if you record* ***Y*** *for "ripe fruits" you should also record* ***Y*** *to "fruits"*

Phenophases not pictured: ***Falling leaves, recent fruit or seed drop***

Version 2, March 2012

Figure 1. *Aesculus californica* species profile (Version 2; March 2012)

SOP3: Selecting and Establishing Monitoring Sites

Version 1.0

Revision History Log:

Version #	Revision Date	Author	Changes Made	Reason for Change
1.00	June 2013	Matthews and Mazer		

Overview

This SOP provides instructions for selecting and establishing monitoring sites that are well-suited to support a participating park's monitoring goals. It is intended for use by both current participating parks and new CPP parks. For information about designing a monitoring program and approach, see SOP1 (which describes for a *new* CPP park the steps to develop a phenological monitoring program and sampling design based on park-specific objectives). Once a park's monitoring goals have been identified and a sampling approach has been selected, SOP3 will guide parks through the process of implementing the selected approach and establishing monitoring sites.

I. Introduction to CPP terminology and monitoring approach

At each park, phenological monitoring occurs at *sites* where individual plants have been selected and labeled with tags, each inscribed with unique identifiers. These unique identifiers are important because they facilitate the primary goals of the infrastructure described here: to locate and to label healthy, geo-referenced individual plants that will be monitored frequently during the phenologically active season and then repeatedly monitored year after year, retaining their unique identification over time. To date, each site typically includes at least 3 individuals representing each of 1-3 species, usually located within a radius of 10-15 meters.

CPP *sites* are often nested within *locations*, which are generally named for a nearby trail, visitor center, or road (e.g., Sandstone Peak trail in the Santa Monica Mountains National Recreation Area; see maps in Appendix F). There is often more than one monitoring *site* at a monitoring *location* (e.g., the Sandstone Peak Trail monitoring location at Santa Monica Mountains NRA has 9 monitoring sites, each with at least 3 tagged plants).

Locations — and the number of *sites* established within each location — are selected depending on the participating park's monitoring objectives. For example, a location may be a trail that permits the establishment of sites across an aridity or elevation gradient. Establishing 6-10 sites (with 2-3 species replicated at each site) at ~150m (~600ft) intervals along such a trail would allow the observation and measurement of the effects of elevation on the onset or duration of phenological events. Alternatively, establishing 2-3 sites at an accessible location (e.g., near a visitor center) that offers a short (e.g., 10-minute) walking loop allows interpretive rangers to offer walks that demonstrate the process of recording phenological data; during such demonstrations, NPS staff could distribute brochures, bookmarks, or index cards with information about the CPP and the USA-NPN (see examples of these materials on the CPP website). Similarly, a location may be chosen because of its proximity to other park activities that attract visitors and/or park staff (e.g., places where school groups come weekly to participate in educational activities led by park staff; popular picnic sites that are staffed by a park ranger; sites where other citizen science projects are taking place; and places that park staff routinely visit to record meteorological data).

II. General guidelines

The approximate number of sites and plants to be established and labeled at each location should be determined by following an assessment of:

2.1 Location attributes

To facilitate efficient data collection, the CPP has generally restricted the size of each location to a linear distance of 1 – 3 km (~.6 –1.8 mi), although some trails that cover a wide elevation gradient are longer. This distance is short enough to permit an observer to spend no more than two hours of walking time in the course of recording phenological data from all labeled plants at the site, but large enough to allow the monitoring of multiple species replicated at multiple sites that may represent different local environmental conditions.

2.2 The number and abundance of target species available for monitoring at the location

Locations are generally chosen because they allow for the monitoring of 10-20 individuals of each of 2-3 species. This criterion allows participants to observe phenological variation among individuals and among sites (within locations) and to recognize variation among species in the timing, duration, and appearance of different phenological events and phenophases. Species that are rare at a given location and cannot be replicated across sites within the location might be excluded from that site simply because their value for addressing scientific questions is limited. On the other hand, species that are infrequent throughout their range may be profitably monitored even if rare at a given location if they are represented at multiple locations.

2.3 Availability of observers

Locations that are established primarily to educate park visitors (e.g., at visitors centers or at other venues for educational activities) might include only one or two sites each with 3-6 plants. The higher the availability and participation of park rangers at a given location, the higher the number of plants that may be regularly monitored. Scheduling this monitoring at a visitors center, for example, could be achieved by dividing the task among park rangers according to a weekly schedule, ensuring that each plant will be monitored twice per week during phenologically active periods of the year. The number of available volunteers or park staff will help to determine the maximum number of plants that can be included at such a site.

2.4 The amount of time available for or allocated to monitoring at a given site

An experienced observer can typically record phenological data on 12 – 15 plants per hour. This estimate can be used to decide how many individuals to label at a given location. For example, if it takes one hour to walk a trail comfortably, and a pair of volunteers is available to conduct monitoring together for three hours one day a week, then 120 minutes of monitoring would allow these volunteers to record data on 24 plants (at 5 minutes per plant). If additional volunteers are available to cover additional 3-hour periods, each group of could be responsible for monitoring another 24 plants.

2.5 Amount of staff time and park resources available for establishing and managing a long-term monitoring program

Larger monitoring programs (e.g, number of monitoring locations and sites, number of observers, number of interpretive programs) require a greater amount of staff time for establishing sites, managing observers, and submitting data to the NPDb. Parks that are considering a phenological monitoring program need to consider the resources available to support a long-term monitoring program and may select to start small (e.g., 1-2 monitoring sites near a visitor center) and gain practical experience before expanding the program.

The guidelines described above, and the details that follow, conform to the recommendations of the USA-NPN for site and individual plant selection. Many parks rely on volunteers and park staff, who have other responsibilities, to conduct phenological monitoring. Consequently, given the high frequency of data-collection needed for high-resolution phenological observation, locations and sites are selected because of their accessibility and the presence and abundance of targeted species. Acceptable procedures for labeling individual plants differ among parks and should be approved by the project coordinator.

III. Equipment and supplies needed to establish new monitoring sites

- *maps* — of all potential monitoring *locations*; will be used to navigate to selected monitoring locations and sites
- *camera* — used to photograph newly established monitoring sites
- *datasheets* — used to record geo-coordinates, unique identifiers, and other information about each site (Table 1)
- *plant tags* (or other marking materials) — for marking new plants
- *GPS units* — used to record geo-coordinates of monitoring sites and tagged plants
- *species identification guides* — preferably use both CPP species profiles and local botanical resources and field guides
- *first aid kits* — should always be carried in the field; see SOP10 for other safety guidelines.

IV. Selection of monitoring locations and sites

Sites (within locations) are selected and set up by NPS staff. Sites are selected for convenience of access, representation of local conditions, and presence of focal taxa.

At each park, CPP monitoring *locations* are selected based upon several criteria, including:

- *park-specific monitoring goals* — monitoring locations should be identified based upon the monitoring goals identified by the park (e.g., parks that want to engage on-going education programs in CPP monitoring should select locations where the education programs are already active, whereas parks that want to focus monitoring on a species of management concern should select location where the species is present and abundant)
- *accessibility* — monitoring locations should be convenient for the anticipated observer groups (e.g., near staff offices, areas used by partner organizations and park visitors, or sites frequently visited by other inventory or monitoring programs); travel time to locations should be considered, as this will affect the level of time commitment needed

- *representation of one or more key environmental gradients*, either within the park or across parks (e.g., elevation, latitude, inland-coastal, etc.)
- *presence* and *abundance of focal species* — CPP focal species should be present and relatively abundant at locations selected for monitoring; ideally, *at least* 2 focal taxa should be present and abundant at each location selected
- *sensitivity to pedestrians and the presence of rare or sensitive species* — trails on soil substrates that are easily eroded due to soil composition or slope require special care when establishing sites; streamsides and steep drainages are generally avoided. Where social trails are easily formed, targeted plants must be limited to those within one meter of the main trails in order to avoid soil erosion (which might also alter hydrological properties and affect plant phenology).

In evaluating these criteria for a given location, compromises must often be made. For example, it is possible that highly accessible sites will not be occupied by as many individuals of a focal species as more remote sites. When selecting among prospective locations, NPS staff representing divisions participating in the CPP (e.g., resources, interpretation, education) should assess the value of each location with respect to these criteria and in light of its educational and scientific objectives and potential. In some cases, partner organizations and volunteers may collaborate with park staff to identify locations that are convenient and appropriate for monitoring.

Six criteria should be considered when selecting sites within locations:

1. *local abundance* of CPP focal species— preferably at least 3 individuals each of at least 2 CPP focal species
2. *accessibility* of individual plants — plants selected for monitoring should be close to the trail or visitor center
3. *environmental conditions and differences from other sites within the location*— sampling of multiple sites representing a range of microenvironments may allow the detection of the effects on a given taxon's phenology of particular environmental variables such as slope, aspect, elevation, and soil type.
4. *distance between sites* — for ease of location, sites may be distributed at a (more or less) consistent density or frequency throughout the location (e.g., at equal linear distances or differences in elevation along a trail)
5. *degree of disturbance or development* — in an effort to balance logistical constraints and statistical considerations, the current CPP monitoring sites represent a gradient of "naturalness." Some sites are selected to emphasize accessibility; these sites are considered *demonstration sites* and are often located close to developed areas, such as visitor centers. Sites located along trails are selected to represent a more natural setting; however, these plants may also be influenced by the presence of the trail.
6. *safety* —sites should be free from trail hazards (e.g., steep and rocky terrain) and should minimize the potential for observers to come in contact with ecologically vulnerable or poisonous plants or animals (e.g., endangered species, poison oak, and venomous snakes); see a detailed discussion of safety considerations in SOP10.

V. Selection of individual plants at monitoring sites

At each monitoring site, at least 2 (and up to 10) individual plants, representing at least one CPP focal species, are selected by NPS staff for repeated monitoring. Most of the criteria used for site-selection also apply to the selection of individual plants (e.g., accessibility). Because replicated monitoring allows measurement of population-level parameters (such as the mean and variance of the dates of phenological events or the proportion of individuals exhibiting a particular phenophase), and also has practical benefits (described above), ideally 3-5 individuals of each focal species are tagged at each site.

Ideally, individuals selected for monitoring should be robust and healthy, occurring in an undeveloped or “natural” setting (i.e., not-irrigated, distant from infrastructure, etc.); however, individuals that do not meet these guidelines need not be necessarily excluded from the study. Explanatory data collected at the level of individual plants would allow the CPP to account for variables that may influence plant phenology (e.g., plant size, the presence of supplemental water, the age of monitored individuals, the distance to infrastructure, the presence of pests and disease, etc.). Collecting this potentially explanatory information might allow the CPP to ask questions related to how local environmental settings and/or individual plant traits affect phenology (e.g., is the length of the flowering season of irrigated individuals of species X statistically different than non-irrigated individuals? does total fruit production vary with the age of the individual plant?).

VI. Marking plants

Individual plants selected for monitoring are marked by NPS staff with unique identifiers; acceptable marking procedures may vary by park and should be defined prior to setting up new monitoring locations or sites. CPP plants are identified by two tags. The first tag includes a 4-part code, which identifies the individual plant as part of the CPP network, and then identifies the park, monitoring location, site, species (and individual number). For example, the code for the *first* individual of *Aesculus californica* (AECA1) to be tagged and monitored at the *first* site at the Foothills Visitor Center in Sequoia and Kings Canyon National Parks (SEKI) would be: **CPP - SEKI - FHVC1 - AECA1.** The *second* individual plant of this species to be tagged at the same site would be identified as: **CPP - SEKI - FHVC1 – AECA2**. The *first* plant to be tagged at the *second* site at FHVC would be identified as: **CPP - SEKI – FHVC2 - AECA1.** A second tag includes a unique number identifier (e.g., **450**); this number must be unique to the individual plant at a given park. When the targeted plants are registered in *Nature’s Notebook* (described below), both identifiers should be used in the plant nickname (e.g., “ERFA1 (479)”).

Figure 1. Metal tags used to mark CPP targeted individuals at SEKI. The long metal tag includes the four-part CPP code (CPP-SEKI-FHVC2-AECA1). The round metal tag includes the unique ID number for this individual.

VII. Parameters to record when establishing a site

For each site and/or for each plant tagged at a site, the following parameters should be recorded during site set-up (using the datasheet templates provided below) and should be updated annually, or if conditions change (e.g., plant removal or death).

- *park* — recorded as a four letter code (e.g., SEKI for Sequoia and Kings Canyon National Parks)
- *location(or trail) code* — also recorded as four letter code (e.g., FHVC for Foothills Visitor Center)
- *site* — if there is more than one site at the monitoring location, sites should be identified by a unique number after the location code (e.g., FHVC1)
- *elevation* — can be recorded in the field or extracted from a GIS layer or topographic map
- *species code* — recorded as a four letter code (e.g., AECA for *Aesculus californica*)
- *individual* — if more than one individual representing a focal species is selected for monitoring at a given site, each individual should be identified with a unique code that follows the species code (e.g., AECA1, AECA2, AECA3, etc.). At each site within a location, the numbering of the individuals may begin at 1.
- *unique plant identifier* — a unique number associated with each plant; these numbers do not need to conform to any order (e.g., increasing with elevation), but they do need to be unique within each park (e.g., two plants at SEKI should not have the unique identifier 450)
- *GPS coordinates* for each tagged plant individual — record coordinates either in decimal degrees or UTMs, referenced to NAD83; geo-coordinates will be used to register monitoring sites in *Nature's Notebook* and to create maps and other visual tools for each monitoring site. *Nature's Notebook* uses a Google maps interface (referenced to WGS84) for mapping monitoring sites; note that some parks may use a different datum standard and, therefore, the reference datum for all coordinates should be recorded. (Note: if the GPS-enabled device used to record coordinates provides an error estimate, this should be recorded as well.)
- *notes regarding plant location relative to landmarks*
- *photo number* — photo number recorded from a digital camera

- *site notes* — may include a description of the trail, notes regarding the sensitivity of the substrate, presence of social trails, alerts to observers about how to locate plants, etc.
- *site map* — it is helpful to sketch the location of individual plants at each site, noting their positions relative to each other, to the trail, and to other notable landmarks (e.g., boulders, signs, cairns, other easily identified taxa, trail intersections, etc.). This sketch might also include site-level information (e.g., aspect) and can often be used to ground truth the geo-coordinates recorded above (Figure 2).

Nature's Notebook allows users to input additional (optional) site and plant-level metadata. Site-level variables include degree of development, distance to road, distance to water, and including shade-status (site-level record) and physiognomy. Plant-level variables include shade status, origin (planted vs. naturally occurring) and gender (for dioecious taxa).

When registering CPP plants in *Nature's Notebook*, the unique plant identifier should be entered as the plant "nickname". The geo-coordinates recorded for each plant should be entered in the comments section for the individual plant (*Nature's Notebook* does not require geo-coordinates for individual plants; instead, geo-coordinates are a site-level variable).

Table 1. Example spreadsheet with a column representing each piece of information to be recorded in the field when establishing a monitoring site. This spreadsheet can be formatted to create a printed field-ready datasheet.

Park (4 letter code)	Location (4 letter code)	Site #	Elevation (ft)	Species Code (4 letter)	Individual #	Unique Plant ID	UTM Zone	Northing	Easting	Photo #	Site or Plant Notes (e.g., plant position relative to trail or other plants, trail description, etc.)
SEKI	FHVC	1	1700	AECA	1	457	11	4040000	336546	11	Plant is adjacent to webcam, behind SNHA building

Site code:
Date:
Photo identifier(s):
Notes:
Aspect:

Figure 2. Example field datasheet templates, with a blank space for sketching maps during site establishment

VIII. Development of maps and other visual tools

Maps and other visual tools can help CPP observers locate monitoring sites and targeted plants; these tools should be made available to CPP observers, either in hard copy or on the CPP and park websites. Three types of visual tools have been created and used successfully by CPP parks: GIS maps; online, interactive maps (e.g., Google maps); and annotated, photographic guides. Each of these tools is described below:

1. GIS-based maps can easily be created using the geo-coordinates that were recorded for each targeted plant during site set-up (see description above). Maps should clearly label both site and plant unique identifiers (described above in the *marking plants* section). This may require producing a set of maps, each at a different spatial resolution; small-scale maps may highlight the location of individual monitoring sites, both in relation to each other and in relation to landmarks (e.g., trails, signposts, boulders, fallen trees, parking areas, visitor centers), whereas large-scale maps may highlight the location of targeted plants in relation to other plants at the monitoring site and in relation to local landmarks. See park-specific monitoring guides (Appendices A to G) for example maps.

2. Online, interactive maps can also be created using the targeted plants' geo-coordinates. Google offers a web-based map application, called Google Maps, which can be used to create publically-accessible online maps (http://maps.google.com). Visit the Google Maps help pages for information about creating maps (http://support.google.com/maps/) and the park pages on the CPP website for links to example online maps (e.g., https://www.usanpn.org/cpp/SEKI/maps).

3. Photographic guides can be created with a digital camera and any software that allows the user to annotate photos with text and symbols (e.g., Adobe Photoshop, Microsoft Powerpoint). These visual guides can display the same information to the user that a traditional map would (e.g., sites and plant identifiers, scale information, etc.). See park-specific monitoring guides in Appendices A to G for example visual guides.

IX. Register sites online at *Nature's Notebook*

All CPP sites must be registered in the USA National Phenology Network's online program, *Nature's Notebook* (www.nn.usanpn.org). Site name(s) and geo-coordinates (latitude and longitude in decimal degrees and referenced to WGS84) are needed for registration. As described above, *Nature's Notebook* also allows the user to supply additional information about the site (e.g., degree of development, distance to roads, and distance to permanent water) and the plant (e.g., shade status). When registering CPP plants in *Nature's Notebook*, the unique plant identifier should be entered as the plant "nickname," and geo-coordinates recorded for each plant should be entered in the "comments" section for the individual plant.

Most CPP monitoring sites are "shared sites" for which multiple observers submit data. A shared site is different from a "public site" (a site or location for which anyone can submit observations). Shared sites are administered by the project coordinator (with support from USA-

NPN NCO staff) and are accessed by a set of trained observers who have been added to the park's network.

To set up a park network comprised of shared sites, the park coordinator must contact USA-NPN by emailing nco@usanpn.org with the name of the network (e.g., SEKI) and a list of registered *Nature's Notebook* users who should be added to the network. Once the network is established, the park coordinator can add shared sites and monitored plants; all of these sites and the plants tagged within them are accessible to all members of the network, who can submit their observations online.

New CPP participants can join park networks in *Nature's Notebook* by choosing "Edit" from their account homepage and then selecting the appropriate network from the list of partner organizations. To do this, first choose "California Phenology Project" as the Partner Organization, and then choose the appropriate park from the drop down menu on the right. The new group member will have access to the network within 24 hours. More detailed information about registering for *Nature's Notebook* and entering data can be found in SOP7, Data Entry and Data Management.

There are many resources available on the USA-NPN website to guide *Nature's Notebook* users through setting up sites and entering data online:

- a 1-page guide is available here: http://www.usanpn.org/files/shared/files/NN-Steps_to_observe-1-pager.pdf
- a summary how to set-up a user account and monitoring sites in *Nature's Notebook* can be found here: https://www.usanpn.org/nn/guidelines
- a training video describing USA-NPN recommendations for site selection can be found here: http://www.usanpn.org/?q=node/2246#site

SOP4: Field Season Preparation and Equipment and Materials Needed

Version 1.0

Revision History Log:

Version #	Revision Date	Author	Changes Made	Reason for Change
1.00	June 2013	Matthews		

Overview

CPP observers record plant phenology in the field throughout the phenologically active growing season. Because the beginning of the growing season varies across California, the timing of pre-field season preparations will vary depending on the prevailing local climate. In desert and Mediterranean ecosystems, for example, pre-field season preparations should occur at the start of the winter rainy season, whereas in mountain ecosystems, pre-field season actions should occur in early spring, prior to plant growth.

Prior to the field season, the *CPP project coordinator* at each park will review the list of recommended equipment and materials and the list of monitoring sites, focal species, and individual plants. Equipment and monitoring materials should be updated and new monitoring sites and targeted plants should be established prior to the field season. Previously established monitoring sites should be visited to ensure that plant tags are in good condition and that maps and other monitoring materials are up to date. The project coordinator should also check with the USA-NPN for monitoring protocol updates, including changes in the targeted phenophases, the format of the datasheets, and new mechanisms for uploading data (e.g., batch-loading options vs. use of the *Nature's Notebook* interface).

I. Equipment and supplies

The equipment and supplies listed below are necessary for establishing and maintaining phenological monitoring sites and for recording phenological observations in accordance with the monitoring protocols of the USA National Phenology Network (USA-NPN).

- *camera* — used to photograph newly established monitoring sites or update existing site photos; observers may also capture images of plant phenophases missing from CPP species profile
- *plant tags* (or other marking materials)-- for marking new plants or replacing damaged or missing tags
- *CPP species profiles and park monitoring guides* — these printed materials are available on-line and provide detailed information about the targeted taxa, the phenophases to be observed for each taxon, and monitoring sites at each participating park; these should be updated and made available to volunteer observers and to park staff prior to each field season (these materials may be available for download on the CPP website)
- *maps of trails and plants* — available for download on the CPP website (see SOP3, Selecting and Establishing Monitoring Sites, for detailed information about developing

these tools)

- *Nature's Notebook datasheets and phenophase descriptions* — available for download on the *Nature's Notebook* website and CPP website (observers may wish to print datasheets on write-in-the-rain paper in wet regions)
- *GPS units* — used to record geo-coordinates of monitoring sites and tagged plants, as described in SOP3, and for locating tagged plants, as described in SOP6, Phenology Site and Trail Monitoring
- *first aid kit* — and appropriate equipment to ensure field safety, including hat, field clothing and shoes, extra water, etc. (see SOP10, Safety, for additional field safety guidelines)
- *clipboards*
- *optional equipment* — *binoculars* for observing phenophases on large trees; *hand lens* for detailed observation of plant phenophases; *three-ring binders* to organize datasheets and to facilitate recording observations in the field; *tablet or smartphone,* with the USA-NPN *Nature's Notebook* App installed (http://www.usanpn.org/nn/mobile-apps)

II. Creating and updating equipment and supplies

Prior to the field season each year, all equipment and supplies should be checked for proper functioning and should be updated, as needed. The project coordinator at each park should communicate with the USA-NPN National Coordinating Office and check the *Nature's Notebook* website (www.nn.usanpn.org) and for any updates to the monitoring protocols (e,g., revised phenophase definitions) and to the online site-registration, plant-registration and data-entry. Monitoring tools and training materials (e.g., CPP species profiles) should be updated annually.

Before the phenologically active season, park staff should review designated monitoring sites and targeted plants to ensure that they still meet selection criteria as described in SOP4 and that a sufficient number of sites and individual plants of each species are have been selected, depending on the scientific, educational, or management goals of the park's phenological monitoring program. Site and plant tags should be updated or replaced, as needed.

All CPP participants should review the FAQ section on the *Nature's Notebook* website (where a description of any updates for the year are posted in January or February) to ensure that they are familiar with revisions to the monitoring protocols. CPP observers should download the most recent *Nature's Notebook* datasheets and CPP species profiles for each focal species, and all observers should attend a training event to review: monitoring protocols; participating park's monitoring sites, focal species, and targeted plants; and monitoring tools (e.g., CPP species profiles and Park Monitoring Guides). Pre-season training events should include hands-on practice monitoring focal species to calibrate observations among observers. See SOP5, Recruiting and Training Phenology Observers, for more information about training procedures for staff and volunteers.

III. Research permits and compliance

Parks should consult their compliance specialist to determine what compliance steps are required, since requirements are likely to vary from park to park. For example, there may be a categorical exclusion for park sponsored research which does not involve destructive sampling or there may be park-specific restrictions on the placement of permanent or semi-permanent monuments such as rebar, highly visible plant tags, or any kind of signage. The compliance burden can often be reduced by monitoring in areas that are already visited or impacted (e.g., along trails or near visitor centers), by avoiding sampling in wilderness areas, and by avoiding marking plants in a way that would cause environmental impacts. The impacts of phenological monitoring can be minimized by locating plants near trails (to avoid the creation of social trails), limiting the installation of markers in the ground (so that there is no ground disturbance), and avoiding rare or endangered plants or communities. Reduced impacts will simplify the compliance process, likely resulting in a simple categorical exclusion and exemption from permit requirements. Should selected species and sites fall within wilderness, a minimum tool analysis is necessary to determine acceptable methods for tagging individual plants. To date, parks have used low profile, inconspicuous tags which do not attract the attention of visitors.

If sampling is conducted under the purview of an NPS biologist, research and collecting permits may be unnecessary. Alternatively, if an outside entity is requesting to conduct phenology monitoring in a NPS unit, they may be required to apply for a Research and Collections Permit. Park staff responsible for reviewing and issuing permits should be consulted if a non-NPS entity inquires about the possibility of implementing a monitoring program.

Unless a park's direct goal is to study the phenology of state or federally protected species, the placement of monitoring sites should not impact Threatened or Endangered species (T&E species). If monitoring T&E species is a purpose of the monitoring, the park is required to consult with U.S. Fish and Wildlife Service and/or the state agency responsible the enforcement of laws pertaining to state protected species (California Department of Fish and Wildlife).

The project coordinator should work closely with the park's natural resources management staff and National Environmental Policy Act (NEPA) compliance coordinator to follow proper NPS procedures for evaluating and documenting potential impacts to park resources. The project may need to be entered into Planning, Environmental, and Public Comment (PEPC) system to document this compliance.

If sampling includes state park or other open space areas, those agencies will have their own compliance and permit policies that will need to be investigated.

SOP5: Recruiting and Training Phenology Observers

Version 1.0

Revision History Log:

Version #	Revision Date	Author	Changes Made	Reason for Change
1.0	June 2013	Matthews		

Overview

For parks that rely on volunteer observers (i.e. non-NPS staff) for much of the data collection effort, building and retaining a volunteer observer network is vital to the success of monitoring efforts. Building a large, diverse, and committed network requires time and energy on the front end, but it can result in a dedicated and knowledgeable network of "local experts" who can provide training and guidance to new recruits and who, collectively, can collect more frequent phenological observations at a larger spatial extent than would be possible by relying solely on NPS employees. This SOP provides specific strategies for recruiting and training phenology observers.

I. Personnel and training preparation

1.1 Building and retaining a volunteer network

Before recruiting volunteers, parks should be completely ready to train volunteers and engage them in the monitoring effort; species-selection, training materials, and site installation should be complete before volunteer recruitment is initiated. Additionally, parks should consider the following questions:

1. What motivates volunteers to give their time and energy to a project?
2. What motivates them to maintain their participation in a volunteer project over the long-term?
3. How can the park provide support and encouragement to their volunteer observers?

Staff familiar with the local community and volunteer base can inform efforts to recruit and retain volunteers, based on local experiences of which approaches work and which do not. Initially, volunteers may be motivated by the desire to learn something new (e.g., skills or subject knowledge), to contribute to a cause (e.g., stewardship of their local public lands or to promote the understanding of the effects of climate change on their native flora), or for social interaction (e.g., to meet like-minded people and to develop new friendships), whereas continued participation may be motivated by appreciation, recognition, positive feedback, gaining scientific knowledge, the gratification of participating in a nationwide project, and tangible rewards (e.g., botanical hikes, volunteer t-shirts, parking passes, nametags).

In recruiting volunteer participants, consider both new partners and organizations that have an ongoing relationship with the park unit. NPS staff may start by identifying local organizations that might be potential partners or from which volunteers may be recruited (e.g., schools, land trusts, local and regional parks, environmental education programs, conservation organizations, botanical gardens, natural history museums) and reach out to those organizations, inviting representatives of these institutions to attend CPP training workshops, public lectures, or field events.

During the pilot phase, many CPP pilot parks were successful in recruiting and engaging organizations that had ongoing relationships with the parks, 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 each of these park units (as well as other NPS units in California and beyond). NatureBridge was invited to CPP workshops at the pilot parks and subsequently implemented monitoring programs with student groups at designated monitoring sites on their campuses. Other pilot parks successfully recruited volunteers from conservation and restoration groups (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). Parks and local institutions (such as museums or botanic gardens) might provide reciprocal efforts to promote and to advertise volunteer opportunities, such that park volunteers would be encouraged to participate in garden-based activities and vice versa.

1.2 Advertisement

CPP training events and ongoing monitoring efforts should be advertised weeks to months ahead of time to maximize participation. Parks may use existing media (e.g., park newspapers, social media, visitor center brochures) to publicize the CPP effort. Promotional flyers for training opportunities work well, especially when distributed broadly (*and more than once*) to mailing lists; flyers must include important logistical information, such as the date, time, and location of training events, as well as basic information about the project and what will be covered in the training event (see sample flyers at the end of this SOP). It is also helpful if promotional flyers include contact information for the project coordinator, as well as the URLs of the CPP, USA-NPN, and *Nature's Notebook* websites. Press releases in local newspapers, especially prior to training events or workshops, have been successful in recruiting local community members to CPP events. By advertising on regional and statewide email lists and bulletin boards, parks can also attract participants from outside of the immediate area. Although this may not contribute to recruitment of local volunteers, these participants may then wish to get involved with a park or program nearer to home.

1.3 Cultivating project buy-in and investment

The CPP volunteer coordinator at each park will be responsible for cultivating broad support for the project, both by partner institutions and by park staff in all divisions. Before each field season, the project coordinator and volunteer coordinator will work together to target partner organizations and institutions and to invite their participation in logistical planning for the upcoming phenologically active season; by providing opportunities to participate in planning and by encouraging feedback throughout the growing season, parks can foster institutional partners whose staff and volunteers may become active members of the local CPP observer network.

The project coordinator will periodically update staff in other NPS divisions about the CPP activities at their park and promote opportunities for co-workers to get involved in the project. As the program progresses, additional park staff may become interested in participating in on-going activities.

1.4 Coordinating data collection

Because the CPP model often requires that many individuals and groups observe plants at shared monitoring sites, coordination of data collection efforts is needed to ensure sufficient monitoring frequency. Some pilot CPP parks have successfully used publicly available online or physical calendars to organize observer schedules (e.g., Golden Gate National Recreation Area and Redwood National Park observers enter their observation times on a shared Google calendar). Other pilot parks have "assigned" monitoring sites to participants (e.g., the monitoring sites in the Headlands area of Golden Gate NRA are monitored by NatureBridge instructors and students at the nearby campus).

1.5 Safety

Before the field season, parks should schedule a brief safety training and discussion with their participants, as described in SOP6. If new participants join the observer network mid-season, additional safety training and discussion opportunities will be scheduled to prepare them for the field monitoring work. Safety trainings cover all the potential safety hazards, the importance of field preparedness, means of communication, emergency contacts, etc.

1.6 Volunteer agreement forms

Volunteers who participate in the program must be registered as Volunteers in Parks (VIP). Before starting work, all VIPs must sign a "Volunteer Services Agreement for Natural Resources" form (OMB 0596-0080). This provides a legal documentation of the volunteer's services and rights, and terms of the work being conducted. Consult with the park's volunteer program coordinator for more information and guidance through the proper volunteer agreement process.

II. Training workshops

Parks will schedule training opportunities for the CPP observer network prior to each field season. Note that the organization of training events does not necessarily require that the volunteer coordinator lead and present workshops. Instead, there may be a volunteer, a seasonal employee, or a permanent staff member at the park who is familiar with the USA-NPN protocols and who may be available to provide the training workshop at his/her park or at nearby parks (see the park-specific monitoring guides for a list of contacts at each pilot park). In addition, the volunteer coordinators may distribute a message on the CPP listserv (see instructions for email the listserv at https://www.usanpn.org/cpp/news/listserv) and invite current CPP participants who live near the park to participate in a training workshop to help teach new volunteers how to record and to upload their phenological observations to *Nature's Notebook*. There are abundant training materials on the CPP and *Nature's Notebook* websites, including tutorials to guide species selection, site selection, identifying phenophases, recording phenological data, and uploading data into *Nature's Notebook*.

The goal of training opportunities is to give new participants and experienced observers the tools they need to record phenological data successfully and with confidence. Although the subject matter may be divided among multiple training events, each CPP participant should attend training events that collectively cover: the background and goals of the CPP; the ecological concepts needed to understand the goals of the CPP (e.g., phenology, climate change, etc.); the botanical terms needed to monitor plant phenology (e.g., bud, flower, fruit); the mechanics of

how to monitor, including a demonstration of the monitoring protocols and hands-on practice using the datasheets (or tablets) and protocols; and the data-entry methods and tools used by the participating park (e.g., *Nature's Notebook*).
Participating parks will develop guidelines that estimate the volunteers hours needed to fulfill monitoring goals (e.g., # of volunteer hours required each week/month/season in order to monitor all targeted plants twice weekly); these guidelines will be updated annually to reflect changes in the number of active monitoring sites and targeted plants. The guidelines will estimate the number of hours expected of each CPP observer and these will be covered during the pre-season training events.

Training events will be scheduled periodically throughout the field season so that CPP participants have the opportunity to interact with others in the observer network, to discuss questions relevant to their region (e.g., phenophases of focal taxa), and to develop solutions and monitoring tools to support monitoring efforts in their ecoregion. Recurring training events also give experienced observers the opportunity to: (1) exercise the knowledge and skills they have developed by helping to lead some of the training activities, (2) calibrate observations among participants and make sure observers are monitoring plants correctly, (3) develop new skills in teaching others, (4) build leadership skills and self-confidence, and (5) help shape the growth and development of the CPP at their park.

In planning for training opportunities, workshop leaders will need to consider the targeted audience and may need to emphasize different skill sets for specific participant groups. Before training events, trainers should survey participants and ask them to identify the skill sets for which they feel confident and those for which they would like additional instruction. For example, some participants may require additional training to feel comfortable using the online interface, *Nature's Notebook*, for data entry, whereas other participants may need additional training to develop the observational skills needed to feel confident in recording their phenological observations on datasheets. Again, experienced observers might facilitate training new observers; for example, it may be helpful to pair an experienced computer-literate observer with a computer-resistant participant so that the former can assist the latter (or take on the responsibility of data entry for observers who cannot manage this final step). It is also possible that some volunteers will wish to avoid certain components of the monitoring process (such as online data entry), and it is completely valid for the project coordinator to delegate particular activities to volunteers who are particularly comfortable with them.

CPP training events and workshops range in length from 90 minute introductory lectures to multi-day training workshops; the goals of each training opportunity should determine the length and content covered. Many training materials are available on the CPP (http://www.usanpn.org/cpp/resources and http://www.usanpn.org/cpp/resources/presentations) and *Nature's Notebook* website (https://www.usanpn.org/nn/guidelines). The CPP encourages park staff and other CPP trainers (e.g., volunteer observers, school teachers, and partner organizations) to adjust and edit CPP training materials as needed.

Based on the experience of CPP trainers during the pilot phase, the *minimum* time required to successfully introduce the following training content is:

- 60 minutes — introduce phenology, climate change, phenological case studies, including the potential for phenological mismatches to disrupt ecological relationships
- 30 minutes — introduce CPP and USA-NPN
- 90 minutes — demonstrate USA-NPN phenological monitoring protocols and hands-on practice using the protocols
- 60 minutes — introduce *Nature's Notebook* and demonstrate key steps to setting up a *Nature's Notebook* account (i.e., registering a site, adding plants, entering data)

These guidelines include time for discussion and questions that are likely to arise among the workshop participants; when these questions are encouraged by workshop leaders, participants generally become more engaged.

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*](http://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: • The link between climate change and phenology • Introduction to the California Phenology Project (CPP) and the USA National Phenology Network (USA-NPN) • Move outside: hands-on practice monitoring plant phenology! • 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 • Logistics of implementing phenological monitoring at natural areas (e.g., learn how to establish monitoring sites, label plants, and record important field information) • How to get involved in the CPP, as an educator, scientist, student, or natural area representative • 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*).*

Figure 1. Sample promotional flyer advertising a California Phenology Project training event at Lassen Volcanic National Park (June 2012).

SOP6: Safety Procedures

Version 1.0

Revision History Log:

Version #	Revision Date	Author	Changes Made	Reason for Change
1.00	June 2013	Matthews		

Overview

This SOP details the safety procedures and issues that are applicable for most parks participating in the CPP. These procedures should be reviewed and understood by all CPP participants, including park staff and volunteers. All participants should have access to a cell phone or radio and know how to report an accident. This safety SOP does not cover first aid, but we encourage CPP participants to take advantage of first aid training opportunities offered by their local park. Volunteers should also be trained in risk avoidance by familiarizing them with common threats (e.g., bees, poison oak, trips and falls, and rattle snakes).

I. Field safety preparation and training

The first step to ensuring safety is to plan ahead and be prepared. This includes: knowing the weather forecast and preparing for or avoiding inclement weather; identifying the skills and abilities of all participants and providing appropriate supervision and guidance for all skill levels; ensuring that all participants have access to appropriate field clothing, equipment, and supplies (e.g., long pants, rain jacket, hat, sunscreen, extra food and water); providing access to first aid kits and training and encouraging everyone carry first aid equipment; and ensuring that participants know how to communicate with their supervisors and emergency response networks. The ***project coordinator*** at each participating park is responsible for ensuring that all staff and volunteers participating in CPP monitoring activities have up-to-date emergency contact information, directions to medical facilities, and other park-specific safety information.

Volunteers who participate in the program must be registered as Volunteers in Parks (VIP). This starts with consulting with the park's volunteer coordinator. Before starting work, all VIPs must sign a "Volunteer Services Agreement for Natural Resources" form (OMB 0596-0080). This provides a legal documentation of the volunteer's services and rights, and terms of the work being conducted.

A Job Hazard Analysis (JHA) is a valuable tool for preventing and mitigating safety hazards. When conducting a JHA the following should be identified:

1. All potential hazards involved in collecting phenology data at each monitoring site during normal and inclement weather conditions;
2. Safety precautions to help eliminate or reduce hazards;
3. Safety materials and resources (first aid kits, radios, local emergency contacts and procedures, etc) that should be provided to observers.

Upon completion, the JHA can serve as a foundational document for developing safety training and procedures.

II. Field safety

2.1 Slips, trips, and falls

Uneven or steep terrain, unstable soils, wet and slippery substrates, dense vegetation, and fatigue are all hazards that could result in a fall. To prevent injuries from falls, observers should wear appropriate footwear (e.g., close-toed shoes or boots), pay attention to the work site and remain alert to hazards, and when navigating to monitoring sites (particularly those off trail), choose the safest route (which is not necessarily the shortest route). Observers should use caution walking on or around loose or wet surfaces. In the mountain parks, ice and snow can also pose a hazard when accessing sites for early and late season monitoring events.

Observers should not walk from site to site carrying a clipboard and other materials. Tripping with both hands full is a common source of injuries and can turn a simple fall into a more serious injury.

2.2 Weather

Storms that produce strong winds and lightning are dangerous and should be avoided. Trail conditions may be dangerous during and after rain, especially on steep, clay soils. A safety assessment should be conducted to determine whether or not some plants should be monitored during wet conditions. Some parks experience very high temperatures in the summer. Observers working under these conditions should be familiar with the symptoms and treatment for heat exhaustion. Steps should be taken to prevent heat exhaustion such as wearing a hat, cooling off in the shade when needed, and drinking plenty of water. If feasible, monitors should avoid collecting data during peak heat of the day. Check the weather forecast and avoid field work on days where inclement weather is expected.

2.3 Poor air quality

Poor air quality is an issue at some of California's National Parks. Observers should limit activity outside on days when air quality indices reach "unhealthy" levels by state and federal standards. Check the air quality index forecasts for the area and adjust activity accordingly.

2.4 Plants and animals

Poison oak (*Toxicodendron* spp.) is present and often abundant in California's National Parks. All CPP participants should learn to recognize poison oak and should take care to avoid contact with any part of the plant. Wearing long sleeves and pants (and wearing boots) can help reduce contact. After monitoring in an area with abundant poison oak, observers should thoroughly wash exposed skin as soon as possible. Observers may also carry Tecnu, a product that facilitates the removal of poison oak oils from exposed skin.

Other hazards include encounters with venomous snakes, mountain lions, bears, elk, mosquitos, bees/wasps/yellowjackets, and ticks. Observers should always be alert and avoid contact with animal hazards. All observers should review park-specific job hazards and understand the appropriate responses to each hazard. Chaps or gators, treated with insect repellent, will help reduce risk from snakes and ticks.

While ensuring the safety of observers is the highest priority, observers should also be aware that they are responsible for maintaining the safety of the plants and animals that they may encounter. For example, they may be reminded to avoid damaging plants that grow in the understory or near the edge of the plants targeted for monitoring, and they should be instructed to give a wide berth to any rare or endangered plants that occupy soils that may be disturbed while monitoring.

2.5 Vehicle safety

Drive within the posted speed limit and stay alert for park visitors who may be viewing wildlife, looking for park features, and generally being disoriented or unfamiliar with their location. Never leave valuables in a car parked at a trailhead.

III. Reporting participant locations

Park staff should be aware of participants' scheduled (or spontaneous) visits to CPP locations and sites for monitoring. Parks may consider implementing a call-in or online sign-in and sign-out procedure so that observers' presence in the park will be known, with the understanding that search-and-rescue measures will be initiated if participants have not called in to report their completion of a scheduled monitoring visit.

IV. Responding to an incident

In the event of a life threatening medical emergency, call **9-1-1** (or other park emergency numbers) and administer first aid to the best of your knowledge, ability, and training. Contact the CPP project coordinator as soon as it is appropriate to do so.

In all other cases, contact the CPP project coordinator as soon as it is appropriate to do so and make sure to follow all park-specific incidence reporting procedures. Each park has a standard communications procedure for emergency situations. This park-specific procedure should be incorporated into the CPP observer training.

V. Reporting accidents and near-misses

All CPP participants should review park-specific accident reporting protocols prior to monitoring. All accidents involving staff and official volunteers must be reported to the phenology project coordinator and the park's safety officer and management; accidents should be documented in the NPS's Safety Information Management System. The project coordinator will follow park specific procedures, which includes reporting injuries to the superintendent within 72 hours. Volunteers should work closely with the project coordinator to ensure they are properly signed up as a park volunteer and working on approved tasks, this will ensure that accident will be covered by the benefiting park's Workers Compensation program. Near-misses should be reported to the project coordinator and the immediate supervisor of the volunteer or staff member. Assessments of all accidents and near-misses should be conducted to determine how to prevent future accidents.

SOP7: Phenology Site Monitoring

Version 1.0

Revision History Log:

Version #	Revision Date	Author	Changes Made	Reason for Change
1.00	June 2013	Matthews and Mazer		

Overview

CPP observers record plant phenology at designated sites using the USA National Phenological Network (USA-NPN) protocols, described below. Repeated, frequent observations are recorded by trained observers, whether volunteers or staff, and are submitted to the USA-NPN National Phenology Database through the online program, *Nature's Notebook.*

I. Datasheets

Most CPP observers will use *Nature's Notebook* datasheets to record their phenological observations. These datasheets, along with the phenophase definitions page, are available for download on the CPP and *Nature's Notebook* websites. On the CPP website, visit the webpage for the species of interest to download the appropriate datasheet; species-specific webpages may be found by clicking on a species name at: http://www.usanpn.org/cpp/CPPcandidatespecies. Each species-specific datasheet includes the targeted phenophases observed, according to the species' growth form (e.g. deciduous shrubs and trees, forbs, etc). On the *Nature's Notebook* website, datasheets can be downloaded from the appropriate species' profile page or directly from your *Nature's Notebook* Observation Deck.

Note: the Paperwork Reduction Act (PRA) regulates data collection by the public for federal agencies (PRA is intended to reduce the amount of paperwork that agencies request of the public). To comply with the PRA, Office of Management and Budget (OMB) must approve data collection and this approval must be renewed every three years. In January 2013, OMB granted the USA-NPN a three year authorization for phenology data collection by the public using *Nature's Notebook* (OMB Control #: 1028-0103). The Privacy Act governs the collection, maintenance, disclosure of information from or about identifiable individuals that is maintained in systems of records by federal agencies. This Act prevents the disclosure of such personal information without written consent of the subject individual. In order to comply with the Privacy Act, data archived in the NPDb does not include personal information.

Before monitoring plants at a designated CPP monitoring site, observers print a copy of the appropriate datasheet and phenophase definition sheet for each targeted plant at the selected site. The datasheet will include a list of the phenophases monitored for the target species. For each phenophase, observers record one of three options: ***"Yes"***, if the phenophase is occurring, ***"No"***, if the phenophase is not occurring, and ***"?"***, if the observer is uncertain whether the phenophase is occurring. Two types of datasheets can be downloaded from *Nature's Notebook.* The first is a species by species datasheet in which each column on the datasheet corresponds to a single observation date. Given that there are many columns on each *Nature's Notebook* datasheet, the same datasheet is intended to be used for multiple observations of the same individual, each recorded on a different date. These datasheets have the advantage that they provide a record of all recently recorded data concerning the phenological status of a given individual plant. When using these datasheets in the field, observers may anticipate upcoming phenophases based on the recently recorded observations of the individual. Observers should be careful to protect species-by-species datasheets until the data are uploaded in *Nature's Notebook*; if datasheets are lost or destroyed (e.g., by rain) before the data are entered online, repeated observations recorded on the datasheets will be lost as well. The second type of datasheet that can be downloaded from *Nature's Notebook* is a day by day datasheet that includes multiple individuals and/or species for a single day.

Observers may also record abundance for phenophases that are occurring (i.e., for phenophases that were recorded as ***"Y" or "?"*** on the datasheet). For example, rather than simply collecting data on the presence of open flowers on a given plant, observers may record both the total number of flowers and the proportion of flowers that are open. The abundance or intensity of each phenophase is estimated and recorded in bins that correspond to distinct ranges of abundance or percentages. For example, for intensity of the "flowers or flower buds" phenophase, the observer records the number of flowers on the plant as: *Less than 3; 3 to 10; 11 to 100; 101 to 1,000; 1,001 to 10,000;* or *More than 10,000.* For the intensity of the "open flowers" phenophase, the observer estimates the percentage of all flowers that are open as: *Less than 5%; 5-24%; 25-49%; 50-74%; 75-94%;* or *95% or more*. Detailed descriptions and instructions for estimating phenophase abundance and intensity are provided on each species' datasheet.

The *Nature's Notebook* datasheets also provide space to record notes in a "comments" section at the bottom of each datasheet. Observers should report any unusual observations or events that might affect the plant's phenology in the comments section of the datasheet (e.g., an insect or microbial infestation on the plant, resulting in loss of leaf cover or photosynthetically active tissue; or the plant is fully or partially covered by snow, hampering accurate observation). Additionally, if an observer misses the occurrence of a phenophase entirely, and sees evidence that the phenophase did occur, this can be noted in the comments section; for example, if a plant flowers in between two observation events and the observers sees dried flowers on the ground below the plant, they can note this in the comments section of the data entry form. Similarly, observers may note that seed-filled fruits have been retained on the plant from the previous season or year.

Some parks have created alternative datasheets that list all of the targeted plants at a site (or at many sites) on a single datasheet, with the appropriate phenophases included as column headers. See example customized datasheets from Joshua Tree NP (Table 1) and Santa Monica Mountains NRA (Table 2) below. In contrast to the *Nature's Notebook* species by species datasheets (which include many columns, each representing a different monitoring date), these alternative datasheets allow observers to record on a single datasheet the phenological status of many plants observed on a given day at a given site or sites. While the species by species *Nature's Notebook* datasheets are preferred by some users (e.g., because they provide the recent phenological status of a given plant), they require that observers carry a datasheet for each plant. The customized datasheets, by contrast, allow observers to record data for multiple plants on a single sheet and require fewer datasheets be brought into the field. These may be preferred to the *Nature's Notebook* day by day datasheets when collecting data on a large number of plants, because the *Nature's Notebook* datasheets are limited in the number of individuals displayed on a single datasheet.

Finally, some parks and partners may choose to collect data using a handheld device (e.g. tablet) or phone that has the *Nature's Notebook* mobile application installed. The USA-NPN is currently developing applications that are capable of functioning offline, which will allow remote parks without consistent cell phone or wireless reception to collect data electronically, thereby reducing the time spent entering data. As of June 2013, offline data collection is supported by the Android application, but not the IPhone application.

II. Finding sites and plants

The CPP has developed a suite of tools to assist observers in locating monitoring sites and individual plants; these include static maps, interactive web-based maps, annotated photographic guides, and tables of geo-coordinates, most of which are available for download on the CPP website and are available as hard copies from the project coordinator. The creation of these visual tools is described in detail in the SOP4.

To facilitate locating sites and plants in the field, visual tools (e.g., maps and photographic guides) should be printed as a hard copy (or moved onto a digital device, such as a tablet, that can be used in the field). CPP site maps are often produced at several spatial scales in order to emphasize specific features of the CPP monitoring infrastructure. For example, most monitoring locations at CPP participating parks have two maps associated with them — one emphasizing the location of monitoring sites in relation to each other and in relation to local landmarks (e.g., trail intersections) and another map that specifies the location of targeted plants at each monitoring site, in relation to each other and to local landmarks (e.g., trails, sign posts, trees). When new staff and volunteers are monitoring tagged plants for the first time, a hand-held GPS unit may be used to facilitate locating sites and plants in conjunction with hard copy maps. Generally after monitoring locations become familiar to data collectors, they may find that the various park-specific maps and photographic guides are sufficient on their own for locating sites and individuals for monitoring. These map resources and geo-coordinates are found in the park specific guides in Appendices A-G.

III. Frequency of visitation

Ideally, monitoring sites and plants should be observed at least twice a week during the growing season and more frequently during periods of rapid phenological change. See SOP1 for additional information regarding alternative schedules for the frequency of data collection. The identification of key phenologically active periods of the growing season, when increased sampling frequency would be most beneficial, requires at least one year of high-frequency (twice weekly) data collection from the site in question. The USA-NPN has created a data visualization tool to help observers with this task (http://www.usanpn.org/data/visualizations).

IV. Datasheet monitoring and transfer to data entry personnel

The data manager at each park (i.e., the person who is in charge of coordinating data upload) should ensure that data recorded on paper datasheets are uploaded to the National Phenology

Database (NPDb). To prevent a back-log in data entry, data should be uploaded at least four times a year (i.e., after each season). Data entry can be accomplished by the data manager or by CPP observers, each of whom can enter their own observations into *Nature's Notebook* with their personal user account (optimally, the data manager will frequently check-in with observers to ensure that their data are being uploaded). Data-uploading can be facilitated (and errors avoided) by conducting it as a two-person task, with one person reading from the datasheets and the other person key-stroking on the *Nature's Notebook* interface (repeating to the first person the data that they're entering). See SOP8, Data Entry and Data Management, for additional details about submitting observations to the NPDb.

V. Person hours required

Based on the current sampling design implemented in the pilot parks, the total person-hours required for monitoring and entering observations can range from 8 to 20+ hours per week, depending on the number of sites and individuals monitored and the time spent traveling to monitoring sites. (Note: this estimate does not include project coordination, which can range from 3 hours per week for a smaller program with well-trained observers, to 20 hours per week for a new program that is in the early stages of training participants.) To estimate the person hours required for field monitoring at a given park, see the recommendations described in SOP3 in the section titled "The amount of time available for or allocated to monitoring at a given site".

VI. Preventing and mitigating impacts from repeated visits to monitoring sites

Observers should be aware of potential sensitivity to foot traffic around the monitoring sites. Trails on soil substrates that are easily eroded due to soil composition or slope require special care when monitoring sites. Where social trails are easily formed, targeted plants must be limited to those within one meter of the main trails in order to avoid soil erosion (which might also alter hydrological properties and affect plant phenology).

Table 1. Example of a customized, alternative datasheet for one site at Joshua Tree National Park. In contrast to the *Nature's Notebook* datasheets, this example allows observers to record data for multiple individuals on a single datasheet, where the datasheet represents all observations on a given date.

Observer(s):
Date:

Plant ID	Northing	Easting	Common Name	Notes	Young Leaves? QNTY	Leaves? %	Flwr buds? QNTY	Open flwrs? %	Fruits? QNTY	Ripe Frts? %
HIVI1-CORA1	3770362	555950	Blackbrush		y n ? ___	y n ? ___	y n ? ___	y n ? ___	y n ? ___	y n ? ___
HIVI1-CORA2	3770366	555945	Blackbrush	Closer to trail than YUSC2	y n ? ___	y n ? ___	y n ? ___	y n ? ___	y n ? ___	y n ? ___
HIVI1-CORA3	3770367	555937	Blackbrush	Downslope from YUSC3	y n ? ___	y n ? ___	y n ? ___	y n ? ___	y n ? ___	y n ? ___
HIVI1-YUBR1	3770362	555950	Joshua Tree		N/A	N/A	y n ? ___	y n ? ___	y n ? ___	y n ? ___
HIVI1-YUBR2	3770366	555945	Joshua Tree		N/A	N/A	y n ? ___	y n ? ___	y n ? ___	y n ? ___
HIVI1-YUBR3	3770367	555939	Joshua Tree		N/A	N/A	y n ? ___	y n ? ___	y n ? ___	y n ? ___
HIVI2-CORA1	3770518	555742	Blackbrush	Marked in center of bush	y n ? ___	y n ? ___	y n ? ___	y n ? ___	y n ? ___	y n ? ___
HIVI2-CORA2	3770512	555752	Blackbrush		y n ? ___	y n ? ___	y n ? ___	y n ? ___	y n ? ___	y n ? ___
HIVI2-CORA3	3770520	555739	Blackbrush	Slightly closer to trail than YUSC	y n ? ___	y n ? ___	y n ? ___	y n ? ___	y n ? ___	y n ? ___
HIVI2-YUSC1	3770518	555742	Mojave Yucca	All stems should be monitored and considered as the same plant	N/A	N/A	y n ? ___	y n ? ___	y n ? ___	y n ? ___
HIVI2-YUSC2	3770512	555752	Mojave Yucca		N/A	N/A	y n ? ___	y n ? ___	y n ? ___	y n ? ___
HIVI2-YUSC3	3770520	555739	Mojave Yucca		N/A	N/A	y n ? ___	y n ? ___	y n ? ___	y n ? ___
HIVI2-ERFA1			CA Buckwheat	North of Trail	y n ? ___	y n ? ___	y n ? ___	y n ? ___	y n ? ___	y n ? ___
HIVI2-ERFA2			CA Buckwheat	West of CORA2	y n ? ___	y n ? ___	y n ? ___	y n ? ___	y n ? ___	y n ? ___
HIVI2-ERFA3			CA Buckwheat	North of Trail	y n ? ___	y n ? ___	y n ? ___	y n ? ___	y n ? ___	y n ? ___

Key Percentage Categories: Leaves, Open Flowers, Ripe Fruit	Numerical Categories: Young Leaves, Flowers, Fruits, Fruit Drop
1: <5%	1: <3
2: 5-24%	2: 3-10
3: 25-49%	3: 11-100
4: 50-74%	4: 101-1000
5: 75-94%	5: 1001-10000
6: 95+%	6: >10000

Table 2. Example of a datasheet modified and customized for a monitoring location (Sandstone Peak, SAPE) at Santa Monica Mountains National Recreation Area.

CPP-SAMO-SAPE	Plant Code		Location Description	Young Leaves <3; 3-10; 11-100, 101-1000, 1001-10,000, 10,000+	Leaves <5%, 5-24%, 25-49%, 50-74%, 75-94%, 95% +	Flowers or flower buds (includes unopened buds) <3; 3-10; 11-100, 101-1000, 1001-10,000, 10,000+	Open Flowers <5%, 5-24%, 25-49%, 50-74%, 75-94%, 95% +	Fruits (ripe and unripe) <3; 3-10; 11-100, 101-1000, 1001-10,000, 10,000+	Ripe Fruits <5%, 5-24%, 25-49%, 50-74%, 75-94%, 95% +	Recent Fruit or Seed Drop <3; 3-10; 11-100, 101-1000, 1001-10,000, 10,000+	Notes
Site 1	ERFA	1	right next to trail, on right about 20 ft up from gate	Y N ? _____	Y N ? _____	Y N ? _____	Y N ? _____	Y N ? _____	Y N ? _____	Y N ? _____	
Site 1	ADFA	1	across trail from ERFA1, right next to trail on the right (going uphill)	Y N ? _____		Y N ? _____	Y N ? _____	Y N ? _____	Y N ? _____	Y N ? _____	
Site 1	ADFA	2	~6ft off the trail, to the left just up from ADFA1	Y N ? _____		Y N ? _____	Y N ? _____	Y N ? _____	Y N ? _____	Y N ? _____	
Site 1	ERFA	2	on trail on R, 5ft up from ADFA2	Y N ? _____	Y N ? _____	Y N ? _____	Y N ? _____	Y N ? _____	Y N ? _____	Y N ? _____	
Site 1	ADFA	3		Y N ? _____		Y N ? _____	Y N ? _____	Y N ? _____	Y N ? _____	Y N ? _____	
Site 2	ADFA	1	20ft from split on L side of clearing	Y N ? _____		Y N ? _____	Y N ? _____	Y N ? _____	Y N ? _____	Y N ? _____	
Site 2	ERFA	1	5ft from ADFA1 on L side of clearing	Y N ? _____	Y N ? _____	Y N ? _____	Y N ? _____	Y N ? _____	Y N ? _____	Y N ? _____	
Site 2	ADFA	2	corner of clearing, on L	Y N ? _____		Y N ? _____	Y N ? _____	Y N ? _____	Y N ? _____	Y N ? _____	
Site 2	ERFA	2	next to ADFA2	Y N ? _____	Y N ? _____	Y N ? _____	Y N ? _____	Y N ? _____	Y N ? _____	Y N ? _____	
Site 2	ADFA	3	corner of clearing, on R	Y N ? _____		Y N ? _____	Y N ? _____	Y N ? _____	Y N ? _____	Y N ? _____	
Site 2	ERFA	3		Y N ? _____	Y N ? _____	Y N ? _____	Y N ? _____	Y N ? _____	Y N ? _____	Y N ? _____	

SOP8: Data Entry and Data Management

Version 1.0

Revision History Log:

Version #	Revision Date	Author	Changes Made	Reason for Change
1.00	June 2013	Gerst		

Overview

All CPP data are uploaded to and stored in the National Phenology Database (NPDb), which is maintained by the USA-NPN. Unless the data coordinator assumes responsibility for submitting all observations collected at a park, observers will enter their observations via the online interface, *Nature's Notebook* (www.nn.usanpn.org). The first time that observers log into *Nature's Notebook,* they need to proceed through the following steps (these steps need only be completed once):

- Create a *Nature's Notebook* account
- Register a site
- Register plants
- Print datasheets

Instructions to carry out these steps are outlined in detail on the Nature's Notebook "Learn How to Observe" page at http://www.usanpn.org/nn/guidelines.

Since most CPP observers participate in an ongoing monitoring program at a park (i.e., where sites and individual plants have already been selected for monitoring), observers will not need to register sites or plants; however, they will need to join the appropriate *Nature's Notebook* network for the park where they are participating (described below). Joining a park-specific network will allow observers to access and to upload observations for all previously registered sites and targeted individuals at a given park.

I. Joining or establishing a CPP network on *Nature's Notebook*

A "shared site" is a site that can be viewed by many observers in their *Nature's Notebook* home page and for which many observers can contribute observations. There are two kinds of "shared sites": (1) public sites, to which any registered *Nature's Notebook* observer can submit observations and (2) a network of group sites, which can only be seen by network members and to which only network members can be submit observations.

Each park contributing data to the NPDb through *Nature's Notebook* has the option of creating public sites or a network of group sites, however group sites have the advantage of limiting data entry to trained observers who are part of the network. Because network members log into their own account for data entry, observations are linked with a known observer. It also allows network administrators to view all of the data that have been submitted for a particular group site in the network and to moderate the group members that are allowed to contribute data.

When creating a *Nature's Notebook* account, observers will have the opportunity to join an existing network using the drop-down menu under the heading "Partner Organizations". Observers should select "California Phenology Project" from the drop-down menu, after which a list of secondary park networks will appear; observers should then select the park(s) where they are participating (an observer can be a member of multiple networks). If a secondary park network is not included in the drop-down menu, contact the USA-NPN National Coordinating Office (NCO) at nco@usanpn.org.

Observers that already have a *Nature's Notebook* account may join a park network by logging into *Nature's Notebook*, selecting "My account", and then selecting the partner organization and secondary park network, as described above.

If established park sites do not show-up as part of the park's shared site network, contact nco@usanpn.org to have the sites transferred into the appropriate park network.

Registered group sites and plants may be edited or added to existing park networks by contacting the NCO. Project coordinators should be listed as network administrators, which give them the ability to edit and add sites or plants to a network (other network members can only add data to existing sites).

II. Bulk upload options

There are circumstances in which it is preferable to enter data offline and upload large bulk files to the NPDb. This would be the case for parks where internet access is not reliable or capable of fast internet connections. This may also be the case for parks for which one person is entering the data in less frequent large increments rather than consistently throughout the monitoring season. The USA-NPN is currently developing a bulk upload system that will automatically generate customizable Excel files based on the individuals and protocols for a selected site. This feature is anticipated to be available in 2014.

III. Quality control and quality assurance

There are a number of quality control and quality assurance measures built into the *Nature's Notebook* observer program. Existing measures for data entered in *Nature's Notebook* can be found in the document, "Data Quality Assurance & Quality Control For *Nature's Notebook*" (http://www.usanpn.org/files/shared/files/USA-NPN_QA_QC_InfoSheet_v1.0.pdf). These include measures to reduce: species identification errors, phenophase status evaluation errors, and data entry errors. This document also describes measures that have been identified as a high priority for future development and implementation by the USA-NPN. These include identification of outliers, crowd-sourced and expert review of observer photos, and flagging phenophase observations that are reported out of expected order.

In addition to the quality control efforts outlined in the document above, the following measures can ensure data quality during the data entry process:

- CPP observers should review their datasheets at the end of each observation day to make sure there are no mistakes. If there are mistakes on the datasheet, observers can often correct these immediately– for example the observer may remember that a tree was actually flowering, but was marked a "no" or left blank by accident, details that would likely be forgotten days or weeks later.

- The project coordinator or data manager at each park should also review data for consistency and outliers. Ideally this review should be done bi-weekly so that anomalous observations can be detected and corrected before volunteers forget or a plant's phenological status has changed. If anomalous data are entered, project coordinators or data managers should consult with the observer and/or physically visit the plant in question to determine whether the data submitted were correct and to check with observer and verify that they are interpreting phenophases correctly.
- The data manager may ask two or three CPP participants at each park to review data entered online and to compare these data with the hand-written datasheets to check for key-stroking errors in phenophase status, individual monitored, date, and abundance categories chosen.
- Data managers may prefer that each observer submits their own data using a personal *Nature's Notebook* account; using this approach, all submitted observations are associated with a specific user account, and if future question arise, data can be verified by the observer. Where phenological observations are conducted in teams (e.g., two or more observers), teams might identify a member who is responsible for data entry.
- The project coordinator may compare data collected by newly trained observers with data collected by experienced observers, who monitor the same individual on the same day, in order to identify issues with data consistency which may need to be addressed through additional training.

Measures to ensure data quality specific to the correct identification of CPP species and phenophases should be carried out during volunteer training sessions and follow-up events (see SOP5).

IV. Management of datasheets

Each park should establish a set of best-practices to ensure the safety and management of hand-written datasheets. Suggested guidelines include:

- Instructing observers to bring their datasheets to a single location (e.g., the data manager's office) for data uploading immediately after data collection.
- Maintaining a 3-ring binder that contains all cumulative datasheets.
- Scanning paper datasheets at the end of each field season.
- Reminding observers who upload data that they must record on each datasheet when the data have been entered into *Nature's Notebook*.

V. Data Archiving

In addition to utilizing the NPDb for data archiving, each park should download their data using the USA-NPN Data Download Tool (https://www.usanpn.org/results/data) on an annual basis and archive the resulting .cvs files according to their park-specific procedures for data management and storage. More information on downloading data can be found in SOP10.

SOP9: Post Field Season Activities

Version 1.0

Revision History Log:

Version #	Revision Date	Author	Changes Made	Reason for Change
1.00	June 2013	Matthews, Samuels		

Overview

Long-term monitoring projects, by the very nature of their longevity, are hopeful but vulnerable endeavors and are subject to staff turnover, change of leadership, budgetary fluctuations, and change in management priorities over time. An essential component to long-term monitoring program stewardship in a given year is post field season documentation. If a system is established early on for updating and archiving, annual work is clearly documented, and original hard copy and digital data and photographs securely archived, it will be easier for future project coordinators to ensure consistent follow-up, and thus will enhance the likelihood that the project will continue once the original project developers are no longer involved.

For some CPP participating parks, observation may continue year-round, but for many monitoring sites, there will be a period when phenological activity is low and monitoring is infrequent (or may cease). This low season will vary among the parks in California, depending upon the prevailing climate regime (e.g., in desert and Mediterranean ecosystems, field monitoring will be infrequent during the late summer and fall, until the winter rains begin, whereas in high-elevation mountain ecosystems, monitoring will cease during the winter and resume in the early spring when temperatures increase and snow melts).

During this phenologically inactive period, the *project coordinator* at each park should: document the names, contact information, and person-hours contributed by NPS staff and CPP volunteers during the previous growing season (see example post field season summary document in section II of this SOP); document changes to the protocols, monitoring sites, or targeted plants and update the park monitoring tools, as necessary; compile photos and datasheets; verify that all observations have been submitted to the USA-NPN; and follow-up with volunteers to thank them for their participation and to distribute tangible rewards (e.g., parking permits, T-shirts, mugs, etc.) when these are available.

It may be useful to establish a CPP binder as a master location for the most up-to-date project documents, but this should not replace archives. Binder tabs may include:

- Current edition of the park monitoring guide,
- Current versions of phenophase description sheets and other relevant photos
- Current version of site photos and maps
- Annual reports (at least the most recent year or two, if not several past years)
- Monthly calendars that document the monitoring schedule of each observer

A note about park archives: Many parks have a process in place for archiving original datasheets, annual reports and other important documents, and a designated archive manager. Often the archive manager is also responsible for museum collections and may be a member of Cultural Resources or Interpretation divisions. Contact the designated archive manager at the park and discuss archiving the CPP documents with them. In some cases archived documents may be readily available to park staff, either via access to the originals or via access to scanned copies; in other cases, original documents may not be readily accessible once archived.

Park archives should include:

- Previous editions of the park monitoring guide, photos, maps and annual reports
- Original datasheets. Note, each park may handle original datasheets differently, however it is highly recommended that original datasheets be retained against the possibility of loss of the electronic data over the long term (either in park or at the USA-NPN). If the volume of datasheets is so high that their physical storage is unreasonable, datasheets may be scanned and backed up in at least two locations.

I. Annual close-out

Include the following steps in your annual close-out. A form is included at the end of this SOP that may be used as an annual report template and modified as necessary. Once completed, include a copy of the Annual Report in the park monitoring guide/binder, as well as in park CPP archives.

1.1 Document names, contact information and person-hours contributed by personnel and volunteers during the previous growing season

- Maintain an up-to-date contact list of CPP participants, including NPS staff and volunteers, who have observed targeted plants each growing season. Remember that Personally Identifiable Information (PII) such as email addresses, phone numbers and addresses must be kept in a secure location (e.g., locked cabinet, encrypted/ password protected electronic file, etc).
- Along with contact information, parks may track person-hours contributed and may reward or acknowledge top observers (e.g., observers who contributed the most records, or observers who contributed the most hours).

1.2 Document changes to the monitoring protocols, sites, or targeted plants and update the park monitoring tools

- CPP sites and targeted plants should be reviewed at the end of every growing season to ensure they still meet the selection criteria described in SOP3.
- Dead plants should be marked as such in *Nature's Notebook,* and damaged tags should be replaced to ensure that targeted plants can be found in the next growing season.
- If new monitoring sites or target plants have been added during the growing season, the project coordinator should make sure that the CPP site maps have been updated and should insert the updated maps into the CPP park monitoring guide.
- Species profiles and park monitoring guides should be updated to include "lessons learned" in the previous growing season and to include phenophase photos (or other visual guides) captured in the previous year.

1.3 Compile new photos, maps and datasheets

- New site photos, maps and other park-specific visual materials should be added to the park monitoring guide (electronic and master binder), and also archived in a secure location according to park protocols.
- If photos have been taken to augment or replace those in the phenophase description sheets, insert them into the phenophase description sheets, and send a digital image file to the USA-NPN for updating.

1.4 Verify that all observations have been submitted to the USA-NPN

- The volunteer coordinator might send out an email reminding volunteers who have agreed to submit their own observations to upload everything to *Nature's Notebook*, and to submit their original datasheets to the volunteer coordinator or data manager.
- Data entered into the USA-NPN's National Phenology Database (NPDb) (either through *Nature's Notebook* or bulk upload) should be subjected to a QA/QC process (See SOP7) for error checking prior to archiving original datasheets. This role would fall under the duties of the data manager (if there is one at a park). Otherwise the park coordinator should ensure that proper data quality measures are taken during data entry.

1.5 Follow-up with volunteers

- Follow-up with volunteers to ensure that all data has been submitted and to solicit feedback to guide future monitoring.
- Share preliminary data summaries and CPP updates to maintain volunteer engagement.
- Thank volunteers and do something to express appreciation for their time and commitment such as VIP reward items, like arrowhead mugs and pens, celebratory picnics and hikes, etc.

1.6 Follow-up with NPS staff and local partners

- Follow-up with staff and partners to share preliminary data summaries and project accomplishments to date.
- Share information on how the park effort is fitting into greater state-wide and national phenological monitoring efforts.
- Share information on how project is meeting the goals of partners and park.

II. Example end-of-season summary form

California Phenology Project Post Field Season Summary, *PARK*

Annual documentation is essential to long-term project success. Please complete the following report during the break between monitoring seasons, and include it in park monitoring guide as well as park CPP archives.

Reporting period From: (month, year) To: (month, year) Date of report:
Report Preparer (name, title):
Park CPP Coordinator for this period (name, title):

Please complete the following, reformatting or expanding as necessary:

1. Location of CPP working documents, tools and equipment: Where are the working documents, tools and equipment stored? Include updated monitoring guide, datasheets, clipboards, training materials etc.

2. Location of archives: Where are project archives stored? List both electronic and physical storage locations.

3. CPP participants: Who has participated in CPP activities this year, in what capacity and how many hours have they contributed? Groups may be listed on one line; this table may be reformatted to meet park-specific needs.
   Who maintains the CPP participant contact information? (Personally Identifiable Information (PII) must be kept in a secure location)

   ____

Name	Is contact information documented in a secure location?	Type (staff, VIP, intern, etc.)	Role (data collection, data entry, VIP management, etc.) List all that apply.	Hours contributed	Comments
Example: Susan Miller	yes	VIP	Data collection, entry	140	Local resident, ongoing VIP

4. Document changes to monitoring protocols, sites, or targeted plants. Update monitoring tools.
   a. Describe any changes that have been made to the monitoring protocols this year, and why.

   b. Which documents have been updated to reflect these changes (park monitoring guide, phenophase sheets, maps etc)? If documents have not been updated, explain why.

5. Have all observations from this year been entered into the USA-NPN online database? If not, explain why and describe what steps are necessary to accomplish this.

6. Have hard copy datasheets, and electronic files such as photos been archived in a secure location? If so, where? If not, where are they currently stored and is there a plan for archiving them?

7. Summary of accomplishments and challenges – please summarize the highlights, accomplishments and challenges of the CPP program this year. Include start and end dates of monitoring, whether all sites were monitored regularly, if any problems came up and how they were resolved and anything else of note.

8. Communication with the USA-NPN National Coordinating Office (NCO). Was there contact with the NCO staff? If so, describe briefly the motivation for the communication and the response or resolution from NCO staff. Examples of reasons to communicate with the NCO include:
   a. establishing new shared sites or editing network members;
   b. requesting assistance with data download or visualization;
   c. requesting revisions or clarifications of the datasheets or phenophase definitions;
   d. requesting clarification of an FAQ listed on the *Nature's Notebook* website.

9. Recommendations for the future – please list any recommendations you may have for future years.

SOP10: Data Summary, Analysis, and Reporting

Version 1.0

Revision History Log:

Version #	Revision Date	Author	Changes Made	Reason for Change
1.00	June 2013	Gerst		

Overview

The purpose of this SOP is to describe procedures for data summary, analysis, and reporting. It is anticipated that the analysis and reporting of CPP data will change as a longer phenological time-series is collected by CPP observers and is archived in the National Phenology Database (NPDb). This SOP focuses on the analysis and reporting already taking place, but also briefly describes future plans for analyses, which will require more data than are currently available. Additionally, the USA-NPN is currently developing methods to generate metrics (e.g., phenophase onset date and duration) that will allow researchers to more easily analyze, model, and interpret the raw data that are archived in the NPDb. Over the long-term, the goal of data analysis will be to make inferences about the magnitude and direction of phenological responses to temporal variation in climate. The CPP will adopt the USA-NPN methods as they become available, and this SOP will be revised to include these methods and analytical tools.

This SOP currently provides step-by-step instructions for producing park-level annual summary reports that document phenological activity patterns and monitoring efforts. These annual reports require downloading and processing raw data from the NPDb and extracting phenological information from the USA-NPN visualization tool. This SOP provides instructions for creating tables and graphs that describe and display phenological activity patterns. The purpose of the annual reporting is to document data collection efforts and to characterize and quantify phenological patterns observed in a park in a given year. Annual reports will also provide data summaries to inform the timing and distribution of future monitoring efforts, as well as management decision-making. Park-level annual reports may include the following components: analysis of the focal year's climate relative to 30 year norms; tables summarizing the data collection effort, summary of periods of activity for key phenophases; graphic displays of patterns of phenological intensity, interpretations of results, and recommendations for planning for future monitoring.

This SOP also provides instructions for data summary using Microsoft Excel software and recommendations for research questions that can be addressed through periodic analysis of CPP data. Park staff will complete the annual data summary reporting. Specialized expertise, however, will likely be needed to conduct statistical analyses and to interpret long-term datasets. These analyses will utilize CPP data representing species that have been observed across many parks and monitoring locations. This work will likely require collaboration among park staff and climatologists, statisticians, and ecologists in both the academic and federal agency communities.

I. Annual Climate Summary

Step 1: To download annual and monthly climate summary information from the National Climatic Data Center (NOAA NCDC) for stations in California, with comparison to 30 year norms, go to the following link: http://www.ncdc.noaa.gov/IPS/cd/cd.html

Step 2: Choose "California" and click the "next" button.

Step 3: Choose the year or year/month of interest and click the "next" button. For example, to get monthly data for all of 2011, choose "2011-ANNUAL". Note that for recent years, there is a delay in the availability of annual report. Open the file as a PDF file.

Step 4: Choose the most appropriate weather station (i.e., a nearby station that is representative of the monitoring sites of interest). A list of suggested stations that are close to the CPP pilot parks is included below; each of these stations have 30-year (1971-2000) climate normals available for download. These stations are listed in the climate report by Divisions, shown in parentheses at the end of the station name. (Parks may also use the Map Search tool to access appropriate weather station data from NOAA NCDC: http://www.ncdc.noaa.gov/cdo-web/search).

1. *Joshua Tree National Park*: TwentyNine Palms or Joshua Tree (Southeast Desert Basins 07)
2. *Santa Monica National Recreation Area:* Woodland Hills (South Coast Drainage 06)
3. *Golden Gate National Recreation Area*: San Francisco Downtown (Central Coast Drainage 04)
4. *John Muir National Historic Trail*: Martinez WTP (Central Coast Drainage 04)
5. *Redwood National Park:* Orick Prairie Creek (North Coast Drainage 01)
6. *Sequoia Kings Canyon National Park:* Ash Mountain or Lodgepole (San Joaquin Drainage 05)
7. *Lassen Volcanic National Park:* Manzanita Lake (Sacramento Drainage 02)

Note: Additional park-level environmental data, including climate data, are available online from NPScape (http://science.nature.nps.gov/im/monitor/npscape/index.cfm).

Step 5: Locate station of interest and copy and paste data into Excel from (a) average monthly and annual temperature summary, and (b) total monthly and annual precipitation summary. In Excel, go to "Data"→"Text to Columns" to separate each value into an individual cell.

Step 6: Construct tables detailing the monthly and annual pattern of average monthly temperature and precipitation for the year compared to the 30 year norm. See tables 1 and 2 below for presentation of this data and summary descriptions for annual reports.

Table 1. Example temperature summary table from 2011 for TwentyNine Palms (representative weather station for Joshua Tree National Park).

	2011 Average Monthly Temperature (^{o}F)	**Departure From 30 year Norm (1971-2000)**
Jan	53.1	2
Feb	51.7	-2.7
March	60.7	0.4
April	66.4	-0.4
May	70.8	-5.1
June	81.4	-2.5
July	87.9	-1.5
August	89.8	1.7
Sep	83.3	1.9
Oct	71.6	1.8
Nov	56	-1.8
Dec	49.1	-0.8
Annual	**68.5**	**0.4**

The average temperature for 2011 was 0.4 ^{o}F warmer than the 30 year normal record. Seven months (e.g., February, April, May, June July, November and December) were cooler than average. Five months were warmer than average (January, March, August, September, and October); with the exception of March, all of these periods were 2^{o} warmer than the 30-year norm.

Table 2. Example precipitation summary table from 2011 for TwentyNine Palms (representative weather station for Joshua Tree National Park).

	2011 Monthly Precipitation (Inches)	Departure From 30 year Norm (1971-2000)
Jan	0	-0.56
Feb	0	-0.52
March	0	-0.49
April	0	-0.14
May	0	-0.12
June	0	-0.01
July	0.2	-0.44
August	1.62	0.86
Sep	0.04	-0.51
Oct	0	-0.17
Nov	0.04	-0.17
Dec	1.83	1.43
Annual	**3.73**	**-0.84**

Overall, 2011 had a total of 3.73 inches of precipitation, 0.84 inches less than the 30 year normal period. There was no rainfall detected for the entire period from January through June, resulting in below average rainfall for the first half of the year. Only two months had above average rainfall (August and December). Thus, 2011 appears to have been both drier than average as well as relatively uneven in the distribution of rainfall events throughout the year, with the majority of rainfall occurring in August and December.

II. Downloading data from *Nature's Notebook*

Download raw data directly from the NPDb to calculate sampling effort in a given year, at a given park, or in a given network and to identify periods of phenological activity for one or more species. It is also extremely important to use this opportunity to carry out Quality Control measures to ensure that entered data matches observations and that any inconsistencies are addressed. See SOP8 (Data Entry and Data Management) for more information on Quality Assurance and Quality Control including a reference to the USA-NPN QA/QC info sheet. See below for step by step instructions to develop a dataset to make these calculations.

Step 1: Access the Data download tool at: https://www.usanpn.org/results/data. Under optional fields, select "Site Name", "Plant nickname", "Observer ID", "Phenophase category" and "Comments". Select the beginning and end dates of the focal year to retrieve data. To retrieve all data for a given park, filter by Partner Organization. Select "California Phenology Project" and wait for a list of secondary options to appear in a box to the right. When the box displays these options, look for the four digit code of the park unit of interest (e.g. SAMO). Be sure to click "Add" after highlighting the park unit of interest. At the bottom of the tool box, select "all options for metadata" and select "Excel 2007 File" for output. Click "download data" button. Large files may take several minutes to download.

Step 2: Copy a new file with the observation data (preserving original download with all metadata in the original file) and assign a file name that describes the location and time span of data within file. (Check to make sure that the file includes the desired time span.) Arrange data so the order of columns conforms to the order observed in "sample data" (Table 3); these are the most crucial variables to include in order to carry out the data summary. Additional columns may be deleted.

Table 3. Sample data from Santa Monica National Recreation Area.

Observation_ID	Observation_Date	DayOf_Year	Latitude	Longitude	Phenophase_Status	Elevation	Genus	Species	Individual_ID	Phenophase_Name	Plant_Nickname	Site_Name
668556	2011-08-15	227	34.145	-118.96	0	273	Adenostoma	fasciculatum	15581	Breaking leaf buds	ADFA-1 (762)	CPP-SAMO-RSVS1
668557	2011-08-15	227	34.145	-118.96	0	273	Adenostoma	fasciculatum	15581	Young leaves	ADFA-1 (762)	CPP-SAMO-RSVS1

Table 3. Sample data from Santa Monica National Recreation Area (continued).

Observation_ID	Observation_ Date	DayOf_Year	Latitude	Longitude	Phenophase_ Status	Elevation	Genus	Species	Individual_ID	Phenophase_Name	Plant_Nickname	Site_Name
668558	2011-08-15	227	34.145	-118.96	0	273	Adenostoma	fasciculatum	15581	Flowers	ADFA-1 (762)	CPP-SAMO-RSVS1
668559	2011-08-15	227	34.145	-118.96	0	273	Adenostoma	fasciculatum	15581	Open flowers	ADFA-1 (762)	CPP-SAMO-RSVS1
668560	2011-08-15	227	34.145	-118.96	1	273	Adenostoma	fasciculatum	15581	Fruits	ADFA-1 (762)	CPP-SAMO-RSVS1

Below is a description of the non-self-explanatory variables contained in the database:

Observation ID = this refers to an individual phenophase status record – the reported status of one phenophase on one individual by one observer on a given day and time. Use this information to calculate the total records for a given period.

Observer ID = this refers to the individual observer who entered this data. The total # of observers contributing data can be calculated from unique instances of this value if data is entered by the same people that collect the data; in other words, if the # of monitors is equal to the # people that entered the data.

Individual ID = this is a unique identifier for an individual plant in the database. This value may be used to determine the total # of individual plants in dataset.

Site Name = this refers to the name given to the Site at which multiple individuals may be sampled. This column may be used to determine the total # of individual sites in the dataset and to determine whether and why any sites are represented by anomalous phenological observations compared to other sites. When a site appears to be associated with outlier phenological observations, it is important to check the original notes and location for that site, and potentially to check the original datasheets if typographical errors during data entry are suspected to have occurred.

Individual nickname = this is the nickname given to an individual plant. It may be useful to retain this column if, for example, an unusual phenological observation has been recorded for a particular individual; in this case, the user may check the notes, location, and/or the handwritten data associated with that individual.

Phenophase name = this column identifies one of the multiple phenophases that the USA-NPN protocol assigns to a given species for monitoring.

Phenophase status = this column includes a code indicating the status of the phenophase and will be either a 1 (YES, the phenophase was observed occurring that day by that observer on that individual), a 0 (NO, it was not observed occurring), or -1 (?, the observer was uncertain whether or not is was occurring)

Note: Future updates to the data download tool and the visualization tool will provide select pheno-metrics (e.g., onset and peak of flowering or leafing) for individuals and sites.

III. Summarizing Data Collection Effort

To summarize effort in a given year, calculate the total number of: unique phenophase status records, observers, days in which monitoring was carried out, species, sites, and individual plants monitored. ***A separate Excel file or Excel workbook tab should be created for each year of data collection in order to make these calculations on annual datasets. This is only necessary if the date filter was not used when downloading the original file from the NPDb.***

Step 1: To calculate the effort metrics, copy and paste the following formula to the bottom of each column of interest (using the data downloaded from the NPDb, as described above); this formula will calculate the number of *unique* values in a given column:

=SUM(IF(FREQUENCY(MATCH(A2:A100,A2:A100,0),MATCH(A2:A100,A2:A100,0))>0,1))

This formula will count values that are repeated multiple times in the columns (such as species) only once. Note that "A" in this formula refers to the focal column, so "A100" is arbitrary; use the total range of rows in the dataset to calculate this formula for an entire column. For large datasets, it may take a few minutes for Excel to make this calculation; be patient and do not click on other areas of worksheet or this may cause the program to crash. Note also that the ObserverID field shows the ID of the person that logged in to NN to enter the data, so this method cannot be used to calculate Total Observers from the ObserverID field values if, at a given park, the number of people that entered the data is different than the number of people that collected the data.

Step 2: Create a Table describing overall effort at a park. This can be broken down by site nested within parks if desired. See Table 4 for an example effort table (based on real data).

Table 4. Example effort table for Santa Monica National Recreation Area for 2012

Year	**2012**
Park	**SAMO**
Total phenophase status records	64,197
Total observers	14
Total days observed	177
Total species observed	6
Total sites monitored	41
Total individuals monitored	206

IV. Data Summary

4.1 Creating phenological activity tables and figures using the USA-NPN visualization tool

A table describing the phenologically active season will aid park staff in planning for the upcoming year's monitoring efforts. For example, the park coordinator can allocate time (for scheduling and coordinating the observers), personnel, vehicles (if needed) and other resources towards periods of peak activity and expected onset dates. The USA-NPN visualization tool provides a simple overview of phenological activity observed at a site, park, or region. To access training slides that describe how to use the visualization tool, visit the following URL: https://www.usanpn.org/files/shared/files/VizToolTraining.pdf.

Step 1: Go to https://www.usanpn.org/nn/connect/visualizations and click on: "click here to access visualizations".

Step 2: Select species of interest, click "Add to List", then "Map!" button. (Note: while the "select a partner" group button will filter the species list to only those targeted by a USA-NPN partner or network, it does not filter the sites that are shown on the map for a given species that was selected and mapped.)

Step 3: Click the "Activate Multiple Site Selection" button along the top of the screen to select all stations within a park. (Note: this can be accomplished for individual sites, locations, or the entire park.) Adjust the map resolution so that the park is in view; drag a box over all sites of interest.

Step 4: For each year that monitoring has occurred, select the species and the year to display the phenophase activity patterns for the selected sites. For example, type in "coyotebrush" in the search box, click on the species name when it appears, click "Add Phenophases for species", and then select the year of interest (see Figure 1). Repeat for each year (for up to three years per display box); only three displays can be shown at any time. If more than three displays are desired (in order to view additional species or individuals), the user must remove data from one or more of the displays before adding more.

Step 5: Use the visualization to identify periods of activity for each species monitored at a given park (e.g, Figure 1). Note: the light grey vertical line segments indicate dates where the observer indicated that a plant was monitored, but the phenophase was not occurring; dark grey represents dates on which the status of the phenophase was uncertain or not recorded. Colored bars represent observations that confirmed the occurrence of a given phenophase.

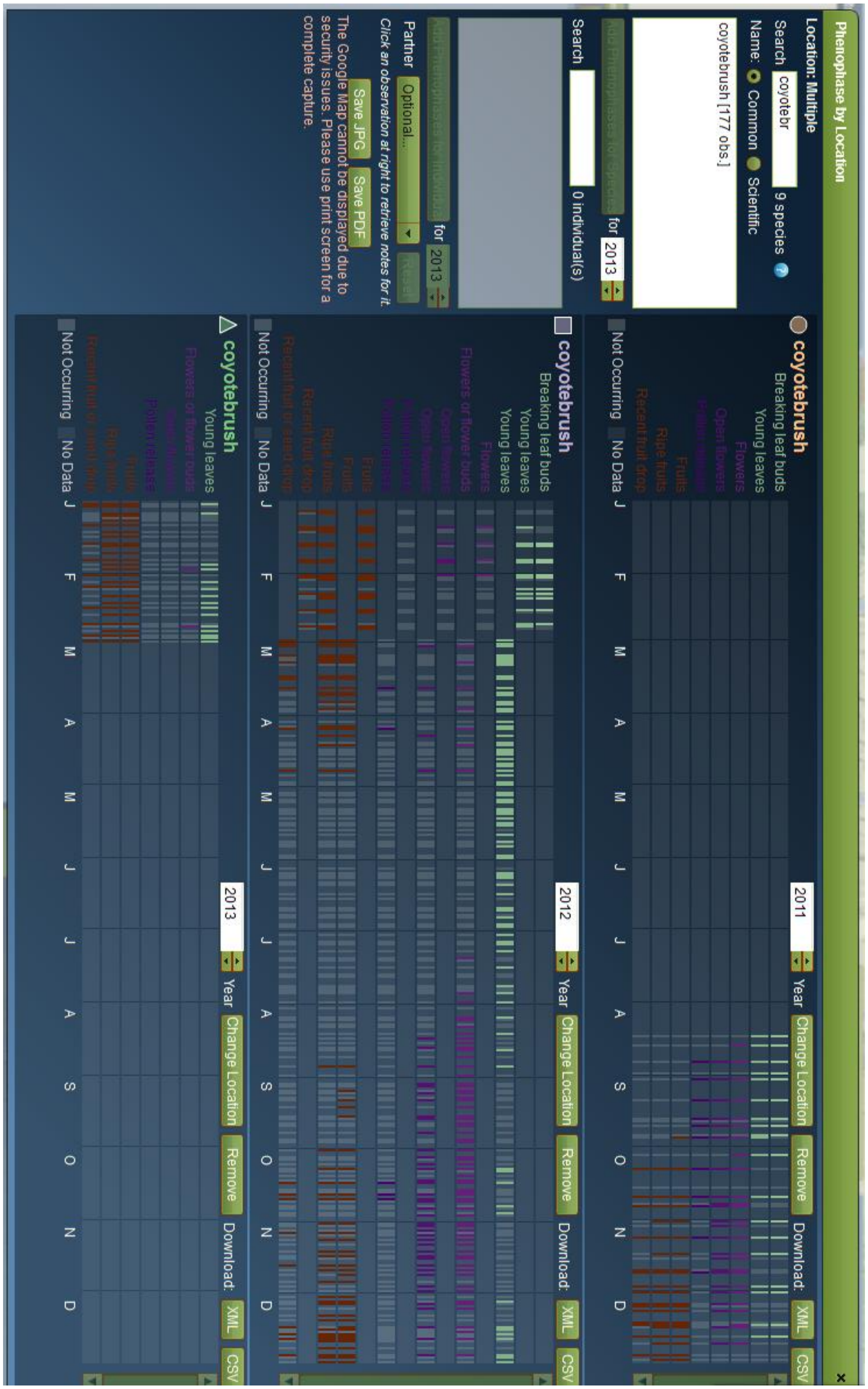


Figure 1. An example of the visualization tool output showing coyotebrush (*Baccharis pilularis*) phenophase activity at Santa Monica National Recreation Area in 2011 (top), 2012 (middle), and 2013 (bottom). Based on these observations, coyotebrush flowering tends to occur between mid-July and continues sporadically through April, with an apparent peak in the fall.

Note: This procedure can be conducted for individual plants or for all individuals at a site or location. Simply modify step 3 to only select individuals or sites of interest for display in activity box.

To show the USA-NPN visualization result in the summary report, use Print Screen (hit Ctrl + Print Screen buttons on the keyboard). Then, open Microsoft PowerPoint, click on a blank slide and then paste the image. Crop the image as needed. Then, copy the image and go to the summary report document and select Paste Special > Image to paste the cropped image. Alternatively use the capture screen option and save the visualization tool results as a saved image in a browser with screen capture functionality, such as Google Chrome.

Step 6: For reporting, use the visualization tool output to complete the last column in phenophase activity tables that document the activity patterns observed at a park (see Table 6).

Note: Following an assessment of the phenological records contributed to *Nature's Notebook* in 2011, some of the USA-NPN phenophase definitions and/or names were modified in early 2012. One result of these changes is that many phenophases for a given individual plant or species are listed twice in the visualization tool or database, with the phenophase for each year associated with a slightly different definition and name (e.g. "Flowers" in 2011 was changed to "Flowers and flower buds" in March 2012). By September 2013, equivalent USA-NPN phenophase protocols (where names have changed over time) will be identified automatically in the data download output and will be integrated in the visualization tool.

4.2 Determining first observed phenophase onset dates and duration of observed activity from raw data

The USA-NPN is currently developing methods to estimate phenophase onset dates and duration, and to identify outliers, from the raw data archived in the NPDb. The CPP will be adopting these methods when they become available in 2014. With the data currently available in the NPDb, however, the time periods during which positive observations were made can be determined by inspecting records that include positive phenophase status data ('1' = YES, the phenophase was occurring). This will allow parks to determine periods of activity in order to plan the timing of future monitoring efforts.

Step 1: Separate each year of interest onto its own tab in the Excel worksheet if data are not already filtered by year.

Step 2: Use "Sort" option in Excel. Sort by "Phenophase status" and erase all records with '0's and '-1's.

Step 3: Create a PivotTable that will display the first and last day of the year in which each phenophase for each species was observed. To do so, go to Insert→PivotTable→PivotTable. Create a PivotTable using all fields in the worksheet on a new tab. For "Row Labels", select Genus, Species, and Phenophase Name (in that order). For each Row calculate the Min and Max "Day of Year". Since all '-1' and '0' records are already filtered out, this will only report the max and min days that the phenophase was observed. To do so, drag "Day of Year" field to the “Σ values”, twice. Then, click on each value and select “Value Field Settings” so that one is calculating “Min” and one is calculating “Max”.

Optional: To make these calculations at the *site* or *individual* level in addition to the park level, drag “Site Name” and “Individual ID” fields into the “Report filter” box. It is then possible to select any combination of sites and individuals to make these calculations. Multiple sites/individuals or *all* sites and individuals can be selected to lump by trail/location. To do so, click the box that says “Select multiple items” under the drop down menu for Site Name and/or Individual ID, which appear at the top of the worksheet. Those drop down menus are visible in Excel, but not in the table below.

Step 4: Create a new column to calculate the duration of activity period. To do so, subtract the minimum Day of Year from the maximum Day of Year. See Table 5 for an illustration (using 2012 SAMO data) of what a table will look like after applying PivotTable filters.

Table 5. Example table of SAMO 2012 data showing observed phenophase activity for two plant species based on raw data downloaded from the NPDb. A max day of year of 366 results from a leap year (e.g. 2012).

Site_Name	(All)		
Individual_ID	(All)		
Row Labels	**Min of Day_Of_Year**	**Max of Day_Of_Year**	**Duration**
Adenostoma fasciculatum	**6**	**366**	360
Breaking leaf buds	6	48	42
Flowers	42	42	0
Flowers or flower buds	67	206	139
Fruits	6	366	360
Open flowers	69	206	137
Recent fruit drop	13	31	18
Recent fruit or seed drop	60	362	302
Ripe fruits	6	366	360
Young leaves	6	366	360
Baccharis pilularis	**5**	**366**	361
Breaking leaf buds	19	54	35
Flowers	12	47	35
Flowers or flower buds	60	362	302
Fruits	5	366	361
Open flowers	12	362	350
Pollen release	60	303	243
Recent fruit drop	5	54	49
Recent fruit or seed drop	60	362	302
Ripe fruits	5	366	361
Young leaves	12	365	353

Step 5: Create a table to show a summary of observed activity in the park (see Table 6 for example format). These data can confirm and complement the observations made from the visualization tool. When preparing the table for the Annual Report, do not report columns that only contain Genus names, these are simply used for sorting by species and do not provide additional value. In addition, convert Max and Min Day of Year values to a calendar date, as shown in the third and fourth columns of Table 6. Copy and paste the Max and Min columns to create two new columns that are formatted as dates rather than numbers. Make sure that the year is correct for these cells; be sure to find and replace all "1900" values with the year of the inquiry (e.g., 2012).

Table 6. Example table describing observed phenophase activity based on raw data from NPDb and visualization tool.

Park = SAMO	**Year = 2012**				
Species	**Phenophase**	**First observed**	**Last observed**	**Duration (days)**	**Notable Patterns of Activity**
California Live Oak (*Quercus agrifolia*)	Breaking Leaf Buds	January 5	October 9	274	Sporadically observed (yeses and nos) throughout year
California Live Oak (*Quercus agrifolia*)	Young leaves	January 19	December 4	320	Sporadically observed (yeses and nos) throughout year
California Live Oak (*Quercus agrifolia*)	Flowers or Flower buds	January 5	August 17	225	Sporadically observed (yeses and nos) throughout year
Coyotebrush (*Baccharis pilularis*)	Open flowers	January 12	December 27	350	January through April (sporadically) AND mid-August through December
Coyotebrush *(Baccharis pilularis*)	Ripe fruits	January 5	December 31	361	January through April AND late-August through December
Black elderberry (*Sambucus nigra ssp. cerulea)*	Fruits	April 26	December 30	248	Once fruits are produced, a portion appears to remain on plant throughout year.

For phenophases for which activity carries over from one calendar year to the next (e.g. coyotebrush, which flowers from early fall through the winter months), be sure to examine the previous year's activity patterns to correctly identify the duration of activity.

Step 6: (*Optional)* Create a visual calendar that shows the phenologically active time for each species, location, site and/or individual of interest. (see Figure 2 for an example). This is in contrast to the park-level info shown above.

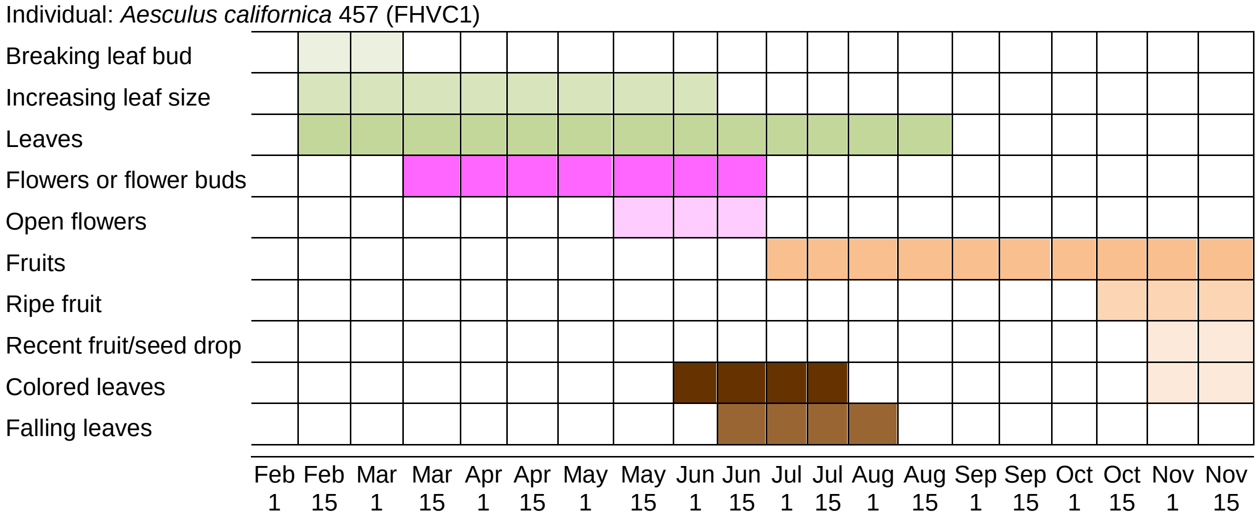


Figure 2. Example annual summary of phenological observations. This figure summarizes the phenological observations recorded in 2012 for a single California buckeye (*Aesculus californica*) monitored at the Ash Mountain Visitor Center in Sequoia and Kings Canyon National Parks. Phenophase status records were pooled in half-month (approximately 15-day) periods; the date shown at the bottom of each column is the first day of the half-month period. Shaded squares indicated periods when the phenophase was observed occurring (i.e., the observer recorded a "Y" in response to the query, "Do you see....[a given phenophase]?"). Green colors represent presence of early leafing phenophases, pink colors represent presence of flowering phenophases, orange shades represent presence of fruiting phenophases, and brown shades represent presence of late leafing phenophases.

4.3 Graphing distribution of phenological intensity to estimate peak activity

Many CPP species are phenologically active for long periods (Table 4). However, this long duration does not necessarily indicate peak activity for multiple individuals, which might be concentrated to a shorter period or which may re-occur throughout the year. There are two approaches to visualizing the distribution of phenological activity at a site or region in order to estimate peak activity. The first is to make a histogram that shows the frequency of "yes" observations for a given phenophase through time at a park, site, or individual. The second is to show the proportion of all observations that are "yes" throughout the year for a given phenophase (see section 4.4).

Step 1: To rapidly make multiple histograms for each species-phenophase combination of interest, return to the dataset used to create the tables of observed phenophase activity which contains only positive ('1') records for the year of inquiry. Go to Insert→PivotTable→PivotChart.

Step 2: Drag the following fields to the "Report Filter" box in this order: "Genus", "Species", and "Phenophase Name". Place "Day of Year" in the Axis Field box. Place "Day of Year" also in the "Σ values". This allows the calculation of a count of how many positive observations on each day of year were recorded.

Step 3: Using the Genus, Species, and Phenophase Name filters, create a graph that shows the distribution of positive observations for a given species-phenophase combination through time.

Step 4: Copy and paste each graph to be included in the Annual Report into a new labeled worksheet. Clearly label the axes and title of the graph (Figure 3).

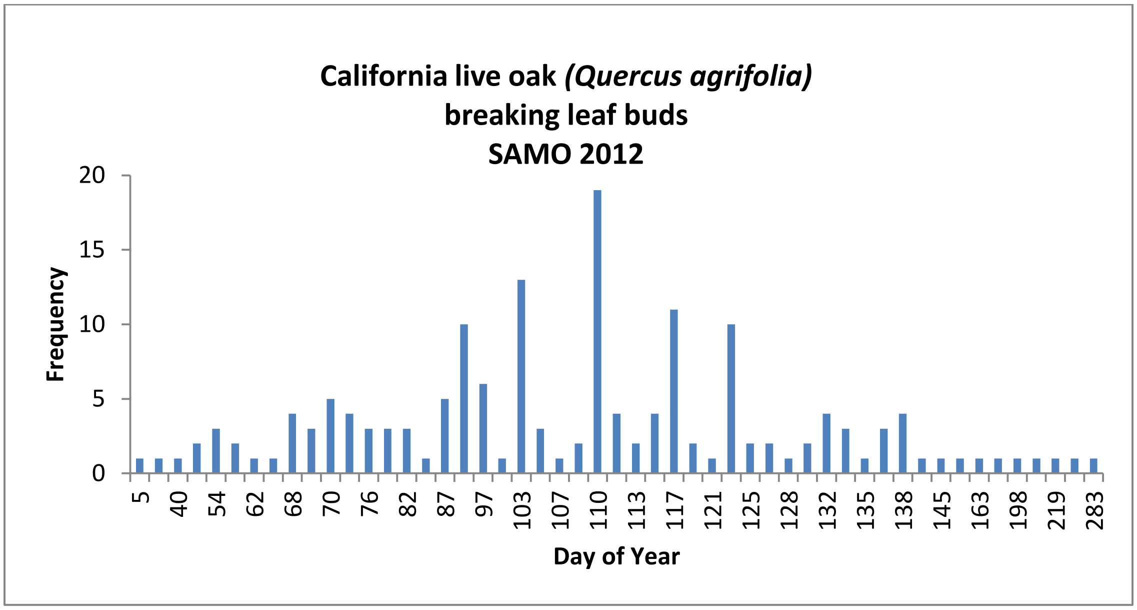


Figure 3. Histogram displaying the frequency distribution of positive ("Yes") observations of breaking leaf buds for California live oak (*Quercus agrifolia*) trees at Santa Monica National Recreation Area (SAMO) in 2012 (N= 164 observations, 19 individuals). Note that although positive observations were made throughout much of the year, peak activity was observed between days 67 and 140. This may have an impact on when to invest personnel resources in frequent monitoring.

Note that this method of visualizing intensity of observation does not account for variation in sampling effort throughout the selected time frame. For example, these data could be biased if fewer plants were being monitored during periods where low frequencies are observed.

4.4 Graphing distribution of phenological activity to show general activity patterns relative to both positive and negative observations.

Another method to show phenophase intensity patterns at a finer temporal resolution, or to show general activity patterns that include both active and inactive periods, is to graph the distribution of the proportion of positive (yes) observations over the monitoring period relative to the *total* number of observations. This requires returning to and using the original dataset that includes negative observations. Begin a new file with the original raw dataset from which all '-1' phenophase status records were eliminated, which indicate that the observer was uncertain whether the phenophase was present.

Step 1: Within the new file that contains only '0's and '1's under the phenophase status column, select the species and phenophases of interest using the sort function. For each desired graphed dataset, save data in a clearly labeled new tab. Because this activity is more time intensive, it is suggested to do it on only a handful of species and phenophases, and preferably those that were particularly well sampled.

Step 2: For each worksheet, sort data by observation date.

Step 3: Make a new column called "date category". To do so, manually assign every record into a 10 day category represented by the last Day of Year for that bin (e.g., 10=Jan1-10, 20=Jan 11-20, 30=Jan21-30, 40 = Jan 31-Feb 9). Note: using this method, the last bin of the year will only have 5 or 6 days. If more appropriate with the resulting data distribution and collection frequency, lump in to 5-, 15-, or 30-day periods).

Step 4: Create a PivotTable as described in section 3.2 above. Select "date category" for the "row label" and place "phenophase status" in the "Σ values" box twice. Alter the "Value Field Settings" category for each such that one is set to display the count and the other to display the average of the phenophase status term. This gives the sample size associated with each date category (N) and the mean of the binomial data for each 10-day period. A mean of binomial (0/1) data represents the proportion of yes responses over the associated 10 day period. Comparing the sample size values will allow for a check for evenness of the data over time (see Table 7 to see variation in sampling throughout year).

Step 7: Create a blank data point for any 10-day period that is missing data.

Step 8: Make a line graph (see example Figure 4) with the date category on the x-axis and proportions on the y-axis.

Step 9: *(Optional)* For comparing patterns of activity across space or time, treat each variable of interest as a separate data series by adding the variable of interest to the column of the pivot table and creating a new line graph that compares values (e.g. sites, locations, years). See Figure 5 for an example of flowering activity at four trail locations at SAMO. Be sure to label axes and titles with relevant information (species, phenophase, site, year).

Note that this method of visualizing data does not account for variation (within and between 10-day periods) in the number of individuals monitored over time nor in the frequency with which individual plants are monitored.

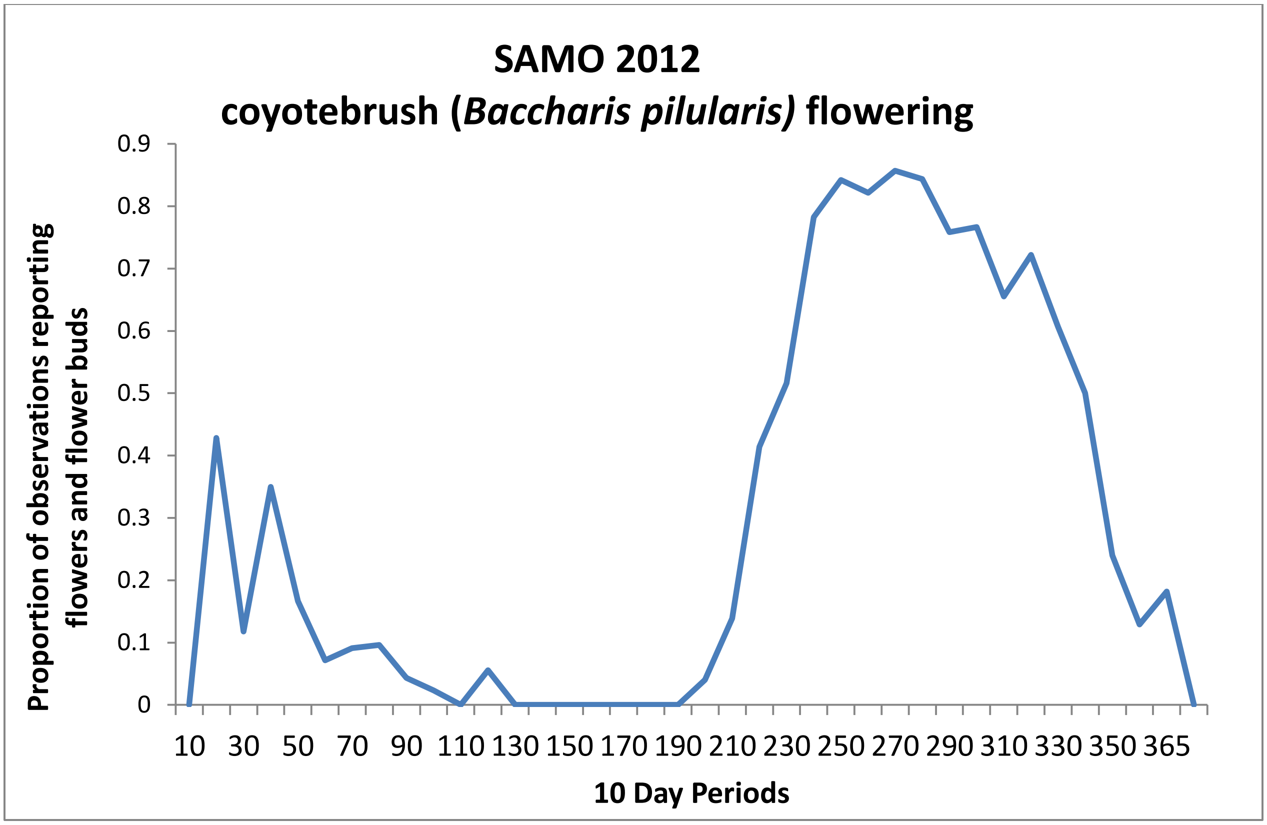


Figure 4. Summary of a 12-month period of coyotebrush (*Baccharis pilularis*) observations pooled across all CPP monitoring sites at Santa Monica National Recreation Area (SAMO) (N= 32 individuals total). Observations are pooled within successive 10-day periods, with the proportion of observations reporting the presence of flowers calculated for each 10-day period.

Note that some individuals may have been monitored multiple times within a single period and not all individuals may have been monitored in each 10 day period. The last day of year for each 10-day period is indicated on the x-axis.

Table 7. The raw data below represent coyotebrush (*Baccharis pilularis*) flowering observed at SAMO in 2012; these data were used to create Figure 4. The sample size (N) in the third column represents the total number of observations, not individuals, included in the data for a given 10 day period. Thus, some individuals may have been monitored multiple times within a single period, and not all individuals may have been monitored in each 10 day period. Note the high variation in the number of observations during any 10 day period.

Date category	Proportion of Observations Reporting flowers	N	Date category	Proportion of Observations Reporting flowers	N
10	0	3	200	0.04	25
20	0.428571429	21	210	0.138889	36
30	0.117647059	17	220	0.413793	29
40	0.35	20	230	0.516129	31
50	0.166666667	24	240	0.782609	23
60	0.071428571	28	250	0.842105	19
70	0.090909091	77	260	0.821429	28
80	0.096153846	52	270	0.857143	35
90	0.043478261	46	280	0.84375	32

Table 7. The raw data below represent coyotebrush (*Baccharis pilularis*) flowering observed at SAMO in 2012; these data were used to create Figure 4. The sample size (N) in the third column represents the total number of observations, not individuals, included in the data for a given 10 day period. Thus, some individuals may have been monitored multiple times within a single period, and not all individuals may have been monitored in each 10 day period. Note the high variation in the number of observations during any 10 day period (contined).

Date category	Proportion of Observations Reporting flowers	N	Date category	Proportion of Observations Reporting flowers	N
100	0.023255814	43	290	0.758621	29
110	0	54	300	0.766667	30
120	0.055555556	54	310	0.655172	29
130	0	40	320	0.722222	36
140	0	65	330	0.607143	28
150	0	19	340	0.5	38
160	0	34	350	0.24	25
170	0	21	360	0.129032	31
180	0	31	365	0.181818	22
190	0	28			

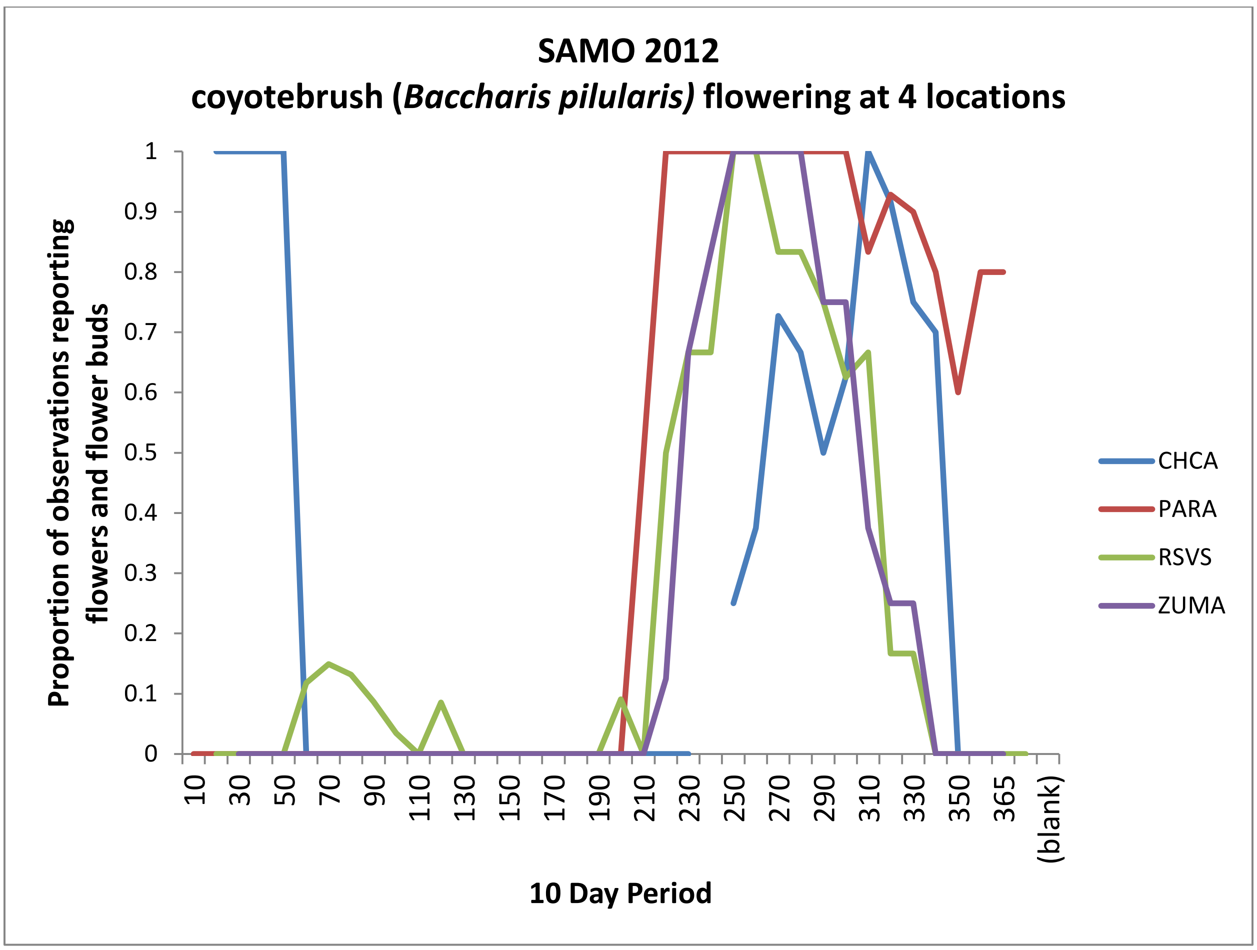


Figure 5. Summary of a 12-month period of coyotebrush (*Baccharis pilularis*) observations grouping sites within trail locations at SAMO (N= 32 individuals total). Observations are pooled within successive

10-day periods, with the proportion of observations reporting the presence of flowers calculated for each 10-day period. *Note that some individuals may have been monitored multiple times within a single period and not all individuals may have been monitored in each 10 day period.* The last DOY of each 10-day period is indicated on the x-axis. Broken lines represent data is missing for a given time period. Location codes are as follows: CHCA= Cheeseboro Canyon (4 individuals), PARA = Paramount Ranch (5 individuals), RSVS= Rancho Sierra Vista/ Satwiwa Culture Center (19 individuals), and ZUMA = Zuma Canyon (4 individuals).

5. Annual Data Summary Reporting

The project coordinator for each participating park will prepare an annual report. This report should contain general information on the amount of data collected (the monitoring effort), a summary of when phenophases were observed, interpretation of these patterns, lessons learned, and recommendations for future monitoring. For an example of an annual summary report and suggested structure, see **Appendix H (Sequoia and Kings Canyon National Parks 2012 Annual Report).**

5.1 Suggested components of park-specific annual reports

The *results* section of the annual report should include the following elements:

- A summary of the climate for the focal year, relative to 30 year norms. See instructions on how to download and summarize monthly and annual temperature and precipitation data from weather stations using resources available at the National Climatic Data Center (www.ncdc.noaa.gov). Alternatively, a park might have access to more detailed climate data collected by the park in closer proximity to monitoring locations. This would allow for a finer-scale analysis related to phenological variation between sites and years within a park. The climate section should include a general description of the climate for the year (e.g. drier or wetter than the "norm") and any anomalous events (e.g. particularly warm winter, abnormal freezes, etc).
- A summary of the data collection effort for the entire park (see Table 4) and for each monitoring location.
- Visualization tool images showing general activity patterns for all species and locations (see Figure 1 and examples in Appendices A-G).
- Phenophase activity summary-- this will include a table detailing the timeframe of activity for each species and phenophase of interest at the park and/or location level based on USA-NPN visualization tool and raw data (see Table 6 and Figures 1 and 2). *Optional: activity tables and figures for each site or for each individual plant.*
- Patterns of intensity for species and phenophases of interest at a particular park (note: this does *not* need to be done for every species/phenophase combination).
    - Histograms displaying distributions of the numbers of positive observations (the number of "Yes" responses recorded) for individual phenophases recorded from January through December in order to identify apparent periods of peak activity for species and phenophases of interest (See Figure 3 for example).
    - Graphs displaying the proportion of all observations that were positive ('yes' observations relative to total observations) for phenophases and species of interest from January through December (See Figure 4 and 5 for example).
    - Parks may choose to display data as *either* histograms *or* proportional activity tables for a given species and phenophase in order to demonstrate patterns of intensity; this will depend on the most appropriate display for the patterns of interest resulting from exploratory analysis. These histograms and graphs may be examined to detect

intraspecific variation in phenology that may be seen among years and across geographic gradients (e.g., elevation or latitude) within the park. The histograms and graphs may also be compared among species to detect inter-specific variation in phenological patterns among years and across geographic gradients.

A section focusing on data interpretation and conclusions, including a discussion of how phenological data can be used by natural resource managers and interpretive staff. For instance, during what time of year should phenology be recorded most frequently? Which species have particularly strong seasonal responses? Are there times of year that are optimal for observing leaf color changes or wildflower displays? Are there species that do not show responses to seasonal transitions or to geographic variation? How does the timing of activity compare to previous years, and how does this qualitatively relate to differences in climate and weather observed between this year and previous years?

A summary of lessons learned and future recommendations for data collection. This section should include a discussion of how the data will be used to inform future monitoring decisions and resource allocation (e.g., are there certain sites, species, or individuals that were either too difficult to monitor or, alternatively, particularly informative? Are there major gaps in the data-either with respect to the number of individuals being monitored or the frequency at a given location or site?).

The annual report should clearly document the name and location of electronic data files, a summary of the number of records for each site, and a description of the QA/QC that was completed at the park.

The post-field season summary is described in SOP9 (Post Field Season Activities). This summary should include:

- the location of CPP documents, tools and equipment
- the location of all project archives, including photos
- a list of active CPP participants
- changes to monitoring protocols, sites, or targeted plants
- summary of data entry and data archiving procedures
- summary of accomplishments and challenges faced in the previous year
- summary of communication with the USA-NPN National Coordinating Office (NCO)
- recommendations for the future of CPP activities in the park

6. Scientific Objectives

The CPP identified research questions to guide project implementation during a workshop in November 2010 (see the Scientific Framework workshop report for more details about this process; Mazer et al. 2010). Four of these research questions can be addressed with the sampling approach and infrastructure developed during the CPP pilot phase; these four questions are presented below, along with a description of an analytical approach that may be used to address each question. A fifth research question will require both longer-term phenological monitoring (e.g., >10 years of data) and co-located climate data (e.g., collected at climate stations adjacent to CPP monitoring sites, such as SEKI’s Ash Mountain climate station and phenological monitoring sites); this question can be addressed when the CPP has collected at least 10 years of phenological data. The CPP is pursuing funding to support the research objectives described below, and it is anticipated that the USA-NPN will develop data analysis tools that will facilitate the analysis of CPP data.

6.1 Priority Research Questions

6.1.A Within a given species, is there spatial variation in phenological parameters (e.g., the onset and duration of leaf and fruit phenophases)? If so, is this phenological variation correlated with geographic gradients known to be associated with climate (e.g., elevation, latitude, or longitude) and which phenological parameters or phenophases are most sensitive to these geographic gradients?

Approach: Observations of *contemporary* phenological patterns collected over local, regional, and state-wide geographic gradients (e.g., latitude and longitude) can be used to quantify intra-specific phenological variation that is associated with spatial variation. The CPP has recorded phenological data across many sites, which allows for analyses that assess the general associations between geographic parameters and phenological behavior. Multivariate statistical analyses should be able to detect (if present) the independent effects of elevation, latitude, and longitude on the timing and duration of phenological events. Species for which there is a high density of phenological records over space should be the focus of these analyses.

6.1.B Within a species, at what ecological level do we observe most of the variance in phenological metrics: (a) among individuals at a site? (b) among sites across latitudes? (c) among sites across elevations? Do we see the same phenological responses to increases in latitude and to increases in elevation? 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 appearance of open flowers? Phenological traits that are most sensitive to environmental variation (within and/or across sites) may also be those that are most responsive to climate change.

Approach: Replicated monitoring allows for the measurement of population-level parameters (such as the mean and variance of the 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-scale geographic gradients may allow the CPP to identify the scale at which the greatest magnitude of variation in each phenological metric is observed and whether this differs among phenological traits.

6.1.C. Are there 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, Eriogonum*) 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 their responses to climate change; we may expect that species that respond to short-term changes in weather with altered phenological activity may also be those that respond most strongly to sustained or unpredictable climate change. How do we best analyze and understand these patterns, what are their implications for conservation and monitoring, and can we categorize the responses by functional type or is there some extrinsic driver? In other words, is this kind of episodic growth primarily a characteristic of individual species or a plastic response to particular environmental conditions independent of taxon? (or a little bit of both?)

6.1.D. Within and across sites, do species differ in the magnitude of variation among individuals in the timing of flowering or leaf emergence (or other phenophases)? Across a similar ecological range of sites, do species differ in the magnitude of variation among site means, and is this phenological variation related to variation in geographic parameters?

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.
The following research question will require additional data (e.g., a longer time series and co-located climate data).

6.1.E. Within and across species, what is the relationship between: (a) the onset of phenological events and the duration of phenophases and (b) current and long-term climatic conditions?

Approach: Once the CPP has recorded phenological data across many climatic conditions (sampled over space and time), the general associations between abiotic conditions and phenological behavior can be assessed. Multivariate statistical analyses should be able to detect likely causal relationships between rainfall, temperature, soil type and the timing and duration of phenological events. Using CPP data collected in association with precipitation data during a given season, 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.

6.2 Statistical Analysis

Data analyses to address the research questions stated above are anticipated to be carried out by future project coordinators and collaborators. Generally, hierarchical linear models have been used to determine the relative influences of climatic and biogeographic factors influencing phenological responses, between and within species (e.g. Both et al. 2004, Crimmins et al. 2010, Cook et al. 2012, Tierney et al. 2013). This is particularly useful when the goal is to quantify change in phenology through time over a long-term record (e.g. shifts in the onset of a phenophase by number of days per year), temperature (e.g. shifts in phenology relative to maximum Spring temperature), or precipitation (e.g. shifts in phenology relative to millimeters of Winter rainfall). Climatic variables of interest include maximum and minimum temperatures and precipitation, whereas biogeographical variables of interest include elevation, aspect, and latitude. Simulated data that matches the characteristics of the existing data and climate trends may be used in instances where data is not sufficient in a particular region. Specific statistical analyses and tools to address these questions will be determined by the nature of focal research questions and from consultation with quantitative ecologists who have expertise in analyzing complex phenological data. These analyses will be carried out by integrating data from *all* parks, in addition to sites outside the NPS system that collect data on CPP target taxa, particularly for species that occur in multiple parks and biogeographic regions.

References

Both, C., A. V. Artemyev, B. Blaauw, R. J. Cowie, A. J. Dekhuijzen, T. Eeva, A. Enemar, L. Gustafsson, E. V. Ivankina, A. Jarvinen, N. B. Metcalfe, N. E. I. Nyholm, J. Potti, P. A. Ravussin, J. J. Sanz, B. Silverin, F. M. Slater, L. V. Sokolov, J. Torok, W. Winkel, J. Wright, H. Zang, and M. E. Visser. 2004. Large-scale geographical variation confirms that climate change causes birds to lay earlier. Proceedings of the Royal Society B-Biological Sciences 271:1657-1662.

Cook, B. I., E. M. Wolkovich, and C. Parmesan. 2012. Divergent responses to spring and winter warming drive community level flowering trends. Proceedings of the National Academy of Sciences. 109: 9000-9005.

Crimmins, T. M., M. A. Crimmins, and C. D. Bertelsen. 2010. Complex responses to climate drivers in onset of spring flowering across a semi-arid elevation gradient. Journal of Ecology 98:1042-1051.

Mazer, S. J., A. G. Evenden, and K. A. Thomas. 2010. Workshop Report: Scientific Framework for California Phenology Project (CPP). Available at: https://www.usanpn.org/cpp/sites/www.usanpn.org.cpp/files/u5109/CPPScientificFrameworkWorkshopReport.pdf (accessed 1 January 2013).

Tierney, G., B. Mitchell, A. Miller-Rushing, J. Katz, E. Denny, C. Brauer, T. Donovan, A. D. Richardson, M. Toomey, A. Kozlowski, J. Weltzin, K. Gerst, E. Sharron, O. Sonnentag, F. Dieffenbach. 2013. Phenology monitoring protocol: Northeast Temperate Network. Natural Resource Report NPS/NETN//NRR—2013/681. National Park Service, Fort Collins, Colorado.

SOP11: Revision Process

Version 1

Revision History Log:

Version #	Revision Date	Author	Changes Made	Reason for Change

Overview

Due to the dynamic nature of this monitoring program, it is likely that revisions and additions to the protocol will be necessary as additional parks join the network and as currently participating parks expand and modify their programs. This may be challenging due to the fact that this is a multi-park effort with diverse programs being carried out at individual parks, each of which follow slightly different models for: (a) project implementation with respect to volunteer training and involvement and (b) the sampling design employed to best fit the park-specific resources and goals. Thus, it is important to have a single coordinated effort among CPP parks, which assign representatives to streamline and agree upon protocol revisions. The general revision process for the protocol and associated documents (e.g., park-specific monitoring guides) is outlined below.

I. Revisions to the Protocol

Revision to the CPP Protocol, SOPs, and other supporting material will take place every 3-5 years; the CPP is currently seeking funding to support the revision process. The project coordinator from each park (or a representative chosen by the park coordinator) will convene to discuss and agree upon:

1. Updates to the protocol and associated documents (e.g., SOPs and park-specific monitoring guides)
2. Task assignments and roles, including writing, revision, communication, and upload of the revised protocol to the CPP website and IRMA repository.

Representatives from participating parks may meet in person, if funding is available, or in a series of webinars or conference calls. The revision process should take no more than 12 months from start to finish. The current version of the CPP Protocol will be electronically available for download (all active and previous versions of the protocol will be archived on the CPP website: www.usanpn.org/cpp).

The CPP Protocol, SOPs, and other supporting information contain version numbers and include a revision history log which will document changes, revision dates, and authors of revisions. Version numbers will be incremented by a whole number (e.g., Version 1.30 to 2.00) when a change is made that significantly affects requirements or procedures. Version numbers will be incremented by decimals (e.g., Version 1.06 to Version 1.07) when there are minor modifications that do not affect requirements or procedures included in the protocol. Rows should be added as needed to the revision tables at the beginning of each SOP for each change or set of changes tied to an updated version number.

II. Revisions to the Park-specific Monitoring Guides

Park-specific monitoring guides will be updated on a more frequent basis, ideally on an annual schedule. The primary purpose of updating these guides will be to document changes to the monitoring infrastructure (plants and sites monitored) and to update the maps. These revisions should be made available on the CPP website. The park coordinator is responsible for carrying out or assigning tasks for the revisions to the park-specific guides as well as uploading files to the CPP website

Parks that need to build a guide from scratch should consult other park-specific guides available on the CPP website for the recommended format. The park-specific monitoring guides also contain version numbers and a revision history log to document changes, revision dates, and author of revisions. Version numbers will follow the same recommendations as those described above for the protocol.

NPS 963/123655, February 2014

National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science
1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525

www.nature.nps.gov

EXPERIENCE YOUR AMERICA ™