TOS PROTOCOL AND PROCEDURE: PHE – PLANT PHENOLOGY

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Change Record

REVISION	DATE	ECO #	DESCRIPTION OF CHANGE
A_DRAFT	10/03/2011	ECO-00280	Initial draft release
B_DRAFT	01/10/2014	ECO-01138	Draft release, updates from field season
C	03/25/2014	ECO-01666	Production release, template change, and other changes as detailed in Appendix C (rev C only)
D	04/10/2014	ECO-01792	Updated Appendix E with site-specific information
E	10/02/2014	ECO-02334	Migration to new protocol template
F	02/24/2015	ECO-02568	Added three new growthForms, growthForm definitions, updated frequency table
G	08/24/2015	ECO-03047	Protocol baseline. Removed phenophase codes throughout (except in Appendix), updated images, added measurement tolerances. Minor clarifications.
H	02/09/2016	ECO-03489	• Addressed error in Table B.1, added reference to foliar chemistry protocol for tissue collection. • Clarified growth form definitions, clarified sampling triggers in Table 1. • Updated colored leaves and colored needles phenophase descriptions and intensity question.
J	03/06/2017	ECO-04337	• Re-organized section 4.1 for clarity • Added Phenocam specific steps to SOP C • Added Appendix F: example sampling schedule at an arid site. • Added Appendix G: steps for dealing with phenocam plots that are constrained by site boundary. • Specified thresholds of % of individuals transitioning phenophases to trigger frequency changes. • Added steps for selection and mapping of phenocam individuals. • Replaced diseaseStatus with plantStatus in annual data collection. • Added species, growth form, and sampling strategies to Appendix E. • Added option for larger patch size for woody species.
K	03/16/2018	ECO-05320	• Added new growth forms, evergreen broadleaf – no leaves, evergreen broadleaf – no leaf buds. • Clarified measurement of % in patches.

REVISION	DATE	ECO #	DESCRIPTION OF CHANGE
			• Removed reference to NEON WebUI. • Clarified sampling interval for each specified frequency. • Added fulcrum app names to appropriate SOPs. • Added phenocam GPS data folder location. • Added term definitions for phenology db selectionStatus. • Added new Appendix D scheduling table.
L	12/19/2018	ECO-05944	• Reformatted Table of Contents. • Removed obsolete RD for ATBD. • Added description of scheduling for phenocam plots located in different sampling area from primary transect. • Acknowledged that mid-season low frequency sampling may be skipped at sites with short growing season. • added detail to table 3 contingent decisions for sampling delays. • Re-organized SOP C.. • Added new procedure for selecting Phenocam individuals. • Clarified that seasonal drop is optional and not appropriate for all scenarios. • Added information about Field Observations vs. Ingest app load delays. • Updated error reporting instructions. • Added references for MODIS datasets. • Updated schedule dates for all sites utilizing MODIS data. • Added field QA checklist to Appendix B. • Added new species to Appendix E. • Added site specific Phase I and Phase II dates to Appendix E.
M	03/30/2021	ECO-06522	• Partial move to new template. • Revised Falling leaves phenophase definition, Appendix A. • Added new Phase I/II schedule to Appendix C. • Added Phase II species to Appendix D.

REVISION	DATE	ECO #	DESCRIPTION OF CHANGE
N	02/08/2024	ECO-07043	• Migrate to protocol template rev L • Updated NEON logo • Added phe phot SOP and site management protocol to Reference documents. • Added semi-evergreen forb growth form. • Split high frequency seasonal sampling intervals into core and gradient sites based on optimization. • Clarified phase II sampling schedules. • Added guidance to redistribute bouts from brief dormant periods at year-round sampling sites to spring transitions. • Added guidance for adding new species to Phenology DB fulcrum application. • Added 0.5m x 0.5m patch size option. • Updated Fulcrum download step. • Split establishment into initial and annual steps. • SOP B.2 - Added option to shift patch location to track target species. • SOP C.6 - Added fields to capture data on dioecious species. • SOP D.2 - Added plantStatus and internalRemarks. • SOP E.2 - Move annual measurement date to child level, add eventID to parent. • SOP E.2 - added plantStatus options. • SOP E.2 - clarified average height for individuals. • Appendix A - Added fruiting phenophase to summary and definitions. • Appendix C - Added phase II schedule with updated MODIS data. • Appendix D - updated species lists.

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1 OVERVIEW

1.1 Background

NEON plant phenology measurements record the seasonal progression of critical biological processes and the timing of ecological events. The NEON phenology measurements track sensitive and easily observed indicators of biotic responses to climate variability by recording and monitoring the timing and duration of phenological stages in plant communities. Phenology (a branch of science focused on relationships between climate and the seasonal timing of biological phenomena, such as bird migration and blooming dates) is one of the most sensitive and easily observed indicators of biotic response to climate variability. Plant phenology is affected by forces such as temperature, timing and duration of pest infestations and disease outbreaks, water fluxes, nutrient budgets, carbon sequestration, and food availability.

NEON employs status-based monitoring in which the phenological condition of an individual is reported any time that individual is observed. At every monitoring bout, records are generated for every phenophase that is occurring as well as for every phenophase not occurring. This approach is a departure from many historical phenological monitoring protocols, but has the advantage that events (such as leaf emergence in Mediterranean climates, or flowering of many desert species) that may occur multiple times during a single year, can be captured. Status monitoring also allows the explicit quantification of uncertainties in phenophase transition dates that are introduced by monitoring in discrete temporal bouts. Additionally, continuous reporting of phenophase status enables quantification of the duration of phenophases rather than just their date of onset.

1.2 Scope

This document provides a change-controlled version of Observatory protocols and procedures. Documentation of content changes (i.e. changes in particular tasks or safety practices) will occur via this change-controlled document, not through field manuals or training materials.

1.2.1 NEON Science Requirements and Data Products

This protocol fulfills Observatory science requirements that reside in NEON's Dynamic Object-Oriented Requirements System (DOORS). Copies of approved science requirements have been exported from DOORS and are available in NEON's document repository, or upon request.

Execution of this protocol procures samples and/or generates raw data satisfying NEON Observatory scientific requirements. These data and samples are used to create NEON data products, and are documented in the NEON Scientific Data Products Catalog (RD[03]).

1.3 Acknowledgments

This protocol is based largely on those defined by the USA National Phenology Network *(Denny et al. 2014)*; where pertinent (e.g., phenophase definitions, recommendations for marking plants), descriptive material has been taken directly from their Nature's Notebook online monitoring program (www.usanpn.org/natures_notebook). The overall sampling framework was developed by the NEON plant phenology technical working group (AD[06]).

2 RELATED DOCUMENTS AND ACRONYMS

2.1 Applicable Documents

Applicable documents contain higher-level information that is implemented in the current document. Examples include designs, plans, or standards.

AD[01]	NEON.DOC.004300	EHS Safety Policy and Program Manual
AD[02]	NEON.DOC.004316	Operations Field Safety and Security Plan
AD[03]	NEON.DOC.000724	Domain Chemical Hygiene Plan and Biosafety Manual
AD[04]	NEON.DOC.050005	Field Operations Job Instruction Training Plan
AD[05]	NEON.DOC.004104	NEON Science Data Quality Plan
AD[06]	NEON.DOC.000907	TOS Science Design for Plant Phenology
AD[07]	NEON.DOC.000912	TOS Science Design for Plant Diversity

2.2 Reference Documents

Reference documents contain information that supports or complements the current document. Examples include related protocols, datasheets, or general-information references.

RD[01]	NEON.DOC.000008	NEON Acronym List
RD[02]	NEON.DOC.000243	NEON Glossary of Terms
RD[03]	NEON.DOC.002652	NEON Data Products Catalog
RD[04]	NEON.DOC.001271	AOS/TOS Protocol and Procedure: DMP – Manual Data Transcription
RD[05]	NEON.DOC.001578	Datasheets for TOS Protocol and Procedure: Plant Phenology
RD[06]	NEON.DOC.003282	NEON Protocol and Procedure: SIM – Site Management and Disturbance Data Collection
RD[07]	NEON.DOC.000987	TOS Protocol and Procedure: VST – Measurement of Vegetation Structure
RD[08]	NEON.DOC.014042	TOS Protocol and Procedure: DIV – Plant Diversity Sampling
RD[09]	NEON.DOC.001324	Phenology quadrat assembly instructions
RD[10]	NEON.DOC.000987	TOS Protocol and Procedure: CFC – Canopy Foliage Sampling
RD[11]	NEON.DOC.003564	NEON Standard Operating Procedure: Plant Voucher Specimen Preparation
RD[12]	NEON.DOC.001025	TOS Protocol and Procedure: PLT – Plot Establishment
RD[13]	NEON.DOC.005369	TOS Standard Operating Procedure: PHE – In Situ Phenophase Observation Photos
RD[14]	NEON.DOC.003282	NEON Protocol and Procedure: SIM – Site Management and Disturbance Data Collection

2.3 Acronyms

Acronym	Definition
DBH	Diameter at breast height (130 cm)
Ddh	Diameter at decimeter height (10 cm)
GPS	Global Positioning System

MDD	Main Drop Down (menu icon on GPS receiver)
SDD	Sub Drop Down (menu icon on GPS receiver)

2.4 Definitions

Cactus - Any member of the family Cactaceae; plants typically have succulent stems and branches with scales or spines instead of leaves.

Deciduous broadleaf (DBL)– Woody plants bearing flat leaves and dormant buds that are large enough to observe; leaves present during growing season then senesce and fall off during dormant periods (typically winter).

Deciduous conifer (DC)- Cone bearing trees; needles last through a single growing season then senesce and fall off during dormant periods.

Drought deciduous broadleaf (DDB)- Dryland-adapted woody plants bearing flat leaves and dormant leaf buds that are too small to observe; leaves may be evergreen in most years or may regularly senesce and drop during dry periods; leaf tissue growth starts and stops opportunistically so a typical "full" leaf size is hard to identify.

Evergreen broadleaf (EBL)- Woody plants bearing flat leaves; leaves may persist for multiple growing seasons, no distinct dormant period.

Evergreen broadleaf – no leaf buds (EBL-NLB)- Woody plants bearing persistent flat leaves that lack dormant, leaf buds.

Evergreen broadleaf - no leaves (EBL-NL)- Woody plants with no distinct dormant period; leaves may be inconspicuous, not present or leaf phenophase transitions are not easily observable and so are not reported.

Evergreen conifer (EC) - Cone bearing plants where needles spread apart during stem elongation (unlike members of the genus *Pinus*); needles persist for multiple growing seasons.

Evergreen conifer – no needles (EC) - Cone bearing plants, typically in the family Cupressaceae, that do not produce dormant overwintering buds and for which annual growth cannot be easily assessed.

Evergreen forb (EF) - Non-woody forbs with aboveground leaf or leaf-like structures that persist for multiple years.

Forb - Annual, biennial, and perennial herbaceous flowering plants and sub-shrubs with no aboveground woody structures; typically die back to the ground in dormant periods.

Fulcrum: Software tool used to create NEON electronic data entry applications.

Graminoid (GRS) - Grasses and grass-like plants; includes all members of the families Poaceae (true grasses), Cyperaceae (sedges), and Juncaceae (rushes).

Growth Form - grouping variable for species with similar life histories. These categories define the applicable phenophases and phenophase intensities for observations and are consistent with the 'plant functional groups' defined by the USA National Phenology Network.

Phenophase - An observable stage or phase in the annual life cycle of a plant or animal that can be defined by a start and end point (definition from USA National Phenology Network).

Pine - Cone bearing plants of the genus *Pinus*; needles, bundled in sets of 1-6, spread apart after stem (candle) elongation; needles persist for multiple growing seasons.

Semi-evergreen broadleaf (SEB) - Woody plants bearing flat leaves and dormant leaf buds that are large enough to observe; leaves are typically evergreen in mild climates but may senesce and drop leaves in more extreme condition or under stress conditions in certain years. This growth form includes phenophases from both deciduous and evergreen growth forms to accommodate the variability in the species across years and geographic region.

Semi-evergreen forb: Non-woody forbs with aboveground leaf or leaf-like structures that are typically evergreen in mild conditions but may die back to the ground in more extreme parts of their range or under stress conditions in certain years.

ServiceNow: Software tool used for problem/incident tracking and resolution.

3 METHOD

NEON Science will use analyses of site-specific species abundance to determine target phenology species at each site. The strategy for phenology sampling is divided into two phases over the life of the Observatory. The first phase focuses on the phenology of dominant species and will last for the first three years of Observatory Operations (i.e., 2018-2020). Sites will transition to Phase II, community sampling in 2021 or after the site has completed three full years of observations, whichever is later (8Appendix C). Typically, the first year of protocol implementation is only a partial year. Establishment will occur in the preceding year (2020, at many sites, see Appendix C for site specific dates) so that the first sampling year will be a full season.

Phase I: Phenology of Dominant Species-

- Three dominant species are selected at each site based on a quantitative survey of the relative abundance of plant species in the tower airshed.
    - In sites with no overstory canopy, the three species with the greatest % cover shall be selected.
    - In sites with a distinct overstory, but <50% canopy closure, the single most abundant overstory species shall be selected along with the two most abundant understory species.
    - At sites with >50% canopy closure, the two most abundant overstory species shall be selected, along with the single most abundant understory species.

Phase II: Community Phenology-

Up to 20 species are selected at each site based on a combination of relative abundance and research interest. These species include:

- The three dominant species from Phase I.
- Any species present already targeted by an existing phenology monitoring network (USA-NPN), and
- Species identified according to relative abundance based on quantitative surveys of plant community in the tower airshed.

Target species will be observed from multiple points along a fixed transect; observations will be made on either an individual plant (e.g., a single tree, shrub or bunch grass), or in the case of low growing herbaceous species or dense continuous cluster of woody plants, on a representative patch of the target species (e.g., mat forming annual grasses, wild strawberry or salal thickets). In the first phase, a target of thirty replicates for each selected species shall be marked for regular observation. In the next phase, a more diverse suite of species will be monitored at each site with fewer replicates per species. In this phase the target number of species is 20 with 5 replicates each. In some cases, the total number of

species monitored may be constrained by diversity at the site (e.g. in agricultural setting it is likely that only one species will be monitored at a time). The total number of individuals shall not exceed 100 and the replicates of any given species shall not exceed 30. The basic sampling protocol, however, will remain the same.

For sites where the tower phenocam field of view does not cover the phenology transect, NEON crews will select and mark an additional 3 individuals of each dominant species within the phenocam view to make explicit linkages between phenocam greenness metrics and *in situ* phenophase observations. In these cases, a secondary phenology plot will be established to the north of the tower, outside the required disturbance buffer zones but within the field of view of the phenocam; additional individuals will be selected for monitoring from within this designated area. Selection of additional individuals to monitor will occur once processed phenocam images become available (**Figure 1**).

The NEON plant phenology protocol consists of three procedures, which are assumed to begin following plot establishment (see RD[12]):

- Initial selection of individuals/patches for phenological monitoring (occurs twice/site for perennial plants, once/season for annual plants)
- Collection of phenology status per monitored individual/patch
- Collection of annual data (location, size) on monitored individuals

Refer to RD [07] for details on phenology transect delineation, placement of permanent markers and steps for annual establishment of the loop.

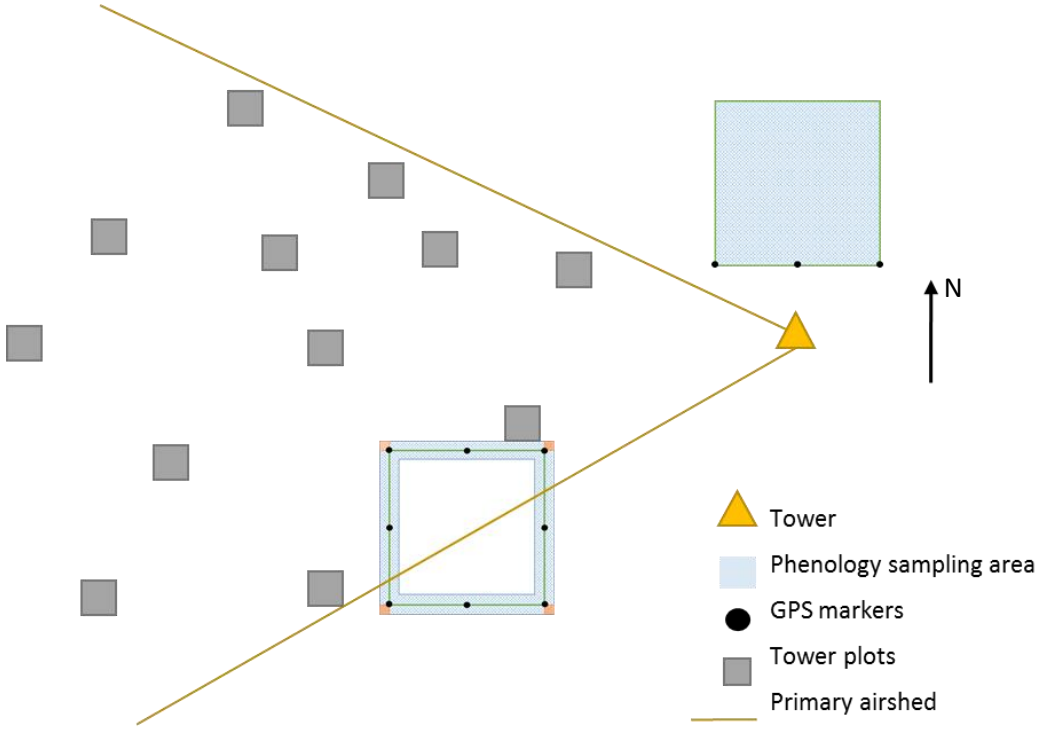


Figure 1. Generic site layout for plant phenology including the primary transect (lower left) and phenoCam plot (top right) in relation to Tower plots and primary airshed.

Standard Operating Procedures (SOPs), in Section 7 of this document, provide detailed step-by-step directions, contingency plans, sampling tips, and best practices for implementing this sampling procedure. To properly collect and process samples, field technicians **must** follow the protocol and associated SOPs. Use NEON's problem reporting system to resolve any field issues associated with implementing this protocol.

The value of NEON data hinges on consistent implementation of this protocol across all NEON domains, for the life of the project. It is therefore essential that field personnel carry out this protocol as outlined in this document. In the event that local conditions create uncertainty about carrying out these steps, it is critical that technicians document the problem and enter it in NEON's problem tracking system.

Quality assurance is performed on data collected via these procedures according to the NEON Science Data Quality Plan (AD[05]).

4 SAMPLING SCHEDULE

4.1 Sampling Frequency and Timing

Table 1. Sampling frequency for Plant Phenology procedures on a per SOP per plot type basis.

SOP	Plot Type	Plot Number	Bout Duration	Bouts Per Year	Bout Interval	Remarks
SOP B: marking the primary transect	Tower	1-2	1 day	1 x per site	Variable	Occurs 1x per plot per site.
	Distributed	NA	NA	NA	NA	Distributed and Gradient plots are not sampled for this protocol.
SOP C: Selecting individuals and patches	Tower	1-2	1 day	1	1 x	Occurs 1x per plot per phase if all species are perennial. Occurs every year or episodically if annual species monitored or management activities dictate.
SOP D: Collecting phenophase observations	Tower – Year round sampling	1-2	2 hrs	~ 50	1 w	1 x / week all year with option to reallocate bouts from limited dormant season to spring transition
	Tower – Seasonal Core	1-2	2 hrs	~ 50	2 d – 2 w	Dynamic frequency - depends active phenophase.
	Tower – Seasonal - Gradient	1-2	2 hrs	< 50	1 w – 2 w	1x/wk during seasonal transitions, reduced to 1x/2wks mid-season
	Tower – Hybrid (phase I only)	1-2	2 hrs	~ 50	2 d – 1 w	Year-round sampling with adaptive frequency based on episodic periods of growth.
SOP E: Collecting annual data	Tower	1-2	1 day	1-3	1 y	> 1 bout optional to capture optimal timing for each growth form; each individual is only measured once per year.

All individuals/patches selected for phenology monitoring within a site will be monitored with the same frequency; the primary transect and the phenocam plot will be monitored on the same schedule unless the primary transect and phenocam plot are in different locations (i.e. not both near the NEON tower).

Phase I Sampling schedules are either: 1) year-round, 2) seasonal, or 3) hybrid.

Phase II Sampling schedules are either: 1) year-round, 2) seasonal – core, or 3) seasonal – gradient.

Year-round sampling schedule. At sites with limited or no pronounced dormant season (e.g., tropical, southeast), or > 1 growing season/year (e.g., desert southwest), observation bouts will occur throughout the entire year at a frequency of 1x/ week. Sampling may be cancelled at year-round sites during brief dormant periods when none of the tagged individuals/patches are phenologically active (i.e., all phenophase statuses = 'no' due to drought or temperature related drivers).

Seasonal sampling schedule. At sites with well-defined, discrete, growing seasons, the seasonal sampling frequency varies to capture rapid changes during phenological transition periods. In phase II, seasonal sampling schedule differs between core and gradient sites. At both site types, the sampling season begins with at least one observation each year within 7 days prior to the onset of springtime activity (variably defined as breaking leaf buds, breaking needle buds, emerging needles, or initial growth; see column 2 in Table 2). Pre-season weekly sampling begins one to two weeks in advance of anticipated leaf/flower bud break, based on MODIS-EVI green up data or data from previous years' sampling at the site. Intensive sampling (3x/week in Phase I, 2x/week in Phase II at Core sites, 1x/week in Phase II at Gradient sites) occurs in conjunction with the onset of springtime phenological activity and continues through the early spring development. Once >50% of leaf/canopy development has occurred sampling can be reduced to once a week until full canopy has developed. Post 95% canopy development, sampling is further reduced to once every other week until reproductive phenophases are complete. A second intensive stage (2x/week in Phase I and phase II at Core sites, 1x/week in Phase II at Gradient sites) begins with the first colored leaf or needle indicating seasonal senescence and continues until all individuals show some sign of fall color change then reduces to once a week through the end of the season. It is not uncommon for sites with short growing season to skip mid-season low frequency sampling intervals because phenophase intensity triggers are not met.

Hybrid sampling schedule. Some sites, including arid or semiarid sites, driven by moisture rather than temperature, or sites where plants do not typically hit the seasonal frequency triggers, are particularly difficult to schedule in advance and do not progress in predictable fashion throughout the year. Such sites may be sampled according to a hybrid schedule. Sampling dates and frequency may be more episodic, but sampling should have the same goal as the seasonal sampling schedule of increasing frequency during periods of rapid change, but are flexible to start and end sampling multiple times throughout the year. One example of a hybrid sampling schedule is starting with year round regular sampling (1x/week), increasing frequency during periods of growth, then dropping to <1x/week during dormant periods (see Appendix E for an example schedule from a semiarid site). The varied intensity is intended to strategically use sampling periods in order to monitor phases of rapid phenological change,

while minimizing labor/disturbance associated with frequent measurements during times of less rapid change or inactivity and still targeting total number of bouts to 50 per year (**Table 2**). A hybrid sampling schedule requires greater flexibility to modify sampling schedule based on local conditions at the site.

Field ecologists are required to record phenological observations on all individuals, on both the primary transect and within the phenocam plot, each time monitoring is performed, unless the end-of-season phenophase/trigger has been reached for a particular individual (seasonal sampling schedule only), in which case, monitoring of that individual is not required for the remainder of the season.

Timing of monitoring bouts based on specified frequency is as follows:

- When sampling at 3x a week frequency, monitoring bouts should be separated by 1-2 days on which bouts are not scheduled. An ideal schedule for 3x/week sampling is Monday, Wednesday, Friday bouts.
- When sampling at 2x a week frequency, monitoring bouts should be separated by 2-3 days on which bouts are not scheduled. For example, if sampling 2x/ week, if first bout is on Monday, the next acceptable day to sample is Thursday or Friday.
- When sampling at 1x a week frequency, monitoring bouts should be 6-9 days apart. Sampling on the same day each week during 1x/week frequency will achieve the appropriate interval.
- When sampling 1x every other week, monitoring bouts should be 10-18 days apart.
- Regardless of sampling frequency, bouts should not be conducted on consecutive days.

Sampling schedule is determined by Field Operations staff in coordination with Science, and is based on local conditions with consideration for the timing and annual patterns of plant growth at the site (**Table 12**).

At sites where the primary transect is not located in the Tower Airshed and is instead collocated with Distributed plots, it may not be practical to observe both the primary transect and individuals in the phenocam plot during the same field visit bout. In this scenario the schedule for each may be decoupled; conduct observation bouts on the primary transect as described above and make observations on the phenocam plot opportunistically when field ecologists are visiting the Tower or Tower Airshed for other activities (e.g. LAI measurements, or regular Tower maintenance).

4.1.1 Priorities for Scheduling Observation Bouts

1. Capture the entire growing season. – It is essential that within a given growing season, monitoring bouts begin *before* early season activity (breaking leaf buds, breaking needle buds, emerging needles, or initial growth) and continues until individuals/patches return to dormancy.
2. Increase observation frequency to capture leaf phenophase transitions. - High frequency bouts are targeted to capture transition dates and characterize rate of change for leaf development phenophases.

3. Capture timing of flower and fruit development. *Note: Flower buds that break before leaf buds do not trigger three times a week sampling frequency; in this situation, sampling frequency should be once a week until leaf bud break occurs.*

4.1.2 Site Specific Modifications to Prescribed Sampling Schedule

To keep phenology monitoring within logistical constraints, Field Operations staff should first select a sampling strategy that matches the site conditions (year round, seasonal, hybrid (phase I only), seasonal – core (phase II only), or seasonal – gradient (phase II only). See **Table 14**) then coordinate with Science to adjust schedule as needed to keep the total number of bouts to approximately 50 per year. Sites most at risk of exceeding the 50 bout target are those that have a seasonal sampling schedule and extended growing seasons or are observing species whose phenology do not align (i.e. leaf development occurs at different times in each species leading to extended periods of increased frequency to capture spring transition). Whenever possible, observed phenology should be the driver of monitoring frequency, not absolute number of monitoring bouts or the scheduled observation bouts. However, the realities of resource limitations may, in some cases, require deviation from the frequency guidelines provided in this protocol.

The preferences for how to eliminate bouts if necessitated by logistics are as follows:

- Consider if year-round sampling is warranted (i.e. there is no clear dormant season).
- Eliminate mid-season bouts intended to capture open flower to prioritize capturing the full growing season.
- Reduce 3x/week early season frequency to 2x/week.

In Phase II, high frequency sampling drops from 3x/week to 2x/week at core sites, and drops to 1x/week at gradient sites to accommodate extended spring transitions and logistical complications associated with the increased number of species. Some sites switch from seasonal sampling to year- round sampling in Phase II to accommodate an extended growing season resulting from the increased number of species.

Table 2. Rule sets for specific growth forms for phenology sampling at sites with a well-defined growing season (i.e. seasonal, season – core, seasonal - gradient or hybrid schedules only)[1]

Growth form	Monitor indicator individual for:	Sample high frequency interval (3, 2 or 1x/week) until all tagged individuals of a given species show[2, 3]:	Sample 1x/week until all tagged individuals of a given species show[3]:	Then[4]:	Then:	Sample 1 or 2x/week until all individuals show[5]:	Sample 1x/week until[3]:	Then:
Cactus	Breaking flower buds	NA	End sampling season when no more fresh flowers are present	NA	NA	NA	NA	NA
Deciduous broadleaf	Breaking leaf or flower buds[2]	>50% of canopy is full with leaves or three consecutive bouts of no change	95% or more of canopy is full with leaves OR three consecutive bouts with no change	Commence every-other week monitoring for open flowers	Monitor indicator individuals for one or more colored leaves	One or more colored leaves	<5% of canopy full with green or colored leaves OR three consecutive bouts with no change	End sampling season
Deciduous conifer	Breaking needle buds	>50% of canopy is full with needles or three consecutive bouts of no change	95% or more of canopy is full with needles OR three consecutive bouts with no change	Commence every-other week monitoring for open pollen cones	Monitor indicator individuals for one or more colored needles	One or more colored needles	<5% of canopy full with green or colored needles OR three consecutive bouts with no change	End sampling season

Growth form	Monitor indicator individual for:	Sample high frequency interval (3, 2 or 1x/week) until all tagged individuals of a given species show[2, 3]:	Sample 1x/week until all tagged individuals of a given species show[3]:	Then[4]:	Then:	Sample 1 or 2x/week until all individuals show[5]:	Sample 1x/week until[3]:	Then:
Drought deciduous broadleaf	Breaking leaf buds	Young leaves	No more young leaves	Commence every-other week monitoring for open flowers	Monitor indicator individuals for one or more colored leaves[6]	One or more colored leaves	<5% of canopy full with green or colored leaves OR three consecutive bouts with no change	End sampling season
Evergreen Broadleaf	Breaking leaf buds	Young leaves	No more young leaves	Commence every-other week monitoring for open flowers	End sampling season when no more fresh flowers are present	NA	NA	NA
Evergreen Broadleaf – no leaf buds	Young leaves	NA	No more young leaves	Commence every-other week monitoring for open flowers	End sampling season when no more fresh flowers are present	NA	NA	NA
Evergreen broadleaf - no leaves	Breaking flower buds	NA	End sampling season when no more fresh flowers are present	NA	NA	NA	NA	NA
Evergreen conifer	Breaking needle buds	Young needles	No more young needles	Commence every-other week monitoring for open pollen cones	End sampling season when no more fresh pollen cones are present	NA	NA	NA

Growth form	Monitor indicator individual for:	Sample high frequency interval (3, 2 or 1x/week) until all tagged individuals of a given species show[2, 3]:	Sample 1x/week until all tagged individuals of a given species show[3]:	Then[4]:	Then:	Sample 1 or 2x/week until all individuals show[5]:	Sample 1x/week until[3]:	Then:
Evergreen conifer – no needles	Pollen cone development	NA	End sampling season when no more fresh pollen cones are present	NA	NA	NA	NA	NA
Evergreen forb	Breaking leaf buds	Young leaves	No more young leaves	Commence every-other week monitoring for open flowers	End sampling season when no more fresh flowers are present	NA	NA	NA
Forb	Initial growth	One or more fully unfolded leaves	NA	Commence every-other week monitoring for flowering phenology	Monitor indicator individuals for evidence of senescence	NA	No more full sized leaves are present OR three consecutive bouts with no change	End sampling season
Graminoid	Initial growth	>50% of plant is green or three consecutive bouts of no change	>95% of plant is green OR three consecutive bouts with no change	Commence every-other week monitoring flowering phenology	Monitor indicator individuals for >5% Leaf senescence (i.e., percentage of plant that is green <95%)	<95% green leaves	<5% of plant is green OR three consecutive bouts with no change for ≥90% of individuals	End sampling season

Growth form	Monitor indicator individual for:	Sample high frequency interval (3, 2 or 1x/week) until all tagged individuals of a given species show[2, 3]:	Sample 1x/week until all tagged individuals of a given species show[3]:	Then[4]:	Then:	Sample 1 or 2x/week until all individuals show[5]:	Sample 1x/week until[3]:	Then:
Pine	Emerging needles or pollen cone development	Young needles	No young leaves	Commence every-other week monitoring for open cone	End sampling season when no more fresh pollen cones visible	NA	NA	NA
Semi-evergreen broadleaf[7]	Breaking leaf or flower buds[2]	Young leaves OR >50% of canopy is full with leaves OR three consecutive bouts of no change	No more young leaves OR 95% or more of canopy is full with leaves OR three consecutive bouts with no change	Commence every-other week monitoring for open flowers	Monitor indicator individuals for one or more colored leaves[5]	One or more colored leaves	<5% of canopy full with green or colored leaves OR three consecutive bouts with no change	End sampling season
Semi-evergreen forb[7]	Breaking leaf or flower buds[2]	No more young leaves	Commence every-other week monitoring for open flowers	End sampling season when no more fresh flowers are present	Monitor indicator individuals for evidence of senescence	NA	No more full sized leaves are present OR three consecutive bouts with no change	End sampling season

[1] This is an idealized sampling schedule and is generally applicable to temperate or boreal systems. Phenophase order may differ for some species or mid-season phenophases may be skipped completely at sites with short growing season if sampling reduction triggers are not met. Sites lacking a distinct growing season where growth occurs year-round or is episodic such that a growing season cannot be defined will be monitored on a weekly basis.

[2] If flowers/pollen release precede leaves in spring development, only increase sampling frequency to once a week until leaf bud break.

[3] Sampling may end or the frequency may be reduced if ≥90% of individuals have experienced 3 consecutive bouts of no change.

[4] If flowering phenology precedes leaf/needle bud break and development, skip the steps outlined in this column and decrease monitoring to watching indicator individuals for fall senescence or end monitoring for the season as specified in the following column.

[5] For sites with extended yet well-defined growing seasons, if increasing frequency just based on indicator individuals is likely to increase the total number of bouts to >50, the threshold for increasing frequency may be that 'once indicator individual displays trigger phenophase, commence 1x/week sampling until 10% of individuals of a given species on the transect transition, then increase to 2x/week sampling.

[6] Seasonal monitoring may end at this point if senescence does not occur.

[7] Semi-evergreen growth forms may be used for species in which life history varies with latitude.

4.2 Criteria for Determining Onset and Cessation of Sampling

The date of onset, sampling duration, and date of cessation for phenology monitoring varies by site and is based on the expected phenology of plant species at the site (**Table 3**).

To estimate start of season for each individual monitored, the first 'yes' record for early season phenophases (initial growth, breaking buds, emerging needles) must be preceded by, at minimum, one 'no' record; therefore, sampling must begin at least seven days *prior to the onset of spring phenology*. Start of sampling will be determined by Field Operations personnel and will differ across the Observatory on a regional and site-specific basis based on knowledge of the local flora and previous phenology data from the site. MODIS-EVI dates in Appendix C)provide the earliest recorded increase in greenness; in the absence of data from previous sampling years, this date provides an estimate of the earliest day of the year when phenology monitoring may begin but should be augmented by observations made at the site (i.e., near the NEON tower) on individuals of the selected phenology species at the site, hereafter referred to as the 'indicator' individuals. At some sites, spring transitions may occur prior to snow melt making definitive observation of the preceding 'no' impossible. In these cases, the first 'yes' may be preceded by one or more 'uncertain' observations.

The swelling of leaf buds and the separation of leaf bud scales will be monitored, throughout the dormant season, using the 'indicatordata' datasheet (RD[05]). Indicator individuals are monitored to help guide the start of seasonal sampling and to inform transition to fall monitoring frequency. There is no set frequency for monitoring indicator individuals, the only requirement is that indicator individuals must be capable of triggering monitoring of the primary transect such that a bout is completed *prior to phenophase transitions occurring on the transect* (i.e., one or more bouts of status='No' observations, for all individuals/patches, are recorded within 7 days of the first status='Yes'). One individual of each dominant species should be monitored opportunistically for phenological activity. Indicator individuals may be located near the NEON Tower or may be in a location demonstrating advanced phenology relative to individuals on the phenology transect; these individuals do not need to be tagged and data not recorded in Fulcrum, the data collection mobile application, but may be recorded on paper datasheets and maintained for internal tracking purposes. Regular phenology sampling begins when the indicator individuals display swelling leaf or flower buds and there is observable spreading of the leaf bud scales (if present). One strategy to address opportunistic monitoring for bud swell is to leverage regular tower maintenance visits; personnel responsible for maintaining the NEON tower would require cross-training on species identification and how to recognize swelling leaf or flower buds.

At temperate sites with defined growing seasons, sampling ends when all individuals reach the 'end sampling season' trigger (**Table 2**). Monitoring of graminoids and semi-deciduous growth forms that do not reach the < 5% live canopy trigger at the end of the growing season may end if ≥90% of individuals are monitored for three consecutive bouts with no observable change.

At sites with limited or no pronounced dormant season (e.g., tropical, southeast), or >1 growing season/year, sampling will take place year-round. As such, there is no specified onset or cessation of

sampling, though sampling may be temporarily discontinued during reliably cold or dry periods if all tagged individuals/patches have returned to dormancy.

Onset and cessation of sampling at sites with variable or multiple periods of growth each year, must be adaptable as timing will be determined by phenology and may not be limited to a pre-defined time of the year.

Table 3. Summary of onset and cessation criteria based on growing season.

Growing season	Onset of sampling	Cessation of sampling	Special considerations
Well defined-Seasonal schedule	Prior to spring phenological activity, directed by MODIS NDVI data, observations of indicator individuals, or based on data from previous years at the site	All individuals reach the 'end sampling season' trigger is reached (Table 1)	Monitoring of graminoids and semi-deciduous growth forms that do not reach the < 5% live canopy trigger at the end of the growing season may end if ≥90% of individuals are monitored for three consecutive bouts with no observable change.
Year-round schedule	No onset or cessation, observation bouts occur all year regardless of phenological activity.		Sampling bouts may be cancelled in response to brief, reliably cold or dry periods during which time all plants are dormant.
Multiple or unpredictable periods of growth – Hybrid schedule	Observation bouts may occur episodically throughout the year based on site specific drivers of phenological activity.	No specified 'end of season' trigger as growth periods may be episodic and occur multiple times in a given calendar year.	Bouts may be distributed as needed throughout the year, target total number of bouts is still 50 per calendar year

4.3 Timing for Laboratory Processing and Analysis

This protocol produces no samples for laboratory analysis, so no timing details are provided.

4.4 Sampling Timing Contingencies

- If field conditions are unsafe, stop work, record location along the phenology loop and resume phenology measurements as soon as possible.

- If sampling must be completed on a different day, begin sampling again from the start point of the transect loop.
- If sampling must be delayed for several days such that 1 or more planned sampling bouts are missed, resume as soon as possible. Be especially mindful of missed phenophase transitions and determine sampling frequency based on the phenology occurring when monitoring resumes.

At many sites, disturbance is a major factor shaping plant communities. If there is a disturbance at a site that affects most or all of the phenology transect (e.g., fire that kills aboveground vegetation, unseasonal freeze event that kills developing leaf buds) and resets the phenology to pre-spring (dormant) status, record disturbance in the remarks field of the Phenophase Observations mobile application for the date and individuals on which the disturbance was observed then drop frequency down to low level, once a week or once every other week depending on severity and monitor for regeneration within the field season. If a Site Management record has not yet been completed for the event, submit a new record according to RD[14]. Resume sampling frequency based on start of season guidelines (**Table 2**).

Table 4. Contingency decisions for Plant Phenology.

Delay/ Situation	Action	Outcome for Data Products
1 - 12 hours	Resume monitoring as soon as is feasible from last sampled location along transect.	None.
12 hours – 2 days	Resume monitoring as soon as is feasible from beginning of transect.	None.
2 days – 2 weeks	Resume monitoring as soon as is feasible.	Potential to miss phenophase transitions, increased uncertainty in estimate of transition dates.
2 weeks – 2 months	Resume monitoring as soon as is feasible.	Potential to miss multiple phenophase transitions, inability to estimate transition dates for missed phenophases.
> 2 months	Suspend phenology monitoring for the year following discussion with Science.	Estimation of transition dates for multiple phenophases for multiple species will not be possible.

4.5 Estimated Time

The time required to implement a protocol will vary depending on a number of factors, such as skill level, system diversity, environmental conditions, and distance between sample plots. The timeframe provided below is an estimate based on completion of a task by a skilled two-person team (i.e., not the time it takes at the beginning of the field season). Use this estimate as framework for assessing progress. If a task is taking significantly longer than the estimated time, a problem ticket should be

submitted. Please note that if sampling at particular locations requires significantly more time than expected, Science may propose to move these sampling locations.

Table 5. Estimated staff and labor hours required for implementation of Plant Phenology.

SOP	Estimated time	Suggested staff	Total person hours
SOP C: Selecting, Marking and Mapping Individuals/patches – Initial Phase I/II establishment	8 h	2	16 h
SOP C: Selecting, Marking and Mapping Annual re-establishment	4 h	2	8 h
SOP D: Collecting Phenophase Observations	2 h	2	4 h
SOP E: Collecting Annual Structure Data	4 h	2	8 h

5 SAFETY

This document identifies procedure-specific safety hazards and associated safety requirements. It does not describe general safety practices or site-specific safety practices.

Personnel working at a NEON site must be compliant with safe field work practices as outlined in the Operations Field Safety and Security Plan (AD[02]) and EHS Safety Policy and Program Manual (AD[01]). Additional safety issues associated with this field procedure are outlined below. The Field Operations Manager and the Lead Field Technician have primary authority to stop work activities based on unsafe field conditions; however, all employees have the responsibility and right to stop their work in unsafe conditions.

5.1 Laser Rangefinder Safety

A laser rangefinder/hypsometer/compass instrument is used to map individuals selected for phenology monitoring, and to measure various stem structural attributes. Safety considerations for this instrument include:

- Avoid staring directly at the laser beam for prolonged periods. The rangefinder is classified as eye-safe to Class 1 limits, which means that virtually no hazard is associated with directly viewing the laser output under normal conditions. As with any laser device, however, reasonable precautions should be taken in its operation. It is recommended that you avoid staring into the transmit aperture while firing the laser.
- Never attempt to view the sun through the scope. Looking at the sun through the scope may permanently damage the eyes.

5.2 Cactus Safety

The potential for injury exists when working with cacti due to the prevalence of spines. As a simple precautionary measure, avoid contacting cacti. Always wear personal protective equipment such as leather boots, long pants, long sleeves, and gloves, and remain cognizant of where you walk.

Most cactus-inflicted wounds should be treated like any other scratch or puncture, that is, cleaned then bandaged if necessary. Use a comb, tweezers, or adhesive to pick out spines that break off in the skin prior to treating the affected area.

Glochids that penetrate the skin may be difficult to extract because of their barbed shafts. To remove glochids, use tweezers or adhesives. Treat any remaining glochids as a wound, keep the area clean and covered to prevent dermatitis.

Segments of *Cylindropuntia* species break off easily and may become attached to footwear, clothing, or skin. To remove segments, use a comb or other solid object (i.e. Leatherman, rocks, etc.) to dislodge the

segment. Symbiotic bacteria living on cactus spines may cause inflammation, which typically subsides without treatment within a few days.

6 PERSONNEL

6.1 Training Requirements

All technicians must complete protocol-specific training as required in the Field Operations Job Instruction Training Plan (AD[04]). Additional protocol-specific required skills and safety training are described here. Assessment entails demonstrated understanding of procedures through written and observation-based evaluation.

6.2 Specialized Skills

Ability to identify regionally specific plants on sight or with a dichotomous key is required for the field ecologist who initially sets up the phenology loop and provides instruction and training to seasonal staff. Once individuals/patches to monitor have been selected and marked and a taxa-specific library of phenophase photos has been developed for each site, individuals without botany training can conduct surveys provided they are trained by a qualified trainer and that a botany lead is available to provide guidance and conduct periodic QA/QC checks in the field and of photos.

All staff conducting phenology observations must be able to recognize all applicable phenophases for species being monitored.

If no member of the field crew is able to identify individuals while they are dormant, contracts with a local botanist to identify and mark individuals for phenological sampling may be employed.

At least one field crew member is required to have hands-on training with the Trimble GPS receiver, TerraSync software, and GPS Pathfinder Office software.

7 STANDARD OPERATING PROCEDURES

SOP Overview

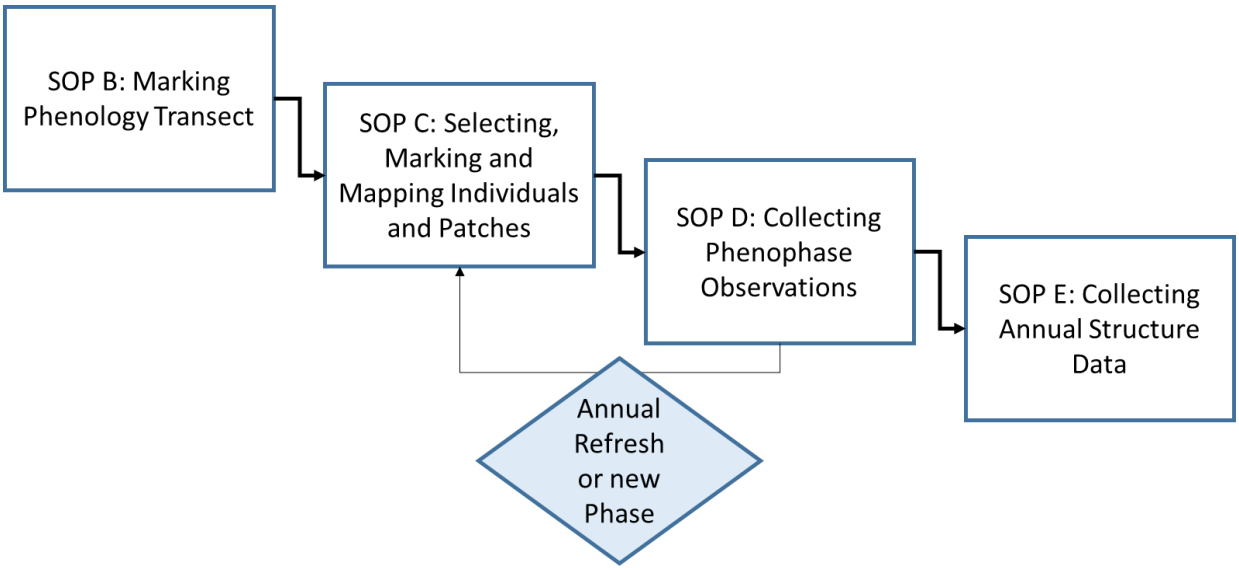


Figure 2. A high level workflow diagram that visually shows how the separate SOPs are sequentially connected.

SOP A: Preparing for sampling – Includes tasks to complete in the domain support facility prior to sampling.

SOP B: Marking phenology transect – Procedure for delineating and placing markers along phenology transect.

SOP C: Selecting, Marking and Mapping Individuals and Patches – Procedure for selecting individuals/patches and mapping relative locations.

SOP D: Collecting Phenophase Observations – Steps for conducting regular observation bouts.

SOP E: Collecting Annual Structure Data – Measurements of size and health of individuals/patches.

SOP F: Data Entry and Verification - Bout completion and QC follow up tasks completed at the domain support facility following field activities.

SOP A Preparing for Sampling

A.1 Preparing for Data Capture

Mobile applications are the preferred mechanism for data entry. Mobile devices should be fully charged at the beginning of each field day, whenever possible.

However, given the potential for mobile devices to fail under field conditions, it is imperative that paper datasheets are always available to record data. Paper datasheets should be carried along with the mobile devices to sampling locations at all times.

Prior to each field season, review pre-selected species for each site (Appendix D).

A.2 Preparing for Selecting Individuals

Initial species selection is based on characterization surveys completed in advance of regular sampling at each NEON site. Characterization data are used to create a list of species present at the site, ranked by relative abundance. This list is used to select species for phenology observation, and is available in the 'Phenology DB' Fulcrum application. Phase I species (3 dominant species) are monitored from initial establishment of the transect at a site until 3 years into the Operations phase of the Observatory; phase II species (n <=20 total) are then added and the number of replicate individuals per species is reduced (typically n=5, see AD[06] for additional detail).

1. If selecting individuals for the first time for either Phase I or Phase II sampling at a site, sync the 'Phenology DB' application on the mobile digital device that will be used in the field so the list of prioritized species is available:
    a. Refer to the National Phenology Network Species List in the Sampling Support Library (SSL) for growth form assignment of all species already monitored in the NPN network, or load this list to your mobile device for reference if needed.
    b. To add locally abundant species not captured in initial site characterization to the Phenology DB application, submit a ServiceNow ticket request. Before accepting the new species for Phase II observations, add an intuitive rank indicating the field staff assessment of relative abundance of the new species.
2. If mapping selected individuals within the phenocam plot, set up GPS receiver for collecting points. GPS collection will be a onetime event over the lifetime of the selected individual.
    a. Set up the Trimble GPS receiver following steps outlined in Appendix B in the Plot Establishment Protocol (RD[12])
    b. Import the "Phenocam_individuals.ddf" data dictionary following steps in A.4 (RD[12]).
        i. The Phenocam data dictionary will be available in the N:\Science\GISData\FOPS\DataDictionaries folder

3. To provide field linkages with the phenocam on the tower the phenocam plot is always placed within the phenocam field of view regardless of the site boundary.
    a. Check Appendix F to see if a portion of the phenocam plot falls outside of the site boundary and whether a different workflow is required to ensure phenocam individuals are selected in the permitted area.

A.3 Review Species-specific Resources and Gather Necessary Equipment

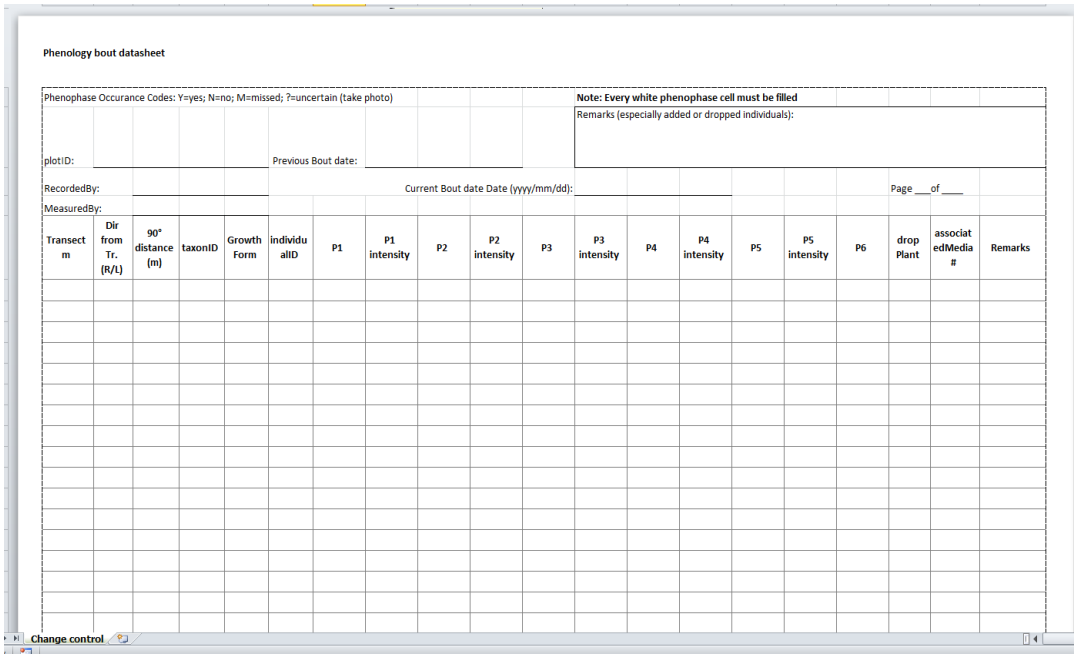
Locate sampling equipment prior to each data collection bout. If the site has species that will be monitored in 0.25 m x 0.25 m or 0.5 m x 0.5 m patches, and this is the first sampling bout or selection of individuals bout, you will need to construct a sampling quadrat (RD[09]). If the site has species that will be monitored in 1 m x 1 m patches, use the sampling frame from RD[08] for establishment and monitoring of patches of woody species. Familiarize yourself with the phenophase definitions (Appendix A) and domain/species-specific photos contained in internal reference materials. Bringing photos with you to the field is advised for all staff.

A.4 Pre-populate Paper Datasheets

If a tablet with the phenology app suite pre-loaded is not available for field data collection, pre-populate paper data sheets to streamline phenology observations. Pre-populate datasheets with individual location, tagID, species and growth form, and format data fields to constrain data entry based on the growth form of the individual/patch being observed. Datasheets should be organized sequentially according to location along transect, in the order that the transect will be sampled. This is only possible for sampling bouts that occur after the initial selection of individuals.

Note: *Pre-populating datasheets is only an option if perindividual data entry has already occurred and a .csv of entered data is available for download.*

- Open the .xls datasheet for Phenology (RD[05], available in the Sampling Support Library).



Phenology bout datasheet

Phenophase Occurance Codes: Y=yes; N=no; M=missed; ?=uncertain (take photo)

Note: Every white phenophase cell must be filled

Remarks (especially added or dropped individuals):

plotID: Previous Bout date:

RecordedBy: Current Bout date Date (yyyy/mm/dd): Page ___of___

MeasuredBy:

Transect	Dir from Tr. (R/L)	90° distance (m)	taxonID	Growth Form	individualID	P1	P1 intensity	P2	P2 intensity	P3	P3 intensity	P4	P4 intensity	P5	P5 intensity	P6	drop Plant	associatedMedia #	Remarks

Change control

Figure 3. Phenophase Observation Datasheet.

Data to prepopulate the data sheet may be gathered directly from Fulcrum or downloaded via the Nightingale Phenology QC application in the NEON Aviary. The steps are the same, but the QC app does not require the same filtering steps and provides the added benefit of being able to download the observations from a previous bout, which is useful if your team is accustomed to having this information in the field.

Fulcrum workflow

Download .csv of records for the target domainID, siteID, and plot type from the 'Plant Phenology - Field Setup [PROD]' application using the download feature in the spreadsheet record view of the Fulcrum desktop application.

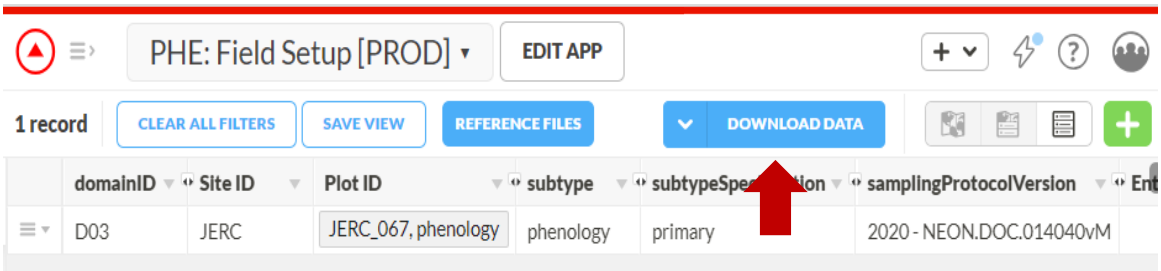
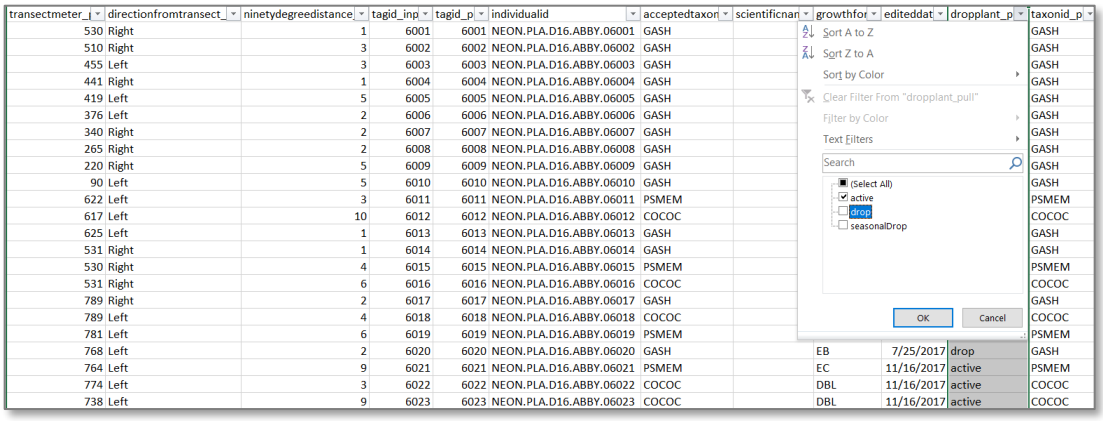


Figure 4. Download data from Fulcrum.

1. Open the file labeled 'plant_phenology_field_setup_prod_children_pertag.csv ' from the downloaded zip file. Filter records to **dropplant_pull** = 'active'

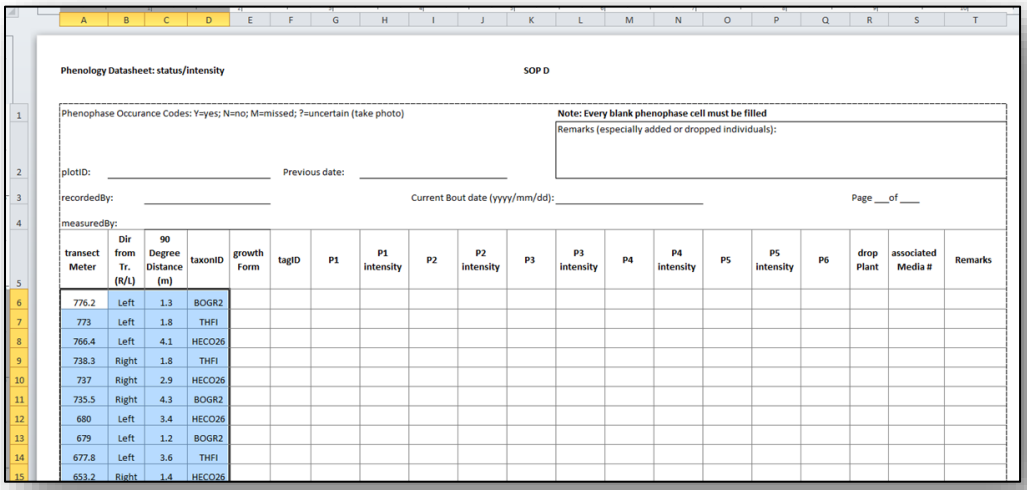


transectmeter_	directionfromtransect_	ninetydegreedistance	tagid_inp	tagid_p	individualid	acceptedtaxon	scientificnar	growthfo	editeddat	dropplant_p	taxonid_p
530	Right	1	6001	6001	NEON.PLA.D16.ABBY.06001	GASH					GASH
510	Right	3	6002	6002	NEON.PLA.D16.ABBY.06002	GASH					GASH
455	Left	3	6003	6003	NEON.PLA.D16.ABBY.06003	GASH					GASH
441	Right	1	6004	6004	NEON.PLA.D16.ABBY.06004	GASH					GASH
419	Left	5	6005	6005	NEON.PLA.D16.ABBY.06005	GASH					GASH
376	Left	2	6006	6006	NEON.PLA.D16.ABBY.06006	GASH					GASH
340	Right	2	6007	6007	NEON.PLA.D16.ABBY.06007	GASH					GASH
265	Right	2	6008	6008	NEON.PLA.D16.ABBY.06008	GASH					GASH
220	Right	5	6009	6009	NEON.PLA.D16.ABBY.06009	GASH					GASH
90	Left	5	6010	6010	NEON.PLA.D16.ABBY.06010	GASH					GASH
622	Left	3	6011	6011	NEON.PLA.D16.ABBY.06011	PSMEM					PSMEM
617	Left	10	6012	6012	NEON.PLA.D16.ABBY.06012	COCOC					COCOC
625	Left	1	6013	6013	NEON.PLA.D16.ABBY.06013	GASH					GASH
531	Right	1	6014	6014	NEON.PLA.D16.ABBY.06014	GASH					GASH
530	Right	4	6015	6015	NEON.PLA.D16.ABBY.06015	PSMEM					PSMEM
531	Right	6	6016	6016	NEON.PLA.D16.ABBY.06016	COCOC					COCOC
789	Right	2	6017	6017	NEON.PLA.D16.ABBY.06017	GASH					GASH
789	Left	4	6018	6018	NEON.PLA.D16.ABBY.06018	COCOC					COCOC
781	Left	6	6019	6019	NEON.PLA.D16.ABBY.06019	PSMEM					PSMEM
768	Left	2	6020	6020	NEON.PLA.D16.ABBY.06020	GASH		EB	7/25/2017	drop	GASH
764	Left	9	6021	6021	NEON.PLA.D16.ABBY.06021	PSMEM		EC	11/16/2017	active	PSMEM
774	Left	3	6022	6022	NEON.PLA.D16.ABBY.06022	COCOC		DBL	11/16/2017	active	COCOC
738	Left	9	6023	6023	NEON.PLA.D16.ABBY.06023	COCOC		DBL	11/16/2017	active	COCOC

Sort A to Z
Sort Z to A
Sort by Color
Clear Filter From "dropplant_pull"
Filter by Color
Text Filters
Search
(Select All)
active
drop
seasonalDrop
OK
Cancel

Figure 5. Sort data.

2. Copy fields:
   - transectMeter
   - directionFromTransect
   - ninetyDegreeDistance
   - Species Code (taxonID)
   - tagID
3. Paste (values only) into corresponding fields in datasheet



Phenology Datasheet: status/intensity SOP D

Phenophase Occurance Codes: Y=yes; N=no; M=missed; ?=uncertain (take photo)

Note: Every blank phenophase cell must be filled

Remarks (especially added or dropped individuals):

plotID: Previous date:

recordedBy: Current Bout date (yyyy/mm/dd): Page ___of___

measuredBy:

transect Meter	Dir from Tr. (R/L)	90 Degree Distance (m)	taxonID	growth Form	tagID	P1	P1 intensity	P2	P2 intensity	P3	P3 intensity	P4	P4 intensity	P5	P5 intensity	P6	drop Plant	associated Media #	Remarks
776.2	Left	1.3	BOGR2																
773	Left	1.8	THFI																
766.4	Left	4.1	HECO26																
738.3	Right	1.8	THFI																
737	Right	2.9	HECO26																
735.5	Right	4.3	BOGR2																
680	Left	3.4	HECO26																
679	Left	1.2	BOGR2																
677.8	Left	3.6	THFI																
653.2	Right	1.4	HECO26																

Figure 6. Paste location and taxon info to datasheet.

Nightingale Workflow

1. Download .csv of records for the target domainID, siteID, year, bout date (last completed) from the "(PHE) 'Nightingale' Phenology QC App" application in using the 'Download Selected Bout.xlsx' option with the 'include previous bout comparison?' option unchecked.

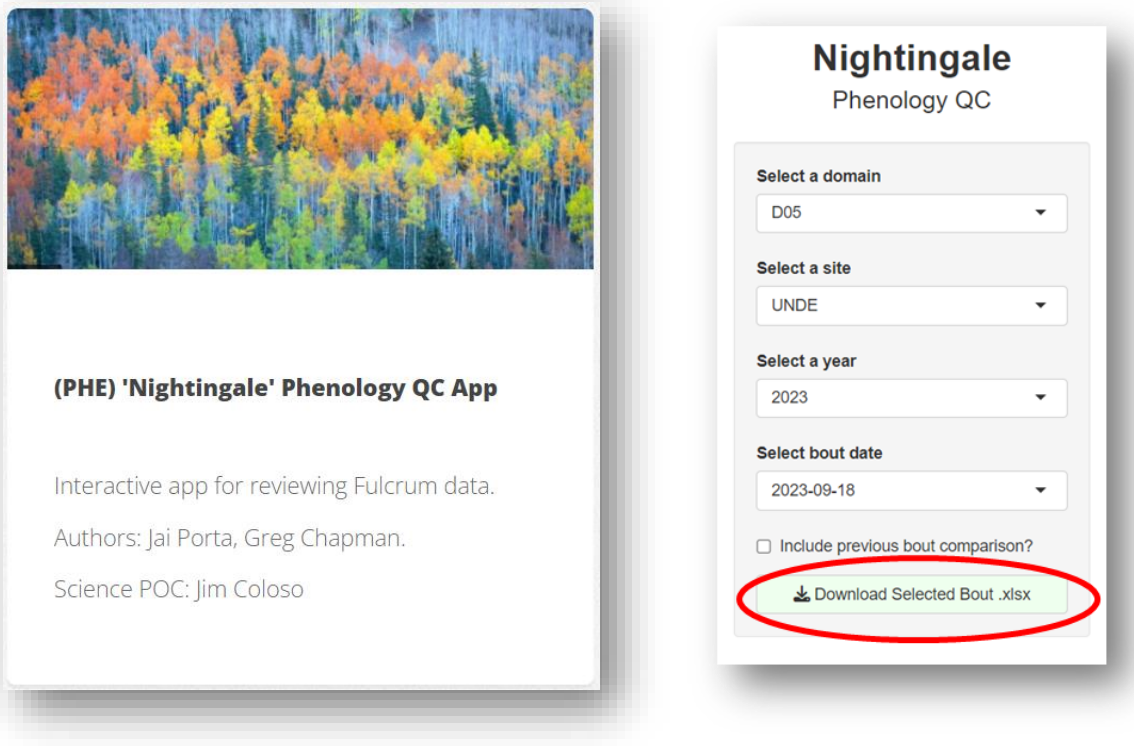


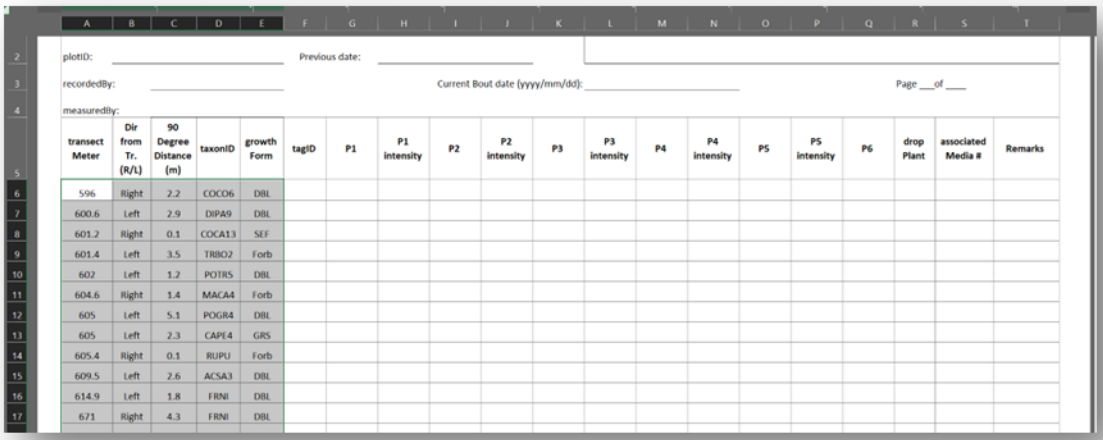
Figure 7. Nightingale Phenology QC Application.

2. Open the downloaded file. Print table with data from the previous bout to take with you to the field (optional).

	A	B	C	D	E	F	G	H	I	J	K	L
1	Site: UNDE	Date: 2023-09-18	Techs: Divana Bynoe, Matias Bambi									
2												
3	tagID	meter	dir	90_dist	taxonID	form	p1	p2	p3	p4	p5	p6
4	06285				ACSA3	DBL	no	no	>= 95%	no	5-24%	no
5	06286				ACSA3	DBL	no	no	>= 95%	no	25-49%	no
6	06100				ACSA3	DBL	no	no	>= 95%	no	5-24%	no
7	06098				POTR5	DBL	no	no	>= 95%	no	< 5%	no
8	06097				POTR5	DBL	no	no	>= 95%	no	< 5%	no
9	06525				POTR5	DBL	no	no	>= 95%	no	< 5%	no
10	06001	596	Right	2.2	COCO6	DBL	no	no	>= 95%	no	< 5%	no
11	06133	600.6	Left	2.9	DIPA9	DBL	no	no	>= 95%	no	< 5%	no
12	06511	601.2	Right	0.1	COCA13	SEF	no	no	yes	no		
13	06791	601.4	Left	3.5	TRBO2	Forb	no		yes	no		
14	06003	602	Left	1.2	POTR5	DBL	no	no	>= 95%	no	5-24%	no
15	06797	604.6	Right	1.4	MACA4	Forb	no		yes	no		

Figure 8. File downloaded from QC app.

3. Copy fields:
    - Meter
    - Dir
    - 90_dist
    - taxonID
    - form
    - tagID
4. Paste (values only) into corresponding fields in data sheet.



plotID: Previous date:

recordedBy: Current Bout date (yyyy/mm/dd): Page ___of ___

measuredBy:

transect Meter	Dir from Tr. (R/L)	90 Degree Distance (m)	taxonID	growth Form	tagID	P1	P1 intensity	P2	P2 intensity	P3	P3 intensity	P4	P4 intensity	P5	P5 intensity	P6	drop Plant	associated Media #	Remarks
596	Right	2.2	COCO6	DBL															
600.6	Left	2.9	DIPA9	DBL															
601.2	Right	0.1	COCA13	SEF															
601.4	Left	3.5	TRBO2	Forb															
602	Left	1.2	POTR5	DBL															
604.6	Right	1.4	MACA4	Forb															
605	Left	5.1	POGR4	DBL															
605	Left	2.3	CAPE4	GRS															
605.4	Right	0.1	RUPU	Forb															
609.5	Left	2.6	ACSA3	DBL															
614.9	Left	1.8	FRNI	DBL															
671	Right	4.3	FRNI	DBL															

Figure 9. Paste location and taxon and growth form data from downloaded file to datasheet.

5. Add filters to the datasheet
    - Highlight the row containing field names.

- In the 'Data' tab click filter, arrows will appear next to field names.

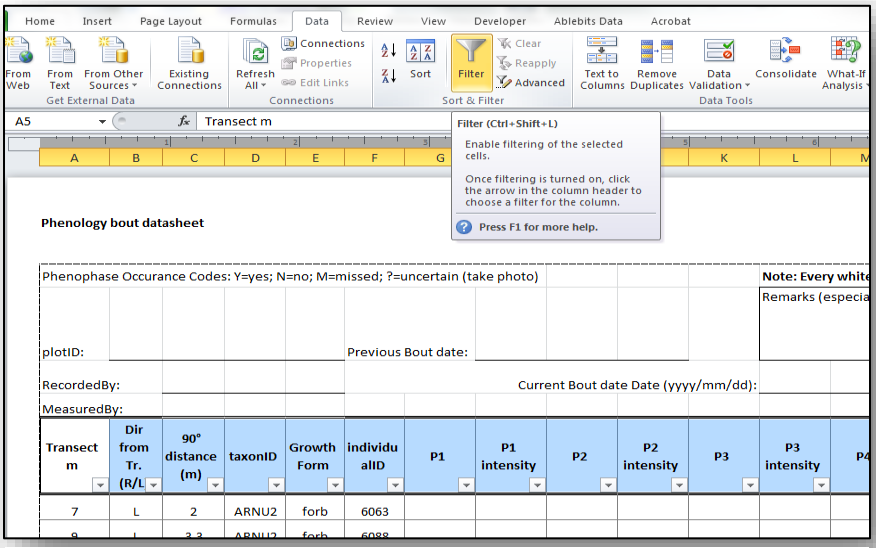


Figure 10. Add filters to sort records.

6. Filter by **growthForm**, select one **growthForm** at a time.

Shade in cells for all phenophases which are not required for that **growthForm** (summary table available in **Table 2**).

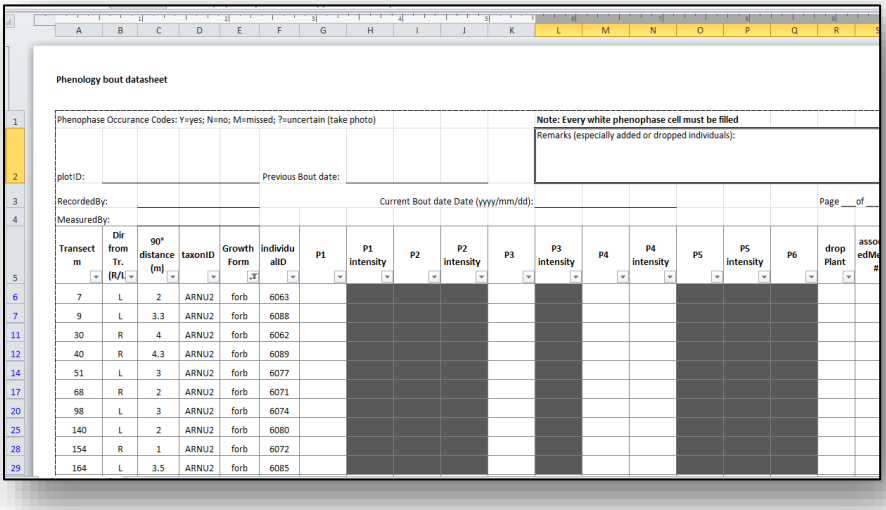
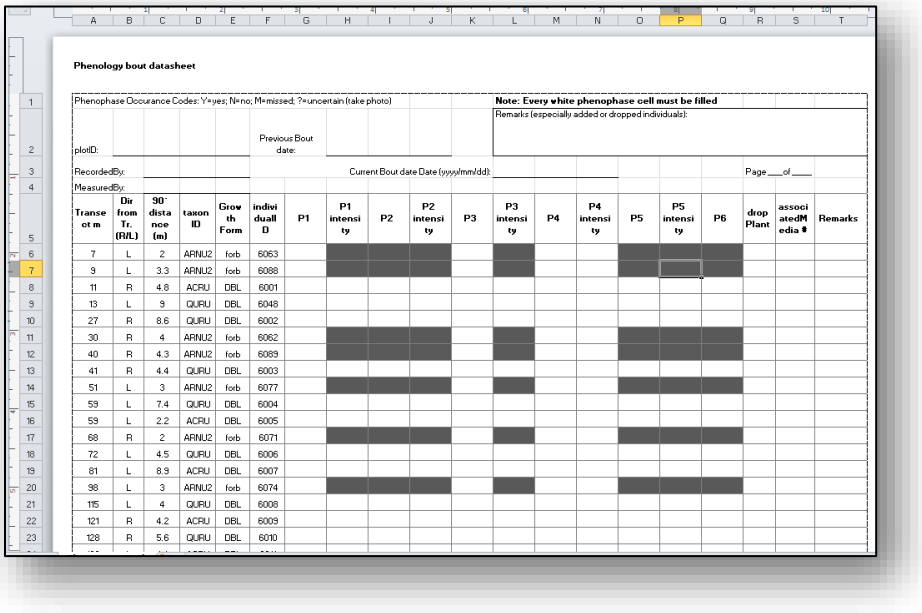


Figure 11. Shade cells for for phenophases not observed.

7. Repeat this process for all **growthForms**.

8. Un-filter **growthForm**s so that all are displayed.



Phenology bout datasheet

Phenophase Occurance Codes: Y=yes; N=no; M=missed; ?=uncertain (take photo)

Note: Every white phenophase cell must be filled

Remarks (especially added or dropped individuals):

plotID: Previous Bout date:

RecordedBy: Current Bout date Date (yyyy/mm/dd): Page ___of ___

MeasuredBy:

Transect m	Dir from Tr. (R/L)	90° distance (m)	taxon ID	Growth Form	individuall D	P1	P1 intensity	P2	P2 intensity	P3	P3 intensity	P4	P4 intensity	P5	P5 intensity	P6	drop Plant	associatedMedia #	Remarks
7	L	2	ARNU2	forb	6063														
9	L	3.3	ARNU2	forb	6088														
11	R	4.8	ACRU	DBL	6001														
13	L	9	QURU	DBL	6048														
27	R	8.6	QURU	DBL	6002														
30	R	4	ARNU2	forb	6062														
40	R	4.3	ARNU2	forb	6089														
41	R	4.4	QURU	DBL	6003														
51	L	3	ARNU2	forb	6077														
59	L	7.4	QURU	DBL	6004														
59	L	2.2	ACRU	DBL	6005														
68	R	2	ARNU2	forb	6071														
72	L	4.5	QURU	DBL	6006														
81	L	8.9	ACRU	DBL	6007														
98	L	3	ARNU2	forb	6074														
115	L	4	QURU	DBL	6008														
121	R	4.2	ACRU	DBL	6009														
128	R	5.6	QURU	DBL	6010														

Figure 12. Remove filtering.

9. Remove filters from field names.
10. Sort by **transectMeter** so that individuals are organized as they occur sequentially along the transect.
11. Save datasheet to local drive.
12. Print datasheets.
13. Update as necessary as individuals are added/dropped.

SOP B Field Sampling

B.1 Initial Transect Establishment

Phenology observations occur along an 800 meter loop transect within the tower airshed. Primary markers are placed at the SW and NE corners of the transect, secondary markers are placed every 100 meters along the transect. Plot establishment for plant phenology (RD[12]) must be completed prior to or concurrently with this procedure.

1. Navigate to the permanent plot marker at the southwest corner; this is the plot origin (meter 0).
2. Use GPS and plot markers to locate the 100 meter secondary marker in the clockwise direction (begin by walking north from the SW corner) along the transect.
3. Stretch a 100 meter tape between each point. Use chaining pins or similar stake at each end to hold the tape in place.

Place a pin flag (or other marker as appropriate for site specific conditions or site host preference) every ten (10) meters along the tape. If visibility is limited such that pin flags are not visible at 10 meter intervals, place flags at shorter distances. Over the course of the season a path will likely develop and extra pin flags may be removed if they are no longer necessary. Use pin flags that differ in color from those used to mark other tower plots to provide a visible, reproducible path to walk while monitoring phenophases.

Note: Due to topography of the transect or drift in the tape caused by vegetation and wind, the distance measured between permanent markers may not be exactly 100 meters. In this case, anchor first to one marker location, stretch the tape between the two points, divide the resulting number by 10 and use that value to guide incremental placement of pin flags within that stretch of transect. For example if the distance measured between point A and point B = 110 m, spacing between pin flags will be 11 m rather than 10 m. Because of the precision of point placement required during initial plot establishment, when there is disagreement between markers and tape, priority goes to the placement of markers and the difference is averaged across that stretch of the transect.

4. Write the transect distance/location information (e.g., 10 m, 20 m…780 m 790 m) with a permanent marker on each pin flag numbered 0-790 in increments of 10 meters.
5. Use flagging to mark an access route to the phenology sampling loop outside of the site-specific tower and soil array buffer area. Field staff must use the designated route when accessing the phenology loop to reduce trampling damage within the tower airshed.
6. Select a sampling start point, this is the corner nearest to the transect access route and will be the location where sampling bouts will begin. This does not have to be the SW corner.

B.2 Annual Transect Establishment

The 800-meter phenology loop transect may require regular re-establishment. At seasonal sites, this should occur annually at the beginning of the sampling season before regular observation bouts are

scheduled to begin. At year round sampling sites, annual establishment may occur during dormant or periods of low phenological activity when it is practical to complete re-establishment. At all sites, full or partial re-establishment may be necessary following a disturbance event. Prior to annual establishment, print or save a spreadsheet or map with active and seasonally dropped plants.

The reference should include:

- transectMeter
- directionFromTransect
- ninetyDegreeDistance
- individualID
- taxonID

To conduct annual establishment:

1. Navigate to the designated **sampling start point.**
2. If the transect pin flags and visible markers have been lost due to disturbance, stretch a tape between permanent markers and re-establish the transect according to SOP B.1 above.
    a. The priority in re-establishing a transect following disturbance is maintaining the time series, not re-mapping all tagged individuals, and not dropping individuals observed solely based on location. If the new line does not match the original transect line, based on **transectMeter** and **ninetyDegreeDistance** to tagged locations, shift the tape to find that original location if possible.
    b. Depending on the severity of the disturbance event some or all plants may need to the replaced.
3. Walk the transect in a clockwise direction.
4. Along the transect, **note the presence and condition of pin flags** placed at regular intervals along the transect.
    a. **Replace** any faded, broken or missing pin flags. Each flag should be marked according to the transectMeter, typically set at 10 meter intervals. If the number has faded or disappeared, use a permanent marker to re-write the numbers.
5. Use the spreadsheet or map to guide progress along the transect, stopping at each mapped individual or patch that will be monitored in the coming season (**SOP C**).
    a. **Verify** that aluminum tags are present and visible on each tagged individual and that nails and/or wire used to attach tags is not causing unintended harm to the plant.
    b. **Replace** any faded, broken or missing plant cards or flagging, to facilitate easy location of previously marked individuals/patches.

Inspect each patch to ensure the target species is present in sufficient density to enable observation.

c. If the location of the target species has shifted such that is no longer well represented in the established patch, shift the lower inside corner of the patch up to 1 m from the original location in any direction to establish a more representative patch (**Figure 13**).

d. Leave a marker in the location of the *original corner*, any shifts in subsequent years must remain within 1 m of this point.

e. If a shift occurs within this 1 m radius of the original location, no update to mapped location is necessary, as this shift is within the margin of uncertainty for phenology locations.

f. ***Note***: It is acceptable to shift the patch location of either woody or herbaceous species, but it may not be possible to evaluate herbaceous species until the growing season begins.

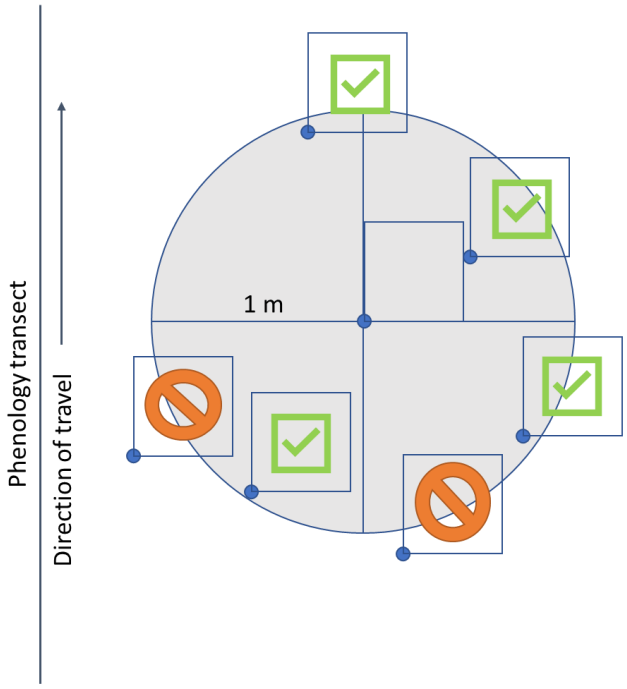


Figure 13. Patch locations may shift to track species movement over short distances from year to year.

SOP C Selecting, Marking, and Mapping Individuals and Patches

C.1 Preparing for Data Capture

Mobile applications are the preferred mechanism for data entry.

Data for recording location information for new individuals are entered in the 'Plant Phenology - Field Setup [PROD]' fulcrum application. This application is used to auto-generate available individuals in the observation and annual applications.

Before going to the field:

- Double check that mobile devices are charged and synched.
- Double check that GPS units are fully charged and have appropriate files loaded.
- If selecting phenocam individuals:
    - Request phenocam IP addresses from the lead Tower Instrumentation Field Ecologist.
    - Print historic phenocam images from a range of seasons for reference while in the field.
    - Determine the season with the greatest visibility through existing vegetation during which species identification is also possible.
    - Determine whether Phase I species and identifiable individuals are present within the viewshed of the phenocam.
    - If the community composition of the phenocam plot differs from the primary transect, identify which species may be viable alternatives, submit a problem ticket Science.

Given the potential for mobile devices to fail under field conditions, it is imperative that paper datasheets are always available to record data. Paper datasheets should be carried along with the mobile devices to sampling locations at all times.

C.2 Primary Transect – Selecting Individuals/Patches

Selection of individuals for phenology monitoring occurs after annual establishment of the phenology transect (SOP B). Though transect establishment and plant selection (SOP C) may be completed on the same day, they should not be completed concurrently. To ensure data quality, complete SOP C in its entirety before moving on to SOP C. Use the 'Plant Phenology - Field Setup [PROD]' digital app or the 'Selection Datasheet' to record data from this SOP.

A list of species and the target number of individuals selected for phenology monitoring will be provided via the 'Phenology DB' mobile application for each phase of phenology monitoring. These lists are developed based on a quantitative survey of plant species and abundance within the Tower airshed. The lists provided by Science are ordered by priority for selection and will include extra 'contingency'

species. Species must be considered in the order they are ranked and may only be skipped or rejected for the following reasons:

- **Skipped –** not qualified for inclusion in this protocol.
    - The record is for a fern, fern ally, or non-vascular species.
    - The record is not to species level resolution (i.e., genus or lower).
- **Rejected –** temporarily not selected for sampling.
    - The species is not present on the transect in sufficient numbers for monitoring.
    - The species is an overstory species and all required overstory species have already been selected.
    - The species is an understory species and all required understory species have already been selected.
    - There are 'special circumstances' (e.g., the most abundant species are all from the same genus), and a problem ticket has been submitted.

If a species is skipped or rejected, record **selectionStatus** = "skipped", "rejected Phase I", or "rejected Phase II" and record the reason for not selecting the individual in the **Reason Plant Not Selected** field in the application, then consider the next ranked species on the list. All species rejected for Phase I sampling will be reconsidered for Phase II species selection.

Phase II species are selected to include:

- The three dominant species from Phase I.
- Any species present already targeted by an existing phenology monitoring network (USA-NPN or Project BudBurst) or flagged as noxious weed of conservation concern.
- Selection from remaining species, ordered by relative abundance. If during initial selection, a target species is not present on the transect for monitoring, move to the next species on the list.

State and Federally recognized Threatened and Endangered (T&E) species will not be selected for phenology monitoring as locality information about these species cannot be made publicly available. T&E species will be stripped from the list of species considered for phenology monitoring, however if any are unintentionally included on the prioritized list of species, these should automatically be skipped, regardless of their presence/abundance on the transect. Record the rationale for skipping as 'The record is too low taxon resolution (i.e., genus or lower)', these records will fuzzed before being published.

Ferns, fern allies and non-vascular species will also be removed from consideration as distinct phenophases have not been defined for these growth forms.

With the identified priority species in mind:

1. Walk the entire phenology loop to **observe the vegetation patterns** along the transect. This must be done by a field ecologist familiar with local flora. Make notes in the field notebook about how the species chosen for phenology monitoring are spaced (i.e., where there are clusters of individuals and where there are gaps) along the transect.
2. Walk the phenology loop transect a second time and select individuals to monitor following the generalized criteria for selection:

- **Health Criteria – Choose individuals/patches that:**
    - Phase I: Represent the average health for that species at the site.
    - Phase II: Appear healthy enough to be expected to survive for the foreseeable future.
    - Appear to be healthy, undamaged, and free of pests and disease (except in cases where the majority of individuals of that species at a site are affected by the disease).
    - If diseased, pick individuals that are representative of the disease status of the majority of the population.
- **Size Criteria:**
    - Choose plants that represent a range of size classes.
    - For species monitored in patches, select the densest patches available along the transect.
    - Include a diversity of sizes if more than a single individual is available within the target zone.
    - Select individuals that are mature enough they are likely to survive, i.e., do not select seedlings or, if the management at the site includes prescribed burning, do not select individuals not likely to survive a typical burn.
    - For woody species that occur in continuous thickets such that it is not practical to select a single stem or distinct group to observe, establish either a 0.5 m x 0.5 m or 1 m x 1 m patch observation points.
- **Location Criteria:**
    - Choose individuals that are visible from the transect that may be observed without leaving the transect (consider visibility at peak green).
    - Target individuals that are:
        - Between 1 and 10 m from the transect.
        - More than 10 m from roads or buildings.
    - Prioritize individuals for monitoring that are included in productivity sampling, if feasible.

- Only select individuals that may be monitored from the transect and without excessive trampling of the productivity plots.
- Reduce total sampling time (i.e., stops along the loop) by selecting collocated groups of individuals of different species.
- Sample individuals of same species from alternating sides of the phenology loop at alternating sample points.

- **Distribution Criteria:**
  - Individuals of a single species should be more or less evenly distributed around the phenology loop.
  - There should be about 24 meters between the thirty, evenly spaced, individuals/patches of a single species for Phase I monitoring.
  - If it is not possible to find individuals that are evenly spaced around the transect, it is acceptable to select groups of more closely spaced individuals.
- **Annual and Biennial Criteria:**
  - For annuals, monitor as a patch, employing an appropriate patch size for the target species.
    - Select a 0.25 m x 0.25 m patch for small herbaceous species that occur in clusters or mats (e.g. Fragaria spp.).
    - Select a 0.5 m x 0.5 m patch for larger annual/biennial species that occur at greater spacing and cannot be reliably monitored in the smaller patch size (e.g. Helianthus spp.).
    - A 1 m x 1 m patch size should only be used for perennial, woody species. Do not select this patchSize for herbaceous species.
    - Avoid selecting locations where the patch is likely to be trampled accessing other phenology individuals or by field staff implementing other sampling protocols.
  - For biennials, avoid choosing the first or the last seedling to emerge in the spring since they may not be representative of the larger population at the site.
  - If at all possible, avoid using patches to observe perennial species as consistent assessment of phenophase intensity is more difficult on patches than on individuals.
- **Dioecious species:**
  - For all growth forms other than ‘Evergreen Conifer - no needles’, do not prioritize selection of male or female individuals for dioecious species, instead select based on

representative proportions in the population and according to other criteria laid out above.

- The only observed phenophase for the 'Evergreen Conifer - no needles' growth form is 'Open pollen cones' so only male individuals should be selected for this growth form.

- Fruiting phenology will not be observed for male individuals.

C.3 Primary Transect - Mapping of Selected Individuals or Patches

Coordinates for each individual/patch will be calculated from the relative position along the transect, utilizing the permanent markers.

1. Measure and record (RD[05]- perindividual):

   - **transectMeter** – the location along the transect (0-**799** m) at which the individual is perpendicular; meter 0=SW corner, 200=NW, 400=NE, 600=SE. Use the permanent markers or labeled flags and tape**,** or the laser rangefinder **in HD mode** (preferred method) to determine the transect meter. The tolerance for transectMeter is +/- 2m along the transect to account for topography and distance from the nearest GPS point that may make greater precision difficult at some locations.

Note: *if transectMeter = 0, 200, 400, or 600 AND directionFromTransect = Left, that is, if the individual/patch is to the outside of one of the transect corners, a decimal point must be included to indicate which side of the corner the individual/patch is measured from (e.g., 199.9/L ok; 200.01/L ok; 200/L not ok). If directionFromTransect = Right, transectMeter must ≥ 1 m from a corner (e.g., 199 or 201, not 199.1-200.9) or the location will violate the minimum 1 meter from transect on the adjacent side.*

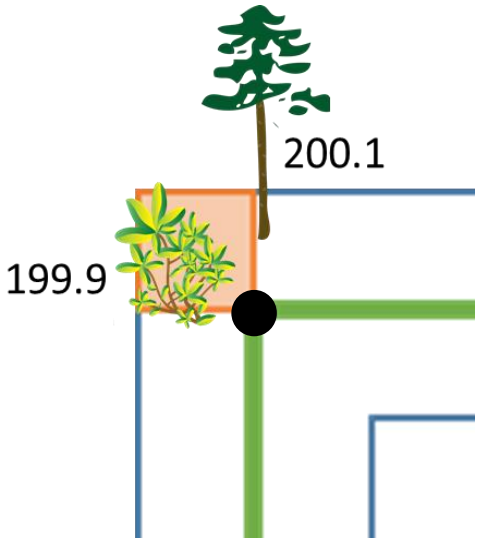


Figure 14. Mapping individuals/patches at transect corners.

- **directionFromTransect -** Direction (right or left) of individual from transect, when transect is walked in a clockwise direction.
- **ninetyDegreeDistance -** Perpendicular distance from transect to the tagged corner of the selected patch (in meters). Use a laser rangefinder (15 cm accuracy) in HD mode or tape measure. Acceptable tolerance for perpendicular distance is +/- 1 m provided the minimum distance of 1 meter from the transect is met. It is anticipated, however, that at most locations +/- 30 cm precision is attainable. *Note: the minimum distance from trail is intended to minimize likelihood of trampling, light gaps or other human mediated potential impacts to observed phenology, ninetyDegreeDistances of <1 m from the transect are permissible if the conditions dictate, after consultation with Science.*
    - The maximum ninetyDegreeDistance is 10 meters from the transect. If there is strong rationale for selecting individuals >10 m away, submit a problem ticket to discuss with Science.

2. Mark according to guidelines in C.6.

C.4 Phenocam Plot - Selecting Individuals

For sites where the primary phenology transect is not located directly north of the NEON tower, a secondary, phenocam plot is established (**Figure 1**). The intent is to enable *in situ* observations of individuals whose phenology is also being captured by the tower-mounted phenocam. Doing so is essential to enabling scaling of phenology data from the individual to the landscape and, ultimately, the continent. Individuals cannot be selected within the phenocam plot until the phenocam has been mounted and images are available. A maximum of 3 species will be selected within the phenocam plot; typically, these will be the Phase I species.

The ideal season for selecting phenocam individuals is likely site specific. Individuals in herbaceous communities may best selected during the growing season whereas the dormant season may be ideal for selecting individuals at sites dominated by deciduous trees.

If the phenocam plot is located at a distance too far from the NEON tower to identify the southern border or selected individuals in phenocam images, submit a problem ticket to Science. Delineating plot boundaries and selecting individuals from within the plot that are also within view of the phenocam requires coordination between team members in the field, and team members located in the instrument hut with access to live feed from the phenocam.

At the hut:

1. Plug in laptop using Ethernet cable or connect to tower wireless network.
2. Navigate to the IP address associated with the phenocam tower top phenocam.
3. Confirm live image is streaming.

4. Compare current image to prints historical phenocam images to assess canopy visibility.
5. Using both live feed and historical images, guide crew members in the field to an acceptable individual.
6. Once selected either mark individuals on print out of phenocam image or take a screenshot of the live feed and mark the location of the selected individuals for the phenology reference manual and training materials (**Figure 15**).

In the field:

1. Use the Trimble to navigate to the southern boundary of the phenocam plot.
2. Wave brightly colored objects (could be safety vest, or piece of fabric, or Mylar balloon, chose any item of sufficient size and contrast to be easily seen in the camera image).
3. Use hand held radio to communicate with crew member located in the instrument hut and confirm visibility.
4. Follow guidance from the hut to navigate to suitable individual that is visible in the phenocam image in multiple seasons.
5. Once an individual has been selected:
    a. Confirm on Trimble that the location is within the phenocam plot.
    b. Confirm the individual is a target species.
6. Mark according to guidelines in SOP C.6.
7. Flag access to path to selected individuals.

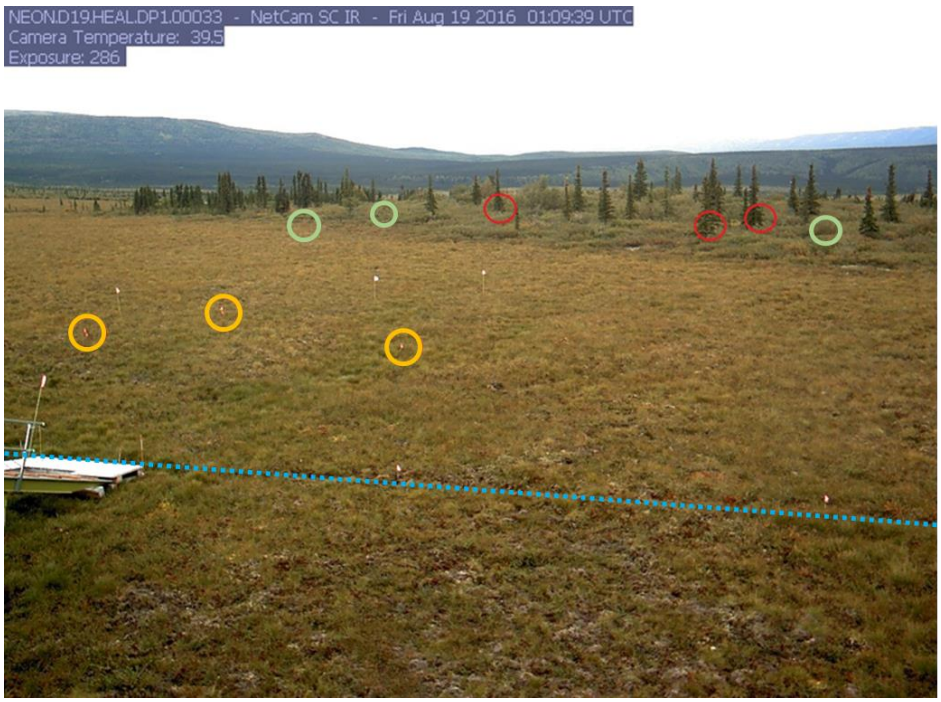


Figure 15. Phenocam image from D19-HEAL with marked individuals. Each color indicates a different Phase I species. Blue dashed line indicates southern boundary of the phenocam plot.

C.5 Phenocam Plot - Mapping Location of Selected Individuals/patches

The phenocam plot is a 200 m x 200 m plot within which individuals are selected. In an area with these dimensions, it is not practical to calculate absolute position from a series of relative position measurements, as is done on the primary transect. Instead, UTM Coordinates will be recorded directly for each individual/patch. This procedure requires data to be recorded on both the Trimble GPS unit and within the "Plant Phenology - Field Setup [PROD]" mobile application.

1. Navigate to the selected individual/patch
2. Make sure you do not have an existing data file open.
    a. To close an existing data file go to the **MDD** (Main Drop Down menu icon in GPS receiver) **> Data** and click **Close.**
3. Create a new data file.
    a. Go to **MDD > Data**, and then go to the **SDD (**Sub Drop Down directly below the MDD) and select **New.**
    b. Use the default settings: **File type** (Rover) and **Location** (Default); Click on the **File Name** field.
4. Enter the file name using the naming convention below.

a. Filename begins with the letter D, followed by the two-digit number for the domain, followed by an underscore: e.g. **D01_**

b. Add the four letter site ID followed by an underscore: e.g. D01_**HARV_**

c. Add the tag ID (1-5 digits) for the phenocam individual you are collecting GPS data for followed by an underscore: e.g. D01_HARV_**1234_**

d. Add "phe" followed by an underscore: e.g D01_HARV_1234_**phe_**

e. To indicate the file contains GPS data add "GPS": e.g. D01_HARV_1234_ phe_**GPS**

5. In **Dictionary Name** choose the "Phenocam_individual" data dictionary

   a. Note- if you did not import the data dictionary before heading into the field choose the generic dictionary and enter the metadata into the comments file.

   b. Click **Create.**

   c. In the screen that pops up:

      i. Antennae height should be **1.000 m.**

      ii. Select Type as **GeoXH XXXX internal** (whichever GeoXH unit you are using) and click **OK.**

6. Open the "Phenocam_individual" feature in the Data screen.

7. There are three metadata fields in the data dictionary.

   a. **tagID:** 1-5 digits assigned to each individual phenocam individual.

      i. default is 1.

      ii. tagID is duplicated in the datafile name.

   b. **taxonID:** Code for the plant's identification.

   c. **comments:** Not a required field, available for any pertinent information.

Collect GPS coordinates.

1. Due to less restrictive accuracy requirements, the external antenna used during plot establishment is not needed to collect the spatial data for the phenocam individuals. However, to ensure best possible logging go to **MDD>Status>Skyplot** and make sure your values are:

   - Position Dilution of Precision (PDOP) is ≤ 6.
   - The Signal to Noise Ratio (SNR) should be ≥ 4.
   - Number of satellites used ≥ 4.

   a. Navigate back to the data collection screen by **MDD>Data.**

2. Determine your logging position.

a. The stature of the plant you are collecting GPS data for will determine where you hold the Trimble unit when you start logging.

   i. If possible, hold the Trimble directly over the plant.

   ii. If the plant is too tall hold the Trimble next to the plant.

3. Start logging positions by clicking Log. Depending on the canopy cover choose the appropriate action:

   a. **Open field or minimal canopy cover:** record GPS data for at least 120 logs using the accuracy-based logging feature.

      i. If you are not able to log a point within the first minute, disable logging feature (see instructions below) and collect the 120 logs regardless of accuracy.

   b. **Semi-open and closed canopy:** record GPS data for at least 300 logs using the accuracy-based logging feature.

      i. If you are not able to log a point within the first minute, disable the logging feature (see instructions below) and collect the 300 logs regardless of accuracy.

4. When holding the Trimble during GPS point collection use the following best practices:

   - Make sure the barometric holes on the underside of the Trimble are not obstructed.
   - Minimize any movement of the Trimble.
   - Hold the Trimble out away from your body.
   - Accuracy is best if the Trimble is oriented toward the South.

5. When you have finished collecting the minimum number of logs hit **Done** and close the data file.

6. Repeat the data file and GPS collection steps above on the remaining phenocam individuals.

Trimble Troubleshooting and Tricks

- To find the "_" when creating the datafile name hit the **CAP** symbol on the keypad.
- Disable Logging Feature
  - Go to MDD > Setup
  - Click on Logging Settings
  - Under Logging Settings click on the wrench to the right of the screen.
  - Scroll down and in the Use Accuracy-based Logging click **No.**
  - Click **Done** for the two following windows.
  - To go back to the data collection go to MDD>Data + SDD>Existing File.
- If you are not able to log:
  - Make sure the receiver is active by going to the **MDD>Setup**; if the satellite icon is not visible: click on the **GNSS** box which should be in upper right side of the screen.

- For more troubleshooting see Appendix H in the Plot Establishment Protocol (RD[12]).

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7. Record tag data in the "Plant Phenology – Field Setup [PROD]" mobile application:
    - Create new field setup record.
    - Select:
        - **siteID**
        - **plotID** (phenocam plot)
        - **Enter per individual information**
            - **Add New tag?** Yes
            - **gpsDatafile** – The name assigned to the Trimble point
            - **logCount** – the number of logs collected
            - **tagID**
            - **taxonID**
            - **growthForm** – Refer to the National Phenology Network Species List in the SSL for growth form assignment of all species already monitored in the NPN network, or consult with Science if this is not known in advance.
            - **dropPlant** – Active
        - Save record.
8. Upon return to the DSF, upload GPS files to N:\Science\GISData\FOPS\PhenoCamPoints and notify Science that files are ready for post processing.
9. Sync tablet when internet connection is available.
10. Verify that new records have been pushed to the "Phenology – Per Individual INGEST [PROD]" application.

C.6 Marking Selected Individuals or Patches

Blue aluminum plant tags with unique numbers 6000-8000, are designated for phenology sampling; plant cards or flagging may be used to increase visibility. Tags will be placed according to the specifications provided in **Table 6** consistent with guidelines in the vegetation structure protocol (RD[07]).

Figure 16. Examples of recommended phenology markers. Photo credit: National phenology network (left), Ben Meadows (center), Forestry Suppliers (right).

1. Record:
    - **tagID –** 1-5 digit number, unique ID by site.
    - **taxonID –** USDA species code (domain specific lists available on Field Operations, TOS page on the NEON intranet).
    - **identificationQualifier –** if species identification is uncertain (i.e., if selection of individuals occurs prior to development of diagnostic morphological features) enter the assumed genus and species and apply an identification qualifier code to note the uncertainty and follow up at a later date.
        - Once positive ID is possible, these records will need to be updated (see SOP F).
    - **dioceous -** true/false
    - **Sex -** male/female (only assessed if dioicous = true)
    - **Remarks –** record the camera assigned file code for photos, if photos are taken.

Table 6. Methods for marking individuals for phenology observations.

Plant Type	Marking Method
Trees	Nail or otherwise attach tag to trunk at height of 1.4 m using site appropriate methods.
Shrubs	Attach tag to a prominent branch or main stem with 20 gauge wire. Mark individual with florescent flagging (if permitted by site host) to aid in finding plant. Small shrubs which cannot easily be tagged according to guidelines in the vegetation structure protocol (e.g., Gutierrezia sp.) may be marked with a tagged stake, similar to grasses and forbs.
Perennial bunchgrasses and forbs	Attach blue tag and plant card (w/ species code and tagID) to a tag stake. Place stake in the ground at the base of the selected individual.
Clonal species (e.g., aspen, staghorn sumac, rhizomatous perennials)	Attach tag to individual ramets from different clones.
Individual already marked for productivity sampling (RD[07])	Punch productivity ID number into a blank blue tag. Replace existing tag with blue tag.
Spreading perennial forbs and grasses	Mark corners, attach blue tag and plant card (w/ species code and Unique ID) to a tag stake. Place stake in the ground in the lower patch corner on the transect side of the patch.
Annual or biennial	Attach blue tag and plant card (w/ species code and Unique ID) to a tag stake. Place stake in the ground in the lower patch corner on the transect side of the patch.
Low growing woody species growing in continuous patches	Monument patch corners with fiberglass posts tall enough to extend above vegetation. Attach flagging and tagID to lower patch corner, on the transect side of the patch.

***Note**: It is important to ensure that the method of marking chosen does not change the growing conditions of the plant or injure the plant in any way. Shrubs* - Wrap wire loosely to avoid damaging stem as the plant grows. One effective method is to "coil" bailing wire around a pencil or other circular tool then wrap the coiled wire around the stem to enable stretching as the stem diameter increases over time (**Figure 17**). *Trees - When nailing tags to trees,* leave room for future tree growth (see RD[07] for details). The nail should be deep enough that it cannot easily be removed, but not flush to the bark.

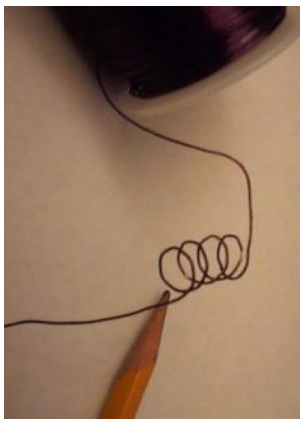

Figure 17. Bailing wire coiled around a pencil.

Table 7. Identification qualifier codes (idQ) to designate species with uncertain identification.

idqCode	Identification Qualifier Description*
CS	cf. species
AS	aff. species
CG	cf. genus
AG	aff. genus
CF	cf. family
AF	aff. family

* cf, roughly equals “not sure”; aff. Roughly equals “similar to, but is not”.

Steps for marking patches

For herbaceous species, small plants, and lower-growing woody plants that grow in patches of individual stems, it can be difficult to single out a few individuals to observe over time. Instead, set up a fixed patch and report on the phenophases for target species within the patch. This method works well for mat-forming grasses, clonal species that tend to grow as a groundcover, very small forbs that tend to grow in clumps of individuals, and woody species with dense growth that cannot be observed as individuals.

- **Lay out a 0.25 m x 0.25 m or 0.5 m x 0.5 m quadrat or 1 m** x **1 m** sampling frame over the densest or most central portion of a group of plants.
- **Mark all four corners** of the square with non-oxidizing metal tag stakes, PVC, fiberglass, or wooden stakes so that the plot frame may be placed in the same location on subsequent monitoring bouts.

Note: *When selecting stakes to mark patches, consider the impact stakes may have on the plants within the patch; avoid placing a broad stake next to a small plant that would shade it or cause root damage. For woody species, select a stake tall enough to extend above the average height of patch.*

- Attach a blue tag to the lower corner of the transect-side of the patch. Though, in the case of annuals or biennials, they will only be used for one or two years, annuals do need to have a permanent aluminum tag used to mark them. This helps ensure that duplicate tagIDs are not assigned to multiple individuals.
- Place a brightly colored plastic plant card in a tag stake in the same corner of the quadrat as the ID tag, write the species and tagID on the card. In the event of disturbance caused by wildlife drawn to brightly colored cards, discontinue use of plant cards and rely instead on location information (transect meter, direction and distance) to relocate and monitor patches.
- Annuals occasionally live more than a single season. In order to capture this if it occurs, do not remove plant ID cards (where allowed) until the following year.
- Primary Transect - Measure and record:
    - **tagID** -unique number from pre-stamped blue tag.
    - **transectMeter** – Distance (in meters) of individual from beginning of transect, when transect is walked in clockwise direction.
    - **directionFromTransect -** Direction (right or left) of individual from transect, when transect is walked in a clockwise direction.
    - **ninetyDegreeDistance -** Perpendicular distance from transect to the tagged corner of the selected patch (in meters).

Flag individuals. Small metal tags can be obscured by vegetation making individuals difficult to locate from afar. Add florescent pin flags and/or flagging tape near marked individuals to aid observers in finding the plant (where permitted by site hosts). Pin flags and flagging do occasionally get eaten or lost, thus pin flags must not be the ONLY method of identification and marking.

Figure 18. Examples of flagging to increase visibility (photo credit: left, K. Jones; right, R. Hufft.

SOP D Collecting Phenophase Observations

D.1 Preparing for Data Capture

Mobile applications are the preferred mechanism for data entry. Mobile devices should be fully charged and synched at the beginning of each field day.

Location and taxon information in the 'Plant Phenology – Field Setup [PROD]' application are used to pre-populate empty bout records for a specific observation date in the 'Plant Phenology-Phenophase Observations [PROD]' fulcrum application where phenophase status and intensity data are recorded. Upon completion of data collection and QC, each bout must be finalized and pushed to the 'Phenology – Observations INGEST [PROD]' application before it can be ingested to the NEON database.

However, given the potential for mobile devices to fail under field conditions, it is imperative that paper datasheets are always available to record data. Paper datasheets should be carried along with the mobile devices to sampling locations at all times.

D.2 Observing Phenophases

Regular data collection, i.e. observation of phenological development, will occur throughout the growing season. Use the Plant Phenology mobile app, or formatted, pre-populated (if available) 'status/intensity' paper datasheets (RD[05]) to record data. You may bring copies of the data from most recently completed bout into the field as a reference for the current bout. Both the primary transect and individuals within the phenocam plot will be observed during every phenology bout.

- Locate the sampling start point of the plant phenology transect.
- Enter metadata (e.g., fieldcollectiondate, recordedBy, measuredBy etc.).

Note: *If roles switch over the course of the transect, indicate in the notes who had which role for each record so that this will be captured when data are entered.*

1. Collect phenophase data from the plant phenology transect.
    - Traverse loop in a clockwise direction, or according to the established trail to phenocam individuals.
    - Stop at each individual/patch listed on the datasheet.

Note: *If it is not possible to assess the entire individual from the mapped transect location, it is acceptable to move along the transect to get a different view or make observations with only a partial view. Leaving the transect to make phenophase observations should only occur in rare instances and in consultation with the lead botanist. Considerations include site impacts, time, and data quality.*

    - Collect data from each individual/patch along the loop.

- When observing patches, observe the entire patch and report phenophaseStatus = 'yes' if the phenophase is occurring anywhere in the patch.

- If the sampling start point is not the SW corner, order the datasheet to begin at the alternate corner. For example, if the NE corner is nearest the access route, begin sampling at meter 400, and still walk in a clockwise direction.

2. At each individual/patch, record the following data (Location, tagID, taxonID and growthForm – should be pre-populated).

    - **date** – YYYYMMDD
    - **phenophaseStatus** – Y/N/?/M/X for each phenophase required for that growth form (see Appendix A for full descriptions of phenophases). Check for **every** required phenophase for every individual/patch during each sampling bout. *Note – due to space constraints, paper datasheets utilize coded values for phenophases. A key to codes is available in the footer of the datasheet.*
        - Yes (Y) – if phenophase *is* occurring.
        - No (N) – if phenophase *is not* occurring.
        - Uncertain (?) – if not certain whether the phenophase was occurring.
            - Take a digital photo of individual to document phenophase, record photo file # on datasheet.
            - Review with local expert (or lead flora field ecologist) to identify phenophase and record per data handling procedure. Update the datasheet and data entered via mobile app to reflect new information.
            - This status may be used if a direct observation is temporarily not possible (e.g., the individual/patch is covered by snow or water but the growing season is still ongoing).
        - Missed Phase (M) – if a phase occurred between sampling bouts in the current growing season such that the previous bout recorded status=N and the current status=N BUT you have reason to believe that the phenophase occurred between the two bouts (such as dried flowers on the ground below the plant).
            - Do NOT record status=M if a phenophase occurred prior to initiating monitoring bouts for the year.
            - Intensity values for missed phenophases are not recorded.
            - Do not use missed for skipped plants, not observed during a given bout.
        - Unnecessary (X) – If data are not being recorded on a formatted, pre-populated, datasheet (SOP A.1) or mobile app, record 'X' if a particular phenophase is not

required for the growth form of the individual to verify that nothing was skipped along the way.

- **phenophaseIntensity** – (**Table 8**) for each phenophase for which 'Yes' is selected. Growth-form specific phenophases and their descriptions are listed in Appendix A).

Table 8. Phenophase intensity values are binned in intensity ranges.

Intensity category	Intensity bins					
# (count)	< 3	3-10	11-100	101-1,000	1,001-10,000	> 10,000
% canopy, flower, ripe fruit	< 5	5-24	25-49	50-74	75-94	≥ 95
% leaf size		< 24	25-49	50-74	75-94	≥ 95

- **plantStatus** – (**Table 10**) the plant status field is only published with the annual data, the field is included in regular observation bouts to facilitate tracking of status throughout the growing season to better inform assessment during annual data collection.
- **internalRemarks** – free form comments intended for field teams.
- **remarks** - standardized free form remarks intended for publication.

Take a photograph of at least 3 examples of that phenophase*intensity combination on the first encounter in each species. Frame the shot so the image may be used to:

- Build site-specific training materials and a reference collection.
- Calibrate observer assessment of status and intensity for all species/phenophase combinations.

D.3 Replacing Lost, Dead, or Diseased Plants

If an individual is lost or killed mid-season, a new individual may be selected from another location along the transect; if no suitable replacement is available, make a note for the individual metadata. Each new individual must receive a new tag with a new unique number; do not re-use tags from individuals that have been dropped from monitoring. If a tagged plant listed on the datasheet cannot be located, dies (perennials only) or has experienced an unrepresentative change in health:

- Assign a new tagID to an individual or patch in a location near where the original was located. Record the new location and identification information in the 'perindividual' datasheet or from within the Observations mobile app without having to open the Field Setup app.
- If a long lived species that was healthy becomes diseased or experiences >50% mortality, replace unless the shift in health status is common (representative) among that species at the site (e.g., pest infestation or widespread disease).
- Record dropped plants as either 'Dropped' (dropped permanently) for one of the reasons listed above (specify the reason in the notes field), or 'Seasonal drop' dropped for the season if the

individual reached the 'end seasonal sampling' trigger. Season drops may only be utilized at sites on a seasonal sampling schedule.

- The 'Seasonally dropped' option is not mandatory and is primarily utilized to manage data collection and track progress towards the end of sampling for the growing season rather than generation of a specific data product. Selecting 'seasonally dropped' does not create a new data record, phenophaseStatus observations must still be reported for the date an individual/patch is seasonally dropped. If new growth occurs (more common in annuals than perennials) after an individual/patch has been dropped for the season, monitoring the individual may be restarted by setting dropStatus to active on the 'Field Setup' mobile app. If using paper datasheets, record data as usual, note date that observation resumed in the remarks field.
- If there is evidence elsewhere at the site or along the phenology transect of new growth in a species that has already been 'seasonally dropped' re-check marked individual and resume monitoring if necessary.
- Returning a seasonally dropped individual to active status within a given calendar year has no scientific impact on data quality. An individual may transition between seasonally dropped and active as many times as necessary based on the phenology of the individual.
- At sites where species may have multiple periods of growth, it is recommended that the 'seasonally dropped' option not be used as this can cause confusion. Simply record all phenophase status = No for dormant individuals throughout the sampling season.

- Ephemeral, herbaceous species that do not emerge, may be permanently dropped after two sampling seasons, and may be seasonally dropped in the first year once field team has determined that the species will not emerge.

Annuals that die do not need to be replaced within a given growing season, the same patch will be observed the following year. For annuals that die:

- Record 0% green leaf.
- Record phenophaseStatus = 'no' for all applicable phenophases.
- If sampling is seasonal or hybrid, end phenology monitoring for that individual/patch for the season.

SOP E Collecting Annual Structure Data

E.1 Preparing for Data Capture

Mobile applications are the preferred mechanism for data entry. Mobile devices should be fully charged at the beginning of each field day, whenever possible.

Data for this SOP are recorded in the 'Plant Phenology - Annual Measurements [PROD]' Fulcrum application.

However, given the potential for mobile devices to fail under field conditions, it is imperative that paper datasheets are always available to record data. Paper datasheets should be carried along with the mobile devices to sampling locations at all times.

E.2 Annual Data

Once each year, record size and location information for each individual/patch selected for phenology monitoring, on both the primary transect and within the phenocam plot. All individuals observed in a given year must also have an annual data record created; if the individual died, only plant status = 'dead' is required. Record these data at peak season for herbaceous plants and forbs, and at the same time of the year (+/- 2 weeks) annually for woody species. If, for example, a site has both a grass and tree as selected phenology species, annual measurements of the grass may be best collected in July whereas the ideal time to collect annual measurements on the tree may be October; there is no requirement that annual measurements be made on all species at the same time. Record these data during a routine data collection bout. Use the Fulcrum application 'PHE: Annual Measurements [PROD]' or the 'perindividual_peryear' datasheet to record data for this SOP.

For the parent record, record:

- **plotID**
- **eventID** - auto created in the Fulcrum application in the format "phe_SITE_YYYY_DOY". Created at the parent level.
- **samplingProtocolVersion**

For each individual (child record), record the following data, using the 'PHE: Annual Measurements [PROD]' Fulcrum application or the 'perindividual_peryear' datasheets:

- **Location Information** (may be pre-populated in mobile app or on a datasheet):
    - transectMeter (0-799m)
    - directionFromTransect (R/L)
    - tagID (tag#)

- **taxonID:** (may be pre-populated) use United States Department of Agriculture Natural Resources Conservation Services (USDA-NRCS) PLANTS species codes.
- **date:** Defaults to date on which data are entered.
- **patchOrIndividual** (may be pre-populated)
- **patchSize:**
    - 0.25 m x 0.25 m for herbaceous species.
    - 0.5 m x 0.5 m for either herbaceous or woody species depending on growth habit.
    - 1 m x 1 m for woody species.
- **canopyPosition:** Consistent with categories used in vegetation structure - **Table 9**.
- **plantStatus:** The physical status of the individual (**Table 10**). Options are the subset of live choices provided in the vegetation structure protocol.
- Record biomass/productivity measurements consistent with NEON vegetation structure protocols (**Table 11** and **Table 9** in RD[07]) with the following exceptions:
    - Use the laser rangefinder (15 cm accuracy) for canopy diameter and height measurements where appropriate.
    - The phenology ingest is only designed to handle 1 stem diameter / tagID. If the selected individual has multiple boles and would qualify for >1 diameter measurement according to the vegetation structure protocol, select just the largest live stem to measure for this protocol. The largest live stem should be the one onto which the tag is affixed but may be additionally marked with a lumber crayon or flagging (if permitted by site host) to facilitate re-measurement in subsequent years.
    - No stem diameter is required for individuals with all stems <1cm diameter. In this instance, record average height and canopy dimensions only. Include remark “all stems < 1 cm diameter”.
    - Vegetation that would be measured according to shrubgroup growth form in the vegetation structure protocol do not require diameter measurements. Record average height and canopy dimensions as the square root of the estimated canopy area.
- **diseaseType:** If known (e.g., cankers, heart rot, root rot, blight, tar spot, anthracnose, powdery mildew…).
- **remarks:** Free form entry for scientifically relevant comments not captured by other data fields.
    - **standardized remarks** are available for common scenarios.
        - All stems < 1 cm diameter.
        - Burned in last year (see site management data product).

Table 9. These are the Canopy Position classes used to categorize individuals/patches.

Class	Description
Open Grown	Full sun, not touching other plants – crowns that received full light from above and from all sides throughout most of its life, particularly during its early developmental period.
Full sun	Crowns extending above the general level of the canopy and receiving full light from above and partly from the sides. These individuals are taller than the average in the stand and their crowns are well developed, but they could be somewhat crowded on the sides. Also, individuals whose crowns have received full light from above and from all sides during early development and most of their life. Their crown form or shape appears to be free of influence from neighboring plants.
Partially shaded	Individuals with crowns at the general level of the crown canopy. Crowns receive full light from above but little direct sunlight penetrates their sides. Usually they have medium-sized crowns and are somewhat crowded from the sides. In stagnated stands, co-dominant trees have small-sized crowns and are crowded on the sides.
Mostly shaded	Individuals that are shorter than dominants and co-dominants, but their crowns extend into the canopy of co-dominant and dominant trees. They receive little direct light from above and none from the sides. As a result, intermediate trees usually have small crowns and are very crowded from the sides.
Full shade	Individuals with crowns entirely below the general level of the crown canopy that receive no direct sunlight either from above or the sides.

(Modified from Forest Inventory Analysis protocols (USDA, Forest Service 2011))

Table 10. plantStatus classes, only a subset of codes used for vegetation structure are relevant to phenology individuals.

Class	Description
Live	Any live Apparent Individual (new, re-measured or ingrowth) that is of typical healthy status for the ecosystem in question; that is, if trace amounts of insect damage to foliage are typical on the majority of individuals, use this code rather than code 4 below.
Live, insect damaged	Note 'crown' or 'bole' damage in **remarks**, and indicate type of insect causing damage if possible (e.g., Mountain Pine Beetle, Gypsy Moth, etc.)
Live, disease damaged	Note 'crown' or 'bole' damage in **remarks**, and indicate type of disease causing damage if possible (e.g., Blister Rust, rot, canker, other (specify), unknown.
Live, physically damaged	Note 'crown' or 'bole' damage in **remarks**, and indicate type of physical damage if possible (e.g., broken stem, bole scar, girdling, snow/ice damage, crushed, lightning, crown scorch, bole scorch)
Live, other damage	Note 'crown' or 'bole' damage in **remarks**, and note cause if possible.
Live, broken bole	Tree with broken spike top, tree with broken main bole and ascending leaders, tree broken and dead at top but live below

Class	Description
Live, senesced before annual measurements	Annual measurement bout occurred after annual senescence of herbaceous species
Dead	Individual did not survive the sampling season, and has been permanently dropped
Unknown	Herbaceous species, did not emerge this sampling year

Table 11. The Biomass and productivity measurements relevant to Annual measurements of Phenology individuals and patches.

Vegetation Structure[1]	Measurements	Tools to Measure
Individuals	• stemDiameter (cm) – woody species only • maxCanopyDiameter: max. diameter (m) • ninetyCanopyDiameter: Perpendicular to max. diameter (m) • Average height (m) - ignore flowering stalks (grasses) and abnormally long singular branches (shrubs) • Average adult leaf length* (Deciduous broadleaf only) (cm)	• Diameter tape • Laser rangefinder • Ruler • Calipers for ddh
Patches	• Cover Percent • Average height (m)	• 0.25 m x 0.25 m calibrated quadrat • 0.5 m x 0.5 m calibrated quadrat • 1 m x 1 m calibrated sampling frame • Ruler or short tape

[1] Annual datasheets and data ingest interfaces do not accommodate shrub group data. If a shrub group has been selected enter the square root of the canopy area in each of the canopyDiameter fields, calculate the average height to record only a single height measurement, use the remarks to record % dead.

***** Leaf length is optional and intended as guidance for estimating Increasing Leaf Size intensity in future years. This field is not used for data product generation. Use these values in the internally developed site-specific reference materials.

Note: *If annual data collection occurs after an herbaceous individual has already senesced such that size and health cannot be assessed, do not record '0' for any size measurements. Instead, delete the individual child record from the bout parent and work with the lead botanist to schedule an earlier annual bout the following year to catch these individuals at peak biomass.*

**** Tips for measuring patches**:

- To make cover estimates more easily, each frame should be calibrated and incrementally marked along the edges.
- Estimate percent cover according to guidelines provided in (RD[08]). Only estimate cover on plants or portions of plants with stems occurring within the quadrat frame.
- Visually group individuals together into a percent cover. Fine tune that estimate by subtracting out any spaces or gaps.
- Cover should be recorded as the total aerial coverage of the target species. Estimates should not exceed 100% for the target species.

E.3 Tissue Samples for Archive

Leaf tissue and voucher specimens will be collected from each species selected for phenology monitoring at NEON sites. Whenever possible, without impacting growth, samples should be taken directly from the individual/patch being monitored. Guidelines for specimen collection and preparation are outlined in the Plant Voucher Specimen Preparation SOP (RD[11]). Tissue collection and preparation for chemical analyses are described in the Plant Diversity Protocol (RD[08]).

SOP F Data Entry and Verification

Mobile applications are the preferred mechanism for data entry. Data should be entered into the protocol-specific application as they are being collected, whenever possible, to minimize data transcription and improve data quality. Mobile devices should be synced at the end of each field day, where possible. Alternatively, devices should be synced immediately upon return to the Domain Support Facility. Additional details for the phenology observation mobile applications (Field Setup, Phenophase Observations, Annual data) are available in the 'Manual for Fulcrum Application: TOS Plant Phenology [PROD] –All SOPs' document in the Sampling Support Library (SSL).

However, given the potential for mobile devices to fail under field conditions, it is imperative that paper datasheets are always available to record data. Paper datasheets should be carried along with the mobile devices to sampling locations at all times. Data collected on paper data sheets must be transcribed within 14 days of collection or the end of a sampling bout (where applicable). See RD[04] for complete instructions regarding manual data transcription.

Protocol-specific instructions and the associated data ingest workbook for entering plant phenology data can be found on the NEON intranet Field Operations TOS site. Be sure to enter data for all active individuals/patches within a bout unless the bout is ended prematurely due to unforeseen circumstances. If an entire bout is missed, no data need to be entered.

F.1 Transferring Phenocam Individual GPS Data

1. See section E.1 in the Plot Establishment Protocol (RD[12]) for GPS Pathfinder Office steps.
2. Transfer the data to the intranet location specified by Science, N:\Science\GISData\FOPS\PhenoCamPoints
3. Alert Science staff that data has been transferred through either a problem ticket or by email.

Science staff will post process the data and add the spatial data to the Fulcrum Web UI.

F.2 Updating Phenology Database with Selected Species

1. Document species selection in the 'Phenology DB' mobile application.
2. In the view data screen of the application, filter visible fields to just those you will need for species selection.

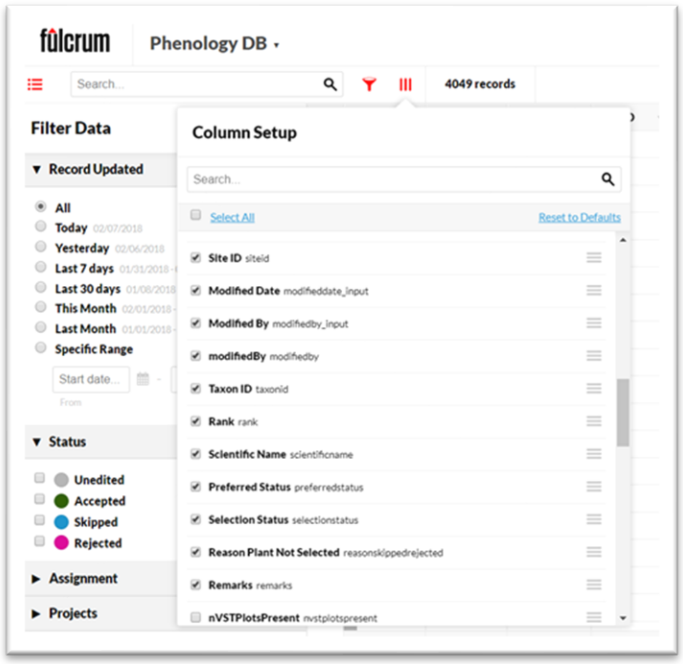

Figure 19. Select fulcrum fields to display.

3. Filter to **Site ID** of interest and order by **Rank**

    a. Select Edit from the dropdown menu to the right of the first species in the list.

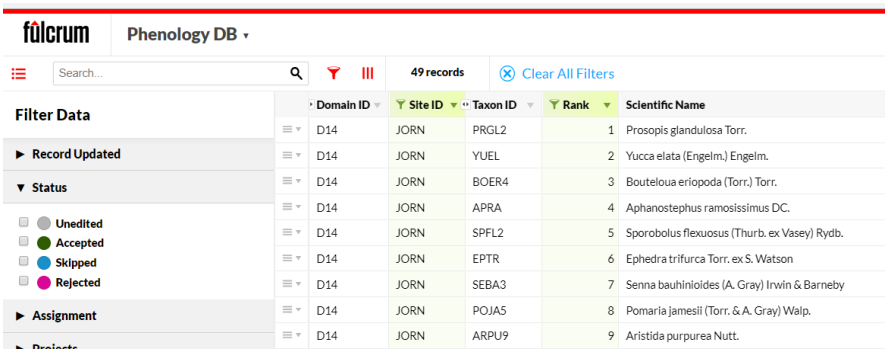

Figure 20. Sort fulcrum records by site.

b. Choose **selectionStatus** from the drop down menu.

    i. For any choice other than “accepted – Phase I”, or “accepted – Phase II” you must enter a rationale for why that species was not selected:

        1) If **selectionStatus** = ‘skipped’, record **Reason Plant Not Selected** as:

            a) Fern, fern ally, or other non-vascular species.

b) TaxonID too low resolution, genus or lower.

2) If selectionStatus = 'rejected Phase I' or 'rejected Phase II', record **Reason Plant Not Selected** as:

a) Overstory species and all required overstory species have already been selected.

b) Understory species and all required understory species have already been selected.

c) Other [remarks required].

4. Select ✓ to save the record.

F.3 Entering and Uploading Observation Data

1. Download photos. Phenology photos will primarily be used to develop site specific reference materials and for training purposes. Organizing and maintaining the phenology image library at each Domain is a Field Operations task.

    - Confirm uncertain phenophases (i.e., phenophaseStatus = ?) with local expert. Update datasheets and note that data were post-corrected in the lab.
    - Verify phenophase/intensity for any data collected by inexperienced staff (i.e., first 3 bouts). All photos must be reviewed and approved by the lead botany field ecologist before being included in phenology reference library.
    - Place all photos from a given year in a single folder labeled by date using the suggested file structure: ~/Site/yyyy
    - Append taxonID_phenophaseName (use camelCase) to the camera-assigned file name to enable searching and maintain link to data.
    - Ex: D16_1692_TSHE_breakingNeedleBud

2. Review data for obvious errors and logical inconsistencies. Use the 'Phenology QA/QC Checklist' available on the SSL and the Phenology QC Shiny App to guide data review.

3. Export finalized Observation records from the 'Phenology - Observations INGEST [PROD]' Fulcrum application based on the date records were finalized. Use fulcrum_id (or _record_id) from the 'phenology_observations_ingest_prod.csv' file to subset records for the current bout in the 'phenology_observations_ingest_prod_child_statusintensity.csv', based on fulcrum_parent_id. Sort and print the csv to take to the field during the subsequent bout.

Note: *Do not finalize 'Plant Phenology-Phenophase Observations [PROD]' records until QC is complete, if subsequent bouts are used to double check validity of observations, wait until the subsequent bout is complete before finalizing. Once pushed to 'Phenology - Observations INGEST*

[PROD]' records will be ingested and locked immediately. Edits will only be possible if the record fails ingest validation.

4. If data were recorded on paper data sheets, scan and print a copy of original data sheets from current bout to bring into the field on the next monitoring bout. Clearly label these sheets as copies to avoid confusion. Transcribe data into phenology Fulcrum desktop application in accordance with data entry and data QA/QC protocols (RD[04]).

IMPORTANT – double check that data are entered for plotID on which data were collected. PlotID **cannot be updated** if recorded incorrectly.

- Training materials for entering phenology data into the mobile applications are available on the Sampling Support Library. Any staff entering data in the mobile or desktop application must review these materials and must enter practice data on the training [CERT] applications before entering actual bout data on [PROD].
- Sync tablets.
- Verify on desktop application that sync was successful.

F.4 Addressing Errors in Field Collected Data

If errors are discovered or information must be updated (e.g., phenophase status = 'uncertain' has been resolved based on photos). Records must be updated.

Perindividual – Field Setup

If the original taxonID assignment was uncertain or an individual is discovered to have been mis-identified, update information in perindividual record. If, for example, the originally assigned **identificationQualifier** changes due to the emergence of diagnostic features during the growing season, update the **taxonID** and **idqCode** to reflect the new status. The same is true for perindividual location information (**transectMeter**, **directionFromTransect, ninetyDegreeDistance**) that must be updated. If a selected individual was incorrectly identified, update the perindividual **taxonID** to the correct species, drop the plant and select a new individual of the correct, target, species.

To update a perindividual record already ingested to the NEON database:

1. Sign into the data entry application for the plot/date combination on which necessary changes to perindividual data were noted.
2. Edit the perindividual data for the selected tagID.

***Note:** this will create a duplicate record that, ultimately, will be visible on the NEON data portal. Users will then be advised that the most recently created record contains the most up to date information. It is very important to QC entered data to the extent possible, when the data are first entered to avoid creating duplicate records on the data portal.*

3. **plotID** fields CANNOT be updated. This field is a primary key for individuals within the NEON sample management system. If errors are found in this field, the **tagID** associated with the incorrect record must be permanently dropped and a new **tagID** assigned.

Updating phenophase observations or annual data already ingested to the NEON database:

1. If errors are discovered in any Phenology applications:
    a. If data have already been ingested, request L0 update through the "Magpie: OS Data Viewer" application (linked via The Aviary).
    b. If data have not yet been ingested, a fulcrum user with edit access to the INGEST application may edit data.

F.5 Equipment Maintenance, Cleaning and Storage

- Double check that all photos have been downloaded then delete photos from camera.
- Charge camera, laser rangefinder, and mobile data recorder batteries.
- Charge GPS unit.

SOP G Sample Shipment

Samples are gathered for archive during annual data collection. Details of sample collection, sample preparation, and shipping are contained in RD[08] .

8 REFERENCES

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APPENDIX A QUICK REFERENCES

A.1 Summary of Phenophases and Intensity Measurements

This table summarizes which phenophases to observe based on the assigned growth form and whether intensity should be recorded as an absolute number (#) or a percentage of the individual /patch on which the phenophase is occurring. There may be multiple phenophases on an individual during a single bout. There may be multiple episodes of a phenophase within a season.

Phenophase Intensity Class Categories

Intensity category	Intensity bins					
# (count)	< 3	3-10	11-100	101-1,000	1,001-10,000	> 10,000
% leaves, flower, color, ripe fruit	< 5	5-24	25-49	50-74	75-94	≥ 95
% Increasing leaf size		< 24	25-49	50-74	75-94	≥ 95

Phenophases by Growth Form

Growth Form	Breaking buds/ Emerging Needles/ Initial Growth	intensity	Increasing Leaf Size/ Young Leaves/ Young Needles	intensity	Leaves/ Needles	intensity	Open Flowers / Pollen Cones	intensity	Colored Leaves/ Needles	intensity	Falling leaves/ Needles	intensity	Fruits+	intensity	Ripe Fruits+	intensity
Cactus	-	-	-	-	-	-	✓	%	-	-	-	-	✓	#	✓	%
Deciduous broadleaf (DBL)	✓	#	✓	%	✓	%	✓	%	✓	%	✓	-	✓	#	✓	%
Deciduous Conifer (DC)	✓	#	-	-	✓	%	✓	%	✓	%	✓	-	-	-	-	-
Drought deciduous broadleaf (DDB)	-	-	✓	#	✓	%	✓	%	✓	%	✓	-	✓	#	✓	%
Evergreen broadleaf (EBL)	✓	#	✓	#	-	-	✓	%	-	-	-	-	✓	#	✓	%
Evergreen broadleaf – no leaf buds (EB-NLB)	-	-	✓	#	-	-	✓	%	-	-	-	-	✓	#	✓	%
Evergreen broadleaf – no leaves (EBL-NL)	-	-	-	-	-	-	✓	%	-	-	-	-	✓	#	✓	%
Evergreen Conifer (EC)	✓	#	✓	#	-	-	✓	%	-	-	-	-	-	-	-	-
Evergreen Conifer – no needles (EC – NN)	-	-	-	-	-	-	✓	%	-	-	-	-	-	-	-	-
Evergreen Forb (EF)	-	-	✓	-	-	-	✓	%	-	-	-	-	✓	#	✓	%
Forb	✓	-	-	-	✓	-	✓	%	-	-	-	-	✓	#	✓	%
Graminoid (GRS)	✓	-	-	-	✓	%	✓	%	-	-	-	-	✓	#	✓	%
Pine	✓	#	✓	#	-	-	✓	%	-	-	-	-	-	-	-	-
Semi-evergreen broadleaf (SEB)	✓	#	✓✓*	#/%	✓	%	✓	%	✓	%	✓	-	✓	#	✓	%
Semi-evergreen forb (SEF)	✓	-	✓	-	✓	-	✓	%	-	-	-	-	✓	#	✓	%

* Both young leaves and increasing leaf size are assessed for semi-evergreen broadleaf individuals.

+ Observed on species specific basis.

A.2 Generalized Phenology Workflow

STEP 1 – Delineate phenology loop or phenocam plot in tower airshed.

STEP 2 – Select individuals and patches to monitor.

STEP 3 – Map location of selected individuals and patches.

STEP 4 – Mark individuals and patches with unique tagIDs.

STEP 5 – Collect phenophase data, including photographs.

STEP 6 – Select replacement individuals as needed (repeat steps 2-4 for new plants).

STEP 7 – Download photographs and indicate phenophase for internal references and training.

STEP 8 – Collect location, size, and health status data on all monitored plants (annually).

A.3 Phenophase Observation QA Checklist

Before leaving DSF

- Make sure tablet and GPS are fully charged.
- Create blank observation bout record from Field Setup application.
- Synch mobile device and verify records are available on mobile device.
- Print or populate Fulcrum records with previous bout data.
- Review and pack internal reference materials with species and phenophase specific information.

While in the field

- Approach transect/plot using designated route.
- Check that tags are organized on the mobile application by transectMeter.
- Start transect at the designated start transectMeter.
- If working with a partner, designate one recorder and one observer.
- Triple check record date before recording any observations.
- Walk in clockwise direction.
- Stop at designated transectMeter or viewpoints to observe individuals/patches.
- Do not leave the transect to make observations unless instructed to do so by the Flora lead.
- Use binoculars or spotting scope to see tall trees.
- Use call-response for each individual and phenophase using full names, questions and intensities to minimize confusion. For example:
    - Recorder: “tagID = 1234, left side”

- Observer: “tagID – 1234, [taxonID]”
- Recorder: “Breaking leaf buds” **Say full phenophase name, do not use codes**
- Observer: “No”
- Recorder: “Increasing leaf size?”
- Observer: “No”
- Recorder: “Leaves”
- Observer “Yes”
- Recorder: “What percentage of the potential canopy space is full with leaves?” **Say full phenophase intensity question.**
- Observer: “Greater than 95 percent” **Say full intensity category, do not use codes.**
- …

- Refer to previous bout and reference materials as needed throughout the bout.
- **SAVE OFTEN!** An unexpected tablet shut down could result in loss of all data up to the last save.
- Take pictures and notes about any phenophase status or intensity you are not confident about.

Post bout actions - DSF

- Sync tablet.
- Review any status = uncertain with Flora lead.
- Flora lead will finalize bout and push records to the Phenology – Observations [PROD] application.
- Generate record for next scheduled bout.

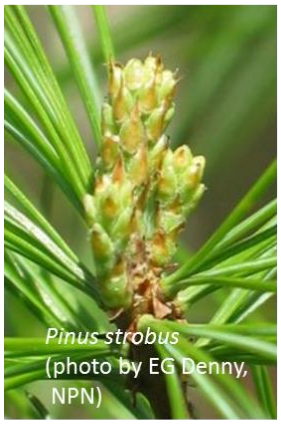
A.4 Phenophase Definitions

Early season growth			
Phenophase Title	**Applicable Growth Forms**	**Status Description**	**Intensity Question**
Breaking leaf buds	DBL EBL SEB	One or more breaking leaf buds are visible on the plant. A leaf bud is considered "breaking" once a green leaf tip is visible at the end of the bud, but before the first leaf from the bud has unfolded to expose the leaf base at its point of attachment to the leaf stalk (petiole) or stem.	How many buds are breaking?
Breaking needle buds	DC EC	One or more breaking needle buds are visible on the plant. A needle bud is considered "breaking" once a green needle tip is visible at the end of the bud, but before the first needle from the bud has unfolded and spread away at an angle from the developing stem, or from other needles in a bundle.	How many buds are breaking?
Emerging needles	Pine	One or more emerging needles or needle bundles (fascicles) are visible on the plant. A needle or needle bundle is considered "emerging" once the green tip is visible along the newly developing stem (candle), but before the needles have begun to unfold and spread away at an angle from others in the bundle.	How many needle bundles are emerging?
Initial growth	Forb GRS SEF	New growth of the plant is visible after a period of no growth (winter or drought), either from above-ground buds with green tips, new green or white shoots breaking through the soil surface, or re-greening of dried stems or leaves. Growth is considered "initial" on each bud or shoot until the first leaf has fully unfolded. For seedlings, "initial" growth includes the presence of the one or two small, round, or elongated leaves (cotyledons) before the first true leaf has unfolded or has fully re-greened.	NA

Initial Growth - GRS

Breaking needle buds - EC, DC

Breaking leaf bud - DBL, EBL, SEB



Emerging needles - Pine

Early Development			
Phenophase Title	**Applicable Growth Forms**	**Status Description**	**Intensity Question**
Increasing Leaf size	DBL SEB	A majority of leaves on the plant have not yet reached their full size and are still growing larger. Do not include new leaves that continue to emerge at the ends of elongating stems throughout the growing season.	What percentage of full size are most leaves?
Young Leaves	EBL EBL-NLB DDB EF SEB SEF	One or more young, unfolded leaves are visible on the plant. A leaf is considered "young" and "unfolded" once its entire length has emerged from the breaking bud, stem node or growing stem tip, so that the leaf base is visible at its point of attachment to the leaf stalk (petiole) or stem, but before the leaf has reached full size or turned the darker green color or tougher texture of mature leaves on the plant. Do not include fully dried or dead leaves. No intensity reported for forbs.	How many young leaves are present?
Young needles*	EC Pine	One or more young, unfolded needles are visible on the plant. A needle is considered "young" and "unfolded" once it has spread away from the developing stem enough that its point of attachment to the stem is visible, or has spread from other **needles** in the bundle (and is no longer pressed flat against them), but before it has reached full size or turned the darker green color or tougher texture of mature needles on the plant.	How many young needles (EC) or young needle bundles (fascicles, Pine) are present?

A Note about Needles

Needles, depending on species, may be solitary (e.g., *Picea sp., Abies sp., or Pseudotsuga sp.*), clustered together on short shoots (e.g., *Larix sp.*), or bundled in fascicles (e.g., *Pinus sp.)*. Fascicled needles are clustered tightly at the base with a small sheath surrounding the base—although that sheath can be deciduous in some species.

Increasing leaf size – DBL, SEB

Young leaves – EBL, DDB, EF, SEB

Young needles – EC, Pine

Growing season duration			
Phenophase Title	**Applicable Growth Forms**	**Status Description**	**Intensity Question**
Leaves	DBL DDB SEB	One or more live, unfolded leaves are visible on the plant. A leaf is considered "unfolded" once its entire length has emerged from the breaking bud, stem node or growing stem tip, so that the leaf base is visible at its point of attachment to the leaf stalk (petiole) or stem. Do not include fully dried or dead leaves.	What percentage of the potential canopy space is full with leaves? Ignore dead branches in the estimate.
Leaves	Forb GRS SEF	One or more live, fully unfolded leaves are visible on the plant. For seedlings, consider only true leaves and do not count the one or two small, round or elongated leaves (cotyledons) that are found on the stem almost immediately after the seedling germinates. Do not include fully dried or dead leaves. No intensity reported for forbs.	GRS - What percentage of the plant is green? Or, for patches, what percentage of the current years' growth of the target species within the patch is green?
Needles	DC	One or more live, unfolded needles are visible on the plant. A needle is considered "unfolded" once it begins to spread away at an angle from the developing stem enough that its point of attachment to the stem is visible, or from other needles in a bundle so that it is no longer pressed flat against them. Do not include fully dried or dead needles.	What percentage of the potential canopy space is full with needles? Ignore dead branches in the estimate.

Assessing intensity class for grasses, sedges, and rushes

For annual grasses measured as patches, report *% green of the target species within the selected patch*, rather than % of patch that is green. For grass, sedge and rush species (GRS) where new growth is from new stems, the plant will probably be 100% green until it begins to turn brown in the late summer or fall. For species where existing stems can turn brown and then re-green, the intensity for the **leaves** may start low at the beginning of the growing season, become higher in the middle of the growing season, and then decline again as the plant turns brown again. In dryland environments where conditions are extreme, it can be particularly difficult to judge what portion of a grass plant is truly dead and what portion has the potential to re-green. If this is the case refer to the reference photobook for phenophase for that species. Take a picture for future reference and discuss with the lead botany field ecologist.

Needles - DC

Leaves – GRS, Forb

Leaves – DBL, DDB, SEB

Flowering phenophases			
Phenophase Title	**Applicable Growth Forms**	**Status Description**	**Intensity Question**
Open flowers	DBL EBL EBL-NLB EBL-NL Forb GRS Cactus DDB EF SEB SEF	One or more open, fresh flowers are visible on the plant. Flowers are considered "open" when the reproductive parts (male stamens or female pistils) are visible between or within unfolded or open flower parts (petals, floral tubes or sepals). Do not include wilted or dried flowers. Tip: for perfect or female flower look for wilted style/stigma or swollen ovary to indicate the phenophase is complete.	What percentage of all fresh flowers (buds plus unopened plus open) on the plant are open? For species in which individual flowers are clustered in flower heads, spikes or catkins (inflorescences), estimate the percentage of all individual flowers that are open.
Open pollen cones	DC EC Pine	One or more open, fresh, male pollen cones (strobili) are visible on the plant. Cones are considered "open" when the scales have spread apart to release pollen. Do not include wilted or dried cones that have already released all of their pollen	What percentage of all fresh pollen cones (unopened plus open) on the plant are open? (Once pollen release is complete pollen cones are no longer considered in count of total pollen cones on the individual)

Assessing intensity class for Inflorescences

When estimating intensity class for **Open Flowers** on plants with inflorescences (including grasses), the percentage of individual flowers open on a single inflorescence (flower heads, spikes or catkins), will often be the same for all inflorescences on the plant. If this is the case, you can choose a single inflorescence, estimate the percentage of open flowers on it, and use that value to represent the entire plant. For larger plants, it is generally a good idea to check a few inflorescences (for example, one towards the bottom of the plant, one in the middle and one towards the top), and average the percentage of open flowers on each of these inflorescences to represent the entire plant.

Open flowers – DBL, EBL, Forb, GRS, Cactus, DDB, EF, SEB

Open pollen cones – EC, DC, Pine

Senescence			
Phenophase Title	**Applicable Growth Forms**	**Status Description**	**Intensity Question**
Colored leaves	DBL DDB SEB	One or more leaves show some of their typical late-season color, or yellow or brown due to drought or other stresses. Do not include small spots of color due to minor leaf damage, or dieback on branches that have broken. Do not include fully dried or dead leaves that remain on the plant.	What percentage of the potential canopy space is full with non-green leaf color? Ignore dead branches in your estimate.
Colored needles	DC	One or more needles show some of their typical late-season color, or yellow or brown due to drought or other stresses. Do not include small spots of color due to minor needle damage, or dieback on branches that have broken. Do not include fully dried or dead needles that remain on the plant.	What percentage of the potential canopy space is full with non-green needle color? Ignore dead branches in your estimate.

Assessing leaf color change on diseased leaves

Leaf discoloration is a common symptom of pathogen infection. If an individual selected for phenology monitoring is diseased, assess the colored leaves / colored needles phenophase on the uninfected portions of the leaves. The disease status will be captured during the annual measurements.

For example: assuming all leaves are still on an individual with 10 leaves and each of these leaves are 50% diseased (5 total leaf area diseased) and of the non-diseased portion, 60% is colored (3 total leaf area colored), intensity is 60%, not 30%.

Colored leaves - DBL, DDB, DEB

Colored leaves - DBL, DDB, DEB

Return to dormancy			
Phenophase Title	**Applicable Growth Forms**	**Status Description**	**Intensity Question**
Falling leaves	DBL DDB SEB	One or more leaves with typical late-season color, or yellow or brown due to other stresses, are falling or have recently fallen from the plant. Do not include fully dried or dead leaves that remain on the plant for many days before falling.	NA
Falling needles	DC	One or more needles are falling or have recently fallen from the plant.	NA

Falling leaves – DBL, DDB, SEB
Falling needles – DC (not shown here)

****SEE SCENARIO BELOW FOR AN EXAMPLE OF LEAVES, COLORED LEAVES AND FALLING LEAVES STATUS AND INTENSITY ASSESSMENT****

Estimating percent canopy with colored leaves/needles (P5)

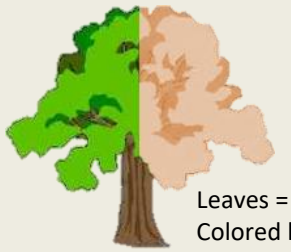
To estimate the percentage of the canopy that is full with **colored leaves/needles**, consider the proportion of colored leaves and needles that are left on the plant relative to the fully leafed out canopy.

For instance, if the plant canopy is 100% full with leaves but about half of them are green and half are colored, you would report that 100% of the canopy is full with leaves, and 50% of the canopy is full with colored leaves. (Scenario A)

If it is windy the next day, and half of the colored leaves fall off (but none of the green leaves fall off), you would now report that 75% of the canopy is full with leaves and 25% of the canopy is full with colored leaves. (Scenario B)

As the days go on, more of the leaves change color and some fall off, and you might eventually find that only half of the leaves remain on the plant and there is no green left in them. At this point you would report that 50% of the canopy is full with leaves and 50% of the canopy is full with colored leaves. (Scenario C)

Note that the percentage of the canopy full with leaves or needles (green plus colored) should steadily decline from 100% to 0% as leaves or needles fall off. However, the percentage of the canopy full with colored leaves or needles may go up and down during this time of leaf/needle fall.

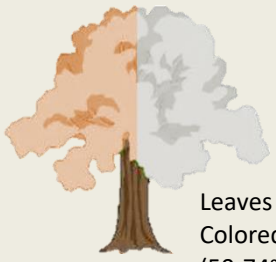


Scenario A

Leaves = 100% leaves on (≥95%)
Colored leaves = 50% (50-74%)
Falling leaves = no

Scenario B

Leaves = 75% leaves on (75-94%)
Colored leaves = 25% colored (25-49%)
Falling leaves = yes



Scenario C

Leaves = 50% leaves on (50-74%)
Colored leaves = 50% colored (50-74%)
Falling leaves = yes

Fruiting Phenophases			
Phenophase Title	**Applicable Growth Forms**	**Status Description**	**Intensity Question**
Fruits	Cactus DBL DDB EBL EB-NLB EBL-NL EF Forb GRS SEB SEF	One or more fruits are visible on the plant.	How many fruits are present?
Ripe Fruits	Cactus DBL DDB EBL EB-NLB EBL-NL EF Forb GRS SEB SEF	One or more ripe fruits are visible on the plant.	What percentage of all fruits (unripe plus ripe) on the plant are ripe?

Fruiting Phenophases are species specific

Inclusion of fruiting phenophases is optional and will be determined by Field Science flora leads based on feasibility of accurately and consistently observing these phenophases on the selected species. Site specific references will need to include species-specific definitions based on the fruit type being observed. Refer to USA-NPN definitions for details.

HOW IS THE PHENOPHASE 'FRUITS' DIFFERENT FROM 'RIPE FRUITS'?

The 'Fruits' phenophase gives you the opportunity to report the presence of developing fruits before you see any of them mature or ripen on your plant. Report "Yes" for this phenophase as long as you see fruits on your plant at any stage of maturity, whether unripe and in the process of developing, or mature and ripe. This means that whenever you report you see 'Ripe fruits', you should also be reporting that you see 'Fruits'. Often some fruits will ripen and be eaten or drop from the plant, while unripe fruits still remain, so you may see fruits for a long period of time with ripe fruits present on the plant during some observation days and no ripe fruits present on other observation days. Sometimes it is hard to tell when fruits first appear. Technically they are present as soon as the flower's ovary is fertilized, but often the ovary does not swell into something resembling a fruit for several weeks. Do not worry about missing this early stage and simply report fruits when you see the fruit as it begins to enlarge. However, once all of the fruits drop all of their seeds, do not report this phenophase even if the pods, capsules, or husks of the fruits remain (or "persist") on the plant.

Unripe (left) and ripe (right) fruits of a) *Vaccinium corymbosum* b) *Scirpus cyperinus* and c) *Acer rubrum*. Photo credit, Ellen Denny.

HELPFUL INFORMATION FOR INTENSITY ESTIMATION

- **Multiple phenophases** may be reported for an individual in a single bout. Evaluate each phenophase independently from the others. For example, for **Breaking buds/ emerging needles / initial growth phenophase**, each leaf bud, needle bud, or shoot should be judged separately. As long as some buds or shoots on the plant are still breaking or initiating growth and have not yet produced an unfolded leaf or needle, you are seeing 'Breaking leaf/needle buds', 'Emerging needles', or 'Initial growth'. For plants that have more than one bud or shoot, in most cases you will still be seeing 'Breaking leaf/needle buds', 'Emerging needles', or 'Initial growth' in some buds or shoots for many days after you first begin seeing 'Leaves/Needles' or 'Young leaves/needles' from other buds or shoots. It is also possible to see multiple episodes of leaf/needle bud break or initial growth within a season. This might occur after a period of frost, drought, or after a plant is defoliated by insects. However, once ALL the active leaf/needle buds or shoots on the plant have at least one unfolded leaf/needle, you should be reporting that you no longer see 'Breaking leaf/needle buds', 'Emerging needles', or 'Initial growth'.

- For grass, sedge and rush species where new growth is from new stems, the plant will probably be 100% green until it begins to turn brown in the late summer or fall. For species where existing stems can turn brown and then re-green, the percentage may start low at the beginning of the growing season, become higher in the middle of the growing season, and then decline again as the plant turns brown again. In dryland environments where conditions are extreme, it can be particularly difficult to judge what portion of a grass plant is truly dead and what portion has the potential to re-green. If this is the case for your plant, you may want to ignore this intensity question and just report on whether or not you see green leaves. (https://www.usanpn.org/nn/faq#percent_green)

- If unsure about the intensity class for the increasing leaf size phenophase for deciduous broad leaf species (DBL), refer to the annual data from the previous year to see the length of an adult leaf for that species. In the first year of operations this will have to be an educated guess since the data will not yet be available for a quantitative assessment. This measurement is included in order to track the length of the "green-up" period, the amount of time it takes leaves to reach full size, an important aspect of a plant's response to climate change.

- Continue to report seeing 'Leaves/Needles' as long as fresh green or colored leaves/needles remain on the plant. Do not include dried, dead leaves or dead, brown needles that remain on the plant, such as occurs with some species throughout the dormant season (e.g., winter or dry season).

- There are no intensity options for Falling Leaves because the percentage of leaves or needles that have fallen from a deciduous plant can be calculated from the percentage of leaves or needles that remains on the plant. This is already captured in the value you reported for percentage of the canopy is full with leaves/needles for the 'Leaves/needles' phenophase.

APPENDIX B REMINDERS

Phenology Sampling

Selecting plants: Be sure to…

- ☑ Select representative plants (in terms of age and health).
- ☑ Wrap wire loosely (if used to attach ID tag).
- ☑ Space selected individuals evenly around the loop.
- ☑ Give preference to plants that are close to the loop over those that are farther away.

Walking the loop

- ☑ Use designated route for accessing loop.
- ☑ Stay out of restricted area.
- ☑ Avoid walking on/trampling plant productivity plots.
- ☑ Stay on the loop as much as possible.
- ☑ Look for all phenophases and assess intensity.
- ☑ Record photo file number on Data Sheet.

Photography tips

- ☑ Flash: Turn off for close-up shots.
- ☑ Macro mode: Use for close-ups.
- ☑ Framing: Position camera so subject fills the frame.
- ☑ Focus: Check this! Brace yourself to reduce movement.
- ☑ Purpose: Keep this in mind.

A middle-distance shot shows intensity.

A close-up captures each flower.

APPENDIX C ESTIMATED DATES FOR ONSET AND CESSATION OF SAMPLING

The Phase I dates in the table below are estimated from satellite MODIS-EVI phenology data averaged from 2005-2014 (Didan 2015), Phase II dates are from MODIS-EVI data from 2012-2021 (Didan 2021). Dates presented here are only a guide, and are derived according to the logic presented in Section 4.2. Because individual years may vary widely from the average dates provided below, it is essential that domain staff monitor real-time conditions to determine when to start (and stop) sampling, as described in Section 4 of this protocol.

The dates were generated from previously collected phenology data from NEON sites or data from the ORNL DACC MODIS/Terra Vegetation Indices (NDVI/EVI) 'MODIS Phenology time series' report for an area 2 km on a side centered on the lat/long of the Tower location at each site. These dates are intended to provide general guidance on historic phenophase transitions to inform scheduling for future sampling seasons.

The date of bud break within a given year for a selected species may be affected by interactions between temperature, precipitation, and day length. Accumulated Growing Degree Days (AGDD) is one variable often associated year to year variability in start of season, and may be useful for tracking temperature accumulation for a given year and predicting when plants at a given site are likely to become phenologically active. The 'Temperature Accumulations, Current Day' maps in the USA-NPN data visualization tool (http://data.usanpn.org/npn-viz-tool/) enables tracking of the current year's AGDD and allows comparison to the previous year and 30-year average for a given site. When planning observation bouts domain staff are encouraged to use the summary of past years' data provided here, direct observations of indicator individuals, and the AGDD maps and forecasts available through the USA-NPN website to plan initiation of sampling at a given site (seasonal sampling) for the calendar year.

Data Fields and assumptions:

- **Domain ID** – Domain identifier
- **Site ID** – Site identifier
- **Schedule** – identifies dynamic (Seasonal, Hybrid) vs. consistent (Year-round) sampling frequency.
- **Data Source** –either NEON collected data from the site or satellite derived, MODIS, EVI transition dates.
- **Source Year** – years of data analyzed.
    - NEON collected data, the first sampling year omitted from, typically not a full season.
    - MODIS data, sites with < 1 full season of data collection or year-round sampling schedule.
- **Spring High Frequency** – early season frequency, reflects iteration with sites to reduce number of bouts conducted during spring transitions, based on extended sampling seasons.

- **Start Season** – NEON data: earliest recorded phenophaseStatus = 'yes' – 7 days (to capture pre-season dormant bout).
    - MODIS: earliest increasing EVI – 14 days.
- **Start Spring High** – earliest recorded phenophaseStatus = 'yes' for 'Breaking leaf buds', 'Breaking needle buds', 'Emerging needles' & 'Initial growth' phenophases.
- **End Spring High** – mean date on which the number of individuals with >50% leaves phenophase intensity peaks.
- **Start Fall High** – forested sites: mean earliest recorded phenophaseStatus = 'yes' date, > end Spring High, for 'Colored leaves' or 'Colored needles' phenophase.
    - Herbaceous dominated sites and Hybrid schedule: mean start of decreasing EVI (greenness) date from MODIS data.
- **End Fall High** - forested sites: latest recorded first date where phenophaseStatus = 'yes' for 'colored leaves' and 'colored needles' peaks.
    - Herbaceous sites and Hybrid schedule: Begin Fall High + 30 days.
- **End Season** – NEON data: latest recorded phenophaseStatus = 'yes' + 7 days (to capture end of season no bout).
    - MODIS: latest return to minimum EVI + 14 days.
- **Suggested Bout Count** – number of bouts recommended by this analysis, details of calculation below.
- **Source Year Mean Bouts** – mean number of bouts conducted at each site across previous full sampling seasons.

Suggested Bout Count Calculation:

- From **start Season** till **start Spring High** = # wks * 1
- From **start Spring High** till **end Spring High** = # wks *springHiFrequency
- From **end Spring High** till **start Fall High** = # wks * 0.5 (1x/2weeks)
- From **start Fall High** till **end Fall High** = # wks * 2
- From **end Fall High** till **end Seaso**n = # wks * 1
- Hybrid Sites: data informed transition dates and sampling bouts provided (sum) as well total number of weeks from **start Season** till **end Season** (wks). Variable sampling frequency based on multiple, episodic periods of growth or species with dissimilar phenologies are expected to result in a total number of bouts between the two values.

Table 12. Suggested Phenology Phase I Scheduling by Site.

Domain ID	Site ID	Phase I schedule	Data Source	Source Year Range	Phase I Spring High Frequency	Start Season	Start Spring High	End Spring High	Start Fall High	End Fall High	End Season	Suggested Bout Count	Source Year Mean Bouts
D01	BART	Seasonal	NEON data	2015-2017	2x/week	30-Mar	23-Apr	18-May	11-Jul	4-Oct	24-Nov	43	48.7
D01	HARV	Seasonal	NEON data	2014-2017	2x/week	5-Mar	12-Apr	10-Jun	23-Jul	12-Oct	4-Dec	50	51.8
D02	BLAN	Seasonal	NEON data	2016-2017	2x/week	17-Feb	24-Feb	13-May	12-Aug	2-Sep	19-Dec	44	51.5
D02	SCBI	Seasonal	NEON data	2015-2017	2x/week	11-Mar	18-Mar	29-Apr	12-Jul	5-Sep	19-Dec	41	53.7
D02	SERC	Seasonal	NEON data	2016-2017	2x/week	23-Feb	2-Mar	22-May	26-Jul	9-Oct	10-Dec	51	47
D03	DSNY	Year round	MODIS	2005-2014								50	
D03	JERC	Year round	MODIS	2005-2014								50	
D03	OSBS	Year round	MODIS	2005-2014								50	
D04	GUAN	Year round	MODIS	2005-2014								50	
D04	LAJA	Year round	MODIS	2005-2014								50	
D05	TREE	Seasonal	NEON data	2016-2017	3x/week	5-Apr	22-Apr	28-May	2-Aug	23-Sep	1-Nov	36	39
D05	UNDE	Seasonal	NEON data	2015-2017	3x/week	3-Apr	10-Apr	4-Jun	6-Aug	27-Sep	10-Nov	42	46
D06	KONZ	Seasonal	NEON data	2016-2017	3x/week	16-Mar	23-Mar	27-May	7-Sep	7-Oct	13-Dec	45	39.5
D06	UKFS	Seasonal	NEON data	2016-2017	2x/week	8-Mar	15-Mar	13-May	16-Jul	4-Oct	19-Dec	48	48
D07	GRSM	Seasonal	NEON data	2016-2017	2x/week	16-Feb	19-Mar	8-May	7-Aug	28-Oct	12-Dec	46	50
D07	MLBS	Seasonal	MODIS	2005-2014	3x/week	24-Mar	07-Apr	6-Jun	8-Aug	7-Sep	29-Nov	42	
D07	ORNL	Seasonal	NEON data	2015-2017	2x/week	23-Feb	6-Mar	7-May	6-Sep	2-Nov	29-Dec	41	50.3
D08	DELA	Year round	MODIS	2005-2014								50	
D08	TALL	Year round	MODIS	2005-2014								50	
D08	LENO	Hybrid	MODIS										
D09	NOGP	Seasonal	NEON data	2017	2x/week	13-Mar	20-Mar	3-Jul	24-Jul	31-Aug	28-Nov	53	45
D09	WOOD	Seasonal	NEON data	2015-2017	3x/week	23-Feb	2-Mar	24-Apr	29-Jul	28-Aug	16-Dec	45	45.7
D10	CPER	Year round	MODIS	2005-2014								50	
D10	RMNP	Seasonal	MODIS	2005-2014	3x/week	5-Apr	19-Apr	3-Jul	2-Aug	1-Sept	19-Oct	48	

Domain ID	Site ID	Phase I schedule	Data Source	Source Year Range	Phase I Spring High Frequency	Start Season	Start Spring High	End Spring High	Start Fall High	End Fall High	End Season	Suggested Bout Count	Source Year Mean Bouts
D11	CLBJ	Year round	MODIS	2005-2014								50	
D11	OAES	Year round	MODIS	2005-2014								50	
D12	YELL	Hybrid	MODIS	2005-2014	3x/week	2-Apr	16-Apr	18-Jun	2-Aug	1-Sep	12-Oct	45	
D13	MOAB	Year round	NEON data	2016-2017	3x/week	15-Feb	22-Feb	12-May	13-Aug	12-Sep	12-Dec	55 (sum); 41 (wks)	34.5
D13	NIWO	Hybrid	NEON data	2016-2017	3x/week	24-May	31-May	3-Jul	8-Aug	7-Sep	1-Nov	28 (sum); 22 (wks)	25.5
D14	JORN	Year round	MODIS	2005-2014								50	
D14	SRER	Year round	MODIS	2005-2014								50	
D15	ONAQ	Year round	NEON data	2015-2017	3x/week	8-Feb	15-Feb	5-May	3-Jun	10-Jun	6-Dec	61 (sum); 42 (wks)	29.3
D16	ABBY	Seasonal	NEON data	2017	2x/week	23-Feb	10-Apr	16-Jun	23-Aug	28-Aug	20-Nov	45	52
D16	WREF	Seasonal	MODIS	2005-2014	3x/week	23-Mar	7-Apr	21-Jun	28-Jul	27-Aug	16-Nov	61	
D17	SJER	Year round	MODIS	2005-2014								50	
D17	SOAP	Year round	MODIS	2005-2014									
D17	TEAK	Hybrid	MODIS	2005-2014	3x/week	4-Mar	18-Mar	7-Jun	8-Jul	7-Aug	26-Nov	59	
D18	BARR	Seasonal	MODIS	2005-2014	3x/week	4-Jun	18-Jun	13-Jul	27-Jul	26-Aug	13-Sep	22	
D18	TOOL	Seasonal	MODIS	2005-2014	3x/week	14-May	28-May	4-Jul	26-Jul	25-Aug	16-Sep	30	
D19	BONA	Seasonal	MODIS	2005-2014	3x/week	21-Apr	5-May	27-Jun	26-Jul	25-Aug	27-Sep	37	
D19	DEJU	Seasonal	NEON data	2017	3x/week	26-Apr	3-May	5-Jun	25-Jul	28-Aug	12-Oct	27	40
D19	HEAL	Seasonal	NEON data	2016-2017	3x/week	30-Apr	7-May	5-Jun	26-Jul	17-Aug	11-Oct	26	30
D20	PUUM	Year round	MODIS	2005-2014								50	

Table 13. Suggested Phenology Phase II Scheduling by Site.

Domain ID	Site ID	Phase II schedule*	Data Source	Source Year Range	Phase II High Frequency (Spring&Fall)	Start Season	Start Spring High	End Spring High	Start Fall High	End Fall High	End Season	Suggested Bout Count	Source Year Mean Bouts
D01	BART	Seasonal - Gradient	NEON data	2015-2022	1x/week	30-Mar	7-Apr	2-Jun	13-Jul	6-Oct	24-Nov	31	46.2
D01	HARV	Seasonal - Core	NEON data	2014-2022	2x/week	5-Mar	22-Mar	7-Jun	26-Jul	6-Dec	13-Dec	50	49.7
D02	BLAN	Year round	MODIS	2012-2021								50	
D02	SCBI	Year round	MODIS	2012-2021								50	
D02	SERC	Year round	MODIS	2012-2021								50	
D03	DSNY	Year round	MODIS	2012-2021								50	
D03	JERC	Year round	MODIS	2012-2021								50	
D03	OSBS	Year round	MODIS	2012-2021								50	
D04	GUAN	Year round	MODIS	2012-2021								50	
D04	LAJA	Year round	MODIS	2012-2021								50	
D05	TREE	Seasonal - Gradient	NEON data	2016-2022	1x/week	31-Mar	22-Apr	4-Jun	1-Aug	23-Sep	2-Nov	25	37.3
D05	UNDE	Seasonal - Core	NEON data	2015-2022	2x/week	23-Mar	6-Apr	7-Jun	5-Aug	2-Nov	16-Nov	48	42.6
D06	KONZ	Seasonal - Core	NEON data	2016-2022	2x/week	8-Mar	15-Mar	25-May	19-Aug	8-Oct	14-Dec	49	43.1
D06	UKFS	Year round	MODIS	2012-2021		25-Feb					8-Dec	50	
D07	GRSM	Seasonal - Gradient	NEON data	2016-2022	1x/week	14-Feb	23-Feb	13-May	20-Aug	29-Oct	20-Dec	36	44.9
D07	MLBS	Seasonal - Gradient	NEON data	2018-2022	1x/week	16-Mar	23-Mar	3-Jun	14-Aug	17-Sep	22-Nov	29	29.8
D07	ORNL	Seasonal - Core	NEON data	2015-2022	2x/week	16-Feb	23-Feb	24-Apr	9-Aug	10-Nov	29-Dec	50	46.2
D08	DELA	Year round	MODIS	2012-2021								50	

Domain ID	Site ID	Phase II schedule*	Data Source	Source Year Range	Phase II High Frequency (Spring&Fall)	Start Season	Start Spring High	End Spring High	Start Fall High	End Fall High	End Season	Suggested Bout Count	Source Year Mean Bouts
D08	LENO	Year round	MODIS	2012-2021								50	
D08	TALL	Year round	MODIS	2012-2021								50	
D09	NOGP	Seasonal - Gradient	NEON data	2017-2022	1x/week	25-Feb	4-Mar	28-May	26-Jul	29-Sep	6-Dec	35	41.3
D09	WOOD	Seasonal - Core	NEON data	2015-2022	2x/week	23-Feb	2-Mar	15-May	10-Aug	1-Sep	16-Dec	48	39.1
D10	CPER	Year round	MODIS	2012-2021								50	
D10	RMNP	Seasonal - Gradient	NEON data	2018-2022	1x/week	12-Apr	19-Apr	6-Jun	18-Sep	1-Oct	11-Nov	20	35.4
D11	CLBJ	Year round	MODIS	2012-2021								50	
D11	OAES	Year round	MODIS	2012-2021								50	
D12	YELL	Year round	MODIS	2012-2021								50	
D13	MOAB	Year round	MODIS	2012-2021								50	
D13	NIWO	Year round	MODIS	2012-2021								50	
D14	JORN	Year round	MODIS	2012-2021								50	
D14	SRER	Year round	MODIS	2012-2021								50	
D15	ONAQ	Year round	MODIS	2012-2021								50	
D16	ABBY	Year round	MODIS	2012-2021								50	
D16	WREF	Year round	MODIS	2012-2021								50	
D17	SJER	Year round	MODIS	2012-2021								50	
D17	SOAP	Year round	MODIS	2012-2021								50	
D17	TEAK	Seasonal - Gradient	NEON data & MODIS	2020-2022	1x/week	24-Mar	31-Mar	21-Jun	7-Aug	6-Sep	1-Dec	31	23.7
D18	BARR	Seasonal - Gradient	NEON data	2018-2022	1x/week	07-May	10-Jun	23-Jul	5-Aug	8-Aug	10-Oct	17	29.8
D18	TOOL	Seasonal - Core	NEON data	2018-2022	2x/week	23-Apr	13-May	8-Jul	16-Jul	30-Aug	19-Oct	37	32.4

Domain ID	Site ID	Phase II schedule*	Data Source	Source Year Range	Phase II High Frequency (Spring&Fall)	Start Season	Start Spring High	End Spring High	Start Fall High	End Fall High	End Season	Suggested Bout Count	Source Year Mean Bouts
D19	BONA	Seasonal - Core	NEON data	2018-2022	2x/week	29-Apr	6-May	18-Jun	3-Aug	30-Aug	11-Oct	28	32.8
D19	DEJU	Seasonal - Gradient	NEON data	2017-2022	1x/week	21-Apr	28-Apr	9-Jun	23-Jul	7-Sep	15-Oct	21	36
D19	HEAL	Seasonal - Gradient	NEON data	2016-2022	1x/week	11-Apr	7-May	12-Jun	27-Jul	26-Aug	11-Oct	19	29.1
D20	PUUM	Year round	MODIS	2012-2021								50	

* For year round sampling schedules, at sites with brief but distinct and predictable dormant periods, bouts may be shifted from dormant periods to spring/fall transitions.

Table 14. Summary of Phase I/II transitions and sampling schedule.

Domain ID	Site ID	Sampling locations*	Primary Transect Collocation	Phase I schedule	Phase I Sampling First Year	Phase II schedule+	Phase II Sampling First Year
D01	BART	2	Tower	Seasonal	2014	Seasonal - Gradient	2021
D01	HARV	2	Tower	Seasonal	2013	Seasonal - Core	2021
D02	BLAN	2	Tower	Seasonal	2015	Year round	2021
D02	SCBI	2	Tower	Seasonal	2014	Year round	2021
D02	SERC	2	Tower	Seasonal	2015	Year round	2021
D03	DSNY	2	Tower	Year round	2013	Year round	2021
D03	JERC	2	Tower	Year round	2014	Year round	2021
D03	OSBS	2	Tower	Year round	2013	Year round	2021
D04	GUAN	2	Tower	Year round	2015	Year round	2021
D04	LAJA	1	Tower	Year round	2016	Year round	2021
D05	TREE	2	Tower	Seasonal	2015	Seasonal - Gradient	2023
D05	UNDE	2	Tower	Seasonal	2014	Seasonal - Core	2022
D06	KONZ	2	Tower	Seasonal	2015	Seasonal - Core	2021
D06	UKFS	2	Tower	Seasonal	2015	Year round	2021
D07	GRSM	2	Tower	Seasonal	2015	Seasonal - Gradient	2021
D07	MLBS	1	Tower	Seasonal	2017	Seasonal - Gradient	2022
D07	ORNL	2	Tower	Seasonal	2014	Seasonal - Core	2021
D08	DELA	2	Tower	Year round	2015	Year round	2021
D08	TALL	1	Tower	Year round	2014	Year round	2021
D08	LENO	2	Tower	Hybrid	2016	Year round	2021
D09	NOGP	2	Tower	Seasonal	2016	Seasonal - Gradient	2022
D09	WOOD	2	Tower	Seasonal	2014	Seasonal - Core	2022
D10	CPER	2	Tower	Year round	2013	Year round	2021
D10	RMNP	2	Distributed	Seasonal	2017	Seasonal - Gradient	2022
D11	CLBJ	2	Tower	Year round	2016	Year round	2022
D11	OAES	2	Tower	Year round	2015	Year round	2022
D12	YELL	2	Distributed	Hybrid	2018	Year round	2023
D13	MOAB	2	Tower	Year round	2015	Year round	2022

Domain ID	Site ID	Sampling locations*	Primary Transect Collocation	Phase I schedule	Phase I Sampling First Year	Phase II schedule+	Phase II Sampling First Year
D13	NIWO	2	Tower	Hybrid	2015	Year round	2021
D14	JORN	2	Tower	Year round	2015	Year round	2022
D14	SRER	2	Tower	Year round	2016	Year round	2021
D15	ONAQ	2	Tower	Year round	2014	Year round	2022
D16	ABBY	2	Tower	Seasonal	2016	Year round	2021
D16	WREF	2	Tower	Seasonal	2018	Year round	2023
D17	SJER	2	Tower	Year round	2017	Year round	2022
D17	SOAP	2	Tower	Year round	2018	Year round	2023
D17	TEAK	2	Tower	Hybrid	2019	Seasonal - Gradient	2024
D18	BARR	2	Tower	Seasonal	2017	Seasonal - Gradient	2022
D18	TOOL	2	Tower	Seasonal	2017	Seasonal - Core	2022
D19	BONA	2	Tower	Seasonal	2017	Seasonal – Core	2022
D19	DEJU	2	Tower	Seasonal	2016	Seasonal - Gradient	2021
D19	HEAL	2	Tower	Seasonal	2015	Seasonal - Gradient	2021
D20	PUUM	1	Tower	Year round	2018	Year round	2023

* Indicates whether sampling occurs at primary transect only (1) or primary transect and phenocam plot (2).

+For year round sampling schedules, at sites with brief but distinct and predictable dormant periods, bouts may be shifted from dormant periods to spring/fall transitions.

APPENDIX D SITE-SPECIFIC INFORMATION

List of species selected for phenology monitoring. Species selection is based on a quantitative survey of vegetation within the NEON Tower airshed. Phase I species represent three of the most dominant species at a site. In forested sites, the two most abundant overstory species and the single most abundant understory are selected for phenology monitoring. Shrublands or ecosystems with few trees, the single most abundant overstory species and the two most abundant understory species are selected. In grasslands, all species are selected from the herbaceous community. Selection of Phase II species is ordered sequentially based on each species relative abundance at the site. All species selected in Phase I are also included in Phase II observations. See the Plant Phenology Science Design (AD[06]) for more details.

Approximate timing for Annual measurements is listed for each site. The actual timing is dependent on phenology at the site in a given year and may differ based on growth form.

D.1 D01 – HARV – Harvard Forest

Annual measurement bout –Forb late July and DBL late September

Phase I Species	Phase II Species
Acer rubrum – Deciduous broadleaf	Acer pensylvanicum - Deciduous broadleaf
Quercus rubra – Deciduous broadleaf	Acer rubrum - Deciduous broadleaf
Aralia nudicaulis – Forb	Acer saccharum - Deciduous broadleaf
	Aralia nudicaulis - Forb
	Betula alleghaniensis - Deciduous broadleaf
	Betula lenta - Deciduous broadleaf
	Fagus grandifolia - Deciduous broadleaf
	Fraxinus americana - Deciduous broadleaf
	Maianthemum canadense - Forb
	Maianthemum racemosum - Forb
	Medeola virginiana - Forb
	Mitchella repens - Evergreen broadleaf - no leaf buds
	Pinus strobus - Pine
	Prunus serotina - Deciduous broadleaf
	Quercus rubra - Deciduous broadleaf
	Trientalis borealis - Forb
	Tsuga canadensis - Evergreen conifer
	Uvularia sessilifolia - Forb
	Vaccinium corymbosum - Deciduous broadleaf
	Viburnum acerifolium - Deciduous broadleaf

D.2 D01 – BART – Bartlett Experimental Forest

Annual measurement bout – late September

Phase I Species	Phase II Species
Acer rubrum – Deciduous broadleaf	Abies balsamea - Evergreen conifer
Fagus grandifolia – Deciduous broadleaf	Acer pensylvanicum - Deciduous broadleaf
Acer pensylvanicum – Deciduous broadleaf	Acer rubrum - Deciduous broadleaf
	Acer saccharum - Deciduous broadleaf
	Aralia nudicaulis - Forb
	Betula alleghaniensis - Deciduous broadleaf
	Betula papyrifera - Deciduous broadleaf
	Epifagus virginiana - Forb
	Fagus grandifolia - Deciduous broadleaf
	Medeola virginiana - Forb
	Mitchella repens - Evergreen broadleaf - no leaf buds
	Picea rubens - Evergreen conifer
	Pinus strobus - Pine
	Populus grandidentata - Deciduous broadleaf
	Trientalis borealis - Forb
	Trillium undulatum - Forb
	Tsuga canadensis - Evergreen conifer
	Uvularia sessilifolia - Forb
	Viburnum lantanoides - Deciduous broadleaf

D.3 D02 – SCBI – Smithsonian Conservation Biology Institute

Annual measurement bout – GRS early September, and DBL late November

Phase I Species	Phase II Species
Liriodendron tulipifera – Deciduous broadleaf	Alliaria petiolata - Forb
Juglans nigra – Deciduous broadleaf	Asimina triloba - Deciduous broadleaf
Microstegium vimineum – Graminoid	Berberis thunbergii - Deciduous broadleaf
	Cercis canadensis - Deciduous broadleaf
	Cornus florida - Deciduous broadleaf
	Elaeagnus umbellata - Deciduous broadleaf
	Elymus villosus - Graminoid
	Juglans nigra - Deciduous broadleaf
	Lindera benzoin - Deciduous broadleaf
	Liriodendron tulipifera - Deciduous broadleaf
	Microstegium vimineum - Graminoid
	Persicaria longiseta - Forb
	Persicaria virginiana - Forb
	Quercus velutina - Deciduous broadleaf
	Rosa multiflora - Deciduous broadleaf
	Rubus phoenicolasius - Deciduous broadleaf

Phase I Species	Phase II Species
	Sassafras albidum - Deciduous broadleaf
	Stellaria media - Forb
	Symphoricarpos orbiculatus - Deciduous broadleaf
	Verbesina occidentalis - Forb

D.4 D02 – SERC – Smithsonian Environmental Research Center

Annual measurement bout – mid November

Phase I Species	Phase II Species
Liriodendron tulipifera – Deciduous broadleaf	Acer rubrum - Deciduous broadleaf
Fagus grandifolia – Deciduous broadleaf	Ailanthus altissima - Deciduous broadleaf
Lindera benzoin – Deciduous broadleaf	Berberis thunbergii - Deciduous broadleaf
	Carpinus caroliniana - Deciduous broadleaf
	Carya tomentosa - Deciduous broadleaf
	Celastrus orbiculatus - Deciduous broadleaf
	Cinna arundinacea - Graminoid
	Claytonia virginica - Forb
	Cornus florida - Deciduous broadleaf
	Fagus grandifolia - Deciduous broadleaf
	Lindera benzoin - Deciduous broadleaf
	Liquidambar styraciflua - Deciduous broadleaf
	Liriodendron tulipifera - Deciduous broadleaf
	Lonicera japonica - Semi-evergreen broadleaf
	Microstegium vimineum - Graminoid
	Mitchella repens - Evergreen broadleaf - no leaf buds
	Podophyllum peltatum - Forb
	Potentilla indica - Forb
	Rosa multiflora - Deciduous broadleaf
	Stellaria media - Forb

D.5 D02 – BLAN – Blandy Experimental Farm

Annual measurement bout – Forb mid-September, DBL mid-November

Phase I Species	Phase II Species
Rhamnus davurica – Deciduous broadleaf	Acer negundo - Deciduous broadleaf
Lonicera maackii – Deciduous broadleaf	Ailanthus altissima - Deciduous broadleaf
Solidago altissima – Forb	Alliaria petiolata - Forb
	Cardamine hirsuta - Forb
	Carex blanda - Graminoid
	Celastrus orbiculatus - Deciduous broadleaf
	Elaeagnus umbellata - Deciduous broadleaf
	Festuca subverticillata - Graminoid
	Juglans nigra - Deciduous broadleaf

Phase I Species	Phase II Species
	Juniperus virginiana - Evergreen conifer - no needles
	Lonicera japonica - Semi-evergreen broadleaf
	Lonicera maackii - Deciduous broadleaf
	Microstegium vimineum - Graminoid
	Potentilla indica - Forb
	Rhamnus davurica - Deciduous broadleaf
	Rubus phoenicolasius - Deciduous broadleaf
	Solidago altissima - Forb
	Tetradium daniellii - Deciduous broadleaf
	Verbesina alternifolia - Forb
	Veronica hederifolia - Forb

D.6 D03 – OSBS – Ordway-Swisher Biological Station

Annual measurement bout – late September

Phase I Species	Phase II Species
Pinus palustris – Pine	Aristida beyrichiana - Graminoid
Quercus laevis – Deciduous broadleaf	Aristida purpurascens - Graminoid
Aristida beyrichiana – Graminoid	Asimina incana - Deciduous broadleaf
	Chapmannia floridana - Forb
	Croton argyranthemus - Forb
	Diospyros virginiana - Deciduous broadleaf
	Eriogonum tomentosum - Forb
	Galactia regularis - Forb
	Liatris tenuifolia - Forb
	Licania michauxii - Semi-evergreen broadleaf
	Pinus palustris - Pine
	Pityopsis graminifolia - Semi-evergreen forb
	Quercus laevis - Deciduous broadleaf
	Schizachyrium stoloniferum - Graminoid
	Sorghastrum secundum - Graminoid
	Sporobolus junceus - Graminoid
	Stillingia sylvatica - Forb
	Tephrosia virginiana - Forb
	Triplasis americana - Graminoid
	Vaccinium arboreum - Semi-evergreen broadleaf

D.7 D03 – DSNY – Disney Wilderness Preserve

Annual measurement bout – late August

Phase I Species	Phase II Species
Andropogon virginicus – Graminoid	Andropogon brachystachyus - Graminoid
Aristida beyrichiana – Graminoid	Andropogon glaucopsis - Graminoid

Euthamia caroliniana – Forb	Andropogon virginicus - Graminoid
	Aristida beyrichiana - Graminoid
	Asimina reticulata - Deciduous broadleaf
	Axonopus furcatus - Graminoid
	Cirsium horridulum - Forb
	Crocanthemum corymbosum - Forb
	Dichanthelium portoricense - Graminoid
	Euthamia caroliniana - Forb
	Helianthus angustifolius - Forb
	Morella cerifera - Evergreen broadleaf
	Pinus palustris - Pine
	Pluchea baccharis - Forb
	Quercus minima - Semi-evergreen broadleaf
	Saccharum giganteum - Graminoid
	Schizachyrium stoloniferum - Graminoid
	Serenoa repens - Evergreen broadleaf - no leaf buds
	Solidago fistulosa - Forb
	Sorghastrum secundum - Graminoid

D.8 D03 – JERC – Jones Ecological Research Center

Annual measurement bout – early September

Phase I Species	Phase II Species
Pinus palustris – Pine	Aristida beyrichiana - Graminoid
Quercus falcata – Deciduous Broadleaf	Diospyros virginiana - Deciduous broadleaf
Aristida beyrichiana – Graminoid	Dyschoriste oblongifolia - Forb
	Ionactis linariifolius - Forb
	Lespedeza bicolor - Deciduous broadleaf
	Pinus palustris - Pine
	Quercus falcata - Deciduous broadleaf
	Quercus hemisphaerica - Semi-evergreen broadleaf
	Quercus incana - Deciduous broadleaf
	Quercus margarettae - Deciduous broadleaf
	Rhus copallinum - Deciduous broadleaf
	Rhynchosia reniformis - Forb
	Rubus cuneifolius - Deciduous broadleaf
	Sassafras albidum - Deciduous broadleaf
	Schizachyrium stoloniferum - Graminoid
	Sericocarpus tortifolius - Forb
	Sideroxylon lanuginosum - Deciduous broadleaf
	Toxicodendron pubescens - Deciduous broadleaf
	Vaccinium darrowii - Semi-evergreen broadleaf
	Vaccinium stamineum - Deciduous broadleaf

D.9 D04 – GUAN – Guanica Forest

Annual measurement bout – early October

Phase I Species	Phase II Species
Bursera simaruba – Drought deciduous broadleaf	Amyris elemifera - Evergreen broadleaf
Gymnanthes lucida – Evergreen broadleaf	Bourreria succulenta - Evergreen broadleaf
Pisonia albida – Drought deciduous broadleaf	Bucida buceras - Drought deciduous broadleaf
Bucida buceras – Drought deciduous broadleaf (Phenocam)	Bursera simaruba - Drought deciduous broadleaf
	Coccoloba diversifolia - Evergreen broadleaf
	Croton lucidus - Evergreen broadleaf
	Erythroxylum areolatum - Drought deciduous broadleaf
	Eugenia foetida - Evergreen broadleaf
	Eugenia rhombea - Evergreen broadleaf
	Exostema caribaeum - Evergreen broadleaf
	Guaiacum officinale - Evergreen broadleaf
	Guaiacum sanctum - Evergreen broadleaf
	Guettarda krugii - Evergreen broadleaf
	Gymnanthes lucida - Evergreen broadleaf
	Krugiodendron ferreum - Evergreen broadleaf
	Leucaena leucocephala - Drought deciduous broadleaf
	Pictetia aculeata - Drought deciduous broadleaf
	Pisonia albida - Drought deciduous broadleaf
	Pithecellobium unguis-cati - Semi-evergreen broadleaf
	Thouinia striata - Drought deciduous broadleaf

D.10 D04 – LAJA – Lajas Experimental Station

Annual measurement bout – early October

Phase I Species	Phase II Species
Pithecellobium dulce – Semi-evergreen broadleaf	Achyranthes aspera - Forb
Cynodon nlemfuensis – Graminoid	Alysicarpus vaginalis - Forb
Urochloa maxima – Graminoid	Bothriochloa pertusa - Graminoid
	Cyanthillium cinereum - Forb
	Cynodon dactylon - Graminoid
	Cynodon nlemfuensis - Graminoid
	Malachra capitata - Forb
	Malvastrum coromandelianum - Forb
	Melochia pyramidata - Forb
	Mimosa pudica - Forb
	Phyla fruticosa - Evergreen forb

	Pithecellobium dulce - Semi-evergreen broadleaf
	Ruellia tuberosa - Forb
	Urochloa maxima - Graminoid
	Wissadula amplissima - Forb

D.11 D05 – UNDE – University of Notre Dame Environmental Research Center

Annual measurement bout – mid October

Phase I Species	Phase II Species
Acer saccharum – Deciduous broadleaf	Abies balsamea - Evergreen conifer
Populus tremuloides – Deciduous broadleaf	Acer rubrum - Deciduous broadleaf
Corylus cornuta – Deciduous broadleaf	Acer saccharum - Deciduous broadleaf
	Betula papyrifera - Deciduous broadleaf
	Carex pedunculata - Graminoid
	Cornus canadensis - Semi-evergreen forb
	Corylus cornuta - Deciduous broadleaf
	Dirca palustris - Deciduous broadleaf
	Fraxinus nigra - Deciduous broadleaf
	Ilex verticillata - Deciduous broadleaf
	Maianthemum canadense - Forb
	Oryzopsis asperifolia - Graminoid
	Ostrya virginiana - Deciduous broadleaf
	Picea glauca - Evergreen conifer
	Picea mariana - Evergreen conifer
	Populus grandidentata - Deciduous broadleaf
	Populus tremuloides - Deciduous broadleaf
	Rubus pubescens - Forb
	Trientalis borealis - Forb
	Vaccinium myrtilloides - Deciduous broadleaf

D.12 D05 – TREE – Treehaven

Annual measurement bout – late October

Phase I Species	Phase II Species
Acer saccharum – Deciduous broadleaf	Abies balsamea - Evergreen conifer
Acer rubrum – Deciduous broadleaf	Acer rubrum - Deciduous broadleaf
Abies balsamea – Evergreen conifer	Acer saccharum - Deciduous broadleaf
	Anemone quinquefolia - Forb
	Carex arctata - Graminoid
	Carex gracillima - Graminoid
	Carex intumescens - Graminoid
	Carex pensylvanica - Graminoid
	Carpinus caroliniana - Deciduous broadleaf
	Coptis trifolia - Evergreen forb

	Cornus canadensis - Semi-evergreen forb
	Dirca palustris - Deciduous broadleaf
	Hieracium aurantiacum - Forb
	Maianthemum canadense - Forb
	Oryzopsis asperifolia - Graminoid
	Ostrya virginiana - Deciduous broadleaf
	Picea glauca - Evergreen conifer
	Pinus strobus - Pine
	Rubus pubescens - Forb
	Trientalis borealis - Forb

D.13 D06 – KONZ – Konza Prairie Biological Station

Annual measurement bout – mid July

Phase I Species	Phase II Species
Sorghastrum nutans – Graminoid	Ambrosia psilostachya - Forb
Schizachyrium scoparium – Graminoid	Amorpha canescens - Deciduous broadleaf
Andropogon gerardii – Graminoid	Andropogon gerardii - Graminoid
	Artemisia ludoviciana - Forb
	Bouteloua curtipendula - Graminoid
	Ceanothus herbaceus - Deciduous broadleaf
	Cornus drummondii - Deciduous broadleaf
	Panicum virgatum - Graminoid
	Quercus muehlenbergii - Deciduous broadleaf
	Rhus aromatica - Deciduous broadleaf
	Rhus glabra - Deciduous broadleaf
	Rosa arkansana - Deciduous broadleaf
	Schizachyrium scoparium - Graminoid
	Solidago missouriensis - Forb
	Sorghastrum nutans - Graminoid
	Symphoricarpos orbiculatus - Deciduous broadleaf
	Symphyotrichum ericoides - Forb
	Symphyotrichum oblongifolium - Forb
	Vernonia baldwinii - Forb
	Zanthoxylum americanum - Deciduous broadleaf

D.14 D06 – UKFS – The University of Kansas Field Station

Annual measurement bout – mid July

Phase I Species	Phase II Species
Symphoricarpos orbiculatus – Deciduous broadleaf	Alliaria petiolata - Forb
Celtis occidentalis – Deciduous broadleaf	Carya ovata - Deciduous broadleaf
Carya ovata – Deciduous broadleaf	Celtis occidentalis - Deciduous broadleaf

	Cornus drummondii - Deciduous broadleaf
	Desmodium glutinosum - Forb
	Diarrhena obovata - Graminoid
	Festuca subverticillata - Graminoid
	Gleditsia triacanthos - Deciduous broadleaf
	Juglans nigra - Deciduous broadleaf
	Laportea canadensis - Forb
	Maclura pomifera - Deciduous broadleaf
	Morus rubra - Deciduous broadleaf
	Parthenocissus quinquefolia - Deciduous broadleaf
	Quercus muehlenbergii - Deciduous broadleaf
	Ribes missouriense - Deciduous broadleaf
	Rosa multiflora - Deciduous broadleaf
	Sanicula odorata - Forb
	Symphoricarpos orbiculatus - Deciduous broadleaf
	Toxicodendron radicans - Deciduous broadleaf
	Ulmus americana - Deciduous broadleaf

D.15 D07 – ORNL – Oak Ridge

Annual measurement bout – mid-November

Phase I Species	Phase II Species
Quercus montana – Deciduous broadleaf	Acer rubrum - Deciduous broadleaf
Liriodendron tulipifera – Deciduous broadleaf	Acer saccharum - Deciduous broadleaf
Cornus florida – Deciduous broadleaf	Carya tomentosa - Deciduous broadleaf
Acer rubrum – Deciduous broadleaf (Phenocam)	Cercis canadensis - Deciduous broadleaf
	Cornus florida - Deciduous broadleaf
	Fagus grandifolia - Deciduous broadleaf
	Liquidambar styraciflua - Deciduous broadleaf
	Liriodendron tulipifera - Deciduous broadleaf
	Lonicera japonica - Semi-evergreen broadleaf
	Nyssa sylvatica - Deciduous broadleaf
	Oxydendrum arboreum - Deciduous broadleaf
	Pinus strobus - Pine
	Prunus serotina - Deciduous broadleaf
	Quercus alba - Deciduous broadleaf
	Quercus coccinea - Deciduous broadleaf
	Quercus montana - Deciduous broadleaf
	Quercus rubra - Deciduous broadleaf
	Toxicodendron radicans - Deciduous broadleaf
	Vaccinium pallidum - Deciduous broadleaf
	Vitis rotundifolia - Deciduous broadleaf

D.16 D07 – MLBS – Mountain Lake Biological Station

Annual measurement bout – late October

Phase I Species	Phase II Species
Acer pensylvanicum – Deciduous broadleaf	Acer pensylvanicum - Deciduous broadleaf
Acer rubrum – Deciduous broadleaf	Acer rubrum - Deciduous broadleaf
Quercus alba – Deciduous broadleaf	Agrostis perennans - Graminoid
	Amelanchier laevis - Deciduous broadleaf
	Amianthium muscitoxicum - Forb
	Castanea dentata - Deciduous broadleaf
	Galax urceolata - Evergreen forb
	Hamamelis virginiana - Deciduous broadleaf
	Ilex montana - Deciduous broadleaf
	Kalmia latifolia - Evergreen broadleaf
	Magnolia acuminata - Deciduous broadleaf
	Nyssa sylvatica - Deciduous broadleaf
	Oclemena acuminata - Forb
	Pinus strobus - Pine
	Prunus serotina - Deciduous broadleaf
	Quercus alba - Deciduous broadleaf
	Quercus coccinea - Deciduous broadleaf
	Quercus rubra - Deciduous broadleaf
	Tsuga canadensis - Evergreen conifer
	Vaccinium pallidum - Deciduous broadleaf

D.17 D07 – GRSM – Great Smoky Mountains National Park, Twin Creeks

Annual measurement bout – mid November

Phase I Species	Phase II Species
Liriodendron tulipifera – Deciduous broadleaf	Acer pensylvanicum - Deciduous broadleaf
Acer rubrum – Deciduous broadleaf	Acer rubrum - Deciduous broadleaf
Acer pensylvanicum – Deciduous broadleaf	Amphicarpaea bracteata - Forb
	Betula lenta - Deciduous broadleaf
	Cornus florida - Deciduous broadleaf
	Halesia tetraptera - Deciduous broadleaf
	Kalmia latifolia - Evergreen broadleaf
	Lindera benzoin - Deciduous broadleaf
	Liriodendron tulipifera - Deciduous broadleaf
	Magnolia fraseri - Deciduous broadleaf
	Oxydendrum arboreum - Deciduous broadleaf
	Prenanthes altissima - Forb
	Pyrularia pubera - Deciduous broadleaf
	Quercus montana - Deciduous broadleaf
	Quercus rubra - Deciduous broadleaf

	Rhododendron maximum - Evergreen broadleaf
	Robinia pseudoacacia - Deciduous broadleaf
	Sanicula canadensis - Forb
	Toxicodendron radicans - Deciduous broadleaf
	Tsuga canadensis - Evergreen conifer
	Vaccinium pallidum - Deciduous broadleaf

D.18 D08 – TALL – Talladega National Forest

Annual measurement bout – late October

Phase I Species	Phase II Species
Pinus palustris – Pine	Arundinaria gigantea - Graminoid
Liquidambar styraciflua – Deciduous broadleaf	Carphephorus odoratissimus - Forb
Vaccinium arboreum – Semi-evergreen broadleaf	Chasmanthium sessiliflorum - Graminoid
	Coreopsis major - Forb
	Cornus florida - Deciduous broadleaf
	Desmodium ciliare - Forb
	Epigaea repens - Evergreen broadleaf
	Gelsemium sempervirens - Evergreen broadleaf
	Liquidambar styraciflua - Deciduous broadleaf
	Liriodendron tulipifera - Deciduous broadleaf
	Oxydendrum arboreum - Deciduous broadleaf
	Pinus palustris - Pine
	Pityopsis graminifolia - Semi-evergreen forb
	Quercus falcata - Deciduous broadleaf
	Quercus montana - Deciduous broadleaf
	Rhus copallinum - Deciduous broadleaf
	Schizachyrium scoparium - Graminoid
	Symplocos tinctoria - Semi-evergreen broadleaf
	Tephrosia virginiana - Forb
	Vaccinium arboreum - Semi-evergreen broadleaf

D.19 D08 – DELA – Dead Lake

Annual measurement bout – late November

Phase I Species	Phase II Species
Celtis laevigata – Deciduous broadleaf	Acer rubrum - Deciduous broadleaf
Ligustrum sinense – Semi-evergreen broadleaf	Arisaema dracontium - Forb
Liquidambar styraciflua – Deciduous broadleaf	Arundinaria gigantea - Graminoid
Quercus alba – Deciduous broadleaf (phenocam)	Asimina triloba - Deciduous broadleaf
Quercus nigra – Deciduous broadleaf (phenocam)	Carex tribuloides - Graminoid
Quercus pagoda – Deciduous broadleaf (phenocam)	Carpinus caroliniana - Deciduous broadleaf
	Carya tomentosa - Deciduous broadleaf

	Celtis laevigata - Deciduous broadleaf
	Ditrysinia fruticosa - Semi-evergreen broadleaf
	Justicia ovata - Forb
	Ligustrum sinense - Semi-evergreen broadleaf
	Liquidambar styraciflua - Deciduous broadleaf
	Morus rubra - Deciduous broadleaf
	Packera glabella - Forb
	Polygonum virginianum - Forb
	Quercus alba - Deciduous broadleaf
	Quercus nigra - Semi-evergreen broadleaf
	Quercus pagoda - Deciduous broadleaf
	Sabal minor - Evergreen broadleaf - no leaf buds
	Triadica sebifera - Deciduous broadleaf

D.20 D08 – LENO – Lenoir Landing

Annual measurement bout – mid November

Phase I Species	Phase II Species
Liquidambar styraciflua – Deciduous broadleaf	Aesculus pavia - Deciduous broadleaf
Carpinus caroliniana – Deciduous broadleaf	Arisaema dracontium - Forb
Ilex decidua – Deciduous broadleaf	Arundinaria gigantea - Graminoid
	Carpinus caroliniana - Deciduous broadleaf
	Chasmanthium sessiliflorum - Graminoid
	Desmodium pauciflorum - Forb
	Dioclea multiflora - Forb
	Elephantopus carolinianus - Forb
	Halesia diptera - Deciduous broadleaf
	Hymenocallis occidentalis - Forb
	Ilex decidua - Deciduous broadleaf
	Ilex opaca - Evergreen broadleaf
	Ilex vomitoria - Evergreen broadleaf
	Liquidambar styraciflua - Deciduous broadleaf
	Packera glabella - Forb
	Polygonum virginianum - Forb
	Poncirus trifoliata - Semi-evergreen broadleaf
	Quercus nigra - Semi-evergreen broadleaf
	Quercus pagoda - Deciduous broadleaf
	Yeatesia viridiflora - Forb

D.21 D09 – WOOD – Woodworth

Annual measurement bout – late July

Phase I Species	Phase II Species
Poa pratensis – Graminoid	Achillea millefolium - Forb

Bromus inermis – Graminoid	Andropogon gerardii - Graminoid
Artemisia absinthium – Forb	Artemisia absinthium - Forb
	Artemisia ludoviciana - Forb
	Bouteloua curtipendula - Graminoid
	Bouteloua gracilis - Graminoid
	Bromus inermis - Graminoid
	Calystegia sepium - Forb
	Cirsium arvense - Forb
	Dalea purpurea - Forb
	Medicago sativa - Forb
	Melilotus officinalis - Forb
	Nassella viridula - Graminoid
	Pascopyrum smithii - Graminoid
	Poa pratensis - Graminoid
	Schizachyrium scoparium - Graminoid
	Solidago canadensis - Forb
	Solidago missouriensis - Forb
	Symphoricarpos occidentalis - Deciduous broadleaf
	Taraxacum officinale - Forb

D.22 D09 – NOGP – Northern Great Plains Research Laboratory

Annual measurement bout – late July

Phase I Species	Phase II Species
Poa pratensis – Graminoid	Artemisia absinthium - Forb
Symphoricarpos occidentalis – Deciduous broadleaf	Artemisia ludoviciana - Forb
Bromus inermis – Graminoid	Bouteloua gracilis - Graminoid
	Bromus inermis - Graminoid
	Cirsium flodmanii - Forb
	Echinacea angustifolia - Forb
	Euphorbia esula - Forb
	Lactuca tatarica - Forb
	Liatris punctata - Forb
	Oligoneuron rigidum - Forb
	Pascopyrum smithii - Graminoid
	Pediomelum argophyllum - Forb
	Poa pratensis - Graminoid
	Ratibida columnifera - Forb
	Rosa arkansana - Deciduous broadleaf
	Schizachyrium scoparium - Graminoid
	Shepherdia argentea - Deciduous broadleaf
	Solidago canadensis - Forb
	Symphoricarpos occidentalis - Deciduous broadleaf

	Symphyotrichum ericoides - Forb

D.23 D10 – CPER – Central Plains Experimental Range

Annual measurement bout – mid July

Phase I Species	Phase II Species
Bouteloua gracilis – Graminoid	Aristida purpurea - Graminoid
Hesperostipa comata – Graminoid	Artemisia frigida - Drought deciduous broadleaf
Thelesperma filifolium – Forb	Bouteloua dactyloides - Graminoid
	Bouteloua gracilis - Graminoid
	Carex duriuscula - Graminoid
	Carex filifolia - Graminoid
	Echinocereus viridiflorus - Cactus
	Elymus elymoides - Graminoid
	Eriogonum effusum - Drought deciduous broadleaf
	Escobaria vivipara - Cactus
	Gutierrezia sarothrae - Drought deciduous broadleaf
	Hesperostipa comata - Graminoid
	Heterotheca villosa - Forb
	Opuntia polyacantha - Cactus
	Pascopyrum smithii - Graminoid
	Picradeniopsis oppositifolia - Forb
	Psoralidium tenuiflorum - Forb
	Sphaeralcea coccinea - Forb
	Thelesperma filifolium - Forb
	Vulpia octoflora - Graminoid

D.24 D10 – RMNP – Rocky Mountain National Park, CASTNET

Annual measurement bout – mid-September

Phase I Species	Phase II Species
Abies lasiocarpa – Evergreen conifer	Abies lasiocarpa - Evergreen conifer
Juniperus communis – Evergreen conifer – no needles	Carex geyeri - Graminoid
Pinus contorta – Pine	Chamerion angustifolium - Forb
Populus tremuloides – Deciduous broadleaf	Chimaphila umbellata - Evergreen forb
	Hieracium albiflorum - Forb
	Jamesia americana - Deciduous broadleaf
	Juniperus communis - Evergreen conifer
	Linnaea borealis - Evergreen forb
	Mahonia repens - Evergreen broadleaf
	Orthilia secunda - Evergreen forb
	Picea engelmannii - Evergreen conifer
	Pinus contorta - Pine

	Pinus contorta - Pine
	Pinus flexilis - Pine
	Pinus ponderosa - Pine
	Populus tremuloides - Deciduous broadleaf
	Pseudotsuga menziesii - Evergreen conifer
	Rosa woodsii - Deciduous broadleaf
	Solidago simplex - Forb
	Thermopsis divaricarpa - Forb
	Vaccinium myrtillus - Deciduous broadleaf

D.25 D11 – CLBJ – LBJ National Grassland

Annual measurement bout – mid October

Phase I Species	Phase II Species
Quercus stellate – Deciduous broadleaf	Ambrosia psilostachya - Forb
Schizachyrium scoparium – Graminoid	Bothriochloa ischaemum - Graminoid
Bothriochloa ischaemum var. songarica– Graminoid	Bouteloua curtipendula - Graminoid
	Callicarpa americana - Deciduous broadleaf
	Dichanthelium oligosanthes - Graminoid
	Helenium amarum - Forb
	Juniperus virginiana - Evergreen conifer - no needles
	Parthenocissus quinquefolia - Deciduous broadleaf
	Paspalum setaceum - Graminoid
	Quercus marilandica - Deciduous broadleaf
	Quercus stellata - Deciduous broadleaf
	Schizachyrium scoparium - Graminoid
	Scleria ciliata - Graminoid
	Sideroxylon lanuginosum - Deciduous broadleaf
	Smilax bona-nox - Deciduous broadleaf
	Sorghastrum nutans - Graminoid
	Symphoricarpos orbiculatus - Deciduous broadleaf
	Toxicodendron radicans - Deciduous broadleaf
	Tridens flavus - Graminoid
	Ulmus crassifolia - Deciduous broadleaf

D.26 D11 – OAES – Klemme Range Research Station

Annual measurement bout – mid May

Phase I Species	Phase II Species
Bouteloua gracilis – Graminoid	Ambrosia psilostachya - Forb
Aristida purpurea – Graminoid	Aristida purpurea - Graminoid

Phase I Species	Phase II Species
Calylophus hartwegii ssp. *fendleri* – Forb	Artemisia ludoviciana - Forb
	Bothriochloa laguroides - Graminoid
	Bouteloua curtipendula - Graminoid
	Bouteloua dactyloides - Graminoid
	Bouteloua gracilis - Graminoid
	Calylophus hartwegii - Forb
	Cirsium undulatum - Forb
	Dalea purpurea - Forb
	Erioneuron pilosum - Graminoid
	Evolvulus nuttallianus - Forb
	Gutierrezia sarothrae - Drought deciduous broadleaf
	Heterotheca canescens - Forb
	Linum rigidum - Forb
	Psoralidium tenuiflorum - Forb
	Schizachyrium scoparium - Graminoid
	Sporobolus compositus - Graminoid
	Thelesperma filifolium - Forb
	Tragia ramosa - Forb

D.27 D12 – YELL – Yellowstone Northern Range (Frog Rock)

Sampling at Phenocam plot at this site will not occur March 10 – July 1

Annual measurement bout – Mid-July

Phase I Species	Phase II Species
Artemisia tridentata – Drought deciduous broadleaf	Achillea millefolium - Forb
Eriogonum umbellatum – Forb	Arnica cordifolia - Forb
Pseudotsuga menziesii – Evergreen conifer	Artemisia tridentata - Drought deciduous broadleaf
	Berberis repens - Evergreen broadleaf
	Eriogonum umbellatum - Drought deciduous broadleaf
	Fragaria virginiana - Forb
	Geranium viscosissimum - Forb
	Geum triflorum - Forb
	Juniperus communis - Evergreen conifer
	Lupinus sericeus - Forb
	Pinus contorta - Pine
	Potentilla arguta - Forb
	Potentilla gracilis - Forb
	Pseudotsuga menziesii - Evergreen conifer
	Ribes setosum - Deciduous broadleaf
	Shepherdia canadensis - Deciduous broadleaf

D.28 D13 – NIWO – Niwot Ridge Mountain Research Station

Annual measurement bout – late July

Phase I Species	Phase II Species
Geum rossii var. *turbinatum* – Forb	Achillea millefolium - Forb
Carex rupestris var. *drummondiana* – Graminoid	Arenaria fendleri - Forb
Minuartia obtusiloba – Forb	Artemisia scopulorum - Forb
	Campanula rotundifolia - Forb
	Carex rupestris - Graminoid
	Erigeron simplex - Forb
	Geum rossii - Forb
	Lewisia pygmaea - Forb
	Luzula spicata - Graminoid
	Minuartia obtusiloba - Forb
	Oreoxis alpina - Forb
	Paronychia pulvinata - Forb
	Phlox pulvinata - Forb
	Polygonum bistortoides - Forb
	Sibbaldia procumbens - Forb
	Silene acaulis - Forb
	Solidago simplex - Forb
	Tetraneuris acaulis - Forb
	Trifolium dasyphyllum - Forb
	Trisetum spicatum - Graminoid

D.29 D13 – MOAB – Moab

Annual measurement bout – late July

Phase I Species	Phase II Species
Ephedra viridis – Evergreen broadleaf – no leaves	Androstephium breviflorum - Forb
Bouteloua gracilis – Graminoid	Aristida purpurea - Graminoid
Krascheninnikovia lanata – Drought deciduous broadleaf	Bouteloua gracilis - Graminoid
	Ephedra viridis - Evergreen broadleaf - no leaves
	Gutierrezia sarothrae - Drought deciduous broadleaf
	Krascheninnikovia lanata - Drought deciduous broadleaf
	Packera multilobata - Forb
	Pleuraphis jamesii - Graminoid
	Sphaeralcea coccinea - Forb
	Vulpia octoflora - Graminoid

D.30 D14 – SRER – Santa Rita Experimental Range

Annual measurement bout – early October

Phase I Species	Phase II Species
Larrea tridentata – Evergreen broadleaf-no leaf buds	Acourtia nana - Forb
Prosopis velutina – Drought deciduous broadleaf	Aristida purpurea - Graminoid
Zinnia acerosa – Drought deciduous broadleaf	Bahia absinthifolia - Forb
	Bouteloua eriopoda - Graminoid
	Carnegiea gigantea - Cactus
	Cenchrus ciliaris - Graminoid
	Cylindropuntia leptocaulis - Cactus
	Cylindropuntia spinosior - Cactus
	Ephedra trifurca - Evergreen broadleaf - no leaves
	Ferocactus wislizeni - Cactus
	Fouquieria splendens - Drought deciduous broadleaf
	Larrea tridentata - Evergreen broadleaf - no leaf buds
	Muhlenbergia porteri - Graminoid
	Opuntia engelmannii - Cactus
	Parkinsonia florida - Drought deciduous broadleaf
	Prosopis velutina - Drought deciduous broadleaf
	Senegalia greggii - Drought deciduous broadleaf
	Streptanthus carinatus - Forb
	Yucca elata - Evergreen broadleaf - no leaves
	Zinnia acerosa - Drought deciduous broadleaf

D.31 D14 – JORN – Jornada LTER

Annual measurement bout – mid October

Phase I Species	Phase II Species
Prosopis glandulosa – Drought deciduous broadleaf	Aphanostephus ramosissimus - Forb
Yucca elata – Evergreen broadleaf – no leaves	Aristida purpurea - Graminoid
Bouteloua eriopoda – Graminoid	Bouteloua eriopoda - Graminoid
	Croton pottsii - Forb
	Desmanthus cooleyi - Forb
	Gutierrezia sarothrae - Drought deciduous broadleaf
	Muhlenbergia porteri - Graminoid
	Pomaria jamesii - Forb
	Portulaca halimoides - Forb
	Prosopis glandulosa - Drought deciduous broadleaf

Phase I Species	Phase II Species
	Senna bauhinioides - Forb
	Setaria leucopila - Graminoid
	Sporobolus flexuosus - Graminoid
	Yucca elata - Evergreen broadleaf - no leaves
	Zinnia grandiflora - Forb

D.32 D15 – ONAQ – Onaqui-Ault

Annual measurement bout – April, June, and September

Phase I Species	Phase II Species
Artemisia tridentata ssp. *tridentata* – Drought deciduous broadleaf	Achnatherum hymenoides - Graminoid
Ceratocephala testiculata – Forb	Artemisia tridentata - Drought deciduous broadleaf
Bromus tectorum – Graminoid	Bromus tectorum - Graminoid
	Ceratocephala testiculata - Forb
	Elymus elymoides - Graminoid
	Erodium cicutarium - Forb
	Malcolmia africana - Forb
	Sphaeralcea coccinea - Forb

D.33 D16 – WREF – Wind River Experimental Forest

Annual measurement bout – mid September

Phase I Species	Phase II Species
Gaultheria shallon – Evergreen broadleaf	Abies sp. - Evergreen conifer
Pseudotsuga menziesii – Evergreen conifer	Acer circinatum - Deciduous broadleaf
Tsuga heterophylla – Evergreen conifer	Achlys triphylla - Forb
	Anemone sp. - Forb
	Clintonia uniflora - Forb
	Gaultheria shallon - Evergreen broadleaf
	Linnaea borealis - Evergreen forb
	Mahonia nervosa - Evergreen broadleaf
	Pseudotsuga menziesii - Evergreen conifer
	Taxus brevifolia - Evergreen conifer
	Thuja plicata - Evergreen conifer - no needles
	Trientalis borealis - Forb
	Trillium ovatum - Forb
	Tsuga heterophylla - Evergreen conifer
	Vaccinium membranaceum - Deciduous broadleaf
	Vaccinium ovalifolium - Deciduous broadleaf
	Vaccinium parvifolium - Deciduous broadleaf
	Vancouveria hexandra - Forb
	Viola sp. - Forb

D.34 D16 – ABBY – Abby Road

Annual measurement bout – late September

Phase I Species	Phase II Species
Gaultheria shallon – Evergreen broadleaf	Acer circinatum - Deciduous broadleaf
Pseudotsuga menziesii var. *menziesii* – Evergreen conifer	Alnus rubra - Deciduous broadleaf
Corylus cornuta var. *californica* – Deciduous broadleaf	Anaphalis margaritacea - Forb
	Chamerion angustifolium - Forb
	Corylus cornuta - Deciduous broadleaf
	Frangula purshiana - Deciduous broadleaf
	Gaultheria shallon - Evergreen broadleaf
	Hieracium scouleri - Forb
	Holodiscus discolor - Deciduous broadleaf
	Leucanthemum vulgare - Semi-evergreen forb
	Lotus aboriginus - Forb
	Mycelis muralis - Semi-evergreen forb
	Pseudotsuga menziesii - Evergreen conifer
	Rubus laciniatus - Evergreen broadleaf
	Rubus spectabilis - Deciduous broadleaf
	Rubus ursinus - Semi-evergreen broadleaf
	Sambucus racemosa - Deciduous broadleaf
	Thermopsis montana - Forb
	Vaccinium parvifolium - Deciduous broadleaf
	Veronica officinalis - Semi-evergreen forb

D.35 D17 – SJER – San Joaquin Experimental Range

Annual measurement bout – Forb and Graminoid - mid-April, SEB - mid-November

Phase I Species	Phase II Species
Quercus douglasii – Semi-evergreen broadleaf	Amsinckia menziesii - Forb
Erodium botrys – Forb	Bromus diandrus - Graminoid
Bromus diandrus – Graminoid	Bromus hordeaceus - Graminoid
	Calandrinia ciliata - Forb
	Carduus pycnocephalus - Forb
	Ceanothus cuneatus - Evergreen broadleaf
	Crassula connata - Forb
	Croton setigerus - Forb
	Dichelostemma capitatum - Forb
	Erodium botrys - Forb
	Hypochaeris glabra - Forb
	Lupinus bicolor - Forb
	Oxalis radicosa - Forb

Phase I Species	Phase II Species
	Phacelia cicutaria - Forb
	Pinus sabiniana - Pine
	Plagiobothrys nothofulvus - Forb
	Pterostegia drymarioides - Forb
	Quercus douglasii - Semi-evergreen broadleaf
	Quercus wislizeni - Evergreen broadleaf
	Thysanocarpus curvipes - Forb

D.36 D17 – SOAP – Soaproot Saddle

Annual measurement bout – mid-October

Phase I Species	Phase II Species
Arctostaphylos viscida – Evergreen broadleaf	Arctostaphylos viscida - Evergreen broadleaf
Quercus kelloggii – Deciduous broadleaf	Bromus diandrus - Graminoid
Chamaebatia foliosa	Bromus hordeaceus - Graminoid
	Bromus tectorum - Graminoid
	Calocedrus decurrens - Evergreen conifer
	Calochortus amoenus - Forb
	Ceanothus integerrimus - Evergreen broadleaf
	Chamaebatia foliolosa - Evergreen broadleaf
	Chlorogalum pomeridianum - Forb
	Claytonia parviflora - Forb
	Dichelostemma capitatum - Forb
	Galium aparine - Forb
	Lactuca serriola - Forb
	Lupinus bicolor - Forb
	Quercus chrysolepis - Evergreen broadleaf
	Quercus kelloggii - Deciduous broadleaf
	Rosa bridgesii - Forb
	Senecio vulgaris - Forb
	Toxicodendron diversilobum - Forb
	Triteleia ixioides - Forb

D.37 D17 – TEAK – Lower Teakettle

Annual measurement bout – Forb – July, EC - late October

Phase I Species	Phase II Species
Abies magnifica – Evergreen conifer	Abies concolor - Evergreen conifer
Abies concolor – Evergreen conifer	Abies magnifica - Evergreen conifer
Dodecatheon jeffreyi – Forb	Dodecatheon jeffreyi - Forb
	Pinus contorta - Pine
	Pinus jeffreyi - Pine

D.38 D18 – TOOL – Toolik Lake

Annual measurement bout – late July

Phase I Species	Phase II Species
Betula glandulosa/nana – Deciduous broadleaf	Andromeda polifolia - Evergreen broadleaf
Eriophorum vaginatum – Graminoid	Arctostaphylos rubra - Semi-evergreen broadleaf
Vaccinium vitis-idaea – Evergreen broadleaf	Betula glandulosa/nana - Deciduous broadleaf
	Calamagrostis stricta - Graminoid
	Carex bigelowii - Graminoid
	Cassiope tetragona - Evergreen broadleaf
	Diapensia lapponica - Evergreen broadleaf
	Empetrum nigrum - Evergreen broadleaf
	Eriophorum vaginatum - Graminoid
	Ledum palustre - Evergreen broadleaf
	Pedicularis lanata - Forb
	Pedicularis lapponica - Forb
	Petasites frigidus - Forb
	Polygonum bistorta - Forb
	Rubus chamaemorus - Forb
	Salix chamissonis - Deciduous broadleaf
	Salix pulchra - Deciduous broadleaf
	Salix reticulata - Deciduous broadleaf
	Vaccinium uliginosum - Deciduous broadleaf
	Vaccinium vitis-idaea - Evergreen broadleaf

D.39 D18 – BARR – Barrow Environmental Observatory

Annual measurement bout – early August

Phase I Species	Phase II Species
Carex aquatilis – Graminoid	Arctophila fulva - Graminoid
Dupontia fisheri – Graminoid	Carex aquatilis - Graminoid
Petasites frigidus – Forb	Dupontia fisheri - Graminoid
	Eriophorum russeolum - Graminoid
	Luzula arctica - Graminoid
	Petasites frigidus - Forb
	Poa arctica - Graminoid
	Ranunculus nivalis - Forb
	Ranunculus pallasii - Forb
	Salix pulchra - Deciduous broadleaf
	Saxifraga cernua - Forb
	Saxifraga foliolosa - Forb

D.40 D19 – BONA – Caribou Creek - Poker Flats Watershed

Annual measurement bout – early July

Phase I Species	Phase II Species
Picea mariana – Evergreen conifer	Alnus viridis - Deciduous broadleaf
Populus tremuloides – Deciduous broadleaf	Betula glandulosa/nana - Deciduous broadleaf
Vaccinium vitis-idaea – Evergreen broadleaf	Betula neoalaskana - Deciduous broadleaf
Ledum groenlandicum – Evergreen broadleaf (phenocam)	Calamagrostis lapponica - Graminoid
Vaccinium uliginosum – Deciduous broadleaf (phenocam)	Cornus unalaschkensis - Semi-evergreen forb
	Eriophorum vaginatum - Graminoid
	Geocaulon lividum - Forb
	Larix laricina - Deciduous conifer
	Ledum groenlandicum - Evergreen broadleaf
	Ledum palustre - Evergreen broadleaf
	Picea glauca - Evergreen conifer
	Picea mariana - Evergreen conifer
	Populus tremuloides - Deciduous broadleaf
	Rosa acicularis - Deciduous broadleaf
	Rubus chamaemorus - Forb
	Salix bebbiana - Deciduous broadleaf
	Salix pulchra - Deciduous broadleaf
	Salix scouleriana - Deciduous broadleaf
	Vaccinium uliginosum - Deciduous broadleaf
	Vaccinium vitis-idaea - Evergreen broadleaf

D.41 D19 – DEJU – Delta Junction

Annual measurement bout – early July

Phase I Species	Phase II Species
Picea mariana – Evergreen conifer	Alnus viridis - Deciduous broadleaf
Vaccinium vitis-idaea – Evergreen broadleaf	Arctostaphylos uva-ursi - Evergreen broadleaf
Betula glandulosa /nana – Deciduous broadleaf	Arnica frigida - Forb
Vaccinium uliginosum – Deciduous broadleaf (phenocam)	Betula glandulosa/nana - Deciduous broadleaf
	Cornus unalaschkensis - Semi-evergreen forb
	Empetrum nigrum - Evergreen broadleaf
	Festuca altaica - Graminoid
	Geocaulon lividum - Forb
	Ledum groenlandicum - Evergreen broadleaf
	Ledum palustre - Evergreen broadleaf
	Lupinus arcticus - Forb
	Pedicularis labradorica - Forb

	Pedicularis lanata - Forb
	Picea glauca - Evergreen conifer
	Picea mariana - Evergreen conifer
	Populus tremuloides - Deciduous broadleaf
	Rosa acicularis - Deciduous broadleaf
	Salix alaxensis - Deciduous broadleaf
	Sanguisorba officinalis - Forb
	Vaccinium uliginosum - Deciduous broadleaf
	Vaccinium vitis-idaea - Evergreen broadleaf

D.42 D19 – HEAL – Healy

Annual measurement bout – late August

Phase I Species	Phase II Species
Betula glandulosa /nana – Deciduous broadleaf	Arctostaphylos alpina - Semi-evergreen broadleaf
Picea glauca – Evergreen conifer	Betula glandulosa/nana - Deciduous broadleaf
Ledum palustre – Evergreen broadleaf	Betula occidentalis - Deciduous broadleaf
	Calamagrostis stricta - Graminoid
	Carex bigelowii - Graminoid
	Empetrum nigrum - Evergreen broadleaf
	Eriophorum vaginatum - Graminoid
	Ledum palustre - Evergreen broadleaf
	Loiseleuria procumbens - Evergreen broadleaf
	Pedicularis labradorica - Forb
	Petasites frigidus - Forb
	Picea glauca - Evergreen conifer
	Rubus chamaemorus - Forb
	Salix bebbiana - Deciduous broadleaf
	Salix glauca - Deciduous broadleaf
	Salix pulchra - Deciduous broadleaf
	Spiraea stevenii - Deciduous broadleaf
	Vaccinium oxycoccos - Evergreen broadleaf
	Vaccinium uliginosum - Deciduous broadleaf
	Vaccinium vitis-idaea - Evergreen broadleaf

D.43 D20 – PUUM – Pu'u Maka'ala Natural Area Reserve

Annual measurement bout – TBD

Phase I Species	Phase II Species
Metrosideros polymorpha – Evergreen broadleaf	Acacia koa - Evergreen broadleaf - no leaf buds
Styphelia tameiameiae – Evergreen broadleaf	Alyxia stellata - Evergreen broadleaf - no leaf buds
Acacia koa – Evergreen broadleaf- no leaf buds	Anthoxanthum odoratum - Graminoid
	Astelia menziesiana - Evergreen forb

	Broussaisia arguta - Evergreen broadleaf - no leaf buds
	Carex alligata - Graminoid
	Cheirodendron trigynum - Evergreen broadleaf - no leaf buds
	Coprosma ochracea - Evergreen broadleaf - no leaf buds
	Ilex anomala - Evergreen broadleaf
	Melicope clusiifolia - Evergreen broadleaf - no leaf buds
	Metrosideros polymorpha - Evergreen broadleaf
	Microlaena stipoides - Graminoid
	Myoporum sandwicense - Evergreen broadleaf - no leaf buds
	Myrsine lessertiana - Evergreen broadleaf
	Myrsine sandwicensis - Evergreen broadleaf
	Rubus hawaiensis - Deciduous broadleaf
	Styphelia tameiameiae - Evergreen broadleaf
	Vaccinium calycinum - Deciduous broadleaf
	Vaccinium reticulatum - Evergreen broadleaf

APPENDIX E EXAMPLE SCHEDULE FOR A HYBRID SITE

D15 – Onaqui-Ault, precipitation driven, nearly year-round potential growing season, species with different environmental drivers of phenology.

ONAQ Plant Phenology Timing driven by each species

Species	Growth Form	Monitor indicator individual for:		**Sample 3x/week** until all tagged individuals of a given species show:		**Sample 1x/week** until all tagged individuals of a given species show:		Flowering **every other week**		Monitor for change	**Sample 2x/week** until all individuals show:		**Sample 1x/week** until:		
CETE5	Forb	Initial growth		One or more fully unfolded leaves		N/A		Commence every-other week monitoring for flowering phenology		Monitor indicator individuals for evidence of senescence	N/A		No more full sized leaves are present OR three consecutive bouts with no change		
(monitored as patches)		Start	End	Start	End	Start	End	Start	End		Start	End	Start	End	
		2/1	3/15	2/15	4/1	N/A	N/A	3/1	4/1		N/A	N/A	4/1	6/1	
Ceratocephala testiculata: "Bur buttercup is a winter annual that emerges, flowers, and sets fruits in the spring, when temperatures climb into the 45-50 degree range."- USU Extension															
BRTE	GRS	Initial growth		>50% of plant is green or three consecutive bouts of no change		>95% of plant is green OR three consecutive bouts with no change		Commence every-other week monitoring for open flowers		Monitor indicator individuals for >5% Leaf senescence (i.e., percentage of plant that is green <95%)	<95% green leaves		<5% of plant is green OR three consecutive bouts with no change		
(monitored as patches)		Start	End	Start	End	Start	End	Start	End		Start	End	Start	End	
		2/1	3/31	3/1	4/15	4/15	4/30	4/30	7/1		5/1	7/1	7/1	8/1	
Bromus tectorum: Germination occurs in fall through winter to early spring & flowering occurs from April to mid-June -USDA Fact Sheet A second, sparse generation of B. tectorum has occurred in summer 2014 and 2015 at ONAQ though they did not fully mature/produce flowers															
ARTR2	DDB	Breaking leaf buds		Young leaves		No more young leaves		Commence every-other week monitoring for open flowers		Monitor indicator Individuals for one or more colored leaves: Seasonal monitoring may end at this point if senescence does not occur.	One or more colored leaves		<5% of canopy full with green or colored leaves OR three consecutive bouts with no change		
		Start	End	Start	End	Start	End	Start	End		Start	End	Start	End	
		3/1	4/1	4/1	5/1	5/1	9/15	8/15	11/30	End ARTR2 Sampling	N/A	N/A	N/A	N/A	
Artemisia tridentata: "Although characterized as an evergreen shrub, *A. tridentata* functionally has a semi-drought deciduous habit" [1] "Growth of vegetative and reproductive structures in *Artemisia tridentata* is temporally separated during the growing season; vegetative growth occurs during spring and early summer …while reproductive growth occurs during summer and fall …"[2] " … There are three types of leaves on most sagebrush species … "persistent , ephemeral… The third leaf type is on the flowering stalk."[3]															

At ONAQ we have two early season annuals: *Ceratocephala testiculata* and *Bromus tectorum*. *C. testiculata* will emerge essentially as the snow is melting and rapidly progress through its phenophases; having fully senesced by the end of May. *B. tectorum* will begin emerging in March (with a slight delay from snow melt) and flower from April to June. Artemisia on the other hand will continuously put on perennial, ephemeral and flowering stalk leaves during the spring and summer; then flower in late summer/fall.

To maintain less than 50 visits per year, re-distributing emphasis on visits during the spring during green-up then a slow in monitoring during the summer which will still capture Artemisia flowering. The proposed sampling schedule allows a little wiggle room for a late pulse in greenness or variability in spring onset/duration of green-up.

Proposed ONAQ Plant Phenology schedule to reduce effort

Pre-Budburst (opportunistic)		3x/week		1x/week		every other week		2x/week		1x/week		Estimated # of Bouts
Start	End	Start	End	Start	End	Start	End	Start	End	Start	End	
2/1	2/15	2/15	4/15	4/15	6/1	6/1	11/30	-		-	-	
2		27 Visits		7 visits		14 visits						**50**

Sources:

1. Kolb, K. J., & Sperry, J. S. (1999). Transport constraints on water use by the Great Basin shrub, Artemisia tridentata. *Plant Cell and Environment*, *22*, 925-936.
2. Evans, R. D., & Black, R. A. (1993). Growth, Photosynthesis, and Resource Investment for Vegetative and Reproductive Modules of Artemisia Tridentata. *Ecology*, *74*(5), 1516-1528.
3. Rosentreter, R. (2005). Sagebrush identification, ecology, and palatability relative to sage-grouse

APPENDIX F PHENOCAM PLOT AND SITE BOUNADRY

The phenocam plots listed below have a portion of the 200m by 200m plot that falls outside of the site boundary. Since phenocam field individuals must be within the permitted area use the following workflow to ensure selected individuals are within the boundary.

1. Before heading out in the field make sure the site boundary .imp file has been uploaded to the Trimble unit.
    - Following steps in A.4 – A.6 (RD [06]) for background files.

When out in the field turn the boundary layer on as a background layer.

- In **MDD** select **Map**
- In **SDD** select **Layers**
- Select **Background Files…**
- Click the box for the boundary layer
- Select **Done**

When in “Map” view your current location will be illustrated by an “X”.

When selecting the phenocam individuals be sure that the “X” is within in the boundary layer.

Domain	Site
D02	BLAN
D05	TREE
D05	STEI
D08	LENO
D06	KONA
D09	NOGP
D10	RMNP

APPENDIX G EQUIPMENT

The following equipment is needed to implement the procedures in this document. Equipment lists are organized by task. They do not include standard field and laboratory supplies such as charging stations, first aid kits, drying ovens, ultra-low refrigerators, etc.

Table 15. Equipment list – Marking phenology transect.

Supplier/ Item No.	Exact Brand	Description	Purpose	Quantity
	N	GPS receiver, recreational accuracy	GPS receiver, recreational accuracy	1
	N	Measuring tape, 100 m	Measure transect distances during annual transect establishment	1
	N	Chaining pins or other suitable anchor	Anchor measuring tapes	2 sets
	N	AA battery	Spare battery for GPS receiver	2
	N	Permanent marker	Record transect distance/location information on pin flag	1
	N	Rectangular unnumbered aluminum tag, yellow	Replace broken or missing markers	Variable
	N	Flagging tape	Mark access route to phenology loop	Variable
	N	Survey marking flag, PVC or fiberglass stake	Delineate sampling area	80

Table 16. Equipment list – Selecting, marking, and mapping individuals and patches.

Supplier/ Item No.	Exact Brand	Description	Purpose	Quantity
Compass Tools: # 88180-04	Y	GPS receiver, decimeter accuracy (e.g., GEO XH 6000, 7X)	Loading data to GPS that generate spatial location of individuals within the phenocam plot	1
	N	Laptop	Connecting to live feed from Phenocam	1
	N	Ethernet Cable	Connecting to live feed from Phenocam	1
	N	Handheld radio	Communicating between instrument hut and field team	2

Supplier/ Item No.	Exact Brand	Description	Purpose	Quantity
	N	Backup mobile data recorder battery, fully charged	Continue data collect in the event tablet loses charge	1
	Y	GPS Pathfinder Office Software	Loading data to GPS that will generate spatial data of individuals within the phenocam plot	1
	N	Hammer	Drive nails	1
	N	Hand stamp steel die set	Label blank tags	1 set
Forestry Supplier: # 91567	Y	Laser Rangefinder, ½ foot (15 cm) accuracy	Measure location information for selected individuals	1
	N	Measuring tape, 100 m	Measure location information for selected individuals	1
EG05390000	Y	0.25 m x 0.25 m quadrat	Delineate patches for monitoring	1
	N	0.5 m x 0.5 m quadrat	Delineate patches for monitoring	
	N	1 m x 1 m sampling frame	Delineate patches for monitoring	
	N	Plastic spike	Delineate patch corners	As needed
	N	Fiberglass driveway marker	Delineate woody patch corners	As needed
	N	Wire cutter	Cut wire to desired length	1
	N	Aluminum nail	Affix tag to stems with DBH ≥ 5 cm	100
	N	Aluminum wire, 20 gauge	Affix tag to stems with DBH ≥ 5 cm	1 spool
	N	Non-ferrous Pigtail stake	Affix tag and plant card to mark grasses and forbs	Variable
	N	Flagging tape	Mark individuals for monitoring	1 roll
	N	Field notebook	Record field notes	1
	N	CR123A battery	Spare battery for laser rangefinder	1-2 each
	N	Rectangular unnumbered aluminum tag, yellow	Tag monitored individual or patch	10

Supplier/ Item No.	Exact Brand	Description	Purpose	Quantity
Ben Meadows: # 227431	Y	Round numbered aluminum tag, blue; 6001-8000	Tag selected woody stemmed individuals for monitoring. Color and number separates phenology tags from vegetation structure tags.	100
Ben Meadows: # 152672	Y	Round unnumbered aluminum tag, blue	Tag woody stemmed individuals selected for both phenology and productivity measurement	1
	N	Survey marking flag, PVC or fiberglass stake	Flag individuals/patches selected for monitoring and replace missing flags	80
	N	Extra battery for GPS receiver	Extend field GPS collection time	1

Table 17. Equipment list – Collecting phenology data.

Supplier/ Item No.	Exact Brand	Description	Purpose	Quantity
	N	Binoculars	Observe tree phenophase at a distance	1
	N	Digital camera, 12 megapixel	Capture images of plants for photo reference book	1
	N	80 mm spotting scope with 20-60x zoom and angled eyepiece	Resolve tiny features e.g., leaf buds and flowers, in tall canopies.	1
	N	Tripod	Hold spotting scope	1
	N	Universal cell phone adapter mount	Mount cell phone camera to spotting scope to take pictures	1
	N	Field guide, Site-specific phenophase photobook	Calibrate phenophase status and intensity observations and taxa-specific image libraries	1
	N	GPS receiver, recreational accuracy	Navigate to sampling location	1
	N	Backup mobile data recorder battery, fully charged	Continue data collect in the event tablet loses charge	1
	N	Hammer	Drive nails	1

Supplier/ Item No.	Exact Brand	Description	Purpose	Quantity
Forestry Supplier: # 91567	Y	Laser Rangefinder, 1 yard accuracy	Measure location information for new/replacement individuals	1
EG05390000	Y	Phenology quadrat	Monitor 0.25 m x 0.25 m patches	1
	N	0.5 m x 0.5 m quadrat	Monitor 0.5 m x 0.5 m patches	1
	Y	Sampling frame, 1m2	Monitor 1 m x 1 m patches	1
	N	Plastic spike	Replace missing markers	As needed
	N	Wire cutter	Cut wire to desired length	1
	N	AA battery	Spare battery for GPS receiver	2
	N	Aluminum nail	Affix replacement tag to stems	10
	N	Aluminum wire, 20 gauge	Affix replacement tag to stems	1 spool
	N	Digital camera battery	Spare battery	2
	N	Laser Rangefinder battery	Spare battery for laser rangefinder	2
	N	Rectangular unnumbered aluminum tag, yellow	Replace tags on woody stemmed individuals	1
Ben Meadows: # 227431	Y	Round numbered aluminum tag, blue; 6001-8000	Tag replacement individuals	10

Table 18. Equipment list – Collecting annual data.

Supplier/ Item No.	Exact Brand	Description	Purpose	Quantity
Forestry Supplier: # 59422	Y	DBH tape, 200 cm	Measure stem diameter. Stems present with diameter > 64 cm	1
Ben Meadows: # 122117	Y	DBH tape, 64 cm	Measure stem diameter. Stems present with 5 cm < diameter < 64 cm	1

Supplier/ Item No.	Exact Brand	Description	Purpose	Quantity
Forestry Supplier: # 59505				
	N	Backup mobile data recorder battery, fully charged	Continue data collect in the event tablet loses charge	1
Compass Tools: # 703512 Forestry Suppliers: # 90998	Y	Foliage filter	Allow laser rangefinder use in dense vegetation	1
	N	Handheld caliper, 0.1 cm precision	Measure stem diameters < 5 cm	1
Forestry Suppliers: # 91567	Y	Laser Rangefinder, ½ foot (15 cm) accuracy	Map stems recruited into the minimum size class; measure stem height, canopy diameter. Brushy; trees with relatively large canopy diameters; slopes ≥ 20%	1
	N	Measuring stick, 2 m folding	Measure heights of small-stature woody vegetation	1
EG05390000	Y	Phenology quadrat	Monitor 0.25 m x 0.25 m patches	1
	N	Sampling frame, 1m2	Monitor 1 m x 1 m patches	1
	N	0.5 m x 0.5 m quadrat	Monitor 0.5 m x 0.5 m patches	1
	N	CR123A battery	Spare battery for laser rangefinder	2