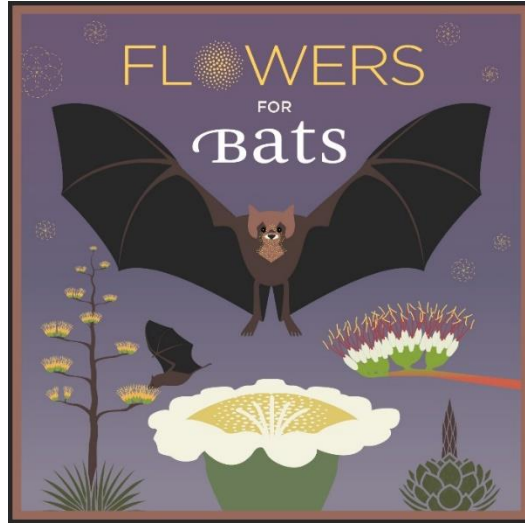


Lesser long-nosed bat (*Leptonycteris yerbabuena*)
forage phenology monitoring protocol



Collaboration between USFWS and USA-NPN

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Abstract:

The USGS-funded USA National Phenology Network (USA-NPN) is collaborating with the US Fish and Wildlife Service (USFWS) to track the phenology of five major forage species for the lesser long-nosed bat (*Leptonycteris yerbabuenae*). The objective of the lesser long-nosed bat forage monitoring program is to document whether forage resource availability is affected by environmental change to the extent that bat occupancy periods are out of sync with forage plant flowering phenology.

In order to track the status of the forage species, we will use the USA-NPN's *Nature's Notebook* plant and animal phenology observation program to record the onset, peak, and duration of flowering of the nectar species essential to the lesser long-nosed bats in southeastern Arizona and other parts of the bat's range. In 2017, we launched a data collection campaign called Flowers for Bats (fws.usanpn.org/Campaigns/flowersforbats) to engage partners and observers in documenting flowering of forage species.

Data from this monitoring approach will help the USFWS determine future resiliency, redundancy, and representation of the lesser long-nosed bat population and will help us assess whether the threshold for resiliency, redundancy, or representation have been exceeded.

Table of Contents

I.	Introduction.....	5
II.	<i>Nature's Notebook</i> Phenology Monitoring Program.....	5
III.	Species.....	7
IV.	Species Protocols.....	7
V.	Monitoring Locations and Design.....	12
VI.	Frequency of Monitoring and Estimated Time Investment.....	15
VII.	Data Processing and Delivery.....	16
VIII.	<i>Flowers for Bats</i> Resources.....	17
IX.	Contacts.....	17
X.	Acknowledgements.....	18
XI.	References.....	18
XII.	Phenophase Photo Guides.....	19

Introduction:

As part of the post-delisting process for the lesser long-nosed bat (*Leptonycteris yerbabuena*) the U.S. Fish and Wildlife Service (USFWS) has created a draft post-delisting monitoring plan that proposes two primary components to monitor the status of the lesser long-nosed bat: continued roost occupancy and threats monitoring, and an assessment of forage availability through phenology and distribution monitoring of lesser long-nosed bat forage resources.

The USA National Phenology Network (USA-NPN; Box 1) is partnering with the USFWS to implement the forage monitoring portion of the lesser long-nosed bat post-delisting monitoring plan. The data collected will help the USFWS track changes in the phenology of important lesser long-nosed bat forage species and evaluate the potential effects of climate change on forage species.

Box 1. The USA National Phenology Network

Established in 2007, the **USA National Phenology Network** (www.usanpn.org) is a national-scale consortium of individuals and organizations that collects, stores, and shares phenological data, value-added data products, and information to advance science and to support natural resource decision-making across a variety of spatial and temporal scales. A diverse range of stakeholders contributes to and utilizes network knowledge, data, and tools, including researcher, resource managers, educators, and the public.

The USA-NPN's *Nature's Notebook* program is a plant and animal phenology observation program appropriate for professional and citizen scientists. Phenology data entered through the *Nature's Notebook* program are made freely available for download through the National phenology Database (NPDb). To ensure that the observational data in the NPDb are robust for use in scientific analyses and decision-making, the USA-NPN employs a range of quality assurance (QA) processes to improve species identification, phenophase status evaluation, and data entry. In turn, quality control (QC) processes evaluate and flag data according to standards of plausibility, validity, and reliability. QA and QC processes and activities are described in Appendix 2 of the USA-NPN Observational Data Documentation (available at www.usanpn.org/data/quality).

***Nature's Notebook* Phenology Monitoring Program:**

In order to track the status of the forage species for the lesser long-nosed bat, we will use the *Nature's Notebook* plant and animal phenology observation program (Rosemartin et al. 2014; Box 2) to record the onset, peak, and duration of flowering of the nectar species (Denny et al. 2014) essential to the lesser long-nosed bats in southeastern Arizona. In 2017, we launched a data collection campaign called Flowers for Bats (fws.usanpn.org/Campaigns/flowersforbats) to engage partners and observers in using *Nature's Notebook* to document flowering of forage species.

Box 2. *Nature's Notebook*

Nature's Notebook is a national phenology program used by professional and citizen scientists to record plant and animal life stages. Participants in *Nature's Notebook* follow rigorous, standardized protocols to report on the phenological status of individual plants and of animal species at given locations and are encouraged to make regular observations over multiple years. Data are stored in the online National Phenology Database (NPDb) and can be accessed publically and freely through several query and visualization tools.

Nature's Notebook is a platform that can be used by individuals and groups alike. Group users are able to contribute data to the same locations, sharing the effort of observations among many.

When a particular Refuge, Park, or other unit is ready to begin monitoring, the designated leader for that site should submit a request (www.usanpn.org/nn/groups/group-interest) to the USA-NPN for their group to be created. Creation of a *Nature's Notebook* account will be required to access the form. The requestor will be notified when the group has been created.

Each member of a group should register an individual *Nature's Notebook* account, and join their respective group during registration. Individual accounts allow each data record collected to be tied back to an individual observer. For groups, a site leader is appointed as the group administrator, and is able to set up observation sites, and register plants at those sites. More than one administrator can be designated for a group. Other members can be set up as data entry technicians, to enter data on behalf of other users or edit existing data for the group.

Data will be entered via either a combination of paper data sheets and data entry via web browser or directly through the *Nature's Notebook* mobile application (which has offline capabilities). Once an administrator has set up observation sites and registered plants at those sites, a data sheet packet will be available for each site on each group member's *Nature's Notebook* Observation Deck within their online account. Data are stored in the National Phenology Database, and are freely available for download at www.usanpn.org/data/observational.

USA-NPN staff will provide eNewsletters to participants as part of the Flowers for Bats *Nature's Notebook* campaign. Any staff member or observer can sign up to receive these messages at fws.usanpn.org/flowersforbats. The messages are sent on an approximately monthly basis and contain reminders to observe, resources for observing, preliminary results, and stories shared by participating observers. The USA-NPN has found that this method of communication promotes observer retention.



Fig 1. Flowers for Bats badge image

A Flowers for Bats badge (Fig 1) is also available in each observer's Observation Deck as a motivator for observer participation. Observers can earn the badge by submitting data on one of the forage species in six separate weeks within the same year.

Species:

Desert agave (*Agave deserti*)

<https://mynpn.usanpn.org/npnapps/species/Agave/deserti>

Palmer's agave (*Agave palmeri*)

<https://mynpn.usanpn.org/npnapps/species/Agave/palmeri>

Parry's agave (*Agave parryi*)

<https://mynpn.usanpn.org/npnapps/species/Agave/parryi>

Century plant (*Agave americana*)

<https://mynpn.usanpn.org/npnapps/species/Agave/americana>

Saguaro (*Carnegiea gigantea*)

<https://mynpn.usanpn.org/npnapps/species/Carnegiea/gigantea>

Organ pipe cactus (*Stenocereus thurberi*)

<https://mynpn.usanpn.org/npnapps/species/Stenocereus/thurberi>

Cardon (*Pachycereus pringlei*)

<https://mynpn.usanpn.org/npnapps/species/Pachycereus/pringlei>

Species Protocols:

In the pilot year of the program, we tracked flowering phenology of panicular agave and saguaro cacti (*Carnegiea gigantean*) found throughout the Arizona portion of the range of the lesser long-nosed bats. Beginning in 2019, the addition of cardon (*Pachycereus pringlei*) and organ pipe (*Stenocereus thurberi*) cactus for monitoring in *Nature's Notebook* will allow the program to expand to other portions of the range including Baja Mexico.

Nature's Notebook uses status monitoring, wherein the same individual plants or patches of plants are observed repeatedly over time. This method provides a comparison of the same plants or populations of plants across years, and helps to determine which climate drivers and other environmental variables influence the phenology of these species.

For each individual plant or patch of plants, observers will document two types of data:

1. Status: A "yes" or "no" response to flower buds and open flowers on any plant in the patch.
2. Intensity: The number of flower stalks and percent of open flowers for the individual plant or for all plants in the patch.

The *Nature's Notebook* protocol that is used for both agave and columnar cactus is shown in Fig 2 below. Observers are asked whether they see “flowers or flower buds” or “open flowers”, and the degree to which they see these **phenophases**, or life cycle events.

Note that flowers or flower buds is an overarching phenophase; when flowers open to expose their reproductive parts, observers should report “yes” for open flowers while also continuing to report “yes” for flowers or flower buds.

Phenophase definitions are provided to help observers know how to answer the questions on the datasheet. The phenophase definitions are written in great detail to take the guesswork out of observations. The definitions are available in the datasheet packets and on the mobile app.

Do you see...?

Flowers or flower buds
One or more fresh open or unopened flowers or flower buds are visible on the plant. Include flower buds or inflorescences that are swelling or expanding, but do not include those that are tightly closed and not actively growing (dormant). Also do not include wilted or dried flowers.
[More...](#)

How many flowers and flower buds are present? For species in which individual flowers are clustered in flower heads, spikes or catkins (inflorescences), simply estimate the number of flower heads, spikes or catkins and not the number of individual flowers.

- Less than 3
- 3 to 10
- 11 to 100
- 101 to 1,000
- 1,001 to 10,000
- More than 10,000

Open flowers
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.
[More...](#)

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.

- Less than 5%
- 5-24%
- 25-49%
- 50-74%
- 75-94%
- 95% or more

Fig 2. *Nature's Notebook* protocol for agave and columnar cacti flowering

Species: **Agave palmeri**
 Common Name: **Palmer's century plant**
 Nickname: **Palmer's century plant-1**

Do you see...?	Check when data entered online: <input type="checkbox"/>
Flowers or flower buds	y n ? ____
Open flowers	y n ? ____
Fruits	y n ? ____
Ripe fruits	y n ? ____
Recent fruit or seed drop	y n ? ____

Fig 3. Example datasheet for *Agave palmeri*

Fig 3 shows the protocol for *Agave palmeri* as it appears on the datasheet and the app. Observers answer “yes” or “no” and then enter the intensity of the phenophase question in the blank space. While using the paper datasheets, observers should refer to the phenophase definitions for the intensity categories (eg Less than 3, 3-10, etc). While using the app, the intensity categories are available in a drop-down menu.

Note that for agave, we are only interested in the flowering phenophases (though fruiting may also be recorded). For columnar cacti, we are interested in flowering and also encourage monitoring the fruiting phenophases, as bats are known to use the fruits of columnar cacti.

The way that we monitor and record agave and columnar cacti flowering is different. Please note that while the question, “How many flowers or flower buds are present” remains the same for all species in *Nature’s Notebook*, for agave we are referring to the stalk as a single “flower”. This reflects the structure of the agave, which is an inflorescence, and allows observers to more easily count the number of flowering stalks in patches of agave. For saguaro, we count each individual flower bud as an individual flower.

Here are some examples to help you know what to report for the yes or no and intensity questions on the datasheets for agave and saguaro.

Agave monitoring:

Do you see flowers or flower buds?

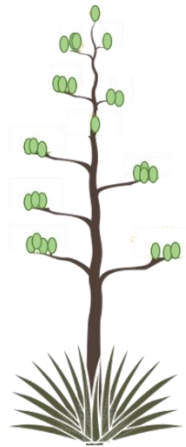
Do you see open flowers?



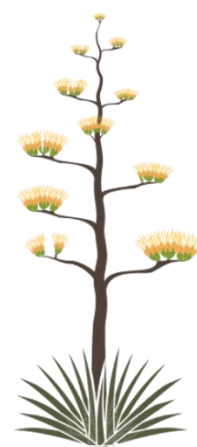
Flowers or Flower buds: No
 Open Flowers: No
 Observe every other week



Flowers or Flower buds: No
 Open Flowers: No
 Start observing once per week

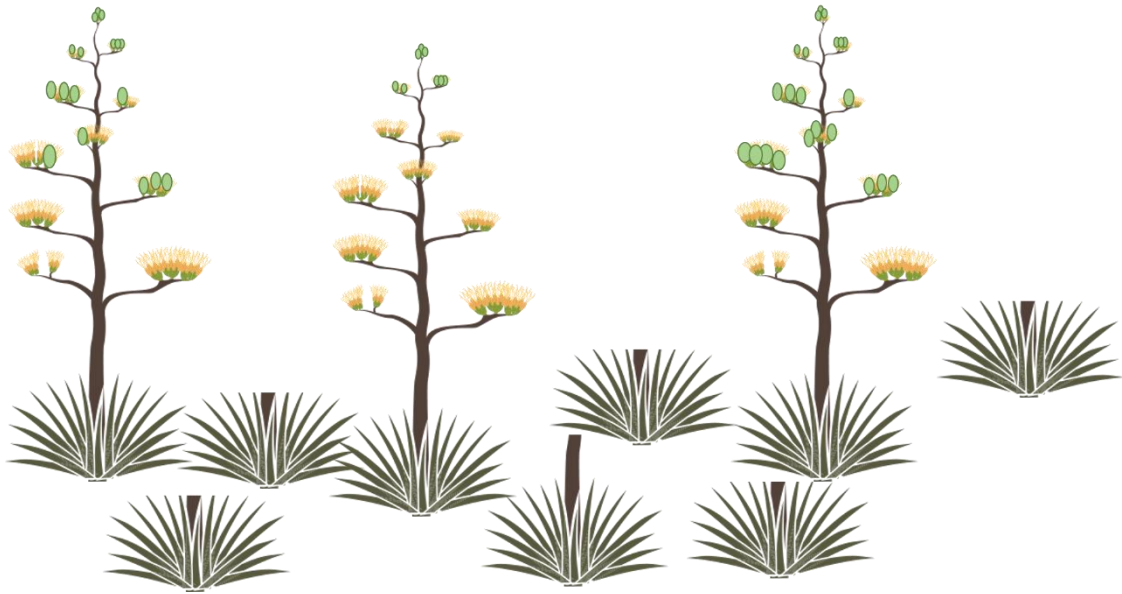


Flowers or Flower buds: Yes
 Open Flowers: No
 Continue observing once per week



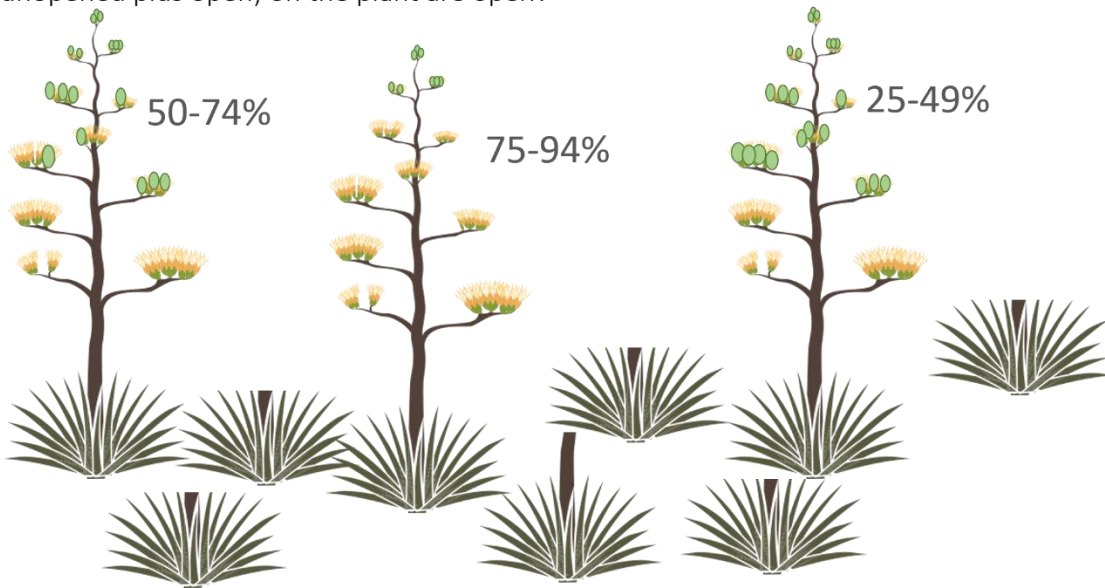
Flowers or Flower buds: Yes
 Open Flowers: Yes
 Continue observing once per week

How many flowers or flower buds are present? **3 for the patch**



What percentage of all fresh flowers (buds plus unopened plus open) on the plant are open?

Average for the patch: 50-74%



Saguaro monitoring:

Do you see flowers or flower buds?

Do you see open flowers?



Flowers or Flower buds: No
Open Flowers: No
Observing once per week



Flowers or Flower buds: Yes
Open Flowers: No
Observing 2-3 times per week



Flowers or Flower buds: Yes
Open Flowers: Yes
Observing 2-3 times per week

How many flowers and flower buds are present?

**11-100
flowers or
flower buds**

What percentage of all fresh flowers (buds plus unopened plus open) on the plant are open?

**50-74% of
flowers
are open**



Monitoring Locations and Design:

We aim to establish lesser long-nosed bat forage phenology monitoring sites within 40 miles of the long-term and acoustic roost monitoring sites (Fig 4). This will allow comparisons between bat use patterns at the roosts and forage resource phenology within the typical foraging distance of each roost being monitored. Our goal is to have a minimum of five phenology monitoring sites for each forage plant species. We anticipate a total of 25 to 30 total forage plant phenology monitoring sites across the range of the lesser long-nosed bat in Arizona and New Mexico.

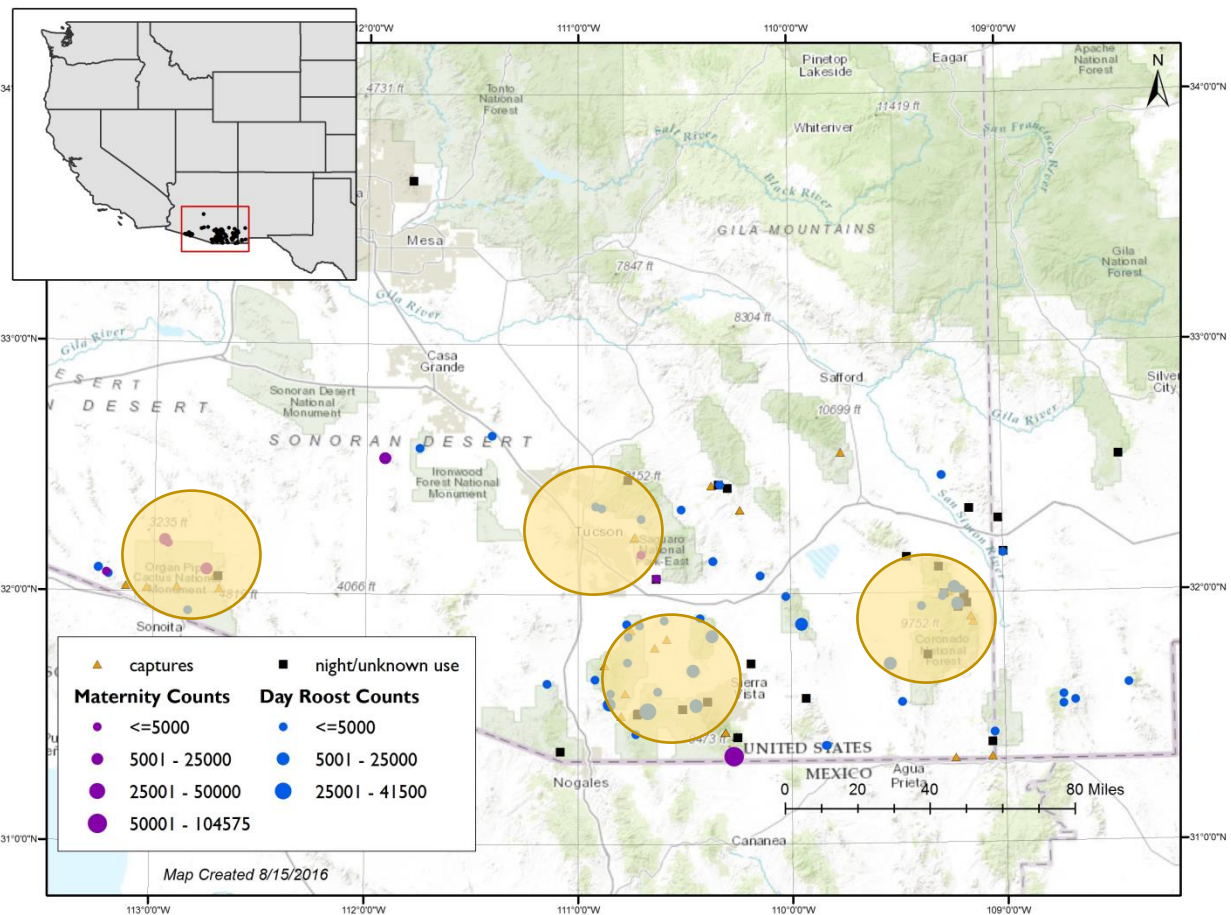


Fig 4. Approximate distribution of the lesser long-nosed bat roosts in Arizona and New Mexico (Map courtesy of BCI). Yellow circles indicate focus areas for forage resource monitoring. Monitoring may also take place outside of these areas.

In the Tucson area, we are interested in finding observers to adopt trails to track flowering of agave. This [Google Map](#) shows the trail locations at which we have found agaves present. Potential trail adopters should contact erin@usanpn.org to learn more about how to get involved.

Sites (Box 3) should be representative of the natural landscape, but may be selected for ease of access. Participants are encouraged to select sites that are already regularly accessed by staff and/or volunteers. Phenology monitoring only takes a few minutes and may be completed alongside other job duties.

Box 3. Definitions for Monitoring Design

Site – The physical observation location at which monitoring occurs, registered in *Nature's Notebook*. An agency or other organization may have more than one site. A site should represent a uniform ecosystem type, such as Sonoran desert scrub. A site should include at least 2-3 individual plants or patches of plants for each species. The size and shape of a site are flexible – a site may be defined by a trail that is walked or road that is driven to observe plants, a grouping of plants of a single species, an area including multiple groups of plants from multiple species, a single individual or patch of plants, etc.

Patch – Used when individual plants are clustered together on the landscape. Registered as an Individual Plant Patch in *Nature's Notebook*. Number of flowering stalks and percent of open flowers are estimated for the patch overall.

Individual Plant – Used when individual plants are dispersed on the landscape. Each plant is registered as an Individual Plant in *Nature's Notebook*. Number of flowers will always be counted as a single flowering stalk. Percent of open flowers are estimated for the individual plant.

Fig 5 below shows examples of sites. Sites may be made up of multiple patches of plants (Example Site #1), or a patch of individual plants that are dispersed along a trail or road (Example Site #2). Sites can be made up of multiple species (Example Site #3) or a site may be composed of only one plant, if no others are available (Example Site #4). A site may have a mix of plants occurring in patches and plants occurring as individual plants.

Nature's Notebook allows an observer to indicate the size of their observation site. This can be found by going to Edit Site and entering the details about the site on the bottom of the page. An observer can also use the Comments field associated with an individual plant to specify the size of the patch, the number of individual plants, the size classes, etc.

Saguaro and organ pipe cactus should always be monitored as individual plants. We recommend selecting at least three individuals per site.

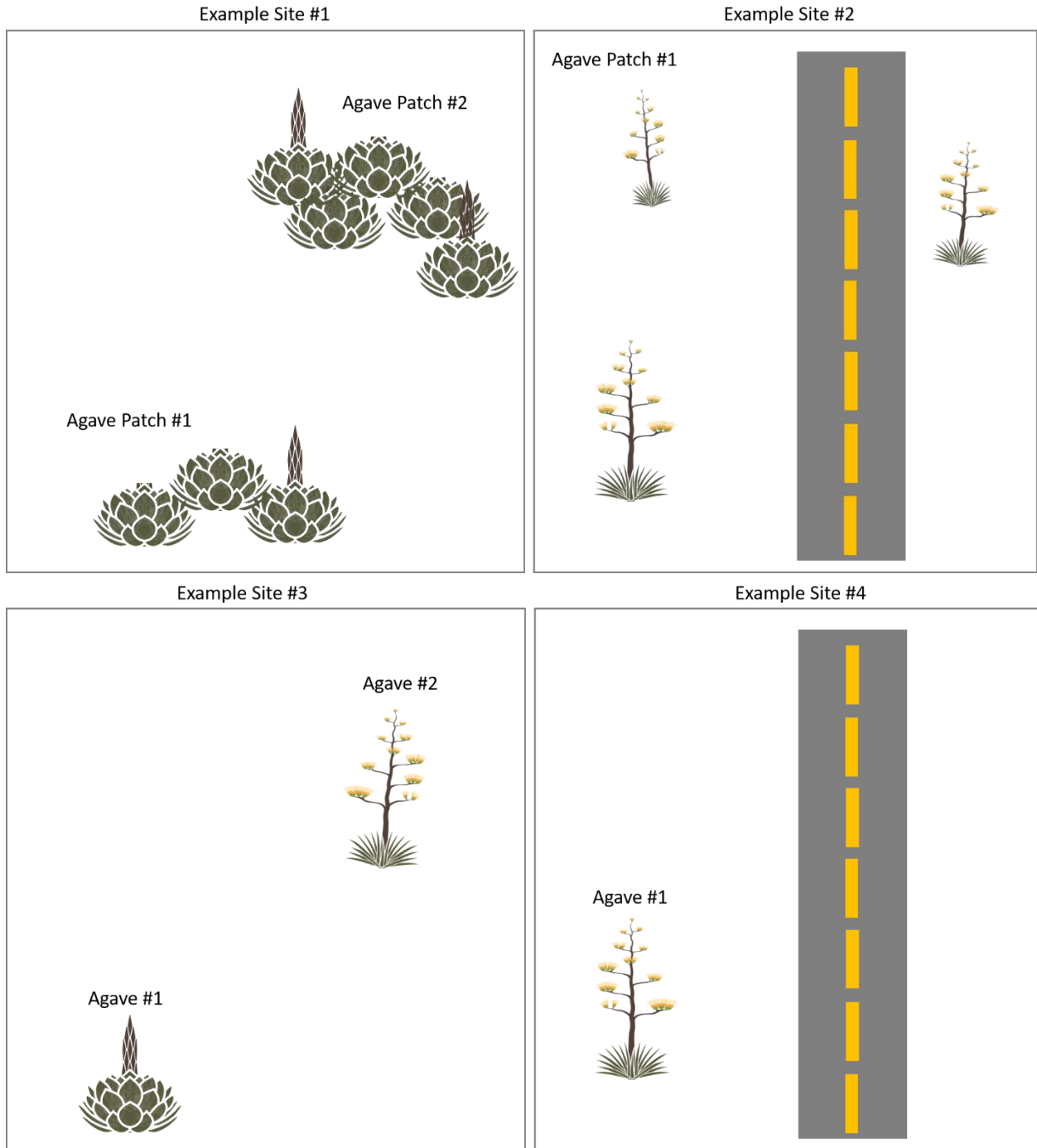


Fig 5. Examples of forage phenology monitoring sites. Sites may include plants that are grouped or a patch of plants that are dispersed along a trail or road. Sites may have multiple species or may include only one plant, if no others are available.

Recommendations for monitoring:

Generally, observers should not attempt to determine flowering stages of agaves or saguaros from a distance of more than 50 feet from the plant. Determination of whether the flowers are closed or open may be aided by the use of binoculars.

Agave monitoring recommendations:

Individual agaves or patches of agaves should be tagged for repeat monitoring. The USA-NPN recommends monitoring at least three individual plants or patches at a site.

Depending on whether agaves are clustered or dispersed on the landscape, we recommend different monitoring methods:

- Clusters of plants – a stationary count method may be used to count flowering stalks and determine percent of open flowers
- Dispersed plants – a walking or driving transect may be used to count flowering stalks and determine percent of open flowers

Columnar cacti monitoring recommendations:

Individual saguaro, organ pipe, and cardon cactus should be selected and tagged for repeat monitoring. Tags may include aluminum tags attached to the plant by wire, stakes or flags placed in the ground near the plant, or other methods appropriate to the individual site. The USA-NPN recommends monitoring at least three plants at a site. A stationary count method may be used to monitor saguaros and organ pipe cactus in most cases.

Because flowers of columnar cacti typically close by midday, we recommend that observations of flowering of these species be completed by 10 am.

Frequency of Monitoring and Estimated Time Investment:

We will focus on tracking flowering phenology, though fruiting phenology may also be recorded. For saguaros, the majority of flowering begins in April and ends in July, though flowering has been reported at other times of the year. For agaves, flowering typically begins in May and ends in September.

The frequency of annual visits will be initially low – only as needed to document the initiation of flowering. For agaves in particular, flowering stalks are large structures and visible from a distance. Agave flowering stalks will typically take at least 2 weeks following initiation of growth of the stalk to form flower buds. After flower buds form, monitoring will ideally occur once per week until flowering has been completed to capture the onset, peak, and end of open flowers.

Table 1. Estimated timeline and frequency of phenology monitoring for saguaro and agave:

	April	May	June	July	Aug	Sep
Columnar Cacti	Begin monitoring weekly	When flowers appear, monitor 1-2 times per week	When flowers appear, monitor 1-2 times per week	Fruits may optionally be recorded 1-2 times per week	No monitoring anticipated	Fall flowering may optionally be recorded
Agave	Begin monitoring monthly	When flowering stalks appear, monitor once per week	When flowering stalks appear, monitor once per week	When flowering stalks appear, monitor once per week	When flowering stalks appear, monitor once per week	When flowering stalks appear, monitor once per week

Estimated training and observing time:

Training. USA-NPN staff will provide training on how to use the *Nature’s Notebook* program. Individual site consultations are available for selecting sites and individual plants. Ideally, observers will attend at least one training. Trainings may be offered at sites around Tucson in April. If you would like to set up a Nature’s Notebook training at your location, contact Erin Posthumus, erin@usanpn.org, 520-621-1670. Training materials are also available on the *Nature’s Notebook* website (see *Nature’s Notebook* Resources section below).

Observing. An experienced observer will spend approximately 2-3 minutes per individual plant or patch of plants. For a single site with 2-3 individual plants, an observer will spend less than 10 minutes observing. Observers can share monitoring duties. For example, if four observers monitor a single site, each observer only needs to monitor once per month.

Observer management. At least one staff member at each unit will need to provide a supervisory role for their observers, as Local Phenology Leader. This person will also be the primary contact in communication with the USA-NPN, whose staff will provide support and answer questions. This Local Phenology Leader should plan to commit 2-3 hours a month to manage observer monitoring calendars, provide support to observers, and communicate with the USA-NPN staff.

Data Processing and Delivery:

Data from this project are stored in the National Phenology Database (www.usanpn.org/data/observational) and freely available for download and use in multiple summarized formats (Rosemartin et al. 2018). Phenology data can be downloaded along with

twenty climate data variables derived from Daymet (gridded, daily surface weather and climate data, daymet.ornl.gov/overview.html). The USA-NPN's Phenology Visualization Tool allows users to explore data and create graphs such as a phenology calendar to display the presence or absence of flowering and activity curves to display the peak in reports of flowering (Fig 6).

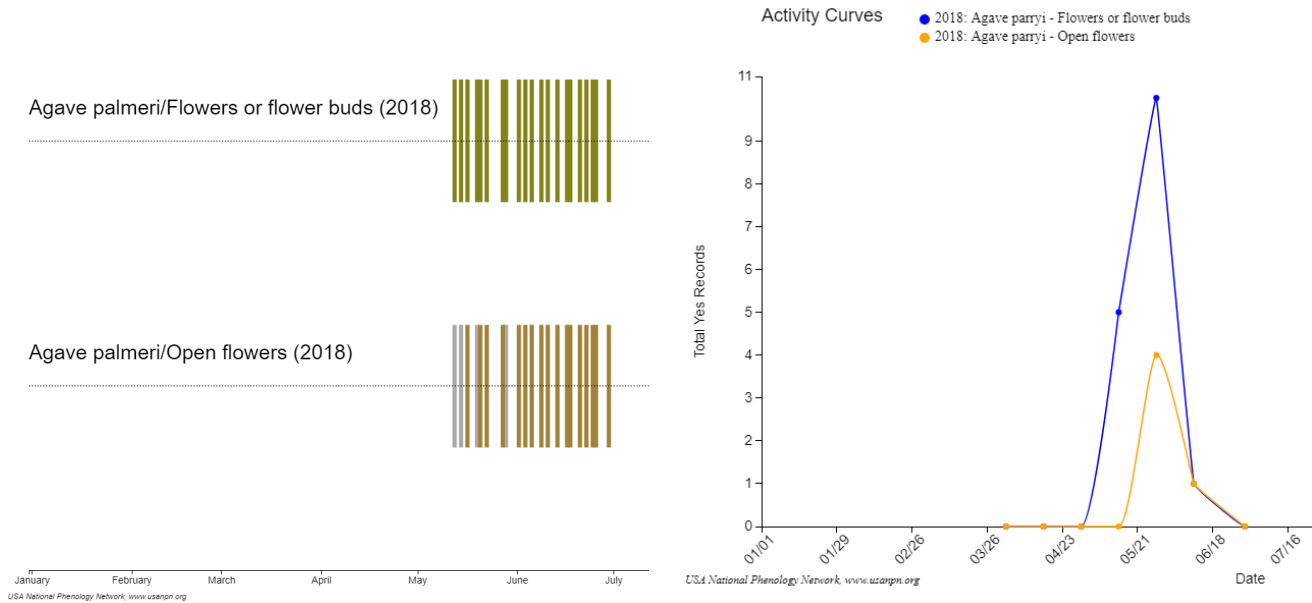


Fig 6. Phenology calendar depicting flowering reports for Agave palmeri in 2018 and activity curve depicting total yes records for flowers or flower buds and open flowers for Agave parryi in 2018. These visualizations were created with the USA-NPN's Phenology Visualization Tool.

Flowers for Bats Resources:

Flowers for Bats Campaign landing page: fws.usanpn.org/Campaigns/flowersforbats

Create a *Nature's Notebook* account: <https://www.usanpn.org/nn/become-observer>

Request a *Nature's Notebook* group for your organization: www.usanpn.org/nn/groups/group-site

Learn how to observe guidelines: www.usanpn.org/nn/guidelines/group-sites

Learn how to use the mobile app: www.usanpn.org/nn/mobile-apps

Phenophase Photo Guides for four species attached.

Contacts:

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This protocol has been peer-reviewed and approved for publication consistent with USGS Fundamental Science Practices (pubs.usgs.gov/circ/1367/).

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