California Sentinel Sites for Nature
Standard Operating Procedures

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Overview

In October 2020, Governor Newsom signed Executive Order N-82-20, commonly referred to as the 30x30 Initiative, to accelerate conservation of California lands and coastal waters in the face of climate change and other stressors to biodiversity by protecting 30% of land and water by 2030. The California Biodiversity Network, composed of academic institutions, NGOs, government agencies, and private entities with expertise in conservation science and practice, was formed to support the launch and implementation of 30x30. In April 2022, The CA Natural Resources Agency released the Pathways to 30×30 strategy document, which included an Appendix compiled by CBN outlining research and information priorities to support implementation of 30×30 in California. A key concept and research priority identified by this community was statewide, long-term biodiversity monitoring to support 30x30 implementation and to monitor efficacy of the initiative, among other benefits to conservation in the state. This collaborative and partner-driven monitoring effort is now known as the **California Sentinel Sites for Nature (CA-SSN) initiative**.

The purpose of this document is to describe the guiding principles of the CA-SSN, a network of coordinated monitoring efforts collecting simultaneous biodiversity and climate information across California's ecosystems. The document defines a Sentinel Site, outlines the overarching goals of the CA-SSN, and describes opportunities to support or join. This document also outlines the main Sentinel Site monitoring components and introduces associated field and data management protocols to be employed by network participants.

It is important to note that this document reflects the current state of the CA-SSN at the time of writing. As such, the processes and monitoring efforts described throughout are not inclusive of all potential types of monitoring that may be applied in the future. The intention of this collaborative is to expand our standardized monitoring efforts over time by capitalizing on the strengths and knowledge of our partners. However, this should not limit CA-SSN members from pursuing monitoring activities outside of the minimum requirements listed here.

This is a living document that will be updated throughout the life of the CA-SSN to ensure that any changes do not disrupt the activities of the CA-SSN nor render the data collected less usable.

CA-SSN Value Proposition

California Sentinel Sites for Nature (CA-SSN) is a statewide network using advanced sensing technologies and consistent data protocols to monitor biodiversity at an unprecedented frequency and scale. By providing reliable, real-time ecological insights, CA-SSN empowers land stewards, scientists, managers, and policymakers to detect early signs of environmental change and take timely conservation action. Designed to serve communities locally while setting a global example, this collaborative framework ensures that biodiversity can be monitored for decades and ultimately protected for generations to come.

- CA-SSN Data Workshop Participants, June 2025

Shared Goals

Below is a list of goals for the CA-SSN:

- Establish a network of multi-jurisdictional biodiversity monitoring sites managed by multiple partner organizations **to establish biodiversity baselines and to assess change over time.**
- **Assemble a network of partners** committed **to long-term monitoring** utilizing shared standardized protocols for a minimum of 5 years (and ideally much longer) to assess long-term biodiversity and climate trends.
- Utilize network data to **quantify biodiversity trends**, particularly in response to climate, land-use change, and other shifting environmental conditions and stressors across the state

- Guide **defensible, science-backed management decisions** designed to sustain biodiversity and functioning ecosystems.
- Build long-term databases that can be used to **inform the goals of 30x30** and related conservation and climate adaptation/mitigation programs and strategies.
- Standardize and aggregate California's climate and biodiversity data into **shared, accessible repositories** to enable regional and statewide temporal assessments of biodiversity.
- Connect and create opportunities for additional monitoring, analysis, and innovation through **resource-sharing among network partners.**
- Pursue opportunities for **education and outreach** related to CA-SSN data collection, analysis, application, and value.
- Create a **highly scale-able model** to allow for easy adoption and growth within California and to serve as a potential model for other interested states, countries, or entities.
- Create **long-term financial and operational sustainability** for the CA-SSN by effectively organizing multiple partners around core principles, goals, and practices, thus providing a strong case for continued funding and resource allocation.

Definitions

This section includes brief definitions of terms commonly used throughout this document.

Sentinel Site: A property or other geographic area where long-term, standardized CA-SSN monitoring and data protocols are being implemented, and instrumentation is installed and maintained to accomplish climate and/or biodiversity monitoring goals. All Sentinel Sites must have a Host entity or organization, as defined below.

California Sentinel Sites for Nature (CA-SSN): The collection of all Sentinel Sites across California (formerly referred to as the Sentinel Site Network).

Long-term Monitoring: Monitoring commitment for a minimum of 5 years and ideally longer than 10 years to capture spatial and temporal variation in biodiversity and climate trends.

Weather Station: Apparatus for collecting meteorological data at a single location.

Motus Station: Apparatus for collecting tagged wildlife movement data using automated radio telemetry.

Biodiversity Monitoring Plot: A single location within a Sentinel Site where in-situ biodiversity data are collected following standard CA-SSN biodiversity monitoring protocols.

Sentinel Site Host: An entity with personnel committed to, and primarily responsible for, establishing and maintaining one or more Sentinel Sites.

Sentinel Site Partner: An entity with personnel or an individual who is actively supporting network goals through means other than hosting a Sentinel Site.

Sentinel Sites for Nature Coordination Committee: The Coordination Committee supports strategic and coordinated growth and persistence of CA-SSN. The Committee is comprised of institutional affiliates of Sentinel Site Hosts who oversee Sentinel Sites with both biodiversity *and* climate monitoring equipment

(i.e. required wildlife monitoring components outlined below plus a weather station and a Motus station).

California Biodiversity Network – Sentinel Site Network Roundtable: CBN's community of practice that informs CA-SSN priorities and actions, including development of protocols for data collection, analyses, and management systems.

Sentinel Sites for Nature: Opportunities to Participate

This section provides additional information about the various CA-SSN roles defined in the previous section.

Sentinel Site Hosts

- CA-SSN Hosts are the organizations primarily responsible for the installation and long-term maintenance of one or more Sentinel Sites, including in-situ biodiversity monitoring equipment, and climate and/or motus equipment where applicable, at one or more Sentinel Sites.
- The Host is ultimately responsible for ensuring that all activities related to collecting, processing, auditing, and submitting data follow CA-SSN protocols.
- Hosts of Sentinel Sites that include both the required wildlife monitoring equipment *and* the recommended weather station and Motus station have the option to join the CA-SSN Coordination Committee with approval by existing CA-SSN Coordination Committee members.
- Hosts are expected to participate in the CBN's Sentinel Site Roundtable.
- In addition to standard biodiversity monitoring, Hosts have the option to pilot new monitoring methods, which may be adopted by the Sentinel Site Network with approval by the CA-SSN Coordination Committee.
- Hosts do not need to be landowners. They can coordinate with other landowners to establish Sentinel Sites (MOUs or other partnership agreements are recommended).

Sentinel Site Partners

Sentinel Site Partners support the CA-SSN in numerous ways, including through supplemental data sharing, data management, analytics, logistics, and engagement. Examples include:

- *Data Management:* Supporting data processing (e.g., volunteer or university student involvement in processing photos).
- *Data Analysis*: Applying Sentinel Site data to answer biodiversity, climate, and/or management questions that advance 30x30 and state conservation objectives.
- *Data Protocols*: Expanding or piloting new monitoring methods through the development of standardized protocols in coordination with a Sentinel Site Host.
- *Equipment installation, deployment, and retrieval*: Supporting Sentinel Site Hosts with implementing and maintaining monitoring equipment, including site setup, calibration, and data collection.
- *Community science*: Developing and/or implementing community science engagement opportunities and outreach efforts at Sentinel Sites.

- *Financial Support*: Fundraising for the CA-SSN, such as sponsoring or supporting equipment purchases and maintenance costs, in-kind contributions, grant writing, or serving as a fiscal sponsor.

Sentinel Sites for Nature – Coordination Committee

The CA-SSN Coordination Committee:

- Is currently composed of institutional affiliates that serve as Sentinel Site Hosts, and that meet the minimum wildlife monitoring requirements *plus* the recommendations for a weather station and Motus station. At the time of writing, this body currently includes the California Department of Fish and Wildlife (CDFW), UC Natural Reserve System (UC NRS), UC Agriculture and Natural Resources (UC ANR), Pepperwood, and TNC personnel. New Hosts that meet these requirements have the option to join the CA-SSN Coordination Committee with approval by existing CA-SSN Coordination Committee members.
- Supports strategic and coordinated growth and persistence of the Sentinel Site Network.
- Reviews and approves requested changes to CA-SSN monitoring and data protocols over time.
- Maintains up-to-date documentation of CA-SSN guidelines, associated protocols, and other organizational documents, and for tracking CA-SSN participation.
- Identifies appropriate repositories for data collected at Sentinel Sites, as described in the "Minimum Monitoring Protocol" section of this document.
- Provides general guidance to CA-SSN members and resolves network-wide issues as they arise. Periodically evaluates participation to ensure that expected data practices are being met by all Hosts.

Sentinel Site Monitoring Protocols: Minimum Requirements for Operating a Sentinel Site

Background

Sentinel Site monitoring protocols are based on the California Environmental Monitoring and Assessment Framework (CEMAF), which was developed by CDFW staff in the Office of Cannabis in response to growing concerns regarding the impacts of land use change in California. Currently, CEMAF wildlife monitoring is ongoing at over 300 locations. These protocols were later adopted by CDFW's Lands Program and Science Institute as part of the development of CDFW's Sentinel Sites, which includes 39 CDFW properties as of January 2025.

While the goal of the CA-SSN is to capture information about all forms of biodiversity across California's diverse landscapes, the current monitoring protocols only address terrestrial vertebrates. A future task for the CA-SSN is to expand monitoring capabilities to include standardized invertebrate and vegetation monitoring, for example, and to update the protocols accordingly. As such, these protocols are subject to change and will evolve as additional protocols are developed and refined. Any changes to the

protocols will be subject to approval by the Coordination Committee and will be clearly communicated to all CA-SSN participants.

Minimum Monitoring Standards

The power of the CA-SSN lies in the application of standardized monitoring protocols, resulting in comparable data that can be used to identify local, regional, and statewide biodiversity and climate trends over different time scales. To that end, below is an overview of the current CA-SSN monitoring protocols, which outline the components necessary for a property to be considered a Sentinel Site.

Detailed monitoring protocols are maintained online as ArcGIS StoryMaps. All Sentinel Sites must follow these designated protocols for equipment deployment and processing data. Data management protocols are provided in the next section.

Sentinel Site Hosts are welcome to monitor additional species or factors outside of what is listed below and may decide to monitor for longer periods of time. The following standards can be viewed as minimum requirements.

Required monitoring components

Each Sentinel Site encompasses four biodiversity monitoring plots. All biodiversity monitoring plots are required to include the following components: two sound recorders, one trail camera, and one knee-high fence (drift fence) leading to a downward facing trail camera. Links to specific monitoring field protocols are embedded below, and you can view the full collection of current CA-SSN monitoring protocols here.

- Four biodiversity monitoring plots are established during the spring, between March 20th and June 30th to overlap with the bird breeding season. Plots are randomly positioned within different vegetation types, including the representative or dominant vegetation type found in the area, and are spaced at least 500m apart, requiring a minimum of roughly 62 acres. CA-SSN monitoring should be conducted during the same date range each year.
- Trail cameras (traditional wildlife camera traps) targeting medium-large mammals, are deployed for a minimum of 10 consecutive weeks.
- Drift fences and downward facing trail cameras, targeting small animals, are deployed for a minimum of 10 consecutive weeks.
- One sound recorder will record birds and other vocalizing taxa (e.g. frogs and canids); this unit will record continuously in the acoustic spectrum, at a minimum, from 20:00 local time to 09:00 the following morning for at least 7 consecutive survey days (ideally to optimize surveying breeding species [optimal date ranges vary throughout California based on latitude and elevation within the state]).
- One sound recorder will record bats; this unit will record in the ultrasonic spectrum, at a minimum, from 15 minutes before sunset until 15 minutes following sunrise for at least 4 consecutive nights (optimal date ranges vary throughout California based on latitude and elevation within the state).

Recommended monitoring components

CA-SSN Hosts are highly encouraged to install weather stations and/or a Motus station at their Sentinel Site where appropriate and feasible. Weather stations can be used to monitor and validate long-term

climatic changes, and to evaluate local impacts of climate change on biodiversity. Motus telemetry stations are used to capture animal movements; the Motus network permits researchers to understand the movements of tagged animals regardless of the ownership or management of the station.

- If establishing a weather station, please consider these minimum conditions:
    a) Weather stations should include research-grade instrumentation.
    b) Stations should collect data on the following: temperature, precipitation, relative humidity, atmospheric pressure, wind speed and direction, solar radiation, and photosynthetically active solar radiation.
    c) Optional: where feasible, stations should include a multi-depth soil moisture probe(s) and fuel stick.
    d) For instructions on how to develop and install a weather station please refer to the equipment manufacturer.

- If establishing a Motus station, please consider these minimum instrumentation requirements:
    a) Receivers must have the capability to detect 434 MHz Motus tags using omnidirectional and/or directional yagis. Optional: have the capability to receive 2.4 GHz Blumorpho and 166 MHz analog transmissions. These two frequencies are optional but are encouraged to increase species detections and provide benefit to researchers worldwide.
    b) Receiver data must be uploaded to Motus at least once per year. It is highly recommended that stations use WIFI or cellular data connectivity.
    c) For guidance on how to set up and install a Motus station, please reference the Motus website.

Sentinel Site Data Protocols: Standards for Processing, Storing and Sharing Data

In addition to collecting data following consistent protocols, the CA-SSN seeks to create centralized repositories for data storage and access to maximize utility. This section includes protocols and guidance for processing, storing, and sharing data collected as part of the CA-SSN effort. The CA-SSN Coordination Committee, with contributions from the CA-SSN Roundtable, will refine these standards to ensure clear guidance on these topics is made available as the initiative grows.

Data Principles

Below is a list of overarching principles related to data processing, storage, and sharing. Entering into the CA-SSN partnership and establishing a Sentinel Site is an agreement by the CA-SSN Host entity to adhere to these principles.

1. All CA-SSN data must be added to the designated repositories outlined in the next section to ensure that the data contributes to the overall CA-SSN goals provided in this document.
2. Processed data will be shared in specified repositories as soon as possible but no more than 2 years after collection and will be accompanied with metadata.

3. CA-SSN Hosts are welcome to store and share data from their Sentinel Sites in additional locations outside of the designated repositories.
4. CA-SSN Hosts and Partners will credit the CA-SSN in publications, presentations, etc. stemming from use of the data collected outside of their site, along with any additional credit requirements of the various repositories.

Data Repositories

Compiling data collected by members of the CA-SSN, which is obtained using consistent methodologies, is a crucial aspect of the CA-SSN and an important step towards creating accessible long-term biodiversity and climate datasets that inform conservation and management decisions. This section provides requirements and recommendations intended to centralize data collected through the CA-SSN, namely by identifying repositories for storing and sharing data.

Several of the repositories described below are only suitable for hosting processed results, however maintaining raw data is important given the rapid rate at which machine learning tools are evolving. Raw data act as museum archives that can be re-analyzed using new technologies, provides the opportunity for additional QA/QC, and facilitate additional data extraction (e.g., counts of the number of animals, vocalization characteristics, sex and age class information). In cases where a raw data repository is not specified, it is the responsibility of the CA-SSN Host to identify a storage location. The Coordination Committee, with the support of the CA-SSN Roundtable, is exploring options for consolidating raw data.

Please note, the requirements described below cover the data types described in the "Minimum Monitoring Protocol" section above. Additional data processing and storage guidelines may be developed and added to this Standard Operating Procedures document over time as the monitoring protocols expand.

In short:

1. Raw and processed camera data will be stored in Wildlife Insights
2. Results from processed ultrasonic data will be submitted to NABat
3. Acoustic data will be added to the Wildlife SoundHub (in development)
4. Raw acoustic and ultrasonic data will be stored by the host entity until a centralized repository is established
5. Motus wildlife tracking data will be added to Motus.org (if applicable)
6. Weather station data will be submitted to Dendra.Science (if applicable)
7. Basic Sentinel Site information will be provided to the Coordination Committee for addition to the CA-SSN website and CDFW's Biogeographic Information Observation System (BIOS)

Camera data: Wildlife Insights (required)

All camera data collected at Sentinel Sites using the traditional camera trap and drift fence and camera trap field protocols should be uploaded to Wildlife Insights. Wildlife Insights provides camera data storage, processing, and visualization tools.

CA-SSN Hosts can access Wildlife Insights under the umbrella of CDFW's CA-SSN Initiative. CDFW will help CA-SSN partners create their own 'project' in Wildlife Insights where they can upload, store and process camera data; this includes the use of AI tools designed to expedite the photo tagging process. Please note, any data uploaded to Wildlife Insights will become fully accessible to CDFW.

To establish a project in Wildlife Insights, please refer to instructions provided in the 'Wildlife Insights for CA-SSN' storymap.

Acoustic data: Wildlife Sound Hub (required upon availability)

Acoustic data must be processed using an auto-classifying tool such as BirdNET. At minimum, CA-SSN hosts must manually vet one observation per species per site to ensure data quality.

UC Berkeley's Geospatial Innovation Facility and Eric and Wendy Schmidt Center for Data Science & Environment are currently working to develop a Wildlife Sound Hub, which aims to 1) centralize and permanently store sound files so they can act as museum specimens; 2) ensure standardized metadata; and 3) provide tools for running acoustic data through BirdNET and other freely available auto-classifiers, as well as tools for manually validating species identifications. The goal is to have a fully automated pipeline for processing acoustic data (identifying vocalizing taxa to species) available in the next 1-2 years. This protocol will be updated once the Wildlife Sound Hub is operational and available to CA-SSN partners to use. In the interim, CA-SSN Hosts must find alternative options for storing processed acoustic data.

CA-SSN Hosts are responsible for storing their raw acoustic data files until a centralized repository is established

Ultrasonic data: NABat (required)

Ultrasonic data must be processed using an auto-classifying tool such as SonoBat. These programs often have false positive detections so CA-SSN hosts are required to manually vet one observation per species per night. The manual vetting portion is critical to ensuring data quality and should only be completed by a trained professional. In the future, we hope to have access to a freely available auto-classifying tool for ultrasonic data, akin to BirdNET for acoustic data.

CA-SSN Hosts are required to upload processed results to NABat. NABat is a multinational, multi-agency coordinated monitoring program across North America that uses standardized protocols to gather data for assessing population status and trends. For more information on uploading data to NABat, please visit the NABat Partner Portal.

CA-SSN Hosts are responsible for storing raw ultrasonic data until a centralized repository is established.

Motus station data: Motus.org (required if applicable)

Any user deploying a Motus station can create a free project in Motus. Data collected through Motus is part of an international research network, and upon registering, data is freely available to anyone with an account. Visit the Motus website for more details.

Climate Data: Dendra.Science (required if applicable)

All data collected via climate stations can be made available on the Dendra.Science as long as it meets the minimum criteria listed in the previous section. The Dendra.Science platform is a free, publicly available site developed by UC Berkeley where each weather station has its own dashboard. CA-SSN Hosts are responsible for maintaining data and performing QA/QC. For more information, contact Collin Bode (UC Natural Reserve System) at Collin.Bode@ucop.edu.

Sentinel Site Basic Information (required)

CA-SSN Hosts will submit information about their Sentinel Sites to the Coordination Committee so that up-to-date maps and information on the Sentinel Site network as a whole can be maintained. Maps will also serve to direct users to associated data streams on both the CA-SSN and BIOS websites. CA-SSN Hosts are expected to annually review their sentinel site data for accuracy and submit updates as needed. A form will be provided for CA-SSN Hosts to submit their data.

Sensitive Species Data (recommended)

CA-SSN Hosts are encouraged to submit sensitive species detections to the California Natural Diversity Database (CNDDB). CNDDB is an inventory of the status and locations of rare plants and animals in California. Visit the CNDDB website to learn more about submitting data to this online database.