California Environmental Monitoring and Assessment Framework Study Plan, 2024 - 2027

California Department of Fish and Wildlife

Cannabis Program

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The California Department of Fish and Wildlife (CDFW) developed this document to detail objectives, planned actions, and desired outcomes for the California Environmental Monitoring and Assessment Framework (CEMAF).

Prepared by:

Originally prepared by Maggie McCann, Betsey Bultema, Erin Chappell, Nicole Cornelius, Kate Crosby, Joseph Kermish-Wells, Elijah Portugal, Ricky Prowse, Lindsey Rich, Kelly Souza, Matt Toenies, and Sean Windell, California Department of Fish and Wildlife, Cannabis Program, November 2021. Revised by Ethan Baruch, Chris O'Keefe, Lindsey Rich, and Kelly Souza, September 2023.

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Project Background, Goals and Objectives

California has committed to ambitious conservation goals (such as the 30x30 initiative) that seek to protect and restore biodiversity, expand access to nature and build resilience to climate change, but lack of long-term species monitoring is a limiting factor for managing and protecting the state's natural resources. To support these conservation goals, fulfill the overarching mission of the California Department of Fish and Wildlife (CDFW) as a public trust agency, and be responsive to Senate Bill 94 which integrated regulations for medical and adult use of cannabis, the CDFW is developing a statewide monitoring framework titled the California Environmental Monitoring and Assessment Framework (hereafter CEMAF or Framework).

Since 2019, the Framework has been developed and piloted by Cannabis Program staff in the Office of Cannabis (formerly staff from Wildlife and Fisheries branches) and Water Branch with the intention of having the Framework locally implemented by new teams of regional monitoring staff and headquarter-managed. The pilot area was concentrated in CDFW regions 2 and 3, and a small part of Region 1. This area was selected based on proximity to headquarters, the ability to leverage existing mapping efforts, the variable amounts of cultivation levels, and because the highly mixed land uses of Region 3 would present a variety of scenarios (e.g. highly urbanized to agricultural) to test the site selection process and sample design. Primary objectives of the regional-scale pilot from 2021-2023 were to 1) assess the feasibility of field sampling the proposed number of sites while utilizing the associated methodologies and operational strategies required 2) develop data management and analysis strategies, and 3) establish an approach to summarize findings at the watershed level.

The Framework outlines the essential components and protocols of the statewide program and provides guidance for implementation. The goal is to implement a comprehensive watershed approach to assessing the direct and indirect effects of cannabis cultivation and other ecological drivers on terrestrial and aquatic species and their habitats in California. Implementation of the framework will provide data needed to assess the direction, magnitude, spatial, and temporal extent of these direct and indirect effects. As a scientifically-grounded monitoring framework designed with an ecosystem approach that considers a range of diverse habitats and species at the statewide scale, it will also help inform California's conservation goals, that seek to protect and restore biodiversity, expand access to nature and mitigate and build resilience to climate change by restoring ecosystem health, function and processes. Because of the complexity of this goal, both in context and in scale, the framework is built around five objectives:

- Habitat: Understand how aquatic and terrestrial habitats are influenced by cannabis cultivation and other ecological processes, and assess how these effects vary spatially, temporally, and in relation to site attributes.

- Community: Understand how cannabis cultivation and other ecological processes influence community composition and structure in different geographic areas such as drainage areas or ecoregions of the state.
- Species: Understand the relationship between presence or abundance of regionally relevant species and cannabis cultivation or other ecological processes in different geographic areas of the state.
- Hydrological: Understand how the timing and duration of biologically relevant instream flow and water quality parameters are jointly affected by water diversions for cannabis cultivation and other land uses, and spatiotemporal climate trends.
- Cumulative Effects: To understand the degree to which cumulative effects are causing significant adverse impacts in specific drainage areas.

In the near term, staff in Headquarters will continue monitoring sites that were established during the 2021-2023 pilot while simultaneously planning for an expansion in higher priority areas of the state, where outdoor cannabis cultivation is most prevalent. We plan to take a "start small" tactic with an iterative approach in increasing the Department's monitoring capabilities and capacity. The 2024 field season will mark the beginning of CEMAF's long-term monitoring phase using standardized field-tested methods and provide a template for expanding into new HUC 12s throughout California. Full expansion is anticipated to be completed by 2027.

Study Design and Site Selection

The Hydrologic Unit Code 12 (HUC 12) subwatershed is the unit of inference. Our study design samples HUC 12s with and without licensed cannabis cultivation to compare how ecological responses may depend on the distribution and coverage of cannabis cultivation in a HUC 12. We used the United States Geological Survey's (USGS) National Hydrography Dataset (NHD), Watershed Boundary Dataset (WBD) to identify HUC 12 boundaries across the state of California. We then used license data from the California Department of Food and Agriculture (now Department of Cannabis Control [DCC]) to identify which subwatersheds encompassed licensed outdoor and/or mixed-light cannabis cultivation. We used license information as a proxy for cannabis density because licensed and unlicensed cultivation have been shown to cluster in close proximity (Butsic and Brenner 2016). In our statistical analyses, we use observed cultivation area from the digitization process (see Site Digitization) so that we are better able to account for both licensed and unlicensed cultivation. We do not include indoor licenses, as indoor cultivation has different effects on fish, wildlife, and their habitats when compared to outdoor and mixed-light cultivation.

Selecting HUC 12 subwatersheds

To create the statewide frame of HUC 12s, we used a Balanced Acceptance Sampling (BAS) approach with post-stratification. We use BAS because it assures spatial diversity, is conceptually simpler than other spatially balanced designs, can be executed quickly, allows for sampling with replacement, and is freely available to download as an R package. Additionally, we can use post-stratification, which is helpful for adjusting to frame imperfections common in environmental monitoring (Robertson et al. 2013, van Dam-Bates et al. 2018). After using BAS to select subwatersheds, we determined the proportion of selected subwatersheds with and without licensed cannabis cultivation in each CDFW region. Within each CDFW region, our goal is to sample a 50:50 split of subwatersheds with and without cannabis. Where we do not achieve this split through the original BAS draw, post-stratification was used to reach our target whenever possible. Due to the uneven distribution of cannabis cultivation across California, not all CDFW regions can meet the 50:50 target. Further, not all monitoring methods can be executed at all sites due to wadeablity, drought conditions, changing accessibility, safety or other unforeseen issues.

So that data can inform both status and trends, we designated ~80% of the selected HUC 12s as stationary, which will be sampled annually with aquatic methods and biennially with terrestrial methods. The remaining ~20% of the selected HUC 12 will be allocated to a 6 or 3-year rotating panel, still to be decided. With the proposed design of 80% stationary sites and 20% rotating sites, sampling will be completed in the full complement of HUC 12s every six years.

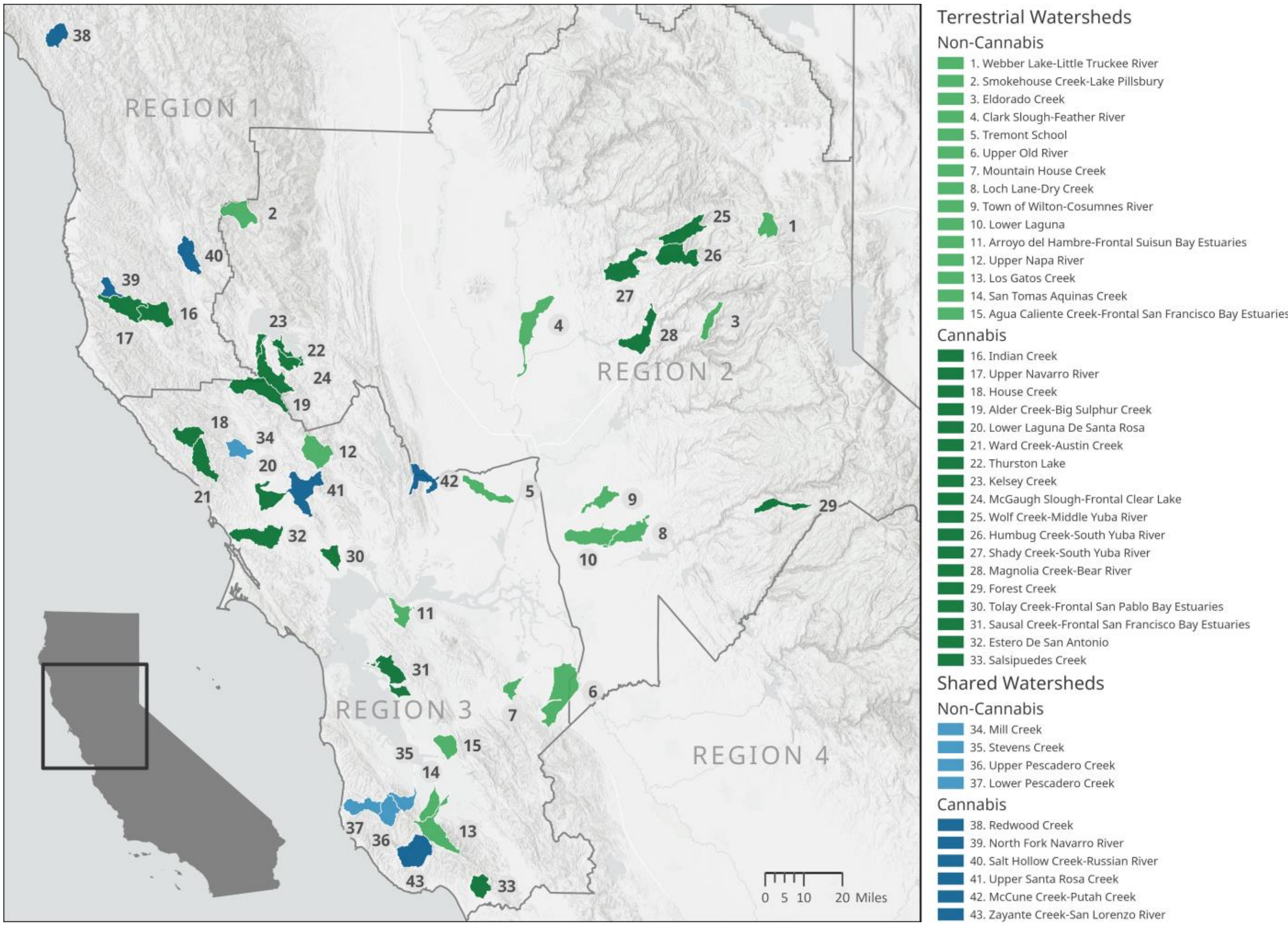

Figure 1. BAS-selected HUC12s for CEMAF monitoring in the pilot study area. Note that terrestrial monitoring is conducted biennially with even and odd year panels and aquatic sampling is conducted annually.

Site digitization

We use aerial imagery to digitize (i.e., manually create polygons outlining cannabis cultivation) cannabis cultivation in every HUC 12 sampled following methods outlined in CDFW 2022, and we will follow a refined version of the protocol for new HUCs sampled in the future. This digitization process enables us to demarcate all types of outdoor cannabis cultivation that is not concealed by canopy cover. Additionally, by using the digitized data in combination with the locations of DCC issued cannabis cultivation licenses, we can differentiate between licensed and unlicensed cannabis cultivation and will account for both types of cultivation in our analyses. Lastly, it helps us to identify visible trespass-style grows that we need to avoid during our on-the-ground sampling.

Selecting within-HUC 12 survey locations

Aquatic Site Selection

Three aquatic sites are selected within each HUC 12 subwatershed. The most downstream site (S1) is placed as close as possible to the mouth of the HUC 12 . The two upstream sites (S2 and S3) are spaced to encompass approximately 66% and 33%, respectively, of the drainage area of the downstream S1. Site placement is as close as logistically possible to these predefined areas however, access, safety, wadeability and other factors may affect exact placement. Here we define 'drainage area' to be the entire contributing area above each sample site. We also ensure that there is downstream connectivity between all three sites (i.e., S2 is in the flow path of S3 and not placed on a tributary). The protocol specifies three sampling locations per HUC 12 to capture within-subwatershed environmental variability. The primary advantages of this approach are, a) increased likelihood of at least one site being located close to cannabis cultivation, b) ability to identify water diversions through discrepancies in flow between sites, and c) subwatershed-wide identification of suitable habit for target species.

Before selecting sample sites, streamflow reaches were filtered for suitability by restricting to Strahler stream orders to 3 – 6 for mainstem sites and 2 – 3 for tributary sites and by the USGS National Hydrography Datasets F-code, which allowed us to exclude unsuitable stream types such as ephemeral streams. Further, sites located in artificial channels, or downstream of dams with substantial influence on flow, or have high levels of subwatershed urbanization, are also excluded. These direct alterations of instream conditions would mask effects of agricultural water diversions or other cannabis impacts and raise safety concerns for field staff.

Terrestrial site selection

For terrestrial sampling, we cluster 2 – 4 sampling sites within each HUC 12 subwatershed. Sites are spaced by 200 – 600 m and the number of sites is based on vegetation heterogeneity (more vegetation types = more sites). Sampling within multiple vegetation types is critical given community compositions are very different in, for example, forests, shrublands, and grasslands. We randomly locate the initial sampling site. To ensure we have overlap with aquatic sites and that we sample near cannabis cultivation, we have four approaches for randomly selecting this initial site (Table 1). By locating terrestrial sites within the same drainage areas where aquatic sites are located, we ensure complete overlap in all HUC 12s with aquatic sampling. By locating terrestrial sites within 1,000 m of cannabis cultivation, we ensure sampling occurs near cultivation.

Table 1. Approaches for selecting the initial terrestrial sampling location in HUC 12 subwatersheds with and without aquatic sampling, and with and without licensed mixed-light and/or outdoor cannabis cultivation.

	Non-cannabis HUC 12s	Cannabis HUC 12s
Shared HUC 12s	Randomly select site within the same drainage area as aquatic sites	Randomly select site within the same drainage area as aquatic sites and within 1,000 m of cannabis cultivation
Terrestrial HUC 12s	Randomly select site from any location	Randomly select site from any location within 1,000 m of cannabis cultivation

To determine locations for the remaining sites within a HUC 12, we identify the vegetation type within which the randomly allocated site was located using Vegetation Classification and Mapping Program (VegCAMP) data. In instances when VegCAMP data is not available, we use lower-resolution Wildlife Habitat Relationship (WHR) classes from the CALFIRE Fire and Resource Assessment Program. Next, we identify the three nearest neighbor vegetation types and randomly locate one site within each of these vegetation types. We require that sites be spaced no closer than 200 m and no further than 600 m. In cannabis cultivation HUC 12s, we also require the remaining sites to fall within the buffered cannabis cultivation area. If there are fewer than three adjacent vegetation types that met these spacing requirements, then we reduce the number of additional sites accordingly. Following site selection, we check site accessibility (e.g., distance to a road or trail, slope, proximity to illegal grows, etc.) and re-assign site locations when necessary.

Coordination Needs

Prior to the start of field season, CEMAST coordinates with regional staff, other monitoring programs and Regional Conservation Districts about the most appropriate party to communicate with landowners while also minimizing landowner contact fatigue. We employ several strategies for maintaining access which includes verbal access, a Temporary Entry Permit which was created with the Office of the General Counsel specifically for CEMAF, or indemnification waivers which are commonly used by local governments. To facilitate within-CDFW coordination and improve safety for field crews and equipment, we are developing GIS tools to track and communicate about planned activity at the parcel scale.

Sampling occurs annually from March – October (Figure 2). We welcome any assistance from regional staff should they be available. In particular, assistance with aquatic gear installation in the spring and periodic discharge measurements two to three times throughout the low-flow gaging season, would be most helpful.

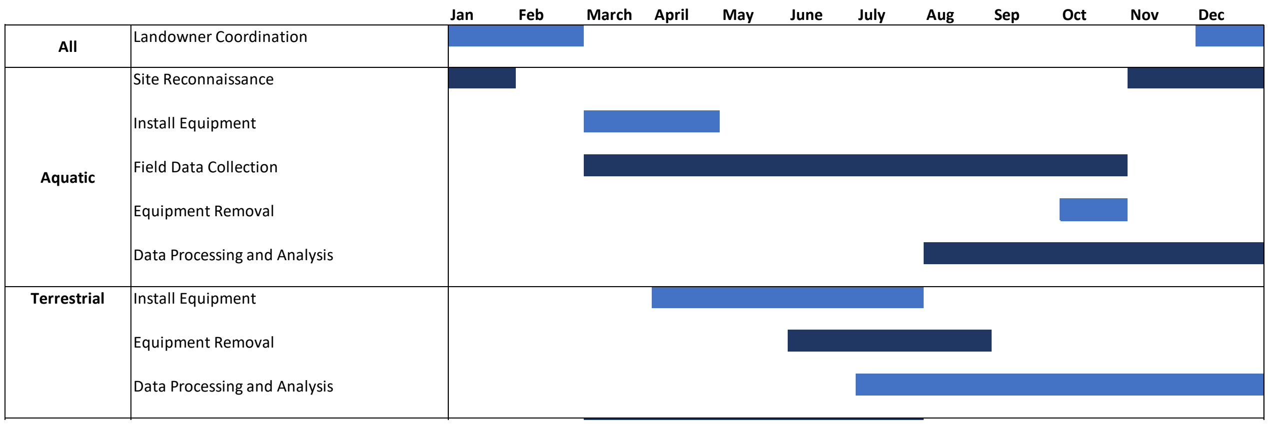

Figure 2: Field based tasks and timing.

ESA Considerations

This monitoring does not propose any mortality or permanent disabling of a specimen, removal of any specimen from the state of California, introduction of any specimens or any of its progeny into an area beyond the historical range of the species or holding of fish and wildlife specimens in captivity. CDFW will maintain records of each federally listed, endangered and threatened fish or wildlife and the disposition of those specimens. Fish and wildlife will be observed by camera traps, acoustic recorders, and direct observation via snorkel surveys. Federally listed endangered and threatened fish (non-anadromous), wildlife or plants that are resident in the State of California as defined in 50 CFR Part 81, will be covered by the Limited Authority Cooperative Agreement between the CDFW and the USFWS (2015) for any qualified employee or agent of the CDFW, in order to carry out conservation programs in accordance with this Cooperative Agreement. NOAA/NMFS was consulted about ESA considerations related to aquatic sampling and ESA listed anadromous species, and regional NOAA/NMFS staff confirmed that snorkel observations are considered to have a minor and immeasurable effect on the species, and therefore a permit is not required. A full list of ESA- and CESA-listed species within our HUC 12s in regions 1 and 3 selected for aquatic sampling can be found in Appendix A. Listed terrestrial species within our HUC 12s selected for terrestrial sampling are listed in Appendix B.

Field Methods

Starting in the fall prior to field season, reconnaissance of new study sites and landowner re-engagement begins (Figure 2). Equipment installation and sampling begin in the early spring and staff will return to the same sites two – seven times (occasionally more if site conditions require), until August (terrestrial) or October (aquatic).

Terrestrial Monitoring

Automated recorders

We use automated recorders to collect species-specific information on bats and birds. We deploy two automated recorders at each site between April and mid-June. To survey bats, we program one automated recorder to record ultrasonic triggers from 30 minutes before sunset until 30 minutes following sunrise for four consecutive nights. This programming aligns with recommendations from the North American Bat Monitoring Program (NABat; Reichert et al. 2018; Rodriguez et al. 2019). To survey diurnal and nocturnal birds, we program the second automated recorder to record continuously from 20:00 to 09:00 for seven consecutive nights. This programming allows us to extract data that aligns with past CDFW efforts like the Ecoregion Biodiversity Monitoring effort (Furnas and Callas 2015; Furnas and McGrann 2018) and it also aligns with previous owl surveys in the state (Wood et al. 2019). For additional details, please see our field protocol.

Camera traps

We use camera traps to collect species-specific information on mammals and reptiles. We deploy two Hyperfire2 HP2X camera traps (Reconyx, Holmen, WI, USA) at each site for ten weeks from April to August. One camera targets medium to large mammals while the remaining camera targets small animals. We strategically deploy cameras targeting medium to large mammals along a trail, four-wheel-drive road, or habitat edge to increase our probability of photographing the target species. If the nearest habitat feature is more than 25 m away, then we deploy the camera at the predetermined site. We cable-lock cameras to trees at knee height and program them to take three photos at each trigger event with a delay of one second between events. For cameras targeting small animals, we use camera trapping in combination with traditional drift fence methods (Martin et al. 2017). We strategically deploy drift fence/camera setups in places that likely support higher herpetofauna diversity (e.g. crossing a habitat edge) if they are within 50 m of the predetermined site. We secure the 7 m drift fence so that it is perpendicular to terrestrial movement corridors and at one end of the fence, install a downward-facing, close-focus camera (camera has a modified, factory-set focal distance of 40 cm). In this setup, small wooden guideboards at the end of the fence funnel animals into the camera's field of view (Boynton et al. 2021; Martin et al. 2017). For additional details, please see our field protocol.

Aquatic Monitoring

Continuous logging equipment

We will collect continuous data on instream conditions using pressure transducers (PT) to measure water stage and temperature, and dissolved oxygen (DO) loggers to measure DO concentration. Stream discharge measurements will be collected at least three more times during different flow conditions (CDFW 2013).

Pressure transducers (water stage and temperature)

We use PTs to collect water stage and water temperature data in 15-minute intervals to understand the timing and duration of instream flows and how these may be affected by surface water diversions or natural variability. Because S1 is our primary site for assessing biological responses (see bioassessment and snorkel survey sections below), we will install two PTs (HOBO U20L-01, Onset Computer Corporation, Bourne, MA, USA) in the S1 pool, so that they serve as fail safes to one another in case one of the loggers is, lost, stolen, or otherwise not recording properly. One PT will be deployed at each S2 and S3. Deployment ideally occurs during the spring recession, when flows are receding from winter highs and have reached safe levels to work in. The PTs will be anchored to the stream bed with t-posts and housed in perforated PVC stilling wells for protection from large debris that could damage the instrument. Installation and data collection practices will be consistent with the State of Utah Division of Water Quality Standard Operating Procedure (SOP) for Pressure Transducer Installation and Maintenance (DWQ 2014). Additionally, a staff plate will be fastened to one of the logger-supporting t-posts.

Within each HUC 12, we will also deploy one (or more) PTs as a barologger in the riparian area to measure barometric pressure and air temperature. These data are used to calculate water stage by correcting for fluctuations in atmospheric pressure (HOBOware software Version 3.7.14). To ensure accurate compensation, barologgers need to be located within 10 miles and within 2,000 ft elevation of the PTs they compensate.

A vertical benchmark will be established, and an auto level survey performed to determine pool stage and PT elevation at the time of deployment. This stage value will be used as an initial reference level for compensating PT data at the conclusion of the sampling season. Auto level surveys will be performed during instrument deployment and removal. This manual survey of pool stage allows for a comparison with stage measured by the PTs to determine if the PTs have moved or if sensor drift has occurred. The staff plate will be read during each site visit to manually track stage at different streamflow levels for additional comparison with the final PT data.

Using a Hach FH950 Velocity Meter (Hach Company, Loveland, CO, USA), three to seven discharge measurements will be taken under different flow conditions while the loggers are deployed, following the Standard Operating Procedure for Discharge Measurements in Wadeable Streams in California (CDFW 2013). We will target five measurements per season per site since more discharge measurements that are taken over a broad range of flows will establish a better relationship between stage and discharge. This relationship is needed to create individual rating curves for each stream monitored, as well as create hydrographs which depict stream flow over the sampling period. As flows decline, the stage of zero flow (SZF) will be identified as the point of lowest elevation on the riffle crest downstream of the gaged pool (where the last bit of water would flow from a pool) and measured during each site visit. When the water surface elevation of the pool is equal to the SZF elevation, stream flow ceases in the downstream adjacent habitat unit. The SZF is a useful measurement that improves the fitted stage-discharge relationship by assigning a discharge value of zero when pool stage is equal to or less than the SZF. In 2021, we encountered extremely low flow conditions that highlighted the need for greater flexibility in protocols, as the conditions were pushing the limits of accuracy in our instruments.

Pressure transducers and barologgers are removed at the conclusion of the sampling season prior to the resumption of high flows.

Dissolved oxygen loggers

Dissolved oxygen loggers will be used to collect temperature and DO data in 15- minute intervals. We will install DO loggers (HOBO U26-01, Onset Computer Corporation) in each study site in the same pools as the PTs, where possible, for a total of three DO loggers per HUC 12. DO loggers will be deployed following the method outlined in Division of Water Quality (DWQ 2014). Loggers will be fit with anti-fouling guards (U26 Guard-2, Onset Computer Corporation), placed in perforated PVC stilling wells, and attached to t-posts approximately six inches above the streambed. We will download DO data in the field during site visits, and the logger will be replaced at the exact same depth in the pool. We will install DO loggers at the same time as PTs and to remove them when the stream dries or prior to the resumption of high flows.

We will continue to investigate the relationship between water depth measured at the Riffle Crest Thalweg (RCT) and dissolved oxygen and temperature recorded by the DO loggers in the downstream pool in alluvial settings. Other researchers throughout northern California have documented a relationship between aquatic habitat quality, streamflow (cfs), and water depth as measured at the RCT in alluvial settings (Rossi 2012, Mierau et al. 2018). We seek to further investigate this relationship in a variety of stream settings and across water year types.

Flow criteria

To determine ecological and species-specific flow criteria, we will use a combination of field and desktop tools. The Natural Flows Database for California (Zimmerman et al. 2019) will be used to determine estimated natural flows, which are flows that would be present in the absence of water-use or land-use impacts to natural hydrology (Zimmerman et al. 2018). The natural flows data will be used as an input for the following desktop analyses: calculation of median monthly flow by water month type, Tessmann’s adaptation of the Tennant method (Tennant 1976; Tessmann 1980), and Hatfield-Bruce method (Hatfield and Bruce 2000). These analyses can be performed at a reach scale within each drainage area.

For the mainstem reach within each HUC 12, we will conduct field surveys to assess habitat maintenance flows using the SOP for the Habitat Retention Method (HRM) in California (CDFW 2018b). Where possible, HRM transects will be located within reaches designated for snorkel surveys. If HRM transects cannot be placed on the most downstream reach, then HRM transects will be located at S2 or S3. The HRM method is used to identify habitat maintenance flows that maintain hydraulic criteria for average depth, average velocity, and wetted perimeter, at the hydraulic control of a riffle. These three parameters are good indicators of flow-related stream habitat quality. Following the methodology in the CDFW's Wetted Perimeter SOP (CDFW 2020c), we will conduct the wetted perimeter method to identify the low-flow component of the hydrologic regime for ecological function and benthic macroinvertebrate production (Annear et al. 2004). The Wetted Perimeter Method (WPM) data will be collected simultaneously while conducting HRM on the same transect. For each reach, we will conduct reconnaissance for appropriate sites (reconnaissance efforts not to exceed boundaries of the snorkel reach), and survey at channel cross-sections of up to three riffles. We will deem the HRM sites as appropriate if the transects 1) represent a constriction point within the reach that would prevent fish passage below certain flow thresholds; 2) have a u-shaped bottom (as opposed to v-shaped); 3) are gravel and cobble dominated; 4) have a clearly defined hydraulic control; 5) are safely wadable; and 6) are near a discharge site without significant natural or artificial gains or losses to surface flow. We will also take discharge measurements within each reach. For either wetted perimeter or HRM, we will conduct survey transects in the same reach as the PTs and DO loggers, or as close as possible and we will verify that no imports or exports of water exist between the continuous logging instruments and the transects.

Bioassessment

We will use a bioassessment method designed to measure the health of California streams to understand how cannabis cultivation and other ecological processes influence aquatic ecosystem integrity. Benthic macroinvertebrate (BMI) samples will be collected following the Surface Water Ambient Water Monitoring Program (SWAMP) SOP (Ode et al. 2016). Reach-wide ambient water chemistry and physical habitat measurements are also collected as a component of the bioassessment. Each HUC 12 will have a singular composite BMI sample collected from within a 150 - 250 m reach encompassing the loggers deployed at S1. Sampling will occur between May - September when stream flow is at or near base flow conditions, or otherwise stable, to produce the most representative results. Samples will be processed by certified taxonomists and we will use the results to calculate the California Stream Condition Index which measures how well as sites' observed condition matches its expected condition.

Snorkel surveys

The snorkel surveys are designed to estimate fish occupancy, over-summer survival rates, and abundance in the downstream portion of the study subwatersheds. Two snorkel surveys are conducted one day apart, by teams of two or three people. In each HUC 12, a 1 km reach encompassing the loggers deployed at S1, is snorkeled in the summer and again in fall. Following Garwood and Ricker (2014), we will count and identify all fish species, as well as collect covariate data (e.g. pool size, large woody debris count, and habitat complexity). We recognize that small property sizes and access options may limit the availability of viable reaches. Criteria may be developed to allow for flexible snorkeling options.

Environmental variables

At each study site, we will measure canopy cover, air temperature, barometric pressure, stream habitat type (pool, riffle, etc.), maximum pool depths, average pool widths, maximum pool lengths, large woody debris counts, pool geology, and depth to bedrock. We will also calculate a number of flow-based metrics including stage of zero flow, riffle crest thalweg (RCT) – DO relationships, recession rates, dates and durations of hydrologic disconnection, and flow levels relative to instream flow thresholds.

Variable information that we will collect via existing GIS layers or through remote sensing include acreage of cannabis cultivation, road density, land use, land ownership, topography, underlying lithology, water demand model parameters, slope, and distance of cultivation to the stream.

Biosecurity in Field Methods

Human activity in both terrestrial and aquatic environments is a primary avenue for the introduction and spread of non-native, invasive species, as well as novel pathogens. To ensure that terrestrial and aquatic monitoring activities do not have a negative conservation impact, field crews follow basic biosecurity measures. Examples may include clearing hiking gear of organic material between survey locations to remove soil and seeds, and regular decontamination of equipment that has come into contact with aquatic environments, in accordance with existing CDFW Aquatic Invasive Species Decontamination protocols (CDFW, 2022).

Calibration Procedures and Frequency

Instrument calibration of pressure transducers, barometric loggers, flow meters, and dissolved oxygen loggers will be undertaken following manufacturers specifications and CDFW SOP's (where available) and all calibration dates will be recorded.

1. Pressure Transducers
2. Barometric Loggers
3. Dissolved Oxygen Loggers
4. Flow Meters
5. YSI Handheld Meter
6. PH Pen

Frequency and timing of calibration

- Factory calibrations will be used before initial deployment. Recalibrations will be performed following manufacturers specifications.
- YSI handheld meters will receive additional on-site field calibrations prior to usage.

Documentation of calibration checks

- Performance of calibration checks will be recorded on data sheets.

Inspection and maintenance of instruments, equipment, and supplies

- This will be conducted as needed and consistent with the manufacturers' specifications and guided by the USGS's National Field Manual for the Collection of Water-Quality

Data (Wagner et al., 2006; Rounds et al., 2013).

Data Management

Data collected following our proposed methods is abundant and in structured (numeric strings related to each other in rows and columns) and unstructured (audio and image files) data type formats (.xlsx, .jpg, .wav, .shp, .mdb, .csv, .kmz, .gpx, .pdf, .hobo, .tif, .mdx). In the field, terrestrial and aquatic survey data is collected through electronic applications on the iPad (e.g., Collector and/or Survey 123), and on paper datasheets in instances where electronic forms are not available (e.g., SWAMP, discharge). Data from the datasheets are quality checked and entered into a database and a scanned image of the datasheet itself is saved. Data from continuous logging equipment (e.g., PT, DO, and barologgers) is downloaded in the field or back in the office. Logger data is processed, then uploaded to the CDFW data management plan (DMP) library with a new or existing DMP, following the Department's Scientific Data Policy. Data from camera traps are uploaded to Wildlife Insights where they are stored and processed (i.e., photographed animals are identified to species). Data from bird acoustic recorders will be processed and stored in an in-development Wildlife Sound Hub, and data from bat acoustic recorders is processed and then species observations are uploaded to the NABat portal and shared publicly at the 10-km^2 scale. Remaining data from digital cameras and GPS units that are collected on memory cards will be uploaded to a computer during and at the end of the sampling season. As part of the development of the CEMAF, we are trialing methodologies to manage this data with the goal of establishing resilient data management strategies prior to a statewide implementation.

Analysis

Terrestrial analyses employ a variety of different occupancy modeling approaches (MacKenzie et al. 2006; Zipkin et al. 2009). Aquatic analyses will include linear mixed models, regression and timeseries modeling for the data collected from passive loggers and occupancy modeling. Additionally, BMI sampling will produce California Stream Condition Index (CSCI) scores calculated by CDFW staff from the Aquatic Bioassessment Laboratory (ABL). Unimpaired flow estimates and criteria to maintain overall ecosystem health will be developed as well. Metrics derived from these analyses will be used to inform a weight of evidence approach that synthesizes the data to reach a conclusion on impairment for a specific geographic areas.

Deliverables

Near-term deliverables will focus on preparing for statewide implementation of the CEMAF. This will include rational and an alternatives analysis for statewide implementation, refinement of the site selection criteria and data management strategies, a weight of evidence approach to synthesizing data in each subwatershed, a training for CDFW staff on the use of a water needs model that predicts water availability and cannabis need, and a finalized aquatic SOP with companion story map. Annual deliverables will include digitized data for all study areas, completion of field work and processing of all field data collected. As more years of data are collected, we anticipate producing a global model that explains how response variables are affected by different levels and distribution of cultivation and other ecological drivers.

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HUC 12 Name	Scientific Name	Common Name	ESA Listed Status	CESA Listed Status
Dutch Bill Creek-Russian River	*Rana draytonii*	California red-legged frog	Threatened	None
	Rana boylii	foothill yellow-legged frog	None	Endangered
	Strix occidentalis caurina	northern spotted owl	Threatened	Threatened
	Cordylanthus tenuis ssp. capillaris	Pennell's bird's-beak	Endangered	Rare
	Alopecurus aequalis var. sonomensis	Sonoma alopecurus	Endangered	None
	Oncorhynchus tshawytscha	California Coastal Chinook Salmon	Threatened	None
	Oncorhynchus kisutch	Central California Coast Coho Salmon	Endangered	Endangered
	Oncorhynchus mykiss irideus	Central California Coast Steelhead	Threatened	None
Estero De San Antonio	*Ambystoma californiense*	California tiger salamander	Threatened	Threatened
	Rana draytonii	California red-legged frog	Threatened	None
	Laterallus jamaicensis coturniculus	California black rail	None	Threatened
	Charadrius alexandrinus nivosus	western snowy plover	Threatened	None
	Brachyramphus marmoratus	marbled murrelet	Threatened	Endangered
	Agelaius tricolor	tricolored blackbird	None	Threatened
	Lasthenia conjugens	Contra Costa goldfields	Endangered	None
	Lupinus tidestromii	Tidestrom's lupine	Endangered	Endangered
	Trifolium amoenum	two-fork clover	Endangered	None
	Limnanthes vinculans	Sebastopol meadowfoam	Endangered	Endangered
	Delphinium bakeri	Baker's larkspur	Endangered	Endangered
	Delphinium luteum	golden larkspur	Endangered	Rare
	Alopecurus aequalis var. sonomensis	Sonoma alopecurus	Endangered	None
	Eucyclogobius newberryi	tidewater goby	Endangered	None
	Oncorhynchus kisutch	Central California Coast Coho Salmon	Endangered	Endangered
	Oncorhynchus mykiss irideus	Central California Coast Steelhead	Threatened	None
Lower Pescadero Creek	*Rana draytonii*	California red-legged frog	Threatened	None
	Rana boylii	foothill yellow-legged frog	None	Endangered
	Charadrius alexandrinus nivosus	western snowy plover	Threatened	None
	Brachyramphus marmoratus	marbled murrelet	Threatened	Endangered
	Riparia riparia	bank swallow	None	Threatened
	Thamnophis sirtalis tetrataenia	San Francisco gartersnake	Endangered	Endangered

	Limnanthes douglasii ssp. sulphurea	Point Reyes meadowfoam	None	Endangered
	Hesperocyparis abramsiana var. butanoensis	Butano Ridge cypress	Threatened	Endangered
	Eucyclogobius newberryi	tidewater goby	Endangered	None
	Oncorhynchus kisutch	Central California Coast Coho Salmon	Endangered	Endangered
	Oncorhynchus mykiss irideus	Central California Coast Steelhead	Threatened	None
McCune Creek-Putah Creek	*Ambystoma californiense*	California tiger salamander	Threatened	Threatened
	Rana draytonii	California red-legged frog	Threatened	None
	Rana boylii	foothill yellow-legged frog	None	Endangered
	Haliaeetus leucocephalus	bald eagle	Delisted	Endangered
	Buteo swainsoni	Swainson's hawk	None	Threatened
	Agelaius tricolor	tricolored blackbird	None	Threatened
	Sidalcea keckii	Keck's checkerbloom	Endangered	None
	Oncorhynchus mykiss irideus	Central Valley Steelhead	Threatened	None
Mill Creek	*Rana draytonii*	California red-legged frog	Threatened	None
	Rana boylii	foothill yellow-legged frog	None	Endangered
	Strix occidentalis caurina	northern spotted owl	Threatened	Threatened
	Cordylanthus tenuis ssp. capillaris	Pennell's bird's-beak	Endangered	Rare
	Oncorhynchus tshawytscha	California Coastal Chinook Salmon	Threatened	None
	Oncorhynchus mykiss irideus	Central California Coast Steelhead	Threatened	None
	Oncorhynchus kisutch	Central California Coast Coho Salmon	Endangered	Endangered
North Fork Navarro River	*Rana draytonii*	California red-legged frog	Threatened	None
	Rana boylii	foothill yellow-legged frog	None	Endangered
	Strix occidentalis caurina	northern spotted owl	Threatened	Threatened
	Astragalus agnicidus	Humboldt County milk-vetch	None	Endangered
	Oncorhynchus kisutch	Central California Coast Coho Salmon	Endangered	Endangered
	Oncorhynchus mykiss irideus	Northern California Steelhead	Threatened	None
Salt Hollow Creek-Russian River	*Rana boylii*	foothill yellow-legged frog	None	Endangered

	Strix occidentalis caurina	northern spotted owl	Threatened	Threatened
	Pekania pennanti	fisher - West Coast DPS	Endangered	Threatened
	Blennosperma bakeri	Sonoma sunshine	Endangered	Endangered
	Oncorhynchus kisutch	Central California Coast Coho Salmon	Endangered	Endangered
	Oncorhynchus mykiss irideus	Central California Coast Steelhead	Threatened	None
Stevens Creek	*Ambystoma californiense*	California tiger salamander	Threatened	Threatened
	Rana draytonii	California red-legged frog	Threatened	None
	Rana boylii	foothill yellow-legged frog	None	Endangered
	Laterallus jamaicensis coturniculus	California black rail	None	Threatened
	Rallus obsoletus obsoletus	California Ridgway's rail	Endangered	Endangered
	Sternula antillarum browni	California least tern	Endangered	Endangered
	Brachyramphus marmoratus	marbled murrelet	Threatened	Endangered
	Reithrodontomys raviventris	salt-marsh harvest mouse	Endangered	Endangered
	Thamnophis sirtalis tetrataenia	San Francisco gartersnake	Endangered	Endangered
	Oncorhynchus kisutch	Central California Coast Coho Salmon	Endangered	Endangered
	Oncorhynchus mykiss irideus	Central California Coast Steelhead	Threatened	None
Upper Napa River	*Rana draytonii*	California red-legged frog	Threatened	None
	Rana boylii	foothill yellow-legged frog	None	Endangered
	Strix occidentalis caurina	northern spotted owl	Threatened	Threatened
	Eryngium constancei	Loch Lomond button-celery	Endangered	Endangered
	Lasthenia burkei	Burke's goldfields	Endangered	Endangered
	Plagiobothrys strictus	Calistoga popcornflower	Endangered	Threatened
	Astragalus claranus	Clara Hunt's milk-vetch	Endangered	Threatened
	Limnanthes vinculans	Sebastopol meadowfoam	Endangered	Endangered
	Poa napensis	Napa blue grass	Endangered	Endangered
	Oncorhynchus kisutch	Central California Coast Coho Salmon	Endangered	Endangered
	Oncorhynchus mykiss irideus	Central California Coast Steelhead	Threatened	None
Upper Santa Rosa Creek	*Ambystoma californiense*	California tiger salamander	Threatened	Threatened
	Rana draytonii	California red-legged frog	Threatened	None

	Rana boylii	foothill yellow-legged frog	None	Endangered
	Haliaeetus leucocephalus	bald eagle	Delisted	Endangered
	Coccyzus americanus occidentalis	western yellow-billed cuckoo	Threatened	Endangered
	Strix occidentalis caurina	northern spotted owl	Threatened	Threatened
	Pekania pennanti	fisher - West Coast DPS	Endangered	Threatened
	Eryngium constancei	Loch Lomond button-celery	Endangered	Endangered
	Blennosperma bakeri	Sonoma sunshine	Endangered	Endangered
	Lasthenia burkei	Burke's goldfields	Endangered	Endangered
	Astragalus claranus	Clara Hunt's milk-vetch	Endangered	Threatened
	Limnanthes vinculans	Sebastopol meadowfoam	Endangered	Endangered
	Alopecurus aequalis var. sonomensis	Sonoma alopecurus	Endangered	None
	Oncorhynchus tshawytscha	California Coastal Chinook Salmon	Threatened	None
	Oncorhynchus mykiss irideus	Central California Coast Steelhead	Threatened	None
	Oncorhynchus kisutch	Central California Coast Coho Salmon	Endangered	Endangered
Zayante Creek-San Lorenzo River	*Rana draytonii*	California red-legged frog	Threatened	None
	Rana boylii	foothill yellow-legged frog	None	Endangered
	Haliaeetus leucocephalus	bald eagle	Delisted	Endangered
	Brachyramphus marmoratus	marbled murrelet	Threatened	Endangered
	Agelaius tricolor	tricolored blackbird	None	Threatened
	Plagiobothrys diffusus	San Francisco popcornflower	None	Endangered
	Erysimum teretifolium	Santa Cruz wallflower	Endangered	Endangered
	Chorizanthe pungens var. hartwegiana	Ben Lomond spineflower	Endangered	None
	Chorizanthe robusta var. hartwegii	Scotts Valley spineflower	Endangered	None
	Polygonum hickmanii	Scotts Valley polygonum	Endangered	Endangered
	Hesperocyparis abramsiana var. abramsiana	Santa Cruz cypress	Threatened	Endangered
	Oncorhynchus kisutch	Central California Coast Coho Salmon	Endangered	Endangered
	Oncorhynchus mykiss irideus	Central California Coast Steelhead	Threatened	None

Appendix A

Aquatic and terrestrial federally listed ESA and state listed CESA species within the 2022 Regions 1 and 3 study HUC12s. ESA statues include “threatened” and “endangered”, while CESA statues include “threatened” and “endangered” for animal species and “threatened”, “endangered”, and “rare” for plant species.

Appendix B

Terrestrial federally listed ESA and state listed CESA species within the 2022 study HUC12s planned for terrestrial sampling within Region 2 and Region 3. ESA statues include “threatened” and “endangered”, while CESA statues include “threatened” and “endangered” for animal species and “threatened”, “endangered”, and “rare” for plant species.

HUC 12 Name	***Scientific Name***	**Common Name**	**ESA Listed Status**	**CESA Listed Status**
Carneros Creek-Frontal San Pablo Bay Estuaries	*Laterallus jamaicensis coturniculus*	california black rail	None	Threatened
	Rana draytonii	california red-legged frog	Threatened	None
	Rallus obsoletus obsoletus	California Ridgway's rail	Endangered	Endangered
	Strix occidentalis caurina	northern spotted owl	Threatened	Threatened
	Reithrodontomys raviventris	salt-marsh harvest mouse	Endangered	Endangered
	Buteo swainsoni	swainson's hawk	None	Threatened
	Agelaius tricolor	tricolored blackbird	None	Threatened
	Charadrius alexandrinus nivosus	western snowy plover	Threatened	None
Clark Slough-Feather River	*Riparia riparia*	bank swallow	None	Threatened
	Vireo bellii pusillus	least bell's vireo	Endangered	Endangered
	Brachyramphus marmoratus	marbled murrelet	Threatened	Endangered
	Buteo swainsoni	swainson's hawk	None	Threatened
	Agelaius tricolor	tricolored blackbird	None	Threatened
	Coccyzus americanus occidentalis	western yellow-billed cuckoo	Threatened	Endangered
Eldorado Creek	*Haliaeetus leucocephalus*	bald eagle	Delisted	Endangered
	Rana draytonii	california red-legged frog	Threatened	None
	Rana boylii	foothill yellow-legged frog	None	Endangered
	Vulpes vulpes necator	sierra nevada red fox	Proposed - endangered	Threatened

Forest Creek	*Rana boylii*	foothill yellow-legged frog	None	Endangered
Humbug Creek-South Yuba River	*Haliaeetus leucocephalus*	bald eagle	Delisted	Endangered
	Rana boylii	foothill yellow-legged frog	None	Endangered
	Vulpes vulpes necator	sierra nevada red fox	Proposed - endangered	Threatened
	Rana sierrae	sierra nevada yellow-legged frog	Endangered	Threatened
Kelsey Creek	*Rana draytonii*	california red-legged frog	Threatened	None
	Rana boylii	foothill yellow-legged frog	None	Endangered
	Strix occidentalis caurina	northern spotted owl	Threatened	Threatened
	Agelaius tricolor	tricolored blackbird	None	Threatened
Loch Lane-Dry Creek	*Ambystoma californiense*	california tiger salamander	Endangered	Threatened
	Buteo swainsoni	swainson's hawk	None	Threatened
	Agelaius tricolor	tricolored blackbird	None	Threatened
Los Gatos Creek	*Rana draytonii*	california red-legged frog	Threatened	None
	Rana boylii	foothill yellow-legged frog	None	Endangered
Lower Laguna	*Haliaeetus leucocephalus*	bald eagle	Delisted	Endangered
	Ambystoma californiense	california tiger salamander	Endangered	Threatened
	Thamnophis gigas	giant gartersnake	Threatened	Threatened
	Brachyramphus marmoratus	marbled murrelet	Threatened	Endangered
	Buteo swainsoni	swainson's hawk	None	Threatened
	Agelaius tricolor	tricolored blackbird	None	Threatened
Lower Laguna De Santa Rosa	*Haliaeetus leucocephalus*	bald eagle	Delisted	Endangered
	Ambystoma californiense	california tiger salamander	Endangered	Threatened
	Agelaius tricolor	tricolored blackbird	None	Threatened

Magnolia Creek-Bear River	*Haliaeetus leucocephalus*	bald eagle	Delisted	Endangered
	Laterallus jamaicensis coturniculus	california black rail	None	Threatened
	Rana boylii	foothill yellow-legged frog	None	Endangered
McGaugh Slough-Frontal Clear Lake	*Haliaeetus leucocephalus*	bald eagle	Delisted	Endangered
	Rana boylii	foothill yellow-legged frog	None	Endangered
	Agelaius tricolor	tricolored blackbird	None	Threatened
	Coccyzus americanus occidentalis	western yellow-billed cuckoo	Threatened	Endangered
Salsipuedes Creek	*Riparia riparia*	bank swallow	None	Threatened
	Rana draytonii	california red-legged frog	Threatened	
	Rana boylii	foothill yellow-legged frog	None	Endangered
	Ambystoma macrodactylum croceum	santa cruz long-toed salamander	Endangered	Endangered
San Tomas Aquinas Creek	*Rana draytonii*	california red-legged frog	Threatened	None
	Rana boylii	foothill yellow-legged frog	None	Endangered
Smokehouse Creek-Lake Pillsbury	*Haliaeetus leucocephalus*	bald eagle	Delisted	Endangered
	Pekania pennanti	fisher - west coast dps	Endangered	Threatened
	Rana boylii	foothill yellow-legged frog	None	Endangered
	Martes caurina humboldtensis	humboldt marten	Threatened	Endangered
	Strix occidentalis caurina	northern spotted owl	Threatened	Threatened
	Empidonax traillii	willow flycatcher	None	Endangered
	Gulo gulo	wolverine	None	Threatened
Thurston Lake	*Haliaeetus leucocephalus*	bald eagle	Delisted	Endangered
	Rana draytonii	california red-legged frog	Threatened	None
	Strix occidentalis caurina	northern spotted owl	Threatened	Threatened

	Agelaius tricolor	tricolored blackbird	None	Threatened
Tolay Creek-Frontal San Pablo Bay Estuaries	*Laterallus jamaicensis coturniculus*	california black rail	None	Threatened
	Rana draytonii	california red-legged frog	Threatened	None
	Rallus obsoletus obsoletus	California Ridgway's rail	Endangered	Endangered
	Reithrodontomys raviventris	salt-marsh harvest mouse	Endangered	Endangered
	Buteo swainsoni	swainson's hawk	None	Threatened
	Agelaius tricolor	tricolored blackbird	None	Threatened
Town of Wilton-Cosumnes River	*Buteo swainsoni*	swainson's hawk	None	Threatened
	Agelaius tricolor	tricolored blackbird	None	Threatened
Upper Eticuera Creek	*Rana boylii*	foothill yellow-legged frog	None	Endangered
Upper Laguna De Santa Rosa	*Haliaeetus leucocephalus*	bald eagle	Delisted	Endangered
	Rana draytonii	california red-legged frog	Threatened	None
	Ambystoma californiense	california tiger salamander	Endangered	Threatened
	Rana boylii	foothill yellow-legged frog	None	Endangered
	Strix occidentalis caurina	northern spotted owl	Threatened	Threatened
	Coccyzus americanus occidentalis	western yellow-billed cuckoo	Threatened	Endangered
Visitacion Valley-Frontal San Francisco Bay Estuaries	*Haliaeetus leucocephalus*	bald eagle	Delisted	Endangered
	Rana draytonii	california red-legged frog	Threatened	None
	Rallus obsoletus obsoletus	California Ridgway's rail	Endangered	Endangered
	Brachyramphus marmoratus	marbled murrelet	Threatened	Endangered
	Agelaius tricolor	tricolored blackbird	None	Threatened
	Charadrius alexandrinus nivosus	western snowy plover	Threatened	None

Ward Creek-Austin Creek	*Rana draytonii*	california red-legged frog	Threatened	None
	Rana boylii	foothill yellow-legged frog	None	Endangered
	Strix occidentalis caurina	northern spotted owl	Threatened	Threatened
Webber Lake-Little Truckee River	*Haliaeetus leucocephalus*	bald eagle	Delisted	Endangered
	Pekania pennanti	fisher - west coast dps	Endangered	Threatened
	Strix nebulosa	great gray owl	None	Endangered
	Grus canadensis tabida	greater sandhill crane	None	Threatened
	Vulpes vulpes necator	sierra nevada red fox	Proposed - endangered	Threatened
	Rana sierrae	sierra nevada yellow-legged frog	Endangered	Threatened
	Empidonax traillii	willow flycatcher	None	Endangered
	Gulo gulo	wolverine	None	Threatened
Wolf Creek-Middle Yuba River	*Haliaeetus leucocephalus*	bald eagle	Delisted	Endangered
	Rana boylii	foothill yellow-legged frog	None	Endangered
	Vulpes vulpes necator	sierra nevada red fox	Proposed - endangered	Threatened
	Rana sierrae	sierra nevada yellow-legged frog	Endangered	Threatened
Woods Creek-Yuba River	*Haliaeetus leucocephalus*	bald eagle	Delisted	Endangered
	Laterallus jamaicensis coturniculus	california black rail	None	Threatened
	Rana boylii	foothill yellow-legged frog	None	Endangered